FEL09 LIVERPOOL

23rd – 28th August

31st International Free Electron Laser Conference

BT Convention Centre, Liverpool, UK

http://fel09.dl.ac.uk

Conference Programme & Abstracts

Science & Technology Facilities Council · The Cockcroft Institute of Accelerator Science and Technology · PSRI Photon Science Research Institute · ASTeC · Northwest Regional Development Agency · J.A.I. · SUPA Scottish Universities Physics Alliance · elettra · FERMI @elettra

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Contents

Welcome

Welcome to Liverpool in 2009! We are honoured to host the 31st International Free Electron Laser Conference and we very much look forward to meeting up with old friends and to making new ones. Liverpool is a famous city but also well-known for being a friendly one. It was chosen to be European Capital of Culture in 2008 and this accelerated a massive redevelopment programme that was already underway. Please take some time to explore this historic city with its seafaring traditions and modern outlook.

Once again the Conference will see the usual excitement associated with new FEL results, especially this year highlighted by the breakthrough into the hard x-ray region by the LCLS project team. The Scientific Programme Committee, under Brian McNeil's expert chairmanship, has assembled an impressive set of talks from the 300 or so abstracts that were submitted. However, we expect that the three poster sessions will also attract their fair share of interest – and even occasional argument! This year you will also find an innovation with the daily Tutorials straight after lunch – why not call in on them?

Our Conference has always valued the social intercourse that has in the past led to so many professional collaborations in our field. The Reception and the Dinner both promise to be memorable events and opportunities to extend and deepen friendships. We look forward to sharing these with you.

Our best wishes for a productive week in the north of England.

Mike Poole
Jim Clarke

General Information

Sponsors

Science & Technology Facilities Council
The Cockcroft Institute
Photon Science Research Institute
Accelerator Science and Technology Centre
Northwest Regional Development Agency
John Adams Institute
Scottish Universities Physics Alliance

Conference Co-Chairs

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J.A. Clarke (STFC Daresbury Laboratory)

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M. Marx
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D. Dunning
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B.W.J. McNeil
M.W. Poole
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J. Dai (IHEP-Beijing)
W.M. Fawley (LBNL)
M. Ferrario (INFN)
H. Freund (SAIC)
G. Geloni European (XFEL & DESY)
L. Giannessi (ENEA)
W. Graves (MIT)
R. Hajima (JAEA)
T. Hara (RIKEN/SPring-8)
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Y.U. Jeong (KAERI)
D.E. Kim (PAL, POSTECH)
B. Kuske (Helmholtz-Zentrum-Berlin)
R. Legg (University of Wisconsin-Madison)
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A. Loulergue (SOLEIL)
P. Michel (FZD)
D. Nguyen (LANL)
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J.-M. Ortega (CNRS)
H. Owen (Manchester University & CI)
P. Piot (Fermilab & Northern Illinois University)
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FEL Prize Committee

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I. Ben-Zvi
A. Gover
G. Neil
J. Rossbach

Useful Information about the UK

Time Zone
The time zone in the UK is UTC/GMT +1 hour (daylight savings).

Electricity
British electrical standards are 50Hz, 240 Volts. Appliances set up for 110/125V will require a transformer if they don't already have built-in voltage adjustment. Britain also uses a specific 3-prong plug.

Weather
The weather in the UK can be changeable and unpredictable! In August, Liverpool has an average maximum temperature of 19°C and an average minimum temperature of 12°C, and rain is generally just as likely as sunshine. It would be advisable to check the weather forecast before arriving.

Currency
Pound sterling (£) is the UK currency. Most hotels, restaurants and shops accept major credit cards. Sterling travellers' cheques can be cashed at all banks, post offices and most travel agents and hotels. Most ATM machines will accept Visa and MasterCard credit cards for withdrawal, though such transactions will usually incur a small additional charge.

Taxis
Delegates will require cash to pay for taxis. Very few taxis in the UK accept credit cards.

Hours of Business
Most shops in the UK are open Monday to Saturday from 9:00 until between 17:00 and 18:00. On Sunday larger stores open but for fewer hours, typically 11:00 to 17:00.

Internet Access
Free wireless internet will be available at the Convention Centre. A password will be required and will be issued at registration. There will also be an internet café available.

Insurance & Liability
The organizers of FEL09 do not accept liability for medical, travel or personal insurance. Delegates are strongly recommended to arrange their own personal insurance.

If you are travelling from a participating European country and have an EHIC card, you will be entitled to receive free medical treatment in the UK. However, this should not be regarded as a replacement for private medical insurance.

Outline of Scientific Programme

	Monday 24th	Tuesday 25th	Wednesday 26th	Thursday 27th	Friday 28th
09:00 – 10:45	Opening, New Lasing & FEL Prize Lectures **(MOOA)** Chairs: Mike Poole & Vladimir Litvinenko	Short Wavelength Amplifier FELs **(TUOA)** Chair: Jianping Dai	FEL Technology I: Accelerators **(WEOA)** Chair: Massimo Ferrario	FEL Technology II: Post-Accelerator **(THOA)** Chair: Bettina Kuske	Stability & Synchronism **(FROA)** Chair: William Graves
10:45 – 11:15	Refreshments				
11:15 – 13:00	FEL Theory **(MOOB)** Chair: Sven Reiche	New & Emerging Concepts **(TUOB)** Chair: Ingolf Lindau	FEL Technology I: Accelerators **(WEOB)** Chair: Hywel Owen	FEL Technology II: Post-Accelerator **(THOB)** Chair: Holger Schlarb	New Science from FELs & Closing Remarks **(FROB)** Chair: Jim Clarke
13:00 – 14:30	Lunch Break				
14:30 – 16:30	Poster Session **(MOPC)** & Refreshments SUPA Tutorial by Rodolfo Bonifacio	Poster Session **(TUPC)** & Refreshments SUPA Tutorial by Paul Emma	Poster Session **(WEPC)** & Refreshments SUPA Tutorial by Jon Marangos	(Leaving at 14:00) STFC Daresbury Laboratory Visit (Returning at 18:30)	
16:30 – 18:00	Oscillator FELs **(MOOD)** Chair: Stephen Benson	Long Wavelength FELS **(TUOD)** Chair: Young Uk Jeong	Coherence & Pulse Length Control **(WEOD)** Chair: Henry Freund		
Evening	Reception (19:00 onwards)		Conference Dinner (19:30 onwards)		

Note that the SUPA Tutorials run in parallel with the poster sessions during the first hour. Please see page xxii **for more information.**

Poster Session Topics

Monday (MOPC)	Tuesday (TUPC)	Wednesday (WEPC)
FEL Theory New & Emerging Concepts Coherence & Pulse Length	Long Wavelength FELs FEL Technology I: Accelerators	Oscillator FELs Short Wavelength Amplifiers FEL Technology II: Post-Accelerator Stability & Synchronism New Science

Conference Venue

Liverpool is a vibrant waterfront city in Northwest England, and was the European Capital of Culture 2008. The Conference will take place at the BT Convention Centre (found within the recently-opened ACC Liverpool) which is situated on King's Waterfront, Liverpool.

Directions

The address of the Conference venue is as follows:
Arena and Convention Centre Liverpool, Monarchs Quay, Liverpool, L3 4FP

The venue website is as follows:
www.accliverpool.com

Arriving by Train

Virgin Trains operate hourly direct services from London Euston to Liverpool Lime Street which take just over 2 hours. Other long-distance rail services also stop regularly at Liverpool Lime Street station. For more detailed information on train times within the UK visit **www.nationalrail.co.uk**. The Conference Centre is a 20 minute walk from Lime Street, or a short taxi ride which will cost less than £5. Alternatively, there are underground Wirral Line trains to James Street station (10 minute walk) that can be caught at Lime Street. There is also a CityLink Route C4 bus service (running 07:00 – 20:00) directly to the Convention Centre.

Arriving by Plane

The Liverpool John Lennon Airport is the closest to the Convention Centre, and a taxi from the airport to the city centre will take approximately 20 minutes and will cost approximately £15. Alternatively, the express bus service Route 500 takes approximately 25 minutes, and this stops within a 5 minute walk of the Convention Centre.

Manchester Airport is 37 miles away, but has very good rail links to Liverpool Lime Street station.

Arriving by Car

If travelling from the north, take the M6 to junction 26 and follow signs for M58 Liverpool. Follow to the end of the M58 and then follow signs for A59 Liverpool. Continue to follow A59 City Centre until picking up signs for the Albert Dock. This will lead off the A59 and onto the A5053, heading for the Albert Dock. Follow the Yellow AA Signs marked Echo Arena.

If travelling from the south, take the M6 to junction 21A, then take the M62 to Liverpool. Follow signs for the City Centre and then for Albert Dock and continue as above.

Conference Venue Layout

The industrial exhibition and poster sessions (held Monday 24th to Wednesday 26th August) will be located in **Hall 3** of the Convention Centre. The presentations and SUPA Tutorial lectures will take place in **Hall 11** of the Convention Centre.

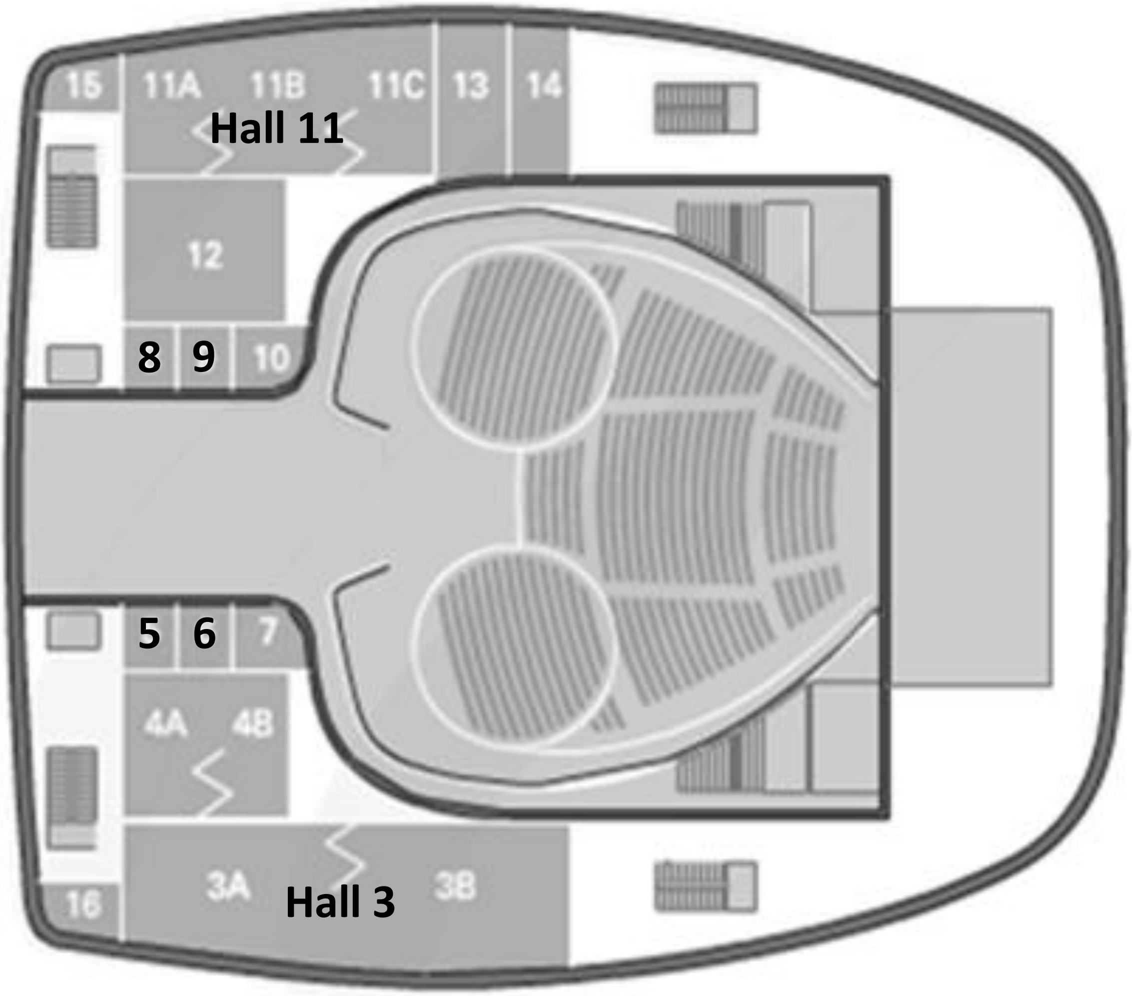
Other areas to note are as follows:

Room 5: Conference Office

Room 6: Editors' Office

Room 8: Speaker Upload

Room 9: Internet Café



Registration

Registration is open from 16:00 to 20:00 on Sunday 23rd August. Registration will take place in the upper level of the Convention Centre. A welcome drink will also be served during this time.

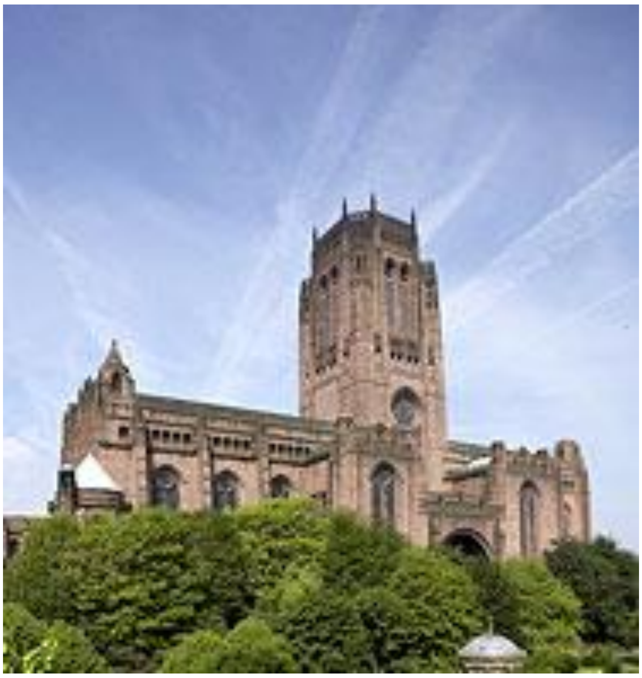
Registration continues on Monday 24th August from 08:00.

Upon registering, you will receive your personal Conference bag which comprises your Conference badge, booklet, tickets and other important items.

If you have not already paid your fee prior to arriving at the Conference, you will be able to do so during these registration periods. Please note that you will only be able to pay by Stirling cheque, or credit card via the PayPal service.

Reception

The FEL09 Conference Reception will be held at the Anglican Cathedral on Monday 24th August, from 19:00 onwards. There will be a 15 minute organ recital performed by Daniel Bishop later in the evening.



Liverpool Cathedral is the largest Cathedral in Britain, and the fifth largest in the world. It has been described as one of the wonders of modern architecture, being built entirely in the twentieth century. With its towering Gothic arches, massive tower and stained glass windows, it is a place of pilgrimage for hundreds of thousands of visitors every year.

The Cathedral can be found by heading towards Albert Dock (which is adjacent to the Convention Centre), on to Wapping, then turning right on to Hanover Street, turning right again on to Duke Street, then carrying on to Upper Duke Street. Refer to the map on the reverse of your ticket (found in the envelope in your Conference bag) for more information.

Conference Dinner

The Conference dinner will take place on Wednesday 26th August at 19:30, in St. George's Hall.

First built in 1841 as a venue to host Liverpool's triennial music festivals, it was reopened to the public in April 2007 after a £23 million restoration. It now has a new Heritage Centre, created to give visitors an exciting introduction to the Hall and its place in the history of Liverpool.

The dinner itself will be held in the Great Hall. Its interior is based on the reconstruction of the tepidarium (the warm baths) of Caracalla in Rome. The ceiling, which is the largest of its kind in the UK, features representations of the coat of arms of Liverpool and Lancashire, images of St. George slaying the dragon, mermaids and symbols of Roman authority.

A Beatles tribute band, The Mersey Beatles, will be playing a short set before dinner begins. After dinner, which will be served at 20:15, the band will play a longer set from approximately 22:15 onwards.

St George's Hall can be found by heading towards Albert Dock (which is adjacent to the Convention Centre), on to Wapping, then turning right on to Hanover Street, carrying on to Ranelagh Street, then turning left on to St. George's Place. Refer to the map on the reverse of your ticket (found in the envelope in your Conference bag) for more information.

STFC Daresbury Laboratory Visit

As part of the Conference there will be a scientific excursion to the nearby STFC Daresbury Laboratory, which includes a tour of the ALICE facility. The visit will be on the afternoon of Thursday 27th August, departing from the Conference venue at approximately 14:00 and returning at approximately 18:30.

Sightseeing in Liverpool

Albert Dock

Situated in the largest group of Grade I listed buildings in the UK, the Albert Dock houses many award-winning visitor attractions including the Tate Gallery, the famous Beatles Story, Merseyside Maritime Museum, International Slavery Museum and the new BugWorld Experience. You can join a city and water tour on the Yellow Duckmarine, and there are also a great selection of Liverpool bars and restaurants. Albert Dock is located next to the Convention Centre.

Everton Football Club

The stadium tour around Goodison Park, home of Everton FC, is a great way to learn more about the history of the club and its team. There will be a stadium tour on Sunday 30th August at 11:00.

Liverpool Football Club

The stadium tour follows the journey taken by the home and away players at every game. See the interview areas, the famous “This Is Anfield” sign and the Liverpool FC Museum, which is home to 5 European Cups.

The Cavern Club & Beatles Week

The Beatles Week will be taking place on the same days as the FEL09 Conference, and involves many different bands, some of whom will be performing in the Cavern Club. The club itself also has its own events many nights of the week.

Liverpool World Museum

There are always many events and exhibitions held in this museum. On Saturday 29th August there is an interactive, light-hearted and funny show for families called “Meet Charles Darwin”, presented by an actor in character as Darwin himself.

Anglican Cathedral

The Wildlife Photographer of the Year photographic competition is run annually by the Natural History Museum in London as well as by the BBC's Wildlife magazine, and is currently on display in Liverpool Anglican Cathedral. It is a highly acclaimed, prestigious exhibition showcasing stunning wildlife images to coincide with Liverpool's 2009 Year of Environment. Entry is free.

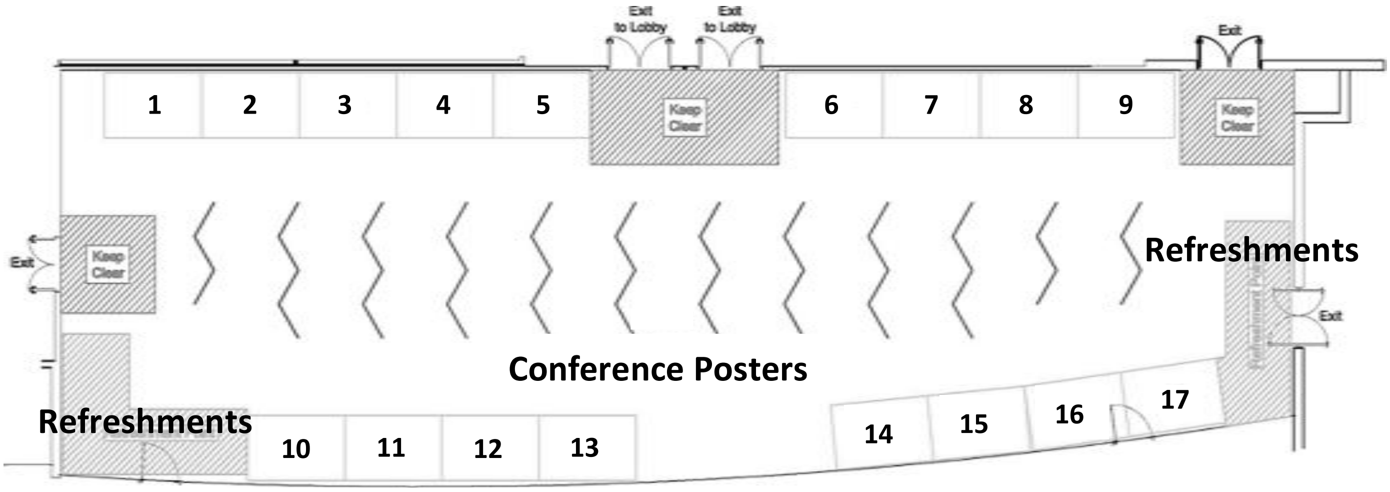
Liverpool Central Library

The Central Library buildings symbolise the cultural legacy of the city's merchants and form an integral part of the World Heritage site in William Brown Street. Apart from the historic buildings, Central Library offers the full range of services expected from a modern public library including a reader-friendly lending service, a comprehensive reference service and free broadband internet access in the People's Network computer suite.

For more information on all the locations and events listed, please visit the FEL09 Conference website at **http://fel09.dl.ac.uk**.

Industrial Exhibition

The industrial exhibition will be held on Monday, Tuesday and Wednesday from 09:00 until 18:00, and will take place in **Hall 3**.



Exhibitors

Stand number	Exhibitor
1	Tech-X Corporation
2	Hytec Electronics Ltd
3	KYMA Srl
4	Shakespeare Engineering
5	Essex X-Ray & Medical Equipment Ltd
6	Thales Electron Devices
7	Metrolab Instruments SA
8	Mitsubishi Heavy Industries Ltd
9	McLennan Servo Supplies
10	Instrumentation Technologies
11	CST
12	Toshiba Electron Tubes & Devices
13	Saint-Gobain Ceramics
14	Transtechnik GmbH & Co KG
15	
16	Research Instruments
17	Advanced Energy Systems, Inc

Scientific Programme

Monday, August 24th

Opening, New Lasing & FEL Prize Lectures

Chairs: Mike Poole & Vladimir Litvinenko

09:00 Opening of FEL09
09:05 **FEL Prize Lecture**: “Stochastic Properties of Self-Amplified Spontaneous-Emission”, S. Krinsky (BNL)
09:50 **Young Scientist FEL Prize Lecture**: “Statistical Theory of the SASE FEL Based on the Two-Particle Correlation Function Equation”, O.A. Shevchenko (Budker Institute of Nuclear Physics)
10:20 New Lasing talks

Refreshments (10:45 – 11:15)

FEL Theory

Chair: Sven Reiche

11:15 **Invited**: “Echo-Enabled Harmonic Generation (EEHG) Free Electron Laser”, G. Stupakov (SLAC)
11:45 **Invited**: “Towards Sub-Ångström Coherent Light Sources: The Quantum FEL”, G.R.M. Robb (University of Strathclyde)
12:15 “Deep Saturation Dynamics in a Free Electron Laser”, R. Bachelard (SOLEIL)
12:30 “Impact on a Seeded Harmonic Generation FEL of an Initial Energy Chirp and Curvature in the Electron Bunch Energy Distribution”, A.A. Lutman (DEEI & Sincrotrone Trieste)
12:45 “Comparison of HGHG and Self-Seeding for the Production of Narrow-Bandwidth Radiation in a Free Electron Laser”, A. Marinelli (UCLA, Los Angeles, California)

Lunch Break (13:00 – 14:30)

Poster Session (14:30 – 16:30) / SUPA Tutorial (14:30 – 15:30)

Poster Topics: FEL Theory, New & Emerging Concepts, Coherence & Pulse Length
SUPA Tutorial by Rodolfo Bonifacio

Oscillator FELs

Chair: Stephen Benson

16:30 **Invited**: “A kW Intracavity Power Storage Ring FEL”, Y. Wu (Duke University)
17:00 **Invited**: “Progress in the Study of an X-Ray FEL Oscillator”, K.-J. Kim (ANL & University of Chicago)
17:30 “Modeling and Operation of an Edge-Outcoupled Free Electron Laser”, M.D. Shinn (JLAB)
17:45 “Study of Optical Frequency Chirping and Pulse Compression in a High-Gain Energy-Recovery-Linac-Based Free Electron Laser”, S. Zhang (JLAB)

Tuesday, August 25th

Short Wavelength Amplifier FELs

Chair: Jianping Dai

09:00 **Invited**: "Lasing and Saturation of the LCLS FEL", P.J. Emma (SLAC)
09:30 **Invited**: "Electron Bunch Compression with Dynamical Non-Linearlity Correction for a Compact FEL", T. Hara (SPring-8/Riken)
10:00 "FEL Gain Length and Saturation Measurements for the Tapered LCLS Undulators", D. Rather (SLAC)
10:15 "Design and R&D Progress of the SDUV-FEL", Z. Zhao (SINAP)
10:30 "Current Status of X-Ray FEL Project at SPring-8", T. Shintake (RIKEN/SPring-8)

Refreshments (10:45 – 11:15)

New & Emerging Concepts

Chair: Ingolf Lindau

11:15 **Invited**: "Towards Table-Top FELs", F.J. Gruener (LMU, Garching)
11:45 **Invited**: "X and Gamma Ray Source Using Laser Plasma Wakefield Accelerators", D.A. Jaroszynski (University of Strathclyde)
12:15 "An Intense kHz and Aberration-Free Two-Colour High Harmonic Source for Seeding FELs from EUV to Soft X-Ray Range", G. Lambert (LOA)
12:30 "Critical Issues in the Coherent Single Spike Mode Operation with Low Charges", Y. Kim (PSI)
12:45 "Suppression of Short Noise and Spontaneous Radiation in Electron Beams", V. Litvinenko (BNL)

Lunch Break (13:00 – 14:30)

Poster Session (14:30 – 16:30) / SUPA Tutorial (14:30 – 15:30)

Poster Topics: Long Wavelength FELs, FEL Technology I: Accelerators
SUPA Tutorial by Paul Emma

Long Wavelength FELs

Chair: Young Uk Jeong

16:30 **Invited**: "Novosibirsk Free Electron Laser Facility: Two-Orbit ERL Operation and Second FEL Commissioning", N. Vinokurov (BINP)
17:00 **Invited**: "Time-Dependent, Three-Dimensional Simulation of Free Electron Laser Oscillators", H. Freund (SIAC)
17:30 "The FEL-THz Facility Driven by a Photo-Cathode Injector", X. Yang (CAEP/IAE, Sichuan)
17:45 "Production of Powerful Spatially-Coherent Radiation in Free Electron Lasers Based on Two-Dimensional Distributed Feedback", N. Ginzburg (IAP, RAS)

Wednesday, August 26th

FEL Technology I: Accelerators

Chair: Massimo Ferrario

09:00 **Invited**: “Measurements of the LCLS Laser Heater and its Impact on the LCLS FEL Performance”, Z. Huang (SLAC)
09:30 **Invited**: “FLASH Status and Upgrade”, B. Faatz (DESY)
10:00 “LCLS Drive Laser Shaping Experiments”, D. Dowell (SLAC)
10:15 “Field-Emission Cathodes for Free Electron Lasers”, J.D. Jarvis (Vanderbilt University)
10:30 “Status and Plans for the LBNL Normal-Conducting CW VHF Photoinjector”, F. Sannibale (LBNL)

Refreshments (10:45 – 11:15)

FEL Technology I: Accelerators

Chair: Hywel Owen

11:15 **Invited**: “Velocity Bunching Experiment at SPARC”, D. Filippetto (INFN/LNF)
11:45 **Invited**: “Optimisation of a Single-Pass Superconducting Linac as a FEL Driver for the NLS Project”, R. Bartolini (Diamond)
12:15 “Molecular Dynamics Simulation of Longitudinal Space-Charge Induced Optical Microbunching”, J. Rosenweig (UCLA)
12:30 “Running Experience of the Superconducting RF Photoinjector at ELBE”, R. Xiang (FZD)
12:45 “ERL-FEL Study Activities at IHEP, Beijing”, X. Zhu (IHEP)

Lunch Break (13:00 – 14:30)

Poster Session (14:30 – 16:30) / SUPA Tutorial (14:30 – 15:30)

Poster Topics: Oscillator FELs, Short Wavelength Amplifiers, FEL Technology II: Post-Accelerator, Stability & Synchronism, New Science
SUPA Tutorial by Jon Marangos

Coherence & Pulse Length Control

Chair: Henry Freund

16:30 **Invited**: “Short Pulse Low Charge Operation of the LCLS”, J. Frisch (SLAC)
17:00 **Invited**: “Study of an HHG-Seeded Harmonic Cascade FEL for the UK’s New Light Source Project”, N. Thompson (STFC)
17:30 “Spatial Characterization of FEL Self-Amplified Spontaneous Emission”, P. Mercere (SOLEIL)
17:45 “Efficiency and Spectrum Enhancement in a Tapered Free Electron Laser Amplifier”, J. Murphy (BNL)

Thursday, August 27th

FEL Technology II: Post-Accelerator

Chair: Bettina Kuske

09:00 **Invited**: “Undulators for the SwissFEL”, T. Schmidt (PSI)
09:30 **Invited**: “LCLS Undulator Commissioning, Alignment and Performance”, H.-D. Nuhn (ANL SLAC)
10:00 “Selection of the Optimum Undulator Parameters for the NLS: A Holistic Approach”, J.A. Clarke (STFC/DL/ASTeC)
10:15 “Undulator Options for Soft X-Ray Free Electron Lasers”, S. Prestemon (LBNL)
10:30 “Undulator K-Parameter Measurements at LCLS”, J. Welch (SLAC)

Refreshments (10:45 – 11:15)

FEL Technology II: Post-Accelerator

Chair: Holger Schlarb

11:15 **Invited**: “Commissioning Results of the SPARC FEL”, M. Ferrario (ENEA, INFN)
11:45 **Invited**: “Results from the Optical Replica Synthesizer at FLASH”, P. Salen (Uppsala University)
12:15 “Numerical Evaluation of Bulk HTSC Staggered Array Undulator by Bean Model”, R. Kinjo (Kyoto IAE)
12:30 “Theory of Edge Radiation, Part I: Foundations and Basic Applications”, G. Geloni (DESY)
12:45 “Photon Diagnostics for the Seeding Experiment at FLASH”, F. Curbis (Uni HH)

Lunch Break (13:00 – 14:00)

STFC Daresbury Laboratory Visit (14:00 – 18:30)

Friday, August 28th

Stability & Synchronism

Chair: William Graves

09:00 **Invited**: "High Performance SASE FEL Achieved by Stability-Oriented Accelerator System and Operation", H. Tanaka (SPring-8)

09:30 **Invited**: "Electron Beam Stabilisation Test Results Using a Neural Network Hybrid Controller at the Australian Synchrotron and Linac Coherent Light Source Projects", E. Meier (Monash University & Australian Synchrotron)

10:00 "Femtosecond Electro-Optical Synchronization System over Distances up to 300 m", J. Tratnik (University of Ljubljana)

10:15 "Timing and Synchronisation Considerations for the NLS Project", G. Hirst (STFC/RAL)

10:30 "RF-Based Detector for Measuring Fiber Length Changes with Sub-5 Femtosecond Long-Term Stability", J. Zemella (DESY)

Refreshments (10:45 – 11:15)

New Science from FELs & Closing Remarks

Chair: Jim Clarke

11:15 **Invited**: "Achieving Microfocus of the 13.5 nm FLASH Beam for Exploring Matter Under Extreme Conditions", A.J. Nelson (LLNL)

11:45 **Invited**: "Evidence for Position Based Electron Entanglement in Resonant Auger Electron Emission from Dissociating O2 Molecules", U. Becker (FHI Berlin)

12:15 "Studying the Secret of Life with FELs", P. Weightman (University of Liverpool)

12:30 "Saturable Absorption with VUV FEL Radiation", S.M. Vinko (University of Oxford)

12:45 "Local Infrared Microspectroscopy with 100 nm Spatial Resolution and Application to Cell Imaging", J.-M. Ortega (LCP/CLIO)

Close of FEL09 Conference (13:00)

Poster Session Information

Poster sessions are scheduled for Monday, Tuesday and Wednesday afternoons, from 14:30 to 16:30, in **Hall 3**. Please refer to the outline of the scientific programme on **page ix** of this booklet for the topics to be presented on each day. Refreshments will be available at the two stands during the poster sessions.

Posters must be mounted in the morning prior to the appropriate session and must be removed at the end of the session. Pins are not to be used, but Velcro dots will be available for mounting posters. The area of the poster board is 116cm (roughly 46") wide and 90cm (roughly 35") high. An ISO A0 sized (118.9cm x 84.1cm) poster will fit landscape on the board, as will an ANSI E (44" x 34"). Only the upper sections of the boards will be used such that portrait-oriented posters may also be accommodated.

Poster Rules

Since no contributions are accepted for publication only, **any paper not presented at the Conference will be excluded from the Proceedings**. Furthermore, the Scientific Program Committee reserves the right to reject publication of papers that were not properly presented in the poster sessions.

Manuscripts of contributions to the Proceedings (or large printouts of them) are not considered as posters and papers presented in this way will not be accepted for publication.

There will be a designated "poster police" to verify that posters have been displayed during the relevant poster session. As mentioned, posters should be manned for at least an hour.

Please bear in mind that papers for posters that are not displayed for the full poster session will not be published in the Proceedings.

SUPA Tutorial Lectures

As part of an educational programme for those new – and perhaps some not so new – to the field of FELs, there are to be three one-hour lectures during the poster sessions from three distinguished physicists: Rodolfo Bonifacio, Paul Emma and Jon Marangos. These SUPA Tutorial Lectures will run for the first hour of each poster session, in parallel with the poster displays themselves. During this time, it is not necessary for the posters to be manned, although after this time they must be manned for the last hour.

Paper Preparation

The International Free Electron Laser Conference is one of several Conference series adhering to the JACoW (Joint Accelerator Conferences Web Site) standard for electronic publication of Proceedings.

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Opening, New Lasing & FEL Prize Lectures

Chairs: Mike Poole & Vladimir Litvinenko

Stochastic Properties of Self-Amplified Spontaneous-Emission (FEL Prize) — MOOA01

Samuel Krinsky (BNL, Upton, Long Island, New York)

We discuss the chaotic behavior of the time evolution of the amplitude and phase of the output radiation from a self-amplified spontaneous-emission free electron laser.

Statistical Theory of the SASE FEL Based on the Two-Particle Correlation Function Equation (Young Scientist FEL Prize) — MOOA02

Oleg A. Shevchenko, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

The startup from noise problem in SASE FELs is usually treated in linear approximation. In this case, amplification of initial density fluctuations may be calculated and averaging over initial conditions may be fulfilled explicitly. In the general nonlinear case, the direct averaging is not applicable. During last year we developed the approach based on the BBGKY hierarchy for the n-particle distribution functions. The interaction of particles in FEL is time-dependent (retarded). Nevertheless, using special time-coordinate transformation, it is possible to make the interaction "time-independent" and then to write down the BBGKI equations. Similar to plasma physics, the equations may be truncated after the second one (for the two-particle correlation function). Using this approach we consider several particular cases which illustrate some peculiar features of the SASE FEL operation.

FEL Theory

Chair: Sven Reiche

Echo-Enabled Harmonic Generation (EEHG) Free Electron Laser (Invited) MOOB01

Gennady Stupakov (SLAC, Menlo Park, California)

The Echo-Enabled Harmonic Generation (EEHG) FEL uses two modulators in combination with two dispersion sections that allow one to generate in the beam a high-harmonic density modulation starting with a relatively small initial energy modulation of the beam*. After presenting the concept of the EEHG, we address several practically important issues, such as the effect of coherent and incoherent synchrotron radiation in the dispersion sections, the beam transverse size effect in the modulator, etc. Using a representative realistic set of beam parameters, we show how the EEHG scheme enhances the FEL performance and allows one to generate a fully (both longitudinally and transversely) coherent radiation.

** G. Stupakov, PRL, 102, 074801 (2009); D. Xiang and G. Stupakov, PRSTAB, 030702 (2009).*

Towards Sub-Ångström Coherent Light Sources: The Quantum FEL (Invited) MOOB02

Gordon Robb, Rodolfo Bonifacio (USTRAT/SUPA, Glasgow), Nicola Piovella (Istituto Nazionale di Fisica Nucleare, Milano; Universita' degli Studi di Milano, Milano)

Short-wavelength Free Electron Lasers (FELs), which have recently produced intense, hard x-rays are currently based on the concept of classical Self-Amplified Spontaneous Emission (SASE). In order to extend the production of intense, coherent radiation to sub-Å wavelengths then an alternative to the conventional SASE-FEL concept will be necessary, as conventional SASE-FELs require long wigglers (~100 m), large accelerators (~km) and produce radiation which has poor temporal coherence. Recently, we have introduced the concept of the Quantum Free Electron Laser (QFEL). The QFEL is characterised by quantised electron momentum recoil and the emission of monochromatic, coherent radiation from a compact apparatus. This makes it appealing for applications requiring a high degree of temporal coherence. We show that a SASE-QFEL may offer the possibility to produce intense, coherent radiation at sub-Å wavelengths via harmonic generation.

Deep Saturation Dynamics in a Free Electron Laser MOOB03

Romain Bachelard, Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Cristel Chandre, Xavier Leoncini (CNRS/CPT, Marseille), Giovanni De Ninno (ELETTRA, Basovizza), Duccio Fanelli, Stefano Ruffo (Università di Firenze, Florence), Pierre de Buyl (Université Libre de Bruxelles, Bruxelles)

The regime of intensity (and bunching) oscillation following the FEL saturation is investigated using the Colson-Bonifacio model. This regime is understood as an out-of-equilibrium metastable state, which slowly relaxes toward thermodynamical (Boltzmann) equilibrium. This dynamic is also characterized by a strong regularity, unexpected for an interaction between waves and large number of particles, as well as by low-dimensional phase-space structures in the electron-beam phase space. In this context, the switch from regimes associated to high gain (for small electron-beam energy spread) or very low gain (for large energy spread) can be interpreted as out-of-equilibrium phase transitions, a phenomenon which was recently explained by a mechanism of entropy maximization.

Impact on a Seeded Harmonic Generation FEL of an Initial Energy Chirp and Curvature in the Electron Bunch Energy Distribution

MOOB04

Alberto Andrea Lutman, Roberto Vescovo (DEEI; Sincrotrone Trieste), Paolo Craievich, Giuseppe Penco (ELETTRA, Basovizza), Juhao Wu (SLAC, Menlo Park, California)

In a Harmonic Generation Free Electron Laser (HG FEL), the electron beam entering the undulator can have an initial energy curvature besides an initial energy chirp. Solving the Vlasov-Maxwell equations within the 1D model, we derive an expression for the Green function for the seeded HG FEL process for the case of the electron beam having both an energy chirp and an energy curvature. We give an asymptotic closed form which is a good approximation in the exponential growth regime, and a series expression that allows the evaluation of the field envelope along the undulator in both lethargy and exponential growth regime. The latter is useful to study the HG FEL behavior in the short modulator, like that of the FERMI@Elettra project. The FEL radiation properties such as central frequency shift and frequency chirp are studied considering Gaussian laser seeds of different temporal duration in respect to the Green functions temporal duration. The energy chirp and curvature of the electron bunch result in a time dependent bunching factor for the FEL start-up process in the radiator of the HG FEL like the FERMI@Elettra. The coherence properties of the FEL are examined.

Comparison of HGHG and Self-Seeding for the Production of Narrow-Bandwidth Radiation in a Free Electron Laser

MOOB05

Agostino Marinelli, Claudio Pellegrini (UCLA, Los Angeles, California), Luca Giannessi (ENEA C.R. Frascati, Frascati (Roma)), Sven Reiche (PSI, Villigen)

Narrow bandwidth FEL operation is one of the main challenges for future FEL facilities. Several schemes have been proposed to obtain a narrower bandwidth than that achievable with self amplified spontaneous emission starting from shot-noise. In this work the properties of two such schemes (high gain harmonic generation and self-seeding) are investigated and compared taking into account several non-ideal beam effects, with particular attention paid to the effect of bandwidth broadening associated to non-linear longitudinal phase-space. The comparison between the two schemes has been carried out with numerical simulations performed with GENESIS 1.3 and PERSEO FEL codes using both an idealized beam and realistic beams obtained with start to end simulations.

Monday Poster Session

SUPA Tutorial by Rodolfo Bonifacio

3D Simulations Proof of Shot Noise Control and Reduction by Collective Coulomb Interaction — MOPC01

Ariel Nause, Egor Dyunin, Avraham Gover (University of Tel-Aviv, Tel-Aviv)

The possibility to control optical frequency current shot-noise by longitudinal collective interaction in an electron beam was suggested recently, based on an extended 1D (single Langmuir mode) model*. This model predicts the possibility to reduce the beam current-noise below the classical shot-noise level. 3D simulations in GPT were executed in order to verify the predicted current shot noise reduction. It was verified numerically that minimal current shot-noise is attainable in a drift length of quarter wavelength oscillation. However, the attainment of the effect requires proper setting of the beam geometrically and current density parameters to avoid interference of higher order Langmuir modes**. The parameters range of which the single mode model is valid and the deterioration effects out of this range were determined. Parameters for future experiments are suggested. This process may be applicable for controlling microbunching instabilities and FEL coherence enhancement.
** Gover A, PRL 102, 154801 (2009). ** Venturini, M. Phys. Rev. ST Accel. Beams 11, 034401 (2008).*

Feasibility Studies for Single Stage Echo-Enabled Harmonic in FERMI FEL-2 — MOPC02

Enrico Allaria (ELETTRA, Basovizza), Xiang Dao (SLAC, Menlo Park, California), Giovanni De Ninno (University of Nova Gorica, Nova Gorica; ELETTRA, Basovizza)

Recently, the second FEL line of the FERMI FEL has been modified in order to extend its tuning range down to 3 nm. In order to reach such a short wavelength starting from the UV seed laser the FERMI FEL-2 system relies on a double cascade of high gain harmonic generation. In this work we study the possibility of using the present FEL-2 layout with minor modifications to demonstrate the feasibility of the recently proposed echo-enabled harmonic generation (EEHG). The final aim is to cover the expected spectral range of FEL-2 with a single cascade. The performance of the EEHG in FERMI FEL-2 is estimated by means of start-to-end FEL simulations.

Self Seeding Configuration at SPARC — MOPC03

Luca Giannessi, Marie Labat (ENEA C.R. Frascati, Frascati (Roma)), Bruno Spataro (INFN/LNF, Frascati (Roma)), Alberto Bacci (Istituto Nazionale di Fisica Nucleare, Milano)

We propose an experiment of self seeding at SPARC. The experiment would be done at visible / UV wavelengths where high-reflectivity mirrors at normal incidence are available and its implementation would require only minor modifications of the existing SPARC layout. The new FEL configuration might significantly extend the SPARC FEL wavelength range of operation and would present several advantages as a higher brightness in wavelength tunable conditions together with a reduction of the demands in terms electron beam peak current and beam quality.

Single Spike Radiation Production at SPARC — MOPC04

Vittoria Petrillo (Universita' degli Studi di Milano, Milano), Giuseppe Dattoli, Luca Giannessi, Marie Labat, Pier Luigi Ottaviani, Concetta Ronsivalle (ENEA C.R. Frascati, Frascati (Roma)), Simonetta Pagnutti (ENEA-Bologna, Bologna), Manuela Boscolo, Massimo Ferrario (INFN/LNF, Frascati (Roma)), Alberto Bacci, Luca Serafini (Istituto Nazionale di Fisica Nucleare, Milano)

We describe a possible experiment aimed at generating sub-picosecond high-brightness electron bunches with the SPARC photoinjector, which produce single spike radiation pulses at 500 nm in the regime of self-amplified spontaneous emission. The purpose of the experiment is the production of short electron bunches as long as a few SASE cooperation lengths by means of the Velocity Bunching technique. The measure of the properties of the electron beam, the determination of shape and spectrum of the radiation pulse and the validation of the single spike scaling laws will be analysed in order to foresee future operations at shorter wavelength with SPARX. We present start-to-end simulations and preliminary experimental data of the beam production and FEL performance, and discuss the layout of the machine, including the diagnostics to measure the radiation spectrum. We will also discuss the validation of the numerical simulations with an accurate theoretical analysis and with a “code” (Parsifel) entirely based on analytical or semi-analytical formulae. The experience gained from this experiment will help in the configuration of the VUV and x-ray FEL SPARX to obtain FEL pulses below 10 fs.

Seeding Option for the Soft X-Ray Beamline of the SwissFEL — MOPC05

Sven Reiche, Rafael Abela, Hans-Heinrich Braun, Bruce Patterson, Marco Pedrozzi (PSI, Villigen)

The x-ray FEL facility SwissFEL, currently planned at the Paul Scherrer Institut, is primarily based on the SASE operation of a hard (1 - 7 Å) and soft (7 - 70 Å) x-ray beamline. However, the soft x-ray FEL beamline is foreseen to allow for seeding down to 1 nm. However the intrinsic shot noise in the electron bunch demands very excellent seeding sources and strategies, which are currently state-of-the-art. This presentation discusses various seeding options for the SwissFEL and evaluates them regarding performance and risk of implementation.

Proposed Extension to the 250 MeV Injector Beamline at PSI for Testing Seeding Options at the SwissFEL — MOPC06

Sven Reiche, Rafael Abela, Bolko Beutner, Hans-Heinrich Braun, Bruce Patterson, Marco Pedrozzi (PSI, Villigen)

The Paul Scherrer Institut is currently proposing an x-ray free electron laser facility operating in the wavelength range of 0.1 to 7 nm. The overall design aims for a compact layout and relies on a low emittance electron beam and short period undulator. As an initial step, a 250 MeV is currently under construction to demonstrate a high brightness electron beam to be sufficient for operating the SwissFEL. An extension to the 250 MeV is planned to test additional key components for the SwissFEL, which are prototypes of the in-vacuum undulator modules as well as the proof-of-principle demonstration of echo-enabled harmonic generation as a possible seeding option for the SwissFEL at 1 nm. The combination of seeding and prototype undulator module allows for saturation of the FEL at 50 nm and first experiments with FEL radiation at the PSI.

Low Charge Operation of the SwissFEL — MOPC07

Sven Reiche, Hans-Heinrich Braun, Yujong Kim, Marco Pedrozzi (PSI, Villigen)

The Paul Scherrer Institut is proposing an x-ray FEL facility, providing a wavelength range between 1 Ångström to 7 nm. The major mode of operation is SASE with a supplemental seeding option for wavelength down to 1 nm. In addition a low charge operation of about 10 pC is considered to achieve single spike operation in the soft x-ray regime and thus overcoming the limitation of seeding sources at that wavelength. This presentation discusses the basic operation as well as expected stability of the performance in energy and spectral power.

On the Brightness of Undulator Radiation and FEL with External Focusing — MOPC08

Vahe Sahakyan, Artur Tarloyan, Vasili Mkrtich Tsakanov (CANDLE, Yerevan)

The spectral brightness of the radiation in a long undulator chain with external periodic FODO lattice is derived taking into account the space-angular distribution of the electron beam. Given as the convolution of the electron and photon beam distributions, the brightness is then explicitly presented via the phase advance per cell and number of FODO lattices along the undulator chain. The extension for the SASE FEL brightness and the optimal external focusing are discussed.

Role of the Thermal Noise in an Undulator Free Electron Oscillator (FEO) — MOPC09

Sergei Georgii Oganesyan, George Sergey Oganesyan (LT CSC, Yerevan), Yelena Hovhannisyan (RC, Dallas)

Using the set of nonlinear semiclassical equations* we have studied the role of a thermal noise in FEO. The latter includes a long undulator, a Fabry-Perot resonator and a space-uniform e-beam. It was adopted that FEO operates in a single mode regime, and the undulator and mirrors have a room temperature. The black radiation produced by their atoms is accumulated within the resonator and causes the noise field. In accordance with **, one can describe the noise with a random polarization vector. We have used the vector in our equations and derived a nonlinear equation for the electric field strength. With the equation one can describe the FEO operation at an initial stage, when the device starts up from the thermal noise. The second stage occurs when the laser field becomes high and the FEO operates in steady-state regime*. Now the role of the noise is negative since it causes fluctuations of the laser parameters*, ***. In particular, it is the electric field amplitude. It is ascertained that for terahertz frequencies the fluctuation value decreases when the resonator volume increases. For larger frequencies the amplitude fluctuation effect is exponentially small.

** S.G. Oganesyan et al, 31-th FEL Conf., UK, 23-28 Aug 2009. ** A. Yariv et al, IEEE J. QE-10 (1974) 509.*
**** S.G. Oganesyan et al, Contr. ID: 1142 –MOOPP 36. 30-th FEL Conf., Korea, 24-29 Aug 2008.*

Nonlinear Theory of a Free Electron Oscillator (FEO) Based on a Density Matrix Approach

MOPC10

Sergei Georgii Oganesyan, George Sergey Oganesyan (LT CSC, Yerevan), Yelena Hovhannisyan (RC, Dallas)

We have considered the problem of theoretical description of FEO operation that takes into account both the saturation effect and a final lifetime of electrons crossing a Fabry-Perot resonator. If an undulator is long then only two types of the electrons are involved in the process of the energy exchange. That allowed us to describe the behavior of an electron with a density matrix of the second order. We have included both the electron number losses in the resonator and the pumping of the active medium due to the implanting of new particles in the equations for the diagonal elements of the matrix, whereas only losses occur in the equations for nondiagonal elements. The self-consistent set of the derived and Maxwell equations has been applied to nonlinear analysis of the FEO operation. The electron current has been calculated by the perturbation theory to the third order accuracy and a nonlinear equation (of the Van Der Pol type) has been obtained for the electric field strength. We have ascertained that the field saturation parameter has purely quantum nature. An expression for the output laser field amplitude has been obtained in the steady-state regime.

Phase Transitions in an Electron Beam and its Coherent Radiation

MOPC11

Raphael Tumanyan (YerPhI, Yerevan)

The possibility of electron beam phase transitions to liquid and crystalline states is considered. The physical and technical aspects of their realization are discussed. It is shown* that in such condensed states the density of the beam is periodical (ordered beam). The possibility of a new type of FEL on the base of ordered beams (oFEL) is elucidated. The laser gain of oFEL in various cases is found. It will be a great achievement to obtain the ordered states of electron beams and to use their coherent radiation as a new type of FEL.
** R.V. Tumanian, L.A. Gevorgian, Reported at NATO Workshop „Photon-Electron Interaction in Dense Media‟, Nor-Hamberd, Armenia, 24-28 Jun., 2001.*

SASE Regime of X-Ray FEL on Coherent Bremsstrahlung in a Crystal

MOPC12

Hamlet Karo Avetissian, Garnik Felix Mkrtchian (YSU), Michel Piché (Centre d'Optique, Photonique et Laser, Québec)

Coherent Bremsstrahlung (CB) in crystals, as a small-setup x-ray FEL mechanism with electron beams of moderate energies has earlier been considered by us in the high-gain regime*. In the present work, the CB of high brightness electron beams in a crystal is studied in the SASE regime, in which the initial shot noise on the electron beam is amplified over the course of propagation through a crystal. The coherence length of this process is confined by the multiple scattering of electrons with the crystal atoms, because of which the lasing threshold increases up to extremely high current densities, at which the destruction of the crystal will occur. However, if an electron beam falls on the crystal in a time less than the crystal destruction time (electron-phonon energy transfer period, which is about several hundred femtoseconds), the electron pulse will not spread significantly and the SASE process will happen before the destruction of the crystal. Hence, the SASE regime of CB in crystals may appear practically acting with high brightness electron beams of ultrashort durations, in particular, for relativistic attosecond electron pulses from a free-space laser-acceleration scheme**.
** H.K. Avetissian et al., Nucl. Instr. and Meth. A. 507, 31 (2003). ** C. Varin, M. Piche, Phys. Rev. E 74, 045602 (2006).*

Temporal and Convective Analysis of a Free Electron Laser in Helical Wiggler and Guide Magnetic Fields

MOPC13

Pankaj Kumar Mishra (University of Ottawa, Ottawa, Ontario)

The full dispersion relation obtained for a free electron laser using helical wiggler circularly polarized magnetic field and an axial guide magnetic field using particle trajectories, their interaction with electric field by method of characteristics making the treatments quite general is reduced to Raman regime approximations in case of tenuous electron beam. The temporal and convective growth rates have been compared between full dispersion relation and Raman dispersion relation in microwave region. Results show the maximum of temporal growth in full dispersion relation and Raman dispersion relation is at the same locations, whereas the maximum of convective growth rate in full dispersion relation is slightly deviated with respect to the Raman dispersion relation. The growth rates in Raman regime in both the cases are enhanced with respect to full dispersion relation for the same plasma frequency and cavity parameters.

Harmonic Generation and Sideband Instabilities in a Free Electron Laser

MOPC14

Tamer Mostafa Abuelfadl, Osman Sayed Mohammed Ahmed, Ahmed Alaa El-deen Abdelhamid Abouelsaood (Cairo University, Giza)

In this work, a nonlinear one-dimensional model for the Free Electron Laser (FEL) is presented. The model takes into account the effect of the space charge and can simulate multiple radiation frequencies which is important to study FEL harmonic generation and sideband instabilities. One of the difficulties in getting an x-ray FEL is the required ultrahigh beam energies to produce x-ray coherent radiation. A possible solution to this problem is to work at the higher harmonics instead of the fundamental. This is studied using the one dimensional model that includes harmonic generation. The possibility of linear harmonic generation for both planar and helical wigglers is studied. A powerful simple one-dimensional model which can be used to simulate off-axis harmonic radiation is studied. The harmonics generated are consistent with those occurring in the synchrotron radiation.

Coherent Smith-Purcell Radiation: Comparison Between Simulations and Experiment

MOPC15

John Thomas Donohue (CENBG, Gradignan), Jacques Gardelle (CESTA, Le Barp)

The results of the CESTA experiment that used a flat, wide, and intense beam to produce coherent Smith-Purcell radiation are compared with 2D and 3D simulations performed with the PIC code "MAGIC". The comparison provides considerable support to the paradigm proposed a few years ago by Andrews and Brau.

Numerical FEL Studies with a New Code ALICE

MOPC16

Igor Zagorodnov, Martin Dohlus (DESY, Hamburg)

We present a fully three-dimensional time-domain simulation code for free electron lasers. Compared to the existing codes, we have implemented different numerical schemes for tracking and field calculations. The equations of motion of the particles are integrated with a leap-frog scheme. The parabolic field equation is resolved with implicit Neumann finite difference scheme based on azimuthal expansion. Additionally we have implemented the open boundary condition with the help of a perfectly matched layer for parabolic equation. The last feature allows for a mesh only in the bunch vicinity. The implemented field solver is accurate and fast. We test the accuracy of the code with different numerical tests and apply the code to estimate the expected properties of the radiation in FLASH facility with 3rd harmonic module.

Harmonic Undulator Radiation and FEL Gain with Two-Peak Electron Beam Energy Distribution

MOPC17

Hussain Jeevakhan (RGPV, Bhopal), Ganeswar Mishra (Devi Ahilya University, Indore), Vikesh Gupta (KCB Technical Academy, Indore)

In the recent past harmonic undulators* are proposed for enhanced free electron laser radiation at higher harmonics. In this paper we include the important influence of beam energy spread on harmonic undulator radiation. A two-peak electron beam energy distribution** is considered to enhance the spectrum broadening and gain reduction in the harmonic undulator free electron laser.
**Hussain Jeevakhan, Vikesh Gupta, G.Mishra, IL Nuovo Cimento B, In Press 2009; G. Mishra, Mona Gehlot, Hussain Jeevakhan, Journal of Modern Optics, In Press 2009; G. Mishra, Mona Gehlot, Hussain Jeevakhan, Nuclear Instruments and Methods in Phy. Res. A, In Press 2009; V. Gupta, G. Mishra, Nuclear Instruments and Methods in Phy. Res. A, vol.574 (2007) p.150. ** F.Ciocci, G.Dattoli, Nuclear Instruments and Methods in Phy. Res. B71 (1992) p.339.*

Three Frequency Undulator Radiation and Free Electron Laser Gain

MOPC18

Sumit Tripathi, Ganeswar Mishra (Devi Ahilya University, Indore), Vikesh Gupta (KCB Technical Academy, Indore), Hussain Jeevakhan (RGPV, Bhopal)

A new three frequency undulator has been proposed*. The authors assume that the electron moves on axis in a three harmonic undulator structure. Let us consider the case of the fundamental. The intensity at this frequency will be further enhanced by the contribution from the modulation at sum-difference frequencies. The fundamental intensity will be raised. For the next odd harmonics of the fundamental, there will be contributions from the harmonic field components to produce an enhanced intensity at the third odd harmonics. At this frequency there will be further contributions from the sum-frequency. However, the intensity contributions from the sum-difference frequency will be small in comparison to the primary odd harmonics and the net result is that the third harmonic intensity will be raised. Thus the three frequency works in a similar way to that of the harmonic undulator scheme. In this paper we calculate the three frequency undulator radiation and discuss the feasibility of free electron laser operation with this undulator scheme.
** V.I.R. Niculescu et al. Rom Journ. Phy.Vol.53, Nos. 5-6, p.775-780, 2008.*

Variable Polarized Harmonic Undulator Free Electron Laser and Effect of Beam Energy Spread

MOPC19

Vikesh Gupta (KCB Technical Academy, Indore), Ganeswar Mishra (Devi Ahilya University, Indore), Hussain Jeevakhan (RGPV, Bhopal)

In the recent past, variable polarized undulators and variable polarized harmonic undulators* are proposed. The scheme consists of two identical linearly polarized magnets with high permeability shims in the gap of the undulator magnets. In this paper we include the important effects of beam energy spread on the variable polarized harmonic undulator radiation and discuss free electron laser gain. We have considered both single and two peak Gaussian beam energy distribution to calculate intensity and gain reduction. We show that the variable polarized harmonic undulator scheme compensates the undesired effects of the beam energy spread in comparison to the standard variable polarized undulator free electron laser.
** G. Dattoli, L. Bucci, Nuclear Instruments and Methods in Phy. Res. A, vol.450 (2000)p.479; G. Dattoli, L. Bucci, Optics Comm., vol.177 (2000) p.323; V. Gupta, G. Mishra, Nuclear Instruments and Methods in Phy. Res. A, vol.574 (2007) p.150; G. Mishra, Mona Gehlot, Hussain Jeevakhan, Nuclear Instruments and Methods in Phy. Res. A, In Press 2009.*

Quasilinear Saturation of the Free Electron Laser in Raman Regime — MOPC20

Amir Chakhmachi (AUT, Tehran)

A quasilinear theory is presented that describes the self-consistent evolution of the electron beam distribution function and fields in a free electron laser when the space charge wave is present. A broad spectrum of waves is assumed in order to have a relatively wide range of resonant particles. A one-dimensional helical magnetic field is considered and the analysis is based on the Vlasov-Maxwell equations. Two coupled differential equations are derived that, in conjunction with conservation laws, describe the quasilinear development by the diffusion of electrons in the momentum space. This leads to the saturation of the free electron laser instability by the plateau formation. Analytical expressions for the growth rate and for the diffusion coefficient are derived that reduce to those in the Compton regime, under appropriate conditions. By use of the linear growth rate and the diffusion coefficient, an analytical expression for efficiency in Raman regime was derived. A numerical analysis is conducted to study the effects of the spectral width of radiation and the thermal spread of the electron beam on the efficiency.

Three-Dimensional Simulation of Harmonic Up Conversion in a Two Beam Free Electron Laser Using Source-Dependent Expansion — MOPC21

Behrouz Maraghechi, Mohammad H Rouhani (AUT, Tehran)

Three-dimensional simulation of harmonic up conversion in a free electron laser amplifier operating simultaneously with two cold electron beams of different energies is presented in the steady-state regime. By using slowly varying envelope approximation, the hyperbolic wave equations can be transformed into parabolic diffusion equations. By applying the source-dependent expansion to these equations, electromagnetic fields are represented in terms of the Hermit Gaussian modes. The electron dynamics is described by the fully three dimensional Lorentz force equation in the presence of a realistic planar magnetostatic wiggler and electromagnetic fields. A set of coupled nonlinear first order differential equations is derived and solved numerically. This set of equations describes self consistently the longitudinal spatial dependence of radiation waists, curvatures, and amplitudes together with the evolution of the electron beam.

Simulation of Raman Free Electron Laser with Planar Wiggler and Ion-Channel Guiding — MOPC22

Behrouz Maraghechi, Mohammad H Rouhani (AUT, Tehran)

A one-dimensional simulation of Raman free electron laser amplifier with planar wiggler and ion channel guiding is presented. Using Maxwell‟s equations and full Lorentz force equation of motion for electron beam, a set of coupled nonlinear differential equations is derived in slowly varying amplitude and wave number approximation and solved numerically. This set of equations describes self consistently the longitudinal dependence of radiation amplitudes, wave numbers, growth rates, space charge amplitudes, and wave numbers together with the evolution of the electron beam. Due to the usage of non-wiggler averaged equation of motion, it is possible to treat the injection of the beam into the wiggler. The electron beam is assumed cold, propagates with a relativistic velocity, ions are assumed immobile and slippage is ignored. The effect of prebunching on saturation can be added to this code. Therefore no driving signal is needed. Ion channel density is varied and the results for group I and II orbits were compared with the absence of ion channel. In contrast to the axial magnetic field, this type of guiding does not produce any drifting motion.

The Relativistic High-Frequency Modes in a Cylindrical Plasma Waveguide with Helical Wiggler Field and Ion Channel Guiding

MOPC23

Masoud Alimohamadi (TMU, Tehran)

An analysis of high-frequency eigenmodes of a cylindrical metallic waveguide completely filled with a helical wiggler and a relativistic electron beam and guiding by an ion-channel is presented. A relativistic nonlinear wave equation is derived in a form including the coupling of EH, HE, HE betatron (HE−Be), and EH betatron (EH−Be) modes due to ion channel guiding and wiggler magnetic field. Six families of eigenmodes are found. The cutoff frequencies in TM, TE modes are illustrated for this configuration.

Guiding Effects on Electron Trajectories in an Electromagnetically Pumped Free Electron Laser

MOPC24

Hassan Mehdian, Ali Hasanbeigi, Saed Jafari (TMU, Tehran)

An analysis of electron trajectories for an electromagnetically pumped Free Electron Laser (FEL) in the presence of a parallel, reversed tapered axial guide magnetic field and ion-channel guiding is presented. Results of numerical calculations are presented to illustrate the effects of the tapered axial magnetic field, reversed field and the electrostatic field-generated by ion-channel, on electron trajectories. It is found that in the parallel tapered guide field, both two groups of the electron trajectories shift and remain stable. In contrast, in the reversed field configuration there is no resonant enhancement in the wiggler-induced transverse velocity and one class of trajectory is found. Using ion-channel guiding in the FEL configuration is shown that there is two groups for electron trajectories and the first part of group I orbits is unstable. Motivated by the need for stable transport of an electron beam in a FEL, a tapered axial guide field can be used rather than an ion-channel guiding.

The Evolution of a Perfect 1D Electron Beam in a SASE FEL

MOPC25

Farzin Mojtaba Aghamir, Masoud Rezvani Jalal (University of Tehran, Tehran), Massimo Ferrario (INFN/LNF, Frascati (Roma))

A one-dimensional numerical program has been developed to study the evolution of electron beams in SASE FELs. The interaction of the beam with the fundamental radiation leads to the density modulation. The energy and density modulation along with the correlation function evolution have been studied. The obtained results are in good agreement with the theoretical investigations as well as simulation works. In this article, the evolution of two mean values of bunching parameter, namely “vector mean value” and “scalar mean value” in different beam position as a function of undulator length, are investigated. It is shown that except for the end parts of the beam, the evolution of scalar mean value through the undulator is the same for all locations in the beam. However, the evolution of vector mean value is dependent on the position within the beam.

Modal Description of Longitudinal Space-Charge Fields in Pulsed-Driven Free Electron Devices

MOPC26

Yuri Lurie, Yosef Pinhasi (Ariel University Center of Samaria, Ariel)

In pulsed beam free electron devices, longitudinal space-charge fields result in collective effects leading to the expansion of short electron pulses along their trajectory. This effect restricts application of intense ultra-short electron pulses, and requests a careful theoretical description. In the present work, longitudinal space-charge fields are considered in the framework of a three-dimensional, space-frequency approach. The basic equations of the model, originally obtained as a solution of the wave equations for the electromagnetic field in a uniform waveguide, are shown to satisfy also Gauss's law. Longitudinal electric field was found in the model analytically for a point-like charge, moving along a waveguide with a constant velocity. This enables consideration and comparison of different components of the resulted longitudinal electric field, such as forward and backward going waves, near and under cut-off frequencies, and so on. Possible simplifications in evaluations of longitudinal space-charge fields in the model are discussed.

Collective Effects in Pulsed Beam Free Electron Lasers Operating in the Terahertz Regime

MOPC27

Yosef Pinhasi, Yuri Lurie (Ariel University Center of Samaria, Ariel)

Free Electron Lasers (FELs) and masers utilize distributed interaction between an electron beam and the electromagnetic field. Our space-frequency theory* is extended to consider collective effects emerging while ultra-short electron pulses are propagating in the interaction region. The total electromagnetic field (radiation and space-charge) is presented in the frequency domain as an expansion in terms of transverse eigen-modes. The mutual interaction between the electron beam and the electromagnetic field is fully described by a set of coupled equations, expressing the evolution of mode amplitudes and electron beam dynamics. The model is used for the study of radiation excitation in pulsed beam free electron lasers operating in millimeter wavelengths and terahertz frequencies. The approach is applied in a numerical particle code WB3D, simulating wide-band interaction of a free electron laser operating in the linear and non-linear regimes, and is utilized to study spontaneous and super-radiant emissions radiated by an electron bunch at the sub-millimeter regime, taking into account three-dimensional space-charge effects playing a role in such ultra short bunches.

** Y. Pinhasi, Yu. Lurie, A. Yahalom: "Space-frequency model of ultra wide-band interactions in millimeter wave masers", Phys. Rev. E 71, (2005), 036503- 1-8.*

Effects of Phase Mismatch Between Electronic Bunches and Ponderomotive Potential at the Entrance of Radiator Section in an Optical Klystron

MOPC28

Giovanni De Ninno (ELETTRA, Basovizza), Afzal Raghavi (Pnum, Mashhad)

The effect of phase mismatch between the electronic bunches and the ponderomotive wave at the entrance of the radiator of an optical klystron is studied. A one-dimensional non-linear method is employed to simulate the wave amplification mechanism during the interaction of a pre-bunched electron beam with the wiggler field of a FEL structure. The simulation is repeated for several different positioning of the electron bunches relative to the ponderomotive wave and the resulting effects are illustrated. The results indicate that both saturation length and maximum power are significantly sensitive to the position of electron bunches in the ponderomotive potential. Accordingly the optimized situations corresponding to the maximum power and minimum saturation length are specified.

Quantitative Studies of the Harmonic Emission of Free Electron Lasers — MOPC29

Giovanni De Ninno (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica), Enrico Allaria, Carlo Spezzani, Mauro Trovo (ELETTRA, Basovizza), Gianluca Geloni (DESY, Hamburg)

The off-axis harmonic emission from helical undulators is normally used in synchrotron beamlines in order to extend the covered spectral range. A similar capability is already exploited at Free Electron Laser (FEL) facilities, and will be likewise beneficial for next generation x-ray FELs. In the case of FELs, coherent harmonic emission from helical undulators is concentrated out of axis, and is very low compared to the fundamental. In this work, we further investigate the harmonic emission mechanism considering the parameters of the Elettra storage-ring FEL, operated in the “single-pass” harmonic generation configuration. We perform a quantitative analysis of the expected performance at the second and third harmonics, using both planar and helical undulators.

Tunability of a Seeded Free Electron Laser Through Frequency Pulling — MOPC30

Carlo Spezzani (ELETTRA, Basovizza), Enrico Allaria, Miltcho B. Danailov, Giovanni De Ninno (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica)

Frequency pulling is the well-known phenomenon leading to the output frequency shift in a conventional laser, when the cavity and the maximum gain frequencies are detuned. In this paper, we demonstrate that a similar mechanism is at play in a seeded Free Electron Laser (FEL), when the seed frequency (or one of its harmonics) is out of resonance. Frequency pulling thus gives the possibility of fine-tuning the FEL frequency. On the basis of numerical simulations, we provide a general formula for the FEL output frequency. Such a formula, which generalizes the one normally used when treating the frequency pulling in conventional lasers, is confirmed by experimental results obtained on the Elettra storage-ring free electron laser.

The Beam Heater and the Landau Damping: What Did We Learn from the FEL Storage Ring? — MOPC31

Giuseppe Dattoli, Elio Sabia (ENEA C.R. Frascati, Frascati (Roma)), Mauro Migliorati (Rome University, La Sapienza, Roma)

In this contribution we discuss the effect of the beam heater on FEL operation. We consider the case of Storage Ring FEL operation and in particular the mechanisms of the instability suppression induced by the onset of the FEL itself. We discuss the central role of the Landau Damping in this type of mechanism and show that the effect of the heater in high gain devices can be ascribed to almost identical mechanisms. The relevance of the Renieri limit to these problems is discussed too.

Transverse Phase-Space Evolution and FEL SASE Dynamics — MOPC32

Giuseppe Dattoli, Franco Ciocci, Alberto Maria Antonio Petralia, Concetta Ronsivalle, Elio Sabia (ENEA C.R. Frascati, Frascati (Roma)), Pier Luigi Ottaviani, Simonetta Pagnutti (ENEA-Bologna, Bologna)

We consider the problems associated with the transverse phase space evolution in FEL SASE dynamics. We consider the problem by including the phase space distribution of the single slice and discuss how the mismatch of the individual slice during the transport contributes to the laser characteristics. We also analyze the effect of the slices on the radiation phase space distribution and discuss the relevant role on the radiation coherence.

Analysis of Efficient Path-Trajectories of Electrons in FEL Using Green Function Method

MOPC33

Zhandos Berikkaliuly Seksembayev, Marat Kumisbekuly Myrzakhmet (ENU, Astana)

We investigate a Free Electron Laser (FEL) that is based on a simple scheme as an ultra-relativistic electron beam enters a strong magnetic field and turns to an angle. Due to a change of electromagnetic impulse, the ultra-relativistic electron particle radiates and comes out of the magnetic field. The outcoming beam is accelerated by the electromagnetic field to ultra relativistic speed again and the process repeats. In this type of FEL, electrons moving in a group as a beam are not symmetrically correlated and each behaves as its own. Using Non-Equilibrium Green‟s function we describe the correlation of electrons in a beam and analyze the efficient trajectory of electrons to follow in order to obtain an efficient FEL. Also we describe the radiation of such FELs. A variety of different paths and different applications of calculations in FELs have been studied.

Simulations of Terahertz Smith-Purcell Radiation Generated from the Periodical Ultrashort Bunched Beam

MOPC34

Wenxin Liu, Wenhui Huang, Chuanxiang Tang (TUB, Beijing)

The THz wave has some unique characteristics resulting in a variety of applications to medical and industrial imaging, biomedical research and material science, etc. The various schemes for generating the THz waves have been employed. At the present time, an intense interest has been raised in the Smith-Purcell devices, for which is a promising alternative in development of a tunable, compact, powerful of THz radiation source. In this paper, the radiation characteristics of terahertz (THz) Smith-Purcell radiation generated from the ultrashort electron beam are analyzed with the help of three-dimensional particle-in-cell simulation, the radiation power and energy are obtained the PIC simulation. The radiation characteristics generated from train bunches are compared with that of single bunch. The formation factors including the longitudinal and transverse are calculated. Through this study, we observe that the radiation power is enhanced and the band width can be adjusted with the train bunches.

Feasibility Study of a Compact XFEL

MOPC35

Tae-Yeon Lee, MoonSik Chae, Mungyung Kim (PAL, Pohang, Kyungbuk)

This paper discusses how compact a XFEL machine can be. The role of gun parameters is particularly studied. Other guns under development, as well as photo-cathode guns, are also discussed.

Emittance Measurements on the PSI 250 MeV Injector

MOPC36

Bolko Beutner, Rasmus Ischebeck, Yujong Kim (PSI, Villigen)

The planned PSI-XFEL facility will supply coherent, ultra-bright, and ultra-short XFEL photon beams covering a wide wavelength range from 0.1 nm to 7 nm, with nominal beam emittances in the range from 0.18 to 0.43 mm mrad. At the 250 MeV Injector test facility for the PSI XFEL the beam quality will be studied to confirm the feasibility of the XFEL requirements. In order to understand and optimise the electron beam, precise measurements of the beam properties are essential. The diagnostics setup consists of various quadrupoles for phase advance scans and a 3.5-cell FODO lattice. Included in the diagnostic setup is a transverse deflecting RF structure for longitudinal resolved measurements. In this paper the techniques for emittance and Twiss parameter reconstruction are discussed. The focus is on transport matrix inversion and tomographic phase space reconstruction using the maximum entropy algorithm. The layout of the diagnostic section, the electron optics setup, and the strategy for measurements of the emittance are presented. Data on the systematic error concerning beam size measurement errors and beam energy uncertainties complete this summary.

Electron Radiation in the Field of Running Linearly Polarized Electromagnetic Waves

MOPC37

Illya Vladimir Drebot, Yurij Grigor'ev, Andrey Yurij Zelinsky (NSC/KIPT, Kharkov)

The results of integration of the Lorentz equation for a relativistic electron in the field of the sum of linearly polarized electromagnetic waves with different frequencies running in the same direction are presented. It was shown that electron velocity is an almost periodic function of time when an electron is moving in the field of running linearly polarized electromagnetic waves. Expansion of the field radiated by the electron in the generalized Fourier series in calculating the spectral-angular distribution of the radiation intensity was used. Expressions for frequency and intensity of direct and back Compton radiation on the combinative harmonics of the external field were obtained.

A Fully 3D Unaveraged, Non-Localised Electron, Parallelized-Computational Model of the FEL

MOPC39

Lawrence Thomas Campbell, Richard Martin, Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

A new un-averaged 3D numerical model has been developed that will allow investigation of previously unexplored FEL physics. Previous 1D models have allowed exploration of the effects of amplification of coherent spontaneous emission and non-localised electron dynamics*. A 3D model was also developed based upon a mixed finite element\Fourier method**. However, due to some limitations in the parallel routines, this restricted somewhat the FEL systems the model could describe. A significantly modified version of this model is presented here which does not require a finite element description and uses only transforms in Fourier space. This allows more effective and consistent data organization across multiple parallel processors enabling larger, more complex FEL systems to be studied. Furthermore, unlike the previous 3D model which uses commercially produced numerical packages, the new simulation code uses only open-source routines which will ultimately allow it to be freely available (open-source).

** BWJ McNeil, GRM Robb & MW Poole, MPPB060, PAC, Portland, USA, 2003. ** C.K.W. Nam, P. Aitken, & B.W.J. McNeil, MOPPH025, FEL Conference, Korea, 2008*

A Two-Dimensional Vlasov-Maxwell System to Study Coherent Synchrotron Radiation Effects in the Jefferson Lab FEL

MOPC40

Gabriele Bassi (The University of Liverpool, Liverpool), Chris Tennant (JLAB, Newport News, Virginia)

Recent measurements at the Jefferson Laboratory Upgrade FEL show evidence of detrimental effects on the beam quality caused by coherent synchrotron radiation (CSR) effects. Measurements suggest that parasitic compressions in the first recirculation arc (Bates bend) contribute to the CSR-induced effects observed downstream of the final compression chicane. Due to the strong coupling between horizontal and longitudinal dynamics in the arc, a proper modeling of CSR effects requires a two-dimensional (2D) code. After the Bates bend the beam goes through full compression in a 4-dipole chicane. Here CSR effects are enhanced in the fourth dipole and a very careful study is required. We apply our 2D Vlasov-Maxwell solver to study CSR effects in these systems.

Vlasov-Maxwell Analysis of Microbunching Instability for the Single Pass Linac of the NLS Project

MOPC41

Gabriele Bassi (The University of Liverpool, Liverpool), Riccardo Bartolini (Diamond, Oxfordshire; JAI, Oxford)

Microbunching instability can play a detrimental role on FEL performance leading to beam quality degradation. A proper study of microbunching requires accurate and reliable modeling. We apply a two-dimensional Vlasov-Maxwell solver to study the microbunching instability for the single pass Linac of the NLS project.

Simulating Sub-Wavelength Temporal Effects in Seeded Free Electron Lasers Driven by Laser-Accelerated Electrons

MOPC42

Svetoslav Bajlekov, Simon Hooker (University of Oxford, Oxford), Riccardo Bartolini (Diamond, Oxfordshire)

Ultrashort electron bunches from laser-driven plasma accelerators hold promise as drivers for short-wavelength free electron lasers*. While full 3D FEL simulation techniques have been successful in simulating lasing at present-day facilities, the novel sources investigated here are likely to violate a number of widely-held assumptions. For instance the HHG seed radiation, as well as the radiation generated by the bunch, do not conform to the slowly-varying envelope approximation (SVEA) on which the majority of codes are based. Additionally, the longitudinal macroparticle binning precludes the full physics of the system from being modeled. In order to more completely simulate the arising sub-wavelength effect we have developed an unaveraged 1D time-dependent code without the SVEA. We highlight some of the additional features that these new systems present through analytical and numerical analyses. We discuss the regimes in which these effects become important, and investigate how they may be used to enhance the lasing process. Finally we outline a framework for full 3D simulation of a short-wavelength FEL driven by a laser-plasma accelerator.

** Leemans et al., Nat. Phys. 2, 696 (2006); Gruner et al., Appl. Phys. B 86, 431 (2007).*

Matlab Based Study of X-Ray Free Electron Lasers

MOPC43

Gregory Penn (LBNL, Berkeley, California), Punit R. Gandhi, Xiao-Wei Gu (UCB, Berkeley, California), Kwang-Je Kim, Ryan Roger Lindberg (ANL, Argonne, Illinois), Jonathan Wurtele (LBNL, Berkeley, California; UCB, Berkeley, California)

We undertake a systematic study of soft x-ray Free Electron Lasers (FELs) using the extended "one-dimensional" formalism developed by Lindberg and Kim*. In this formalism, the transverse profile of the laser beam is expanded using the Gauss-Hermite basis and the FEL equations are integrated over the transverse dimensions. The result is a system of equations for the particles, a slowly varying complex radiation field amplitude, and transverse mode parameters that characterize its divergence and radius. This system of ODE's has been implemented in Matlab and bench-marked against Genesis. The Matlab code is used to investigate the performance of soft x-ray FEL oscillators and amplifiers over a wide range of system parameters. In particular, the capabilities of FELs driven by high-brightness electron beams are discussed.

** R.R. Lindberg and K.J. Kim, submitted to PRST-AB (2009).*

Derivation of Bunching for Poisson Statistics

MOPC44

Robert Arthur Bosch (UW-Madison/SRC, Madison, Wisconsin), Ronald James Bosch (Harvard School of Public Health, Boston)

We derive the average and rms bunching for Poisson statistics. For a bunch with a large number of particles, the results are practically equivalent to a bunch with a fixed number of independent particles.

Effects of Energy Chirp on Echo-Enabled Harmonic Generation Free Electron Lasers — MOPC45

Zhirong Huang, Daniel Ratner, Gennady Stupakov, Dao Xiang (SLAC, Menlo Park, California)

We study effects of energy chirp on Echo-Enabled Harmonic Generation (EEHG). Analytical expressions are compared with numerical simulations for both harmonic and bunching factors. We also discuss the EEHG free electron laser bandwidth increase due to an energy-modulated beam and its pulse length dependence on the electron energy chirp.

FEL and Optical Klystron Gain for an Electron Beam with Modulated Energy Distribution — MOPC46

Gennady Stupakov, Yuantao Ding, Zhirong Huang (SLAC, Menlo Park, California)

If the energy spread of a beam is larger then the Pierce parameter, the FEL gain length increases dramatically and the FEL output gets suppressed. We show that if the energy distribution of such a beam is modulated on a small scale, the gain length can be noticeably decreased. Such an energy modulation is generated by first modulating the beam energy with a laser via the mechanism of inverse FEL, and then sending it through a strong chicane. We show that this approach also works for the optical klystron enhancement scheme. Our analytical results are corroborated by numerical simulations.

Electron Beam Quality and Stability Effects in FEL Amplifiers and Oscillators — MOPC47

Joseph Blau, William B. Colson, Robert Edmonson, Robert Alexander Neuerman (NPS, Monterey, California)

The effects of electron beam quality in Free Electron Laser (FEL) amplifiers and oscillators are studied. Simulations are used to model the combined effects of longitudinal and transverse emittance on FEL gain, extraction, and induced energy spread. Parameters for realistic electron beams from existing and proposed particle accelerators are used in the simulations. For the FEL amplifier simulations, the undulator taper rate and taper start position are optimized for each case. For the FEL oscillator simulations, the electron beam radius and optical cavity focus parameters are optimized for each case. The effects of shifting and tilting the electron beam and the mirrors are also considered.

SASE Regime of X-Ray Laser on Fast High-Density Ion Beams

MOPC48

Hamlet Karo Avetissian, Garnik Felix Mkrtchian (YSU), Michel Piché (Centre d'Optique, Photonique et Laser, Québec)

The weakness of free electron-photon interaction cross section, which causes large generation lengths of the order of several ten to hundred meters with the current x-ray FEL wigglers, can be compensated, and the quality of the output x-ray radiation can be improved with hybrid schemes of FEL and conventional atomic lasers due to the existence of bound electron states as well. It can be achieved by means of fast high-density ion beam interaction with a strong counterpropagating pump laser field or with a crystal periodic electrostatic potential*. In the present work the SASE regime of x-ray lasing on a relativistic high-density ion beam interacting with a strong counterpropagating pump laser field is investigated analytically, based on the self-consistent set of the Maxwell and relativistic quantum kinetic equations. In the considered scheme a pump wave resonantly couples only with two internal ionic levels; hence there is no requirement for an initial population inversion of the ionic levels for lasing. It is shown that the cross section of laser-ion interaction, and consequently the SASE power, is resonantly enhanced by several orders with respect to the Compton x-ray FEL**.

** H.K. Avetissian, G.F. Mkrtchian, Nucl. Instr. and Meth. A. 528, 530 (2004); ibid. 528, 534 (2004). ** H.K. Avetissian, G.F. Mkrtchian, Phys. Rev. ST AB 10, 030703 (2007).*

Volume Free Electron Laser with a "Grid" Photonic Crystal with Variable Period: Experiment and Theory

MOPC49

Alexandra Gurinovich, Vladimir Grigorievich Baryshevsky, Nikolai Anatolievich Belous, Victor Alexandrovich Evdokimov, Evgeny Alexandrovich Gurnevich, Pavel Valerievich Molchanov (Belarussian State University, Minsk)

Electrodynamical properties of a crystal-like artificial periodic structure (photonic crystal) formed by a periodically strained metallic threads have been studied both theoretically* and experimentally**. In the present paper operation of Volume Free Electron Laser using a "grid" photonic crystal with variable period is considered. Theoretical analysis of properties of the photonic crystal built from metallic threads in a cylindrical resonator is accompanied with discussion of the experimental results. Dependence of radiation output on guiding magnetic field is analyzed. Radiation spectrum and polarization for different configurations of the photonic crystal are considered.

** Baryshevsky V.G., Gurinovich A.A., NIM B252 (2006) p.92. ** Baryshevsky V.G., Belous N.A., Gurinovich A.A., Lobko A.S., Molchanov P.V., Stolyarsky V.I., Proc. of FEL2006, P.331.*

Radiation from a Laser-Plasma Accelerated Electron Beam Passing Through an Undulator

MOPC50

Romain Bachelard, Fabien Briquez, Marie-Emmanuelle Couprie, Alexandre Loulergue (SOLEIL, Gif-sur-Yvette), Giovanni De Ninno (ELETTRA, Basovizza), Marie Labat (ENEA C.R. Frascati, Frascati (Roma)), Ahmed Ben Ismail, Sebastien Corde, Jerome Faure, Guillaume Lambert, Olle Lundh, Victor Malka, Antoine Rousse, Kim Ta Phuoc (LOA, Palaiseau)

In the quest for compact FEL ultra-compact sources, a test experiment is under preparation, to couple an electron beam from a laser driven plasma accelerator, stable and tunable in energy, to an undulator. The electron beam is generated in the colliding laser pulses scheme, by focusing two short and intense laser pulses in an underdense plasma plume. The electron bunch has an energy tunable in up to a few hundreds MeV with 1% energy spread, a length 10 fs, a charge in the 10 pC range, while its radius and divergence are respectively 1 µm and 3 mrad. As a first step toward a FEL experiment, the transport and radiation through an undulator of this short and compact electron beam is studied. The spontaneous emission through a 60 cm undulator in the 40-120 nm range is presented, and criteria to reach the threshold of Self-Amplified Spontaneous Emission are discussed.

Millimeter / Submillimeter Bunching of Electrons Using an External 800 nm Laser: Laser-Induced "Narrowband Coherent Synchrotron Radiation"

MOPC52

Serge Bielawski, Clement Evain, Christophe Szwaj (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Akira Mochihashi (JASRI/SPring-8, Hyogo-ken), Miho Shimada (KEK, Ibaraki), Toshiharu Takahashi (KURRI, Osaka), Masahito Hosaka, Yoshifumi Takashima (Nagoya University, Nagoya), Toru Hara (RIKEN/SPring-8, Hyogo), Masahiro Adachi, Masahiro Katoh, Shin-ichi Kimura (UVSOR, Okazaki)

When 800 nm picosecond pulses from a Sapphire-Titanium laser interact with an electron bunch, it is well known that bunching occurs at optical wavelengths (at 800 nm and its harmonics). However, if the laser pulses are long (10-300 ps here), and present a longitudinal amplitude modulation (at a picosecond scale), this can also induce a bunching at a submillimeter / millimeter scale. Narrowband coherent THz emission by the bunched beam then occurs. An undulator is required for the laser-bunch interaction, but the narrowband emission simply occurs in downstream bending magnets (it does not require a specific radiator with periodic magnetic field). We present a detailed experimental and theoretical study of this effect in the UVSOR-II storage ring, using interaction in the FEL optical klystron. In particular, we show that the bunching can be maintained over more than one full turn in the storage ring.

Design Considerations for a Table-Top Free Electron Laser Demonstration Experiment

MOPC53

Andreas Richard Maier, Matthias Fuchs, Thorben Seggebrock (LMU, Garching), Carl Bernhardt Schroeder (LBNL, Berkeley, California), Florian Josef Gruener (LMU, München)

The rapid progress in laser-plasma electron accelerators showed the generation of stable electron beams at the GeV-scale. Recently these beams have been used to generate spontaneous undulator radiation in the soft x-ray range. The unique properties of the laser-accelerated electron beams suggest to further extend the concept to a laboratory-size Free Electron Laser (FEL). A significant reduction in size is expected by the high peak currents on the order of 10 kA. We discuss degrading effects typical for this extreme parameter regime, such as space charge and wakefield induced energy chirps. We present possible solutions and discuss a proof-of-concept experiment.

Potential of FLASH FEL Technology for Construction of a kW-Scale Light Source for the Next Generation Lithography

MOPC54

Evgeny Saldin, Evgeny Schneidmiller, Vladimir Vogel, Hans Weise, Mikhail Yurkov (DESY, Hamburg), Evgeny Syresin (JINR, Dubna, Moscow Region)

The driving engine of the Free electron LASer in Hamburg (FLASH) is an L-band superconducting accelerator. It is designed to operate in a pulsed mode with 800 microsecond pulse duration and repetition rate of 10 Hz. Maximum accelerated current over macropulse is about 10 mA, and with the energy of electrons of 1 GeV average output power is about 72 kW. Expected power of the FEL radiation generated by FLASH is about 40 W. We show that FLASH technology holds great potential for increasing average power of the linear accelerator and increase of the transformation efficiency of the electron kinetic energy to the light. Thus, it will be possible to construct FLASH-like free electron laser operating at the wavelength of 13.5 nanometer with an average power in a kilowatt range. Such a source meets the requirements to the light source for the next generation lithography (NGL).

Status of the THz / XUV Pump Probe Beamline at FLASH: Challenges and Opportunities

MOPC55

Nikola Stojanovic, Gianluca Geloni, Evgeny Saldin, Evgeny Schneidmiller, Franz Tavella, Mikhail Yurkov (DESY, Hamburg), Michael Gensch (DESY, Hamburg; Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Wolfgang Seidel (FZD, Dresden), Ulrich Schade (Helmholtz-Zentrum Berlin f Materialien und Energie GmbH, Berlin), J. Michael Klopf (JLAB, Newport News, Virginia)

At the Free electron LASer in Hamburg (FLASH) a dedicated beamline* transports coherent terahertz (THz) pulses to the experimental station at of one of the XUV beamlines. The wavelength of the THz pulses is tuneable in the range of 1.5 – 30 THz (200 – 10 µm) and the pulse durations scale from a few picoseconds down to a few hundreds of femtoseconds. The pulse energies are in the micro Joule range, rivalling that of dedicated THz-FEL facilities. A long period undulator uses the same electron bunch as the XUV undulators to generate the THz pulses. These pulses are thereby synchronized to the ultrashort XUV better than 10 fs**. In this contribution we present the current layout of the beamline. We discuss recent results of the beamline commissioning, analyzing the THz pulses with different novel techniques in the time and frequency domain. We give an outlook on the status of currently prepared first user THz pump XUV probe experiments and discuss plans for future upgrades of the beamline.

** M. Gensch et. al., Infrared Phys. Technol. 51 (2008) 423 -425. ** U. Fruehling et. al., submitted; M. Gensch et. al., submitted.*

Photon Diagnostics Requirements and Challenges at the European XFEL

MOPC56

Jan Gruenert (European X-Ray Free Electron Laser Project Team, Hamburg)

The European XFEL will provide x-ray radiation with properties that challenge diagnostics. Especially its unique pulse train structure of up to 3000 pulses of 100 fs duration, each at only 200ns spacing between neighbouring pulses, asks for new approaches to the characterization of these x-ray photons. Also, the highly intense peak power of 20 GW rules out many of the conventional techniques developed for 3rd generation SR sources. The intensity and position monitors will use the interaction of the photons with dilute gases, other online devices could also use parasitically available scattered light, while intrusive but removable detectors will be dedicated to commissioning and optimization before user runs. This is in particular the K-monochromator which ensures during the photon based undulator alignment that the magnetic gap and the phasing between modules are correctly adjusted. The paper presents an overview of the baseline components of the XFEL facility diagnostics system and the requirements to them which result from the extreme radiation conditions.

The Fundamental Coherence Limits of Free Electron Lasers

MOPC57

Avraham Gover, Egor Dyunin (University of Tel-Aviv, Tel-Aviv)

The temporal coherence of atomic maser oscillators is limited by ambient temperature (Gordon, Zeiger, Townes limit - 1955), and of laser oscillators – by quantum noise (spontaneous emission) (Schawlow, Townes limit - 1958), and so are corresponding maser and laser amplifiers. The coherence of current FEL oscillators and amplifiers is considered to be limited by the e-beam current shot-noise*. We show that at least up to optical frequencies, e-beam current shot-noise can be reduced by Collective Coulomb interaction down to the beam velocity noise limit**. Consequently, the coherence of e-beam radiators is limited in this range by the beam energy spread. At higher frequencies, it is ultimately limited by quantum noise. We present the noise phase-space transformation processes required to be operated on the e-beam transport line for minimizing FEL radiation noise output. We identify the frequency range at which they can be employed with current technology. The implications on the attainable coherence properties of seeded (HHG or HGHG) FELs will be presented as well.

** A. Gover et al. PR-A35, 164, 1987; A. Gover, FEL Prize Lecture, Berlin Jacow, 2006. ** A. Gover, E. Dyunin, PRL 102, 154801 (2009)*

Intracavity Backscattering of FEL Radiation as a Source of Positrons — MOPC58

Elio Sabia, Giuseppe Dattoli, Antonio Dipace, Marcello Quattromini (ENEA C.R. Frascati, Frascati (Roma))

We consider the possibility of exploiting a FEL oscillator device as a candidate for the production of polarized beams, to be exploited for the production of a relatively intense beam of positrons. The scheme we propose is based on the use of a FEL oscillator, driven by a 500 MeV linac and operating in the VUV region around 120 nm. The cavity and the e-beam bunch structures are designed in such a way that gamma ray beam, with energies of several tenths of MeV, is produced in an intracavity Compton backscattering process. The gamma photons are then directed on a suitable heavy metal target use as converter. We make the comparison with different schemes proposed for the CLIC injection and discuss the relative advantages and disadvantages as well.

Development of a Compact Smith-Purcell Radiation Source — MOPC59

Dazhi Li, Kazuo Imasaki (ILT, Suita, Osaka), Makoto R. Asakawa (Kansai University, Osaka)

Compact terahertz radiation sources are necessary in many applications such as biophysics, material science and industrial imaging. We are trying to develop a terahertz radiation source based on a Smith-Purcell radiation device, which is driven by a moderate energy electron beam. The electron beam is generated from Spindt cathode. The Spindt cathode used in our research contains 10,000 pairs of ultrasmall needles and gate electrodes in a 1 mm diameter area. A tiny cathode, i.e., each pair of needle and electrode, generates an electron beamlet with a diameter around 1 μm, and these tiny cathodes are arrayed with a spacing of 10 μm. The electron beam can be readily generated by applying a gate voltage of 70 V because of the high electric field on the emission needle. Electron beam emitted from the Spindt cathode are then accelerated toward the collector electrode, which is followed by the double slab type resonator. The maximum acceleration voltage is 100 kV. In this paper, we report the latest results of this research.

Chirped Pulse Amplification Using a Free Electron Laser — MOPC60

Xiaojian Shu (IAP, Beijing), Tangchao Peng (Wuhan University, Wuhan)

It is proposed that a chirped pulse can be amplified using a free-electron laser. Chirped pulse amplification (CPA) technology is one of the major ways to get a high power and ultra short FEL pulse. Linear chirped pulse amplification at single pass FEL amplifier is studied through numerical simulations using our 1D time-dependent code GOFEL-P. The processes of chirped pulses with different chirped parameters being amplified by normal FEL amplifier or the FEL amplifier with energy-chirped beam are studied. The peak power and width of the final compressed pulse with different chirped parameters have been calculated. The results show that, the normal FEL amplifier can amplify the chirped pulse, the peak power of the final compressed pulse can reach 10s GW and the width of the pulse can be 10s fs with the parameters of TTF. In the case of using the energy-chirped beam to amplify chirped pulse, the gain bandwidth of the FEL amplifier will be wider and the chirped parameter will be larger. The peak power of the final compressed pulse can even reach near 10 times larger and the width of the pulse 10 times shorter than that with normal electron beam.

Neutral Gas Aided Electron Propagation in Free Electron Lasers **MOPC61**

Jiasheng Jiang, Nelson Carreira Lopes (Instituto Superior Tecnico, Lisbon)

Electron bunches in the GeV range with femtosecond durations can be produced from laser-plasma accelerators (LPA). The bunch charge can reach up to 1 nC leading to currents over 10 kA, which opens the way to compact, high brilliance XFELs. However, applications of such high current, relativistic electron beams typically require external transport & focusing system that efficiently delivers a stable beam. In order to simplify the FEL design, an alternative to the external focusing is self-focused transport. In this work we consider a compact undulator statically filled with gas background driven with the electron beam from LPA. A basic model has been set up to analyze the feasibility of self-focused transport of typical electron bunches produced by LPA. We conclude that, for different gases and pressures, it is possible to guide GeV level, high current, nC electron bunches through without great beam loss and expansion. The ionization of the gas by the electron bunches could lead to the partial neutralization of beam space charge allowing damping beam instability injected from LPA. Finally we present a scheme of a neutral gas aided electron propagation FEL with suggested parameters.

Beam Transverse Size Effects in the OTR Spectrum as a High Resolution Diagnostic Tool **MOPC62**

Gian Luca Orlandi, Bolko Beutner, Rasmus Ischebeck, Volker Schlott, Bernd Steffen (PSI, Villigen)

Diagnostics with a transverse spatial resolution in the order or even higher than the intrinsic limit of the traditional OTR light spot imaging techniques is required for high energy and low emittance electron beams by FEL driver linac. High resolution measurements of the beam transverse size can be performed by moving the radiation detection from the space of the electron transverse coordinates to the Fourier conjugate space of the radiation angular distribution. The development of such a new diagnostic technique is related to the experimental investigation of the beam transverse size effects in the angular distribution of the OTR spectral intensity. The status of the experimental investigation of such a phenomenon at the SwissFEL project and the main features of such a new diagnostic technique will be presented.

Gun Laser Systems for the Low-Emittance SwissFEL **MOPC63**

Christoph P. Hauri, Romain Ganter (PSI, Villigen), Pierre-Marie Paul, Fabien Ple (AT, EVRY)

The SwissFEL requires an emittance in the range from 0.18 to 0.43 mm mrad. To achieve this ambitious goal we are developing a wavelength-tunable laser system providing powerful UV pulses with arbitrary temporal shape in the range of 3 - 10 ps. The system should allow exact matching of the photon energy to the work function of the cathode material and consequently the reduction of the thermal emittance. Transverse and longitudinal laser pulse shaping is foreseen to minimize nonlinear space charge forces in the electron bunch to maintain lowest emittance during acceleration. In this paper we present the design and concept of this novel laser system and show first experimental results.

New Effective Bandwidth, Energy Spread, Energy Chirp Control Method in Ultra-Compact XFEL Facilities

MOPC64

Yujong Kim, Hans-Heinrich Braun, Terence Garvey, Marco Pedrozzi, Jean-Yves Raguin, Sven Reiche (PSI, Villigen), Tsumoru Shintake (RIKEN/SPring-8, Hyogo)

Recent XFEL designs employ rather low driver-linac energies. The SwissFEL for example has a nominal electron beam energy of 5.8 GeV and a undulator length of about 60 m. For such low energy XFEL facilities, bandwidth of XFEL photon beams tends to be wide due to a large energy chirp and a large projected energy spread of the electron beams. However, with a careful choice of RF frequency, RF gradient, RF phase, and bunch compressor parameters, the bandwidth of XFEL photon beams, projected energy spread, and energy chirp can also be effectively reduced with lower energy FEL driver linacs. In this paper, we describe the effective methods used to reduce the bandwidth of XFEL photon beams down to about 0.05% and projected energy spread down to about 1.0 e-4 order even though beam energy of linac is only 5.8 GeV.

Design Considerations for a THz Pump Source at the SwissFEL

MOPC65

Anne Oppelt, Rafael Abela, Bolko Beutner, Bruce Patterson, Sven Reiche (PSI, Villigen)

A powerful THz source is being considered for THZ-pump / x-ray probe experiments at the planned SwissFEL. The source should deliver half-cycle pulses of less than 1 ps duration with an energy of 100 µJ in a focal region of 1 mm^2. Design considerations and simulations for such a source fulfilling the challenging parameter combination will be presented.

Effect of Intensive Blue Light Emission in Cold-Cathode Magnetron Electron Gun and Hypothesis of Transaction Laser in Cathode Surface

MOPC66

Sergiy Cherenshchykov, Valentin Kotsubanov, Igor Nikolskii (NSC/KIPT, Kharkov)

Extremely intensive light emission in cold-cathode magnetron injection gun was observed. The magnetron injection gun consists of a coaxial arrangement that includes a tube anode and cylinder consol cathode, located in an approximately homogeneous magnetic field. The gun generates an annular electron beam with current up to 5 A at voltage up to 20 kV and a magnetic field nearly 0.05 T in the pressure range 10-4 - 10-6 torr. A character feature of the gun performance is intensive electron bombardment of the cathode surface. The blue color of the light corresponds to the transaction radiation. But high intensive light emission is not explained by spontaneity radiation. Due to very smooth surface of cathode a surface wave mode of light radiation in the case of azimuthal direction of propagation may perform as resonator with very high quality. We propose hypothesis of laser effect nearly cathode surface for explaining extremely intensive light emission. It may correspond to novel type of laser with semi free electrons. Methods of the hypothesis checking are discussed.

Features of Induced Radiation of Relativistic Particles Under the Cherenkov Extreme Condition and the Problem of Tandem High-Energy FEL Creation

MOPC67

Mykhaylo Vysotskyy, Vladimir Vysotskii (National Taras Shevchenko University of Kyiv, Kiev)

The possibility of essential optimization of FEL is considered. The peculiarities of induced emission and absorption on the basis of relativistic particles channelling in crystals under Cherenkov extreme condition are also considered. It is shown that the correct account of quantum recoil effect at this condition leads to the possibility of realisation of several abnormal radiation effects which do not have analogues in optics. In particular possibilities of simultaneous cooling of the fast particle beam both as during radiation, as during absorption are predicted. The possibility of creation of a tandem FEL, for which the consecutive quantum emission of radiation at normal and abnormal Doppler effects leads to the restoration of the initial state of quantum system and to the possibility of multiple repeat of radiation cycle, is also predicted. It is shown that the main difficulties, which prevent direct realization of these effects in x-ray and gamma range, are connected with the necessity to use mediums with positive dispersion. Possibility of creation of such dispersion by the change of an effective medium susceptibility at radiation diffraction is considered.

Threshold Conditions and Features of X-Ray Laser Generation on Optimal Relativistic Positron Beam in Perfect Crystal Under X-Ray Bragg Condition

MOPC68

Mykhaylo Vysotskyy, Vladimir Vysotskii (National Taras Shevchenko University of Kyiv, Kiev)

The problem of realization of stimulated emission and laser generation of x-ray radiation at channeling of optimal relativistic positron beam in wide channels (like zeolite or nanotube) in a perfect crystal under Bragg condition is discussed. In this system the process of x-ray amplification is connected with stimulated transitions between the nearest energy levels of the channelling*. At such conditions the effect of both strong suppression of absorption of generated radiation and optimization of threshold conditions for beam of relativistic charged particles takes place. At the same condition the formation of distributed feedback for laser generation inside the area of stimulated inter-level radiation transitions is possible. We have calculated the threshold conditions and necessary parameters of initial beam, including energy of relativistic beam and its dispersion, density of current and angular dispersion of the beam, etc. It was shown that at the realization of such optimal (and real for the best modern accelerators) conditions the creation of x-ray free positron laser is possible in the nearest future.

** Vysotskii V.I., Kuzmin R.N. Gamma-Ray Lasers, MSU Publ. House, Moscow, 1989.*

Start-to-End Simulations of SASE and HHG-Seeded Mode-Locked FEL

MOPC69

David Dunning, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Peter Williams (Cockcroft Institute, Warrington, Cheshire; STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

Start-to-end modelling of a SASE mode-locked FEL amplifier scheme* is presented using a superconducting re-circulating linac design**. Locking of the modes is achieved by modulating the electron beam energy at the mode frequency spacing. Previous studies*** have shown that in a High Harmonic Generation (HHG) seeded mode-coupled FEL amplifier scheme (no electron beam energy modulation), although the attosecond pulse train structure of the seed is amplified through to saturation, temporal broadening of the individual pulses occurs. An HHG seeded mode-locked FEL amplifier scheme is modelled and it is seen that the temporal spikes of the HHG seed must be correctly phase-matched with the electron beam energy modulation for successful operation. By using a filtered HHG seed, which removes the seed‟s attosecond pulse train structure, no such phase matching is required. Despite the absence of an initial attosecond pulse structure, a modal structure develops and is subsequently amplified to generate an attosecond pulse train with the good temporal coherence properties of the seed, significantly shorter individual pulse widths and higher peak powers than may be achieved in the other schemes.

** N.R. Thompson, B.W.J. McNeil, Phys. Rev. Lett. 100, 203901 (2008). ** P. H. Williams et al, WE5RF, 23rd PAC, Vancouver (2009). *** B.W.J. McNeil et al, MOCAU04, 30th Int. FEL Conf., Gyeongju (2008).*

JLAMP: A Next Generation Photon Science Facility at Jefferson Laboratory — MOPC70

Fay Elizabeth Hannon (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Stephen Vincent Benson, David Douglas, Pavel Evtushenko, J. Michael Klopf, George R. Neil, Chris Tennant, Gwyn P. Williams, Shukui Zhang (JLAB, Newport News, Virginia)

Jefferson Laboratory is proposing to construct a next generation light source that capitalizes on the existing infrastructure of the Energy Recovery Linac (ERL) based Free Electron Laser (FEL) that has been operational since 1998. The new user facility, called JLAMP, will feature a two-pass superconducting linac to accelerate electron bunches to 600 MeV with the possibility of energy recovery. The photon source will be a seeded amplifier FEL that covers the 10 to 100 eV energy range, capable of providing up to seven orders of magnitude increase in average brightness over existing sources. At longer wavelengths the device will also have the option of operating as a high gain resonator for users who desire a higher repetition rate. The design options and technical challenges associated with the development of the JLAMP machine are presented here.

The ALPHA-X Beam Line: Toward a Compact FEL — MOPC71

Maria Pia Anania, David Clark, Riju Issac, Dino Anthony Jaroszynski, Albert J. W. Reitsma, Gregor Welsh, Samuel Mark Wiggins (USTRAT/SUPA, Glasgow), Ulrich Schramm (LMU, München), Marieke de Loos, Bas van der Geer, Kees van der Geer (Pulsar Physics, Eindhoven), James Clarke, Michael W. Poole, Ben Shepherd (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

Recent progress in developing laser-plasma accelerators is raising the possibility of a compact coherent radiation source that could be housed in a medium-sized university department. Beam properties from laser-plasma accelerators have been traditionally considered as not being of sufficient quality to produce amplification. Our work shows that this is not the case. Here we present a study of the beam characteristics of a laser-plasma accelerator. We also highlight the latest results on the ALPHA-X compact FEL. We show how the beam properties of the ALPHA-X beam line have been optimized in order to drive a FEL. We discuss the implementation of a focussing system consisting of a triplet of permanent magnet quadrupoles and a triplet of electromagnetic quadrupoles. The design of these devices has been carried out using the GPT (General Particle Tracer*) code, which considers space charge effects and allows a realistic estimate of electron beam properties along the beam line. The latest measurements of energy spread and emittance will be presented. Currently we have measured energy spreads less than 0.7% and, using a pepper pot, put an upper limit on the emittance of 5 pi mm mrad.

** S.B. van der Geer and M.J. de Loos, "General Particle Tracer code: design, implementation and application" (2001).*

Towards a Gamma Ray Source: from Free Electron Lasers to Betatron Sources Based on Laser-Driven Accelerators

MOPC72

Silvia Cipiccia (USTRAT/SUPA, Glasgow)

The free electron laser represents a source of coherent electromagnetic radiation with an extremely wide frequency range covering microwaves to x-rays. An alternative compact source of high brightness radiation is emission from electrons undergoing betatron oscillation in a laser driven plasma channel. When a relativistic laser, with a pulse duration shorter than the plasma wavelength, propagates through an under-dense plasma the ponderomotive force expels electrons from the laser axis leaving a cavitated region (bubble) behind the laser pulse. Electrons, expelled radially and trapped at the back of the bubble, experience both a longitudinal and transversal electrostatic restoring force that accelerates them longitudinally* while undergoing transversal oscillations. The bubble acts as a wiggler leading to emission partially spatially coherent betatron radiation. The presence of the laser field in the bubble results in resonance with the laser** and electrons can emit intense radiation at high harmonics of the fundamental frequency. The operating mechanism, harnessing and future experiment for direct measurement of the FEL-betatron radiation will be discussed.
** Mangles, S. P. D. et al. Nature 431, 535, 2004; Geddes, C. G. R. et al. Nature 431,538,2004; Faure, J. et al. Nature 431, 541, 2004. ** Pukhov, A. et al J. Phys. Plasma 6, 2847. 1999.*

Synchronized Attosecond Pulses for X-Ray Spectroscopy

MOPC73

Gregory Penn, Alexander Zholents (LBNL, Berkeley, California)

Attosecond x-ray pulses are an invaluable probe for the study of electronic and structural changes during chemical reactions. The wide bandwidth of these pulses is comparable to that of the valence electronic states, and is well suited to probing valence electron excitations using core electron transitions. We investigate a method for creating two synchronized, attosecond soft x-ray pulses in a free electron laser, through optical manipulation of electrons located in two distinct sections of the electron bunch. Each x-ray pulse can have energy of the order of 20 nJ and pulse width of the order of 300 attoseconds. The central frequency of each x-ray pulse can be independently tuned to separate core electron transition frequencies of specific atoms in the molecule. The time interval between the two attosecond pulses is tunable from a few femtoseconds to a few hundred femtoseconds with a precision better than 100 attoseconds.

Progress on Laser-Plasma Acceleration Using Spatially Tailored Plasmas

MOPC74

Carl Bernhardt Schroeder, Michael Bakeman, Eric Esarey, William M. Fawley, Cameron Guy Robinson Geddes, Anthony J. Gonsalves, Wim Leemans, Chen Lin, Kei Nakamura, Csaba Toth (LBNL, Berkeley, California)

Progress on laser-plasma acceleration experiments at Lawrence Berkeley National Laboratory (LBNL) to improve beam quality and stability for free-electron laser applications is presented. Control of the laser propagation and beam generation is obtained via tailored plasmas. Transverse shaping of the plasma distribution in hydrogen-filled discharge capillaries (plasma channel formation) is used to guide the laser over extended distances. Longitudinal shaping of the plasma distribution is used to control the trapping of background plasma electrons and bunch formation. Tailored plasmas yield improved stability and beam quality, as well as enhanced tunability. Experiments carried out using a 40 TW laser interacting with cm-scale spatially tailored plasma have demonstrated stable production of several hundred MeV electron beams. Prospects for a free electron laser driven by ultra-short (fs) laser-plasma-accelerated electron bunches is discussed, as is the design of a VUV FEL driven by the LBNL laser-plasma accelerator.

Start-to-End Simulation of a Compact Terahertz Smith-Purcell Free Electron Laser — MOPC75

Philippe Regis-Guy Piot , Christopher Robert Prokop (Northern Illinois University, DeKalb, Illinois), M.C. Lin, Peter Stoltz (Tech-X, Boulder, Colorado)

Terahertz (THz) radiation occupies a very large portion of the electromagnetic spectrum and has generated much recent interest due to its ability to penetrate deep into many organic materials without the damage associated with ionizing radiation such as x-rays. One path for generating copious amount of tunable narrow-band THz radiation is based on the Smith-Purcell Free Electron Laser (SPFEL) effect first proposed by Walsh. In this paper we present the design and start-to-end simulation of a compact SPFEL. The device is based on a low energy (20-40 keV) electron accelerator capable of producing sheet electron beams needed to enhance the SPFEL interaction. The beam tracking simulations are carried with a quasistatic particle-in-cell program (Astra from DESY) while the beam dynamics and electromagnetics of the SPFEL interaction is modeled using a finite-difference time-domain electromagnetic solver (VORPAL from Tech-X Corporation).

Compact Tunable Compton Scattering Gamma-Ray Sources — MOPC76

Fred V. Hartemann (LLNL, Livermore, California)

Recent progress in accelerator physics and laser technology have enabled the development of a new class of gamma-ray light sources based on Compton scattering between a high-brightness, relativistic electron beam and a high intensity laser pulse produced via chirped-pulse amplification (CPA). In this talk, the current state-of-the-art will be reviewed, along with important applications, including nuclear resonance fluorescence. The design of a precision gamma-ray source will also be discussed, along with the key technologies chosen for the project: X-band linac and photo-injector, photo-cathode laser pulse shaping, and hyper-dispersion CPA.

Microbunching with a Twist — MOPC77

Erik Hemsing (UCLA, Los Angeles), Agostino Marinelli, Pietro Musumeci, James Rosenzweig (UCLA, Los Angeles, California)

An electron beam subject to the canonical FEL microbunching instability is microbunched longitudinally in both density and velocity. At higher harmonic interactions, however, more exotic three-dimensional microbunching structures can be generated in which the electrons become rearranged according to the higher-order geometry of the resonant ponderomotive phase bucket. We briefly describe the analytic and practical motivations for this topic, as well as a new experimental effort designed to generate and measure the first helically microbunched e-beam.

Beyond Single Spike: FELs and Advanced Accelerators with Sub-fs Electron Pulses — MOPC78

James Rosenzweig (UCLA, Los Angeles, California)

Operation of FEL injectors with low charge, in the pC range, has been predicted to yield beams with fs duration and with brightness increased by two orders of magnitude. Further, in our studies we have found that soft x-ray SASE FELs can access the single spike regime with such pulses. Here we extend these investigations, in which single spike performance in hard x-ray FELs such as the LCLS is simulated. Further, we exploit the increased brightness using a state-of-the-art undulator to examine operation at wavelengths as short as 0.1 Ångströms. We look at some novel aspects of sub-fs beam operation, such as the generation of sub-cycle coherent optical pulses using edge or transition radiation. Finally, we examine a synergistic application use of such beams in high energy physics, in driving multi-100 GV / m plasma wakefield accelerators.

Feasibility Study for a Seeded Hard X-Ray Source Based on a Two-Stage Echo-Enabled Harmonic Generation FEL

MOPC79

Dao Xiang, Zhirong Huang, Gennady Stupakov (SLAC, Menlo Park, California), Daniel Ratner (Stanford University, Stanford, Califormia)

We propose and analyze a scheme to achieve a seeded hard x-ray source based on a two-stage Echo-Enabled Harmonic Generation (EEHG) FEL. In the scheme a 180 nm seed laser covering the whole bunch is first used to modulate the beam when beam energy is 2 GeV. After passing through a strong chicane complicated fine structures are introduced into the phase space. The beam is again modulated by a short 180 nm laser that only covers the rear part of the beam and then accelerated to 6 GeV. A weak chicane is then used to convert the energy modulation to density modulation. The density-modulated beam is sent through a radiator to generate intense 6 nm radiation which will be time-delayed to interact with the front fresh part of the bunch. Finally, we generate in the beam density modulation at the 1199th harmonic of the seed laser. We will discuss the issues related to the realization of the seeded hard x-ray FEL.

Generation of Attosecond X-Ray Pulses Beyond the Atomic Unit of Time Using Laser Induced Microbunching in Electron Beams

MOPC80

Dao Xiang, Zhirong Huang, Gennady Stupakov (SLAC, Menlo Park, California)

We propose a scheme that combines the echo-enabled harmonic generation technique with the bunch compression and allows one to generate harmonic numbers of a few hundred in a microbunched beam through up-conversion of the frequency of an ultraviolet seed laser. A few-cycle intense laser is used to generate the required energy chirp in the beam for bunch compression and for selection of an attosecond x-ray pulse. Sending this beam through a short undulator results in an intense isolated attosecond x-ray pulse. Using a representative realistic set of parameters, we show that 1 nm x-ray pulse with peak power of a few hundred MW and duration as short as 20 attoseconds (FWHM) can be generated from a 200 nm ultraviolet seed laser. The proposed scheme may enable the study of electronic dynamics with a resolution beyond the atomic unit of time (~24 attoseconds) and may open a new regime of ultrafast sciences.

Two-Chicane Compressed Harmonic Generation of Soft X-Rays

MOPC81

Daniel Ratner (Stanford University, Stanford, Califormia), Alex Chao, Zhirong Huang (SLAC, Menlo Park, California)

We propose a single-stage scheme to produce coherent soft x-ray radiation directly from a UV seed laser. Seeding an electron bunch prior to compression simultaneously shortens the laser wavelength and increases the modulation amplitude. The final x-ray wavelength is tunable by controlling the compression factor with the RF phase. Photocathode beams with large energy spreads require corresponding large modulation amplitudes, leading to strong over-bunching during compression in the first chicane. We introduce a second chicane to unwind and restore the bunching. We also show that transportation of fine compressed modulation structure is feasible due to recompression in the second chicane.

Experiment on Suppression of Spontaneous Undulator Radiation at ATF

MOPC82

Vladimir N. Litvinenko, Vitaly Yakimenko (BNL, Upton, Long Island, New York)

We propose a demonstration experiment at Accelerator Test Facility at BNL on suppression of spontaneous undulator radiation from an electron beam. We describe the method, the proposed layout and possible schedule.

Evolution of Electron Beam Phase Space Distribution in a High-Gain FEL

MOPC83

Stephen Davis Webb, Vladimir N. Litvinenko (BNL, Upton, Long Island, New York)

FEL-based coherent electron cooling offers a new avenue to achieve high luminosities in high energy colliders such as RHIC, LHC, and eRHIC. Traditional FEL treatments treat the FEL as an amplifier of optical waves with specific initial conditions, and obtain the resulting field. This new approach requires knowledge of the phase space distribution of the electron cloud in the FEL. We present 1D analytical results for the phase space distribution of an electron cloud with an arbitrary initial current profile, and discuss approaches of expanding to 3D results.

Oscillator FELs

Chair: Stephen Benson

A kW Intracavity Power Storage Ring FEL (Invited) MOOD01

Ying K. Wu (FEL/Duke University, Durham, North Carolina)

High repetition rate linacs and ERLs are preferred accelerators to drive high power FELs in the kW to hundreds of kW region. The storage ring FEL, given its well-known extracted power limit, has not been considered as a high power photon source. A high-intensity Compton gamma source requires a high-power photon source, which can be made available inside an FEL resonator. The Duke storage ring FEL has been developed as a high intracavity photon source for a world-class Compton gamma-ray source, High Intensity Gamma-ray Source (HIGS). Recently, the HIGS has reached a total flux of few 1E10 g / s at few to 10 MeV, enabled by a few-kW intracavity average power storage ring FEL. In this work, we report our recent experimental study of kW intracavity FEL operation in visible and near-IR wavelengths. In particular, we will present our novel approach to suppress wiggler power loading on the downstream FEL mirror using in-cavity apertures, a critical step to achieve kW intracavity power. We envision that this wiggler radiation power control technique be adopted by other high power resonator FELs driven by linacs and ERLs in their pursuit of further increasing the FEL power.

Progress in the Study of an X-Ray FEL Oscillator (Invited) MOOD02

Kwang-Je Kim (ANL, Argonne, Illinois)

An X-ray Free Electron Laser Oscillator (XFELO)* promises to be an ideal hard x-ray source, particularly for applications requiring high spectral purity such as Moessbauer spectroscopy and inelastic scattering. Progress has been made in several areas of XFELO study: Performance of concrete XFELO cases with tunable, four-diamond crystal cavities** in the 9 - 20 keV range was calculated using the modified GINGER code***. We measured the reflectivity of the diamond crystal at 23.7 keV to be near the theoretical value and the thermal expansion coefficient below 100 K to be small, indicating that the heat load will not adversely affect XFELO operation. A null feedback system has been implemented that stabilizes the crystal orientation to within 50 nr of the Rocking curve maximum, an encouraging first step towards achieving the <10 nr stability requirements. We are refining the conceptual design of an injector satisfying the XFELO requirements, starting from a thermionic cathode in a low-frequency rf cavity and followed by various beam filtering and manipulation stages. A 300 kV DC cathode assembly is under construction to demonstrate the production of ultralow-emittance beams.
** K.-J. Kim, Y. Shvyd'ko, and S. Reiche, PRL 100, 244802 (2008). ** K.-J. Kim and Y. Shvyd'ko, PRST-AB, 12, 030703 (2009). *** R.R. Lindberg and K.-J. Kim, submitted to PRST-AB.*

Modeling and Operation of an Edge-Outcoupled Free Electron Laser MOOD03

Michelle Diane Shinn, Stephen Vincent Benson, George R. Neil, Anne Watson (JLAB, Newport News, Virginia), Ramin Lalezari (ATF, Boulder), Peter van der Slot (Twente University, Enschede)

We report the design, and broadly tunable operation, for the first time, of a high average power free electron laser using edge-outcoupling. Using the FEL in this configuration, we achieved a maximum stable output power of 270 W at 2.53 µm, and could tune with an output of 20 W or higher from 0.8 to 4.2 µm. The output was in the form of a continuous train of sub-ps pulses at 4.68 MHz. Measurements of gain, loss, and the output mode are compared with models.

Study of Optical Frequency Chirping and Pulse Compression in a High-Gain Energy-Recovery-Linac-Based Free Electron Laser

MOOD04

Shukui Zhang, Stephen Vincent Benson, David Douglas, George R. Neil, Michelle Diane Shinn (JLAB, Newport News, Virginia)

In this paper we report a direct experimental investigation of optical frequency chirping effects induced by ultrashort electron bunches in a high-gain Energy-Recovery-Linac (ERL) Free Electron Laser (FEL) cavity. Our measurement and analysis shows clear evolution of the optical pulse chirp verses the electron bunch energy chirp. Further study also provides important evidence that under certain conditions much shorter FEL pulses can be obtained through properly chirping electron bunches and optical pulse compression. Although studies about the chirp measurement on Self-amplified-spontaneous-emission (SASE) FEL were reported recently, we believe this paper for the first time provides a comprehensive and close observation into the very unique temporal and spectral characteristics of ultrashort optical pulses from a high-gain ERL FEL. This is made possible by the stable operation and unique capability of the Jefferson Lab machine to change the electron bunch energy chirp with no curvature. Preliminary simulations will also be presented.

Short Wavelength Amplifier FELs

Chair: Jianping Dai

Lasing and Saturation of the LCLS FEL (Invited) TUOA01

Paul J. Emma (SLAC, Menlo Park, California)

The Linac Coherent Light Source (LCLS) is a SASE 1.5 - 15 Å x-ray Free Electron Laser (FEL) facility under construction at SLAC*, and presently in an advanced phase of commissioning. The injector, linac, and new bunch compressors were commissioned in 2007 and 2008, establishing the necessary electron beam brightness at 14 GeV. The final phase of commissioning, including the FEL undulator and the long transport line from the linac, began in November 2008, with first 1.5 Å FEL light and saturation observed in mid-April 2009. We report on the accelerator, undulator, and FEL operations, including the new suite of x-ray diagnostics, which have just begun commissioning.
** J. Arthur et al. SLAC-R-593, April 2002.*

Electron Bunch Compression with Dynamical Non-Linearlity Correction for a Compact FEL (Invited) TUOA02

Toru Hara, Hitoshi Tanaka, Kazuaki Togawa (RIKEN/SPring-8, Hyogo)

To realize a compact FEL facility, a high frequency accelerator is indispensable to shorten the accelerator length. Then, a high-harmonic cavity used for nonlinear correction of a beam energy chirp encounters a technological difficulty of an extremely high frequency RF system. In order to overcome this difficulty, a method of over-correction is proposed. In this method, a correction cavity is installed before any bunch compressors. Since the effective frequency of the correction cavity is increased as the electron bunch length compressed, the same RF frequency as main accelerators can be used for the correction cavity.

FEL Gain Length and Saturation Measurements for the Tapered LCLS Undulators TUOA03

Daniel Ratner, Axel Brachmann, Franz-Josef Decker, Yuantao Ding, David Dowell, Paul J. Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Richard Iverson, Henrik Loos, Alan Miahnahri, Heinz-Dieter Nuhn, James Leslie Turner, James Welch, William White, Juhao Wu, Dao Xiang, Gerald Steven Yocky (SLAC, Menlo Park, California), William M. Fawley (LBNL, Berkeley, California)

We present experimental studies of the gain length and saturation levels from 1.5 nm to 1.5 Å for a variety of conditions at the Linac Coherent Light Source (LCLS). By disrupting the FEL process with an orbit kick, we are able to measure the x-ray intensity as a function of the undulator length. This kick method is cross-checked with the method of removing undulator sections. We measure the FEL gain length as a function of x-ray wavelength, laser-heater induced energy spread, beta function and peak electron current. We also study the x-ray intensity level and FEL-induced electron energy loss after saturation as a function of undulator K value to determine the optimal taper. The experimental results are compared to analytical formulae and simulations.

Design and R&D Progress of the SDUV-FEL — TUOA04

Zhentang Zhao, Yongzhong Chen, Zhimin Dai, Haixiao Deng, Qiang Gu, Dongguo Li, Dong Wang, Kairong Ye, Minghua Zhao, Xiaofeng Zhao, Qiaogen Zhou (SINAP, Shanghai)

The SDUV-FEL is a HGHG-based FEL test facility under development at the SINAP campus. It was designed as a single stage HGHG-FEL driven by a 300 MeV linac in the beginning, but now it is being integrated towards a two stages of cascading HGHG driven by a 160 MeV linac. In this paper, we present the design progress and report the R&D status of the photo cathode RF gun, the magnetic bunch compressor and the undulators for this test facility.

Current Status of X-Ray FEL Project at SPring-8 — TUOA05

Tsumoru Shintake (RIKEN/SPring-8, Hyogo)

XFEL/SPring-8 is SASE-FEL project aimed at generating an intense coherent x-ray beam, which uses the thermionic gun with velocity bunching injector, 8 GeV normal conducting C-band accelerator, followed by 80 m long in-vacuum undulators*. Those key components have been verified at the SCSS test accelerator. Target wavelength is 1 Ångström at 8 GeV beam and peak power level 20 GW. Machine construction is going well. Schedule is as follows: March 2009: Building construction completed; April 2009 - September 2010: Hardware installation; October 2010: High power operation of RF system and check; April 2011: Beam commissioning of x-ray FEL. We have great opportunity to apply feedback in design from our experiences in daily operation of the SCSS test accelerator (VUV SASE-FEL for user application). The talk covers those updated design work and current status of mass production of 400 m long C-band accelerator system and undulators.

** http://www.riken.jp/XFEL/eng/index.html.*

New & Emerging Concepts

Chair: Ingolf Lindau

Towards Table-Top FELs (Invited) TUOB01

Florian Josef Gruener (LMU, München), Carl Bernhardt Schroeder (LBNL, Berkeley, California), Matthias Fuchs, Andreas Richard Maier, Thorben Seggebrock (LMU, Garching)

Recent breakthroughs in the field of laser-plasma electron accelerators have led to intrinsically ultrashort (supposedly ~5 fs rms) electron beams with energies on the GeV-scale. In these accelerators, a high-power laser beam is focussed into a gas target and excites a plasma wave, whose fields can accelerate electrons to ultrarelativistic energies over distances of only a few centimeters. Owing to their unprecedented features, these electron beams are suited for driving a next generation of ultrashort x-ray light sources. Both spontaneous undulator light sources with femtosecond to attosecond pulse duration and, later, FEL-emission could be realized on a laboratory-sized scale. In this talk, we will present the first experimental breakthroughs towards this end, manifesting itself in a laser-driven soft x-ray undulator source. We will also discuss a design for a first table-top FEL demonstration experiment.

X and Gamma Ray Source Using Laser Plasma Wakefield Accelerators (Invited) TUOB02

Dino Anthony Jaroszynski, Maria Pia Anania, Enrico Brunetti, Sijia Chen, Silvia Cipiccia, Bernhard Ersfeld, John Farmer, Mohammad Ranaul Islam, Riju Issac, Gaurav Raj, Albert J. W. Reitsma, Richard Peter Shanks, Gregory Vieux, Gregor Welsh, Samuel Mark Wiggins, Xue Yang (USTRAT/SUPA, Glasgow), João Dias, Nuno Lemos, Luis O. Silva (GoLP, Lisbon), Rodolfo Agüero Bendoyro, Frederico Fiuza, Michael Marti, Joana Martins (Instituto Superior Tecnico, Lisbon), Simon Hooker (OXFORDphysics, Oxford, Oxon), Michael W. Poole (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Peta Foster, Rajeev Pattathil (STFC/RAL, Chilton, Didcot, Oxon), Allan MacLeod (UAD, Dundee), William Allan Gillespie (University of Dundee, Nethergate, Dundee, Scotland), Dzmitry Maneuski, Val O'Shea (University of Glasgow, Glasgow), Nicolas Bourgeois, Thomas Ibbotson (University of Oxford, Oxford)

We describe the latest results to develop brilliant incoherent and coherent radiation sources based on laser-plasma wakefield accelerators. We demonstrate both experimentally and theoretically a brilliant gamma ray sub 10 femtosecond source based on betatron radiation in the plasma density wake trailing behind an intense laser pulse. Furthermore, experimental and theoretical progress towards a compact free electron laser based on a laser-plasma wakefield accelerator will be discussed.

An Intense kHz and Aberration-Free Two-Colour High Harmonic Source for Seeding FELs from EUV to Soft X-Ray Range — TUOB03

Guillaume Lambert, Julien Gautier,Jean-Philippe Goddet, Tatiana Marchenko, Gilles Rey, Maxime Ribiere, Stephane Sebban, Fabien Tissandier, Constance Valentin, Philippe Zeitoun (LOA, Palaiseau), Marta Fajardo, Anna Sardinha (GoLP, Lisbon), Christoph P. Hauri (PSI, Villigen)

Free electron lasers have been recently evolving very fast in the extreme-ultraviolet to soft x-ray region. Once seeded with high harmonics, these schemes are considered as next generation soft x-ray light sources delivering ultrashort pulses with high temporal and spatial coherence. Here we present a detailed experimental study of a kHz two-colour (fundamental + second harmonic) high harmonic generation and investigate its potential as a suitable evolution of the actual seeding sources. It turns out that this source (both odd and even harmonics) is highly tuneable, and delivers intense radiations with only one order of magnitude difference in the photon yield from 65 nm to 13 nm. We also observed an astonishing aberration-free character of these harmonics (aberration below λ / 17 rms at 44 nm). Finally, the variable linear polarization of the harmonics was revealed to be easily controllable with the generation conditions. Then, the implementation of this technique on seeded FELs would allow amplifications, with perfect beam quality, to be achieved at wavelengths shorter than previously accessible.

Critical Issues in the Coherent Single Spike Mode Operation with Low Charges — TUOB04

Yujong Kim, Hans-Heinrich Braun, Terence Garvey, Marco Pedrozzi, Jean-Yves Raguin, Sven Reiche, Thomas Schilcher, Volker Schlott (PSI, Villigen)

Recently, several groups suggested a new FEL operation mode with low single bunch charge to generate sub-fs long longitudinal coherent XFEL photon pulses, so called single spike lasing mode. At PSI, we studied this mode to generate single spike XFEL photon beams at 1 nm and 0.1 nm. We report several critical issues which we found with such an operation mode, namely, ultra-tight RF jitter tolerances, alignment tolerances, and challenging beam diagnostic specifications for the stable single spike lasing mode.

Suppression of Short Noise and Spontaneous Radiation in Electron Beams — TUOB05

Vladimir N. Litvinenko (BNL, Upton, Long Island, New York)

Short noise in electron beam distribution is the main source of noise in high-gain FEL amplifiers ranging single- and multi-stage HGHG FEL to FEL amplifier for Coherent Electron Cooler. This noise also imposes a fundamental limit on FEL gain to about six orders of magnitude, after which SASE FEL does saturate. There is a number of advantages can be gain if short noise in the electron beam and corresponding spontaneous radiation are strongly suppressed. A traditional passive method used in low-energy microwave electronic devices* has a number of significant limitations and hardly can be used for highly inhomogeneous beams used in modern high gain FELs. In this paper we present a novel active method of suppressing the short noise in relativistic electron beams by many orders of magnitude. We present theoretical description of the process, the fundamental limitation of the process. We also discuss potential experiment demonstrating the proposed technique.

** I.e. waiting for plasma oscillation to transfer short noise in the density distribution into the velocity noise. This technique is very successful for low-energy DC beams with constant peak current.*

Tuesday Poster Session

SUPA Tutorial by Paul Emma

Emittance Dilution of Cavity Random Tilts in XFEL Linac — TUPC01

Bagrat Grigoryan, Vasili Mkrtich Tsakanov (CANDLE, Yerevan), Winfried Decking (DESY, Hamburg), Andranik Tsakanian (Uni HH, Hamburg), Ilona Margaryan (YSU, Yerevan)

The emittance preservation of the electron beam in linear accelerator for X-ray Free Electron Lasers (XFEL) is one of the stringent requirements to obtain the design goals of the facility. The cavity random tilts induce the beam coherent oscillations along the linac and lead both the wakefield and chromatic emittance dilution of the beam. In this paper, the beam chromatic and wakefield emittance dilutions in long linear accelerator with randomly tilted cavities are studied. The analytical formulas for emittance dilution are evaluated using two-particle model of the beam. The tracking simulation results for European XFEL project are compared with the analytical predictions.

Energy Bandwidth Enhancement by Dispersion Correction at FLASH — TUPC03

Eduard Prat, Winfried Decking, Torsten Limberg (DESY, Hamburg)

This paper studies the impact of transverse dispersion on the SASE radiation power sensitivity with respect to the electron beam energy off-set. Both measurements and simulations are presented. By correcting the spurious dispersion inside the undulator region, the electron beam energy bandwidth is increased considerably, which decreases the SASE power jitter due to electron energy fluctuations.

Beam Tilt at the First Bunch Compressor at FLASH — TUPC04

Eduard Prat, Christopher Gerth, Kirsten Elaine Hacker (DESY, Hamburg)

At the Free electron LASer in Hamburg (FLASH), when the electron beam is accelerated some degrees off-crest (typically 8 or 9 degrees) in the first accelerator module as during SASE operation, a correlation between the longitudinal position and the beam energy is induced. Between the second and the third dipole of the first bunch compressor (BC), the horizontal beam position correlates linearly to the beam energy. Therefore, with additional vertical dispersion, the beam is tilted in the x-y plane in the region between the second and the third dipole of the BC. Due to this effect, the projected vertical emittance is increased. This paper studies in a systematic way how vertical dispersion tilts the beam at the BC and causes an increase of the vertical emittance. The dispersion is generated by applying vertical trajectory bumps through the first accelerator module.

New Generation for High-Voltage-All-Solid-State-Modular-Power-Supplies HiVoMoPS for FEL Applications

TUPC05

Maik Hohmann (Transtechnik, Holzkirchen)

The High-Voltage-all-solid-state-Modular-Power-Supplies HiVoMoPS-concept is a patented solution for a solid state Klystron Modulator or High-Voltage Power supply, as a special type of Marx-Generator. In applications for klystron modulators like the XFEL-project (especially the 3th-harmonics, or main klystron supply), the biggest advantages are that the pulse length for the klystrons can change between 0.5ms (or shorter) to 3.0ms, repetition rate can be up to 30Hz (or higher) by up to 50kV (or higher, >100kV), and the pulseform can be changed by additional submodules and software features. Additional advantages for this HiVoMoPS are no kind of pulse transformer, bouncer circuits or crowbar circuits.

Electron Bunch Momentum Distribution Modulations at PITZ

TUPC07

Marc Hänel (DESY Zeuthen, Zeuthen)

The Photo Injector Test facility at DESY, Zeuthen site, PITZ, develops and optimizes high brightness electron sources for free electron lasers such as FLASH and the European XFEL. In last year"s shutdown period, different components of the facility have been upgraded. One of the key upgrades was the installation of a new laser system with a larger spectral bandwidth. This allows for rise- and fall-times of less than 2 ps of the temporally flat top laser pulses having a FWHM of up to 25 ps. In this paper we report on the investigations of modulations in the electron bunch momentum spectra when modifying parameters of the laser system such as bandwidth or longitudinal pulse shape.

Recent Emittance Measurement Results for the Upgraded PITZ Facility

TUPC09

Sakhorn Rimjaem, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Marc Hänel, Yevgeniy Ivanisenko, Mikhail Krasilnikov, Marek Otevrel, Bagrat Petrosyan, Sabine Riemann, Juliane Roensch, Roman Spesyvtsev, Frank Stephan (DESY Zeuthen, Zeuthen), Klaus Floettmann, Sven Lederer, Siegfried Schreiber (DESY, Hamburg), Dieter Richter (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Galina Asova, Lazar Staykov (INRNE, Sofia), Andrey Shapovalov (MEPhI, Moscow), Grygorii Vashchenko (NSC/KIPT, Kharkov), Levon Hakobyan, Martin Avetic Khojoyan (YerPhI, Yerevan)

The Photo Injector Test facility at DESY, Zeuthen site, (PITZ) develops and optimizes high brightness electron sources for Free Electron Lasers (FELs) like FLASH and the European XFEL. The PITZ facility was upgraded towards the next stage during the shutdown period in year 2008. A new 1.6-cell L-band RF gun cavity treated with improved surface cleaning technique, a new photo cathode laser system with broader spectral bandwidth for allowing shorter rise- and fall-times of the temporal flat-top distribution, and several new diagnostics components have been installed. Since the transverse emittance is a key property of high brightness electron sources, a major part of the measurement program at PITZ is devoted to the transverse phase space optimization. The recent results of emittance measurements using the upgraded facility will be reported and discussed in this contribution.

The Main Beam Dump Transfer Line for the FERMI@ELETTRA Linac

TUPC10

Ornella Ferrando, Emanuel Karantzoulis (ELETTRA, Basovizza)

A beam dump transfer line (Main Beam Dump TL) has been designed to transport the electrons from each FERMI radiator to the beam dump. The line matches the e-beam optics from the end of the undulator chains of FEL1 and FEL2 for all photon wavelengths and polarizations required by the FERMI project. The transfer line is also equipped with different types of instrumentation to characterize the beam in terms of emittance, energy spread and jitter of the electron bunches and so demands a flexible optics interchangeable between measurements and normal operations. The line may also accommodate a coherent infrared source with particular requirements on the optics. The beam optics, the line design, and the various operating modes will be presented and discussed.

Laboratory Characterization of Electro Optical Sampling (EOS) and THz Diagnostics for FERMI by Means of a Laser Driven Pulsed THz Source

TUPC12

Marco Veronese, Mario Ferianis (ELETTRA, Basovizza), Daniele Filippetto (INFN/LNF, Frascati (Roma)), Steven Jamison (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

EOS and coherent radiation based diagnostics of sub-psec electron bunches, are adopted diagnostics for FERMI and other 4th generation light sources. Both kind of diagnostics deal with materials properties in the THz spectral range. As a consequence they present similar needs in terms of characterization of the spectral response and properties of the used materials and components. To perform a laboratory characterization of such materials in this spectral range is a non trivial task, often only possible with CW sources. The extensive use of fsec lasers in the accelerators field has recently made available laboratory pulsed THz sources. In this paper we report about measurements with THz pulses produced with photoconductive emitters and optical rectification. Our main goal was the characterization of EO crystals such as ZnTe and GaP as well as of THz windows, materials and detectors. Good agreement is found between experimental results and theoretical calculations.

The Alignment of the SPARC Facility

TUPC13

Marco Esposito, Marco Paris, Francesco Sgamma, Sandro Tomassini, Mauro Troiani (INFN/LNF, Frascati (Roma))

The SPARC project is a collaboration between ENEA and INFN on an R&D activity oriented to the development of a high-brightness photoinjector to drive SASE FEL experiments. Tolerances for the alignment of the accelerator components were very tight and it has been quite a challenge to obtain them using standard techniques and instruments such as optical levels, theodolites and laser trackers. A description of the alignment and fiducialisation procedures of the accelerator components is presented.

Characterization of Pure Permanent Magnet Blocks for Undulators in 4th Generation Light Sources

TUPC14

Mauro Zambelli, Mirko Kokole, Tadej Milharcic (KYMA, Trieste), Bruno Diviacco (ELETTRA, Basovizza), Giorgio Soregaroli, Marco Tedeschi (Euromisure srl, Pieve S. Giacomo (CREMONA))

Today‟s forefront of light source facilities is represented by the so-called 4th generation light sources, i.e. linear accelerators of electrons named “Free Electron Lasers” or “FELs”. In FELs, electrons are not accumulated in a storage ring, but they are generated and accelerated with a “single-pass” process. In these conditions the only possibility of generating light is through the use of long chains of undulators. The characteristics and performances of the magnetic material used in undulators is pushed to the limit of the available technology. In spite of the high accuracy of manufacturing, these magnet blocks must be further characterised one by one and appropriately coupled in order to achieve optimal uniformity of magnetic characteristics of the finished undulator. This presentation illustrates the work carried out at the Elettra light source facility of Sincrotrone Trieste SCpA (ST) and at Kyma (spin-off company of ST) in order to characterize pure permanent magnet blocks used in manufacturing of undulators for the next 4th generation facility being built at the Basovizza site of ST, i.e. the new free electron laser called “FERMI@Elettra”.

A Probe Laser Source for Single-Shot EO-Based 3D Bunch Charge Distribution Monitor

TUPC15

Shin-ichi Matsubara (RIKEN/SPring-8, Hyogo), Hiromitsu Tomizawa (JASRI/SPring-8, Hyogo-ken), Akira Maekawa (The University of Tokyo, Ibaraki-ken)

High-brightness electron bunches are required with low slice emittance and bunch length of 30 fs (FWHM) in a targeting lasing part for XFEL/Spring-8. In order to obtain maximum brightness, it is very important to measure 3D bunch charge distribution (BCD) in real-time for future x-ray light sources (XFEL, ERL, etc). Therefore, we are developing a single-shot, non-destructive, and real-time 3D-BCD monitor based on Electro-Optical Sampling with a manner of spectral decoding. The monitor system requires for a probe laser source to realize a higher temporal resolution. The laser source has a broad spectrum of over 400 nm width and a linear-chirp of over 3,000 fs2 to be few ps pulse duration. Then, the shape in the frequency regions is rectangular. The liner-chirp is supplied by using a broadband AO-modulator (DAZZLER) which is possible to remove higher order dispersions. The laser pulses will be amplified to be micro-joule pulse-energy with a manner of NOPA. The laser source with such as the properties is mentioned in this report. We expect the feasibility of 20 fs temporal resolution by using this laser source with an organic crystal such as a DAST crystal.

Effects on Emittance Asymmetry Caused by Asymmetry Fields of Travelling Wave Accelerator Structure

TUPC16

Akihiko Mizuno, Hideki Dewa, Hirofumi Hanaki, Tsutomu Taniuchi, Hiromitsu Tomizawa (JASRI/SPring-8, Hyogo-ken)

Generally, vertical and horizontal emittance asymmetry is recognized as one of the problems of the high brightness, low emittance electron source like photo-cathode RF gun. As for the SPring-8 photo-cathode RF gun, the asymmetry also exists; the vertical emittance is always bigger than the horizontal one. We have tackled this problem for several years and been eliminated some causes. Though, the asymmetry still remained. We calculated 3D electro-magnetic fields data of S-band travelling accelerator structure by MW STUDIO and calculated emittance by self-made 3D particle tracking code using these data. As a result, radial displacement of the magnetic field from mechanical center in a coupler cell of the accelerator structure is turned out to be one of the cause of these asymmetry. Though a slice emittance in the bunch keep constant, projected emittance of the whole bunch becomes worse in the coupler cell, since the fields' displacement effect on the each slice emittance is changed with RF time evolution. In the paper, we show simulation results and comparative discussion with experimental results.

Development of a 500 kV Photo-Cathode DC Gun for the ERL Light Sources in Japan

TUPC17

Nobuyuki Nishimori, Ryoichi Hajima, Hokuto Iijima, Ryoji Nagai (JAEA/ERL, Ibaraki), Masao Kuriki (HU/AdSM, Higashi-Hiroshima), Yosuke Honda, Tsukasa Miyajima, Toshiya Muto, Masahiro Yamamoto (KEK, Ibaraki), Makoto Kuwahara, Tsutomu Nakanishi, Shoji Okumi (Nagoya University, Nagoya)

Energy Recovery Linac (ERL) based next generation light sources such as x-ray oscillators require a high brightness electron gun. We have developed a 500 kV, 10 mA photocathode DC gun by the collaboration efforts of JAEA, KEK, Hiroshima Univ. and Nagoya Univ. A segmented cylindrical ceramic insulator with guard rings is employed to improve stability and robustness at high voltage operation by keeping secondary electrons away from the ceramic surface. A Cockcroft-Walton power supply is installed in a SF6 tank and a high voltage test up to 550 kV was successfully done. All the vacuum chambers are made of chemically polished titanium alloy with very low out-gassing. A photocathode preparation system was assembled and vacuum test is performed. An up-to-date status of the gun development will be presented in detail.

Development of a Thermionic Triode RF Gun

TUPC18

Kai Masuda, Mahmoud Abdel Aziem Bakr, Keisuke Higashimura, Toshiteru Kii, Ryota Kinjo, Hideaki Ohgaki, Taro Sonobe, Satoshi Ueda, Kyohei Yoshida (Kyoto IAE, Kyoto)

A triode RF gun* is being developed, which is aimed at a drastic reduction of electrons back-streaming and hitting the thermionic cathode. Thermionic RF guns in general show advantages over photocathode guns such as low cost, easy operation and high averaged current (high repetition rate), which are suitable for FELs for various uses. They do, however, suffer from the electron back-bombardment resulting in limited macro-pulse duration of several micro seconds. In order to reduce the back-streaming electrons, the triode RF gun employs an RF cavity much shorter (e.g. ~2 mm) than the RF wavelength as the first cell with a thermionic cathode. The phase and amplitude of the RF field in the first short cell are then controlled independent from the successive cells. We have designed a triode RF gun and fabricated the additional short RF cavity which is to be installed in the S-band 4.5-cell RF gun used in the KU-FEL. The results from PIC simulations showed that the back-bombardment power is expected to reduce drastically by more than 80% without any loss of beam brightness. Preliminary results from the cold testing and RF conditioning of the additional cavity will be also presented.
** K. Kanno et al., Japanese J. Applied Physics 41 (2002) 62-64, and K. Masuda et al., Proc. of 27th Intnl. FEL Conf. 2005 (2006) 588.*

Design Study of THz & VUV Coherent Source by Laser Seeding at UVSOR-II

TUPC19

Takanori Tanikawa (Sokendai, Okazaki, Aichi), Masahito Hosaka, Yoshitaka Taira, Naoto Yamamoto (Nagoya University, Nagoya), Masahiro Adachi, Masahiro Katoh, Heishun Zen (UVSOR, Okazaki)

Light source technologies based on laser seeding are under development at the UVSOR-II electron storage ring. In the past experiments, we have succeeded in generating coherent THz radiation with various spectral properties and coherent DUV radiation with various polarizations. We carried out these experiments by utilizing a part of the existing free electron laser system and an SR beam-line opened for users. Last year, we started a new five year project, which contains construction of new undulators and beam lines dedicated to the source developments and also upgrade of the laser system. We have designed the seeding laser system and the undulators based on numerical simulations. A spectrometer for VUV has been constructed. A seeding light source based on HHG is under development. In this presentation, we report the results from the design studies and the preliminary experiments.

Development of a Photocathode RF Gun for an L-Band Electron Linac — TUPC20

Shigeru Kashiwagi, Kenichiro Furuhashi, Goro Isoyama, Ryukou Kato, Yutaka Morio, Yoshikazu Terasawa (ISIR, Osaka), Masao Kuriki, Chie Shonaka (HU/AdSM, Higashi-Hiroshima), Hitoshi Hayano, Harue Sugiyama, Junji Urakawa, Ken Watanabe (KEK, Ibaraki)

We have begun the development of an L-band photocathode RF gun for the 40 MeV L-band linac at ISIR, Osaka University to advance studies such as FEL and pulse radiolysis experiments in the future with the high-intensity and low emittance electron beam. Before the RF gun is installed at Osaka University, we plan to develop and commission the L-band RF electron gun for the Superconducting RF Test Facility (STF) at High Energy Accelerator Research Organization (KEK). While waiting for delivery of an RF cavity and an input coupler from the Fermi National Accelerator Laboratory, we have fabricated a test RF gun cavity and a coaxial input coupler made from Aluminium and investigated the RF properties of them. The resonant frequency and field balance of the real RF gun cavity have been adjusted using a tuning apparatus at KEK-STF. Some results of the development are reported, including the tuning of RF characteristics of the cavity, design of an input coupler and solenoid magnet for emittance compensation, and computer simulation for characteristics of the accelerated electron beam.

Transverse Slice Emittance Measurements of High-Brightness Electron Beams — TUPC21

Ryukou Kato, Kenichiro Furuhashi, Goro Isoyama, Shigeru Kashiwagi, Yutaka Morio, Yoshikazu Terasawa (ISIR, Osaka)

The performance of the free electron laser based on self-amplified spontaneous emission strongly depends on time-sliced characteristics of the electron beam, such as longitudinal charge distribution, slice energy spread and transverse slice emittance. We have developed a longitudinal phase space measurement system consisted of a Cherenkov radiator, a bending magnet and a streak camera and reconstructed the longitudinal phase-space image of the high brightness electron beam accelerated by the L-band electron linac at ISIR, Osaka University*. Using a quadruple magnet instead of the bending magnet, this technique can be applied to measure the transverse slice emittance of the electron beam. A few slice emittance measurement techniques were already studied and turned into actual utilization; however our idea provides a simpler and more convenient technique. This paper describes a design conceptual of the slice emittance measurement system.

** R. Kato et al., "Study on Longitudinal Phase-space of High-brightness Electron Beams at ISIR, Osaka University Proceedings of EPAC"08, Genoa, Italy, June 23 - 27, 2008, pp.1161-1163.*

Beam Property of Independently Tunable Cells (ITC) Thermionic RF Gun — TUPC22

Hiroyuki Hama, Ken-ichi Nanbu, Fujio Hinode, Masayuki Kawai, Fusashi Miyahara (Tohoku University, Sendai)

A thermionic RF gun has been developed at Laboratory of Nuclear Science, Tohoku University. The gun is specially designed in order to produce very short electron bunch by manipulating longitudinal phase space. The ITC RF gun is consisted with two independent cells so that the relative strength of accelerating field and RF phase can be varied*. Because of a bunch compression scheme (alpha-magnet, off-crest acceleration and magnetic chicane) requires proper initial phase space distribution toward the shortest bunch length, the freedom for the longitudinal phase space of the ITC RF gun is significant. We report some experimental results obtained the first beam extraction from the ITC RF gun, and discuss prospect for femto-second electron beam that is crucial for production of coherent THz radiation.

** T. Muto et al., "COHERENT THz LIGHT SOURCE USING VERY SHORT ELECTRON BUNCHES FROM A THERMIONIC RF GUN", Proc. 29th Int. FEL Conf., Novosibirsk, Russia (2007).*

Femto-Second Profile Monitor Using Pulsed Laser Storage in an Optical Cavity — TUPC23

Kazuyuki Sakaue (RISE, Tokyo)

We have been developing a pulsed-laser storage technique in a super-cavity for compact x-ray sources. The pulsed-laser super-cavity enables to make high peak power and small waist laser at the collision point with the electron beam. Recently, using 357 MHz mode-locked Nd:VAN laser pulses which stacked in a super-cavity scattered off a multi-bunch electron beam, we obtained a multi-pulse x-rays through the laser-Compton scattering. Detecting an x-ray pulse-by-pulse using high-speed detector makes it possible to measure the three-dimensional beam size with bunch-by-bunch scanning of the laserwire target position and pulse timing. This technique has a feasibility of measuring femto-second bunch length by stacking femto-second pulse in an optical cavity. Design study of femto-second laserwire monitor and the experimental demonstration using pico-second pulse storage and multi-bunch electron beam will be presented at the conference.

Development of an S-Band RF Deflector at IHEP — TUPC24

Jianping Dai, Jingru Zhang (IHEP Beijing, Beijing)

Transverse RF deflectors are widely used for the measurements of ultra-short bunch length and other slice parameters. This paper presents the development of an S-band LOLA-type RF deflector and the bunch length measurement of the electron beam produced by the photocathode RF gun of Shanghai DUV-FEL facility. The deflector"s VSWR is 1.06, the whole attenuation 0.5 dB, and the bandwidth 4.77 MHz for VSWR less than 1.1. With laser pulse width of 8.5 ps, beam energy of 4.2 MeV, bunch charge of 0.64 nC, the bunch lengths for different RF input power into the deflector were measured, and the averaged rms bunch length of 5.25 ps was obtained.

A 6.5 cm Period Electromagnetic Modulator Using Sheet Copper for the Coils in SDUV FEL — TUPC25

Miao Zhang (SINAP, Shanghai)

An inexpensive electromagnetic modulator, developed in SDUV FEL, has ten 6.5 cm periods with maximum field of 0.4 T and gap of 1.2 cm. The coil design uses copper sheet material cut to serpentine shapes and is assembled in stacks insulated with polymer film. The coils are conduction cooled with imbedded cooling water tubes. Details of construction, measurement methods and excellent wiggler performance are presented.

Design Study for 0.1 nm X-Ray Free Electron Laser at PAL — TUPC26

Eun-San Kim (Kyungpook National University, Daegu), Moohyun Yoon (POSTECH, Pohang, Kyungbuk)

We present the results on design study for SASE-FEL at PAL that consists of a 10 GeV linac and 100 m long undulator. A S-band linac with a 550 m long is designed to provide the optimal beams for the radiation of the wavelength of 0.1 nm in the 100 m long undulator. With the careful choices of beam and accelertaor parameters, the start-to-end tracking simulations show the radiation power of around 6 GW in the in-vacuum undulator with 5.3 mm full gap. We also show sensitivities of the beam parameters due to RF jitters in the system and optimal beam parameters for a low-charge option.

Status and Prospect on Laser-Driven Electron Acceleration at KAERI for Nuclear Applications

TUPC27

Seong Hee Park, Yong-Ho Cha, Young Uk Jeong, Byung Cheol Lee, Ji Young Lee, Kitae Lee, Yong Woo Lee, Kwon-Hae Yea (KAERI, Daejon)

A 30 TW Ti:Sapphire laser system with energy of 1 J and pulse width of 30 fs has developed at KAERI for the generation of laser-induced protons, neutrons, and electrons for nuclear applications. Recently, the generation of quasimonoenergetic electron beams in a self-injected laser-wakefield accelerator was investigated at KAERI. The laser beam was focused on a He gas jet target using an off-axis parabola (OAP) mirror with a focal length of 272 mm. We measured energy spectrum of electrons generated via laser-plasma interaction. Tens of MeV electrons were observed with a divergence of ~10 mrad, but with quite broad energy spread. The laser was operated in two different powers of 10 TW and 30 TW so that the dependence of electron acceleration on laser beam waist and Rayleigh range be investigated, by keeping the intensity at a gas target as ~1.3×10^{19} W / cm^2. We will discuss the status of the KAERI activity on the generation of the ultra-fast, high-energy particles for the prospects of nuclear applications.

S-Band RF System for 0.1 nm SASE FEL at PAL

TUPC28

Woon Ha Hwang, Ki Man Ha, Kyung-Ryul Kim, Sang-Hee Kim, Seung Hwan Kim, Soung Soo Park, Yoon-Gyu Son (PAL, Pohang, Kyungbuk), Moohyun Yoon (POSTECH, Pohang, Kyungbuk)

Pohang Accelerator Laboratory, PAL, has been proposing a 0.1 nm SASE FEL. This machine will be designed with an S-band RF linear accelerator to produce a 10.053 GeV electron beam. The output power of klystron is 80 MW at the pulse width of 4 μs and the repetition rate of 30 Hz. The beam energy spread is 0.037% (rms), and RF phase stabiltity is 0.1 degrees (rms). The SASE FEL needs the modulator stability of 0.1%. We developed the modulator DeQing system to use the existing modulator systems that are “line type modulator system”. And we also are considering an inverter power supply to meet the required specification of the FEL machine. We are developing the phase amplitude detection system (PAD) and phase amplitude control (PAC) system to obtain the required RF stability. This paper describes the RF system for PAL XFEL (PxFEL).

Design and Implementation of Bipolar Power Supply for Corrector Magnet

TUPC29

Seong-Hun Jeong, Dong Eon Kim, Ki-Hyeon Park (PAL, Pohang, Kyungbuk), Bong-Koo Kang (POSTECH, Pohang, Kyungbuk)

This paper presents the corrector magnet power supply for the PLS II. The required current for the magnet was ±30 A, with a high stability of ~5 ppm and a high resolution of about 1 ppm to accomplish a stable beam orbit correction. This power supply has been implemented by a digital signal processing technology, and it shows high stability and other good output responses. Various experimental results such as stability, bandwidth and simulation are given in this paper.

Usage of Solid-State Photo Multipliers for Not Destroying Synchrotron Diagnostics of Proton Beams

TUPC31

Anatoly Andreevich Maltsev (JINR, Dubna, Moscow Region)

The opportunity application of the not destroying infra-red diagnostics method for measurement of intensity and geometrical parameters of proton beam in synchrotron using solid-state photo multipliers is considered.

The Opportunity to Use Scyntillation Solid-State Detector in Complex Control System for Electronuclear Installation

TUPC32

Anatoly Andreevich Maltsev (JINR, Dubna, Moscow Region), Marina Maltseva (TENZOR, Dubna, Moscow Region)

For registration of x-ray, scale and neutron radiations, their distribution in volume of installation it is offered to use the optics-electronic method. It means to use blocks of detecting scintillation solid-state. During registration of radiation is carried out double transformation: first the ionizing radiation cooperates with scintillation thus photons in light area of a spectrum are formed, and then quantums of light are registered by the solid-state photo multiplier.

Characterisation of the Beam from Thermionic RF Gun Adapted for Photo Cathode Operation

TUPC33

Nino Cutic, Sara Thorin, Filip Lindau, Sverker Werin (MAX-lab, Lund), Francesca Curbis (Uni HH, Hamburg)

Existing thermionic RF gun (tungsten-BaO) at the MAX-lab linac injector has been adapted for photocathode operation (with 10 ps laser pulses at 263 nm). Important parameters of this gun for free electron laser experiments, like emittance and charge, were measured giving 5.5 mmmrad and 200 pC. Here we report more detail on that setup, including laser and electron optics.

The Test FEL Facility at MAX-Lab

TUPC34

Sverker Werin, Nino Cutic, Filip Lindau, Sara Thorin (MAX-lab, Lund), Johannes Bahrdt, Karsten Holldack (BESSY GmbH, Berlin), Christian Erny (Lund Laser Centre, Lund)

A facility for seeding and harmonic generation utilizing an optical klystron is under commissioning at MAX-lab. The facility utilizes the 400 MeV linac accelerator, improved operation of an RF gun, an undulator system of two undulators and a magnetic chicane, combined laser system for gun and seeding. The goal is to seed the electron beam at 266 nm and generate the harmonics 2-5 (133-54 nm). Currently the system is under commissioning. We report on the operation of the sub-systems and the latest results on the commissioning towards achieving harmonic generation.

Commissioning of a Diode / RF Photogun Combination at PSI

TUPC35

Romain Ganter, Bolko Beutner, Stefan Binder, Hans-Heinrich Braun, Manuel Broennimann, Miroslaw Dach, Terence Garvey, Christopher Gough, Christoph P. Hauri, Martin Heiniger, Rasmus Ischebeck, Sladjana Ivkovic, Yujong Kim, Frederic Le Pimpec, Kevin Li, Roland Luescher, Peter Ming, Anne Oppelt, Martin Paraliev, Marco Pedrozzi, Jean-Yves Raguin, Leonid Rivkin, Thomas Schietinger, Thomas Schilcher, Bernd Steffen, Albin Friedrich Wrulich (PSI, Villigen)

In the frame of the PSI – XFEL project, an electron gun based on diode acceleration followed by a two cell RF cavity is under test at PSI. The diode consists of a photocathode / anode assembly and is driven with a voltage pulse of 500 kV maximum in 200 ns FWHM. The metal photocathode is illuminated by a Nd:YLF laser operating at 262 nm wavelength with a pulselength of 10 to 35 ps (FWHM) producing electron bunches of up to 200 pC. The distance from cathode to anode can be varied from 0 to 30 millimeters with a typical cathode field of 50 MV / m during the commissioning phase. Electrons leave the diode through an anode aperture and enter a two-cell RF Cavity (1.5 GHz), which accelerates the beam to a maximum energy of 5 MeV. Beam characteristic measurements are presented and compared with simulations.

Advanced Beam Diagnostic Section for the PSI 250 MeV Injector — TUPC36

Yujong Kim, Bolko Beutner, Hans-Heinrich Braun, Terence Garvey, Rasmus Ischebeck, Marco Pedrozzi, Volker Schlott (PSI, Villigen)

To develop and test various advanced accelerator and FEL related technologies for the planned SwissFEL project, PSI is presently constructing a 250 MeV injector test facility. Its building construction was completed in March 2009 and its gun commissioning will start from October 2009. To measure projected emittance, bunch length, slice emittance, slice energy spread, longitudinal phase space, arrival time jitter, Twiss parameters without changing any optics, we have designed an advanced beam diagnostic section for the 250 MeV injector test facility. For the SwissFEL project, the same module-type diagnostic sections will be used. In this paper, we describe the design concept, layout, and performance of this advanced beam diagnostic section.

Design Concepts of the Ultra-Compact SwissFEL Driving Linac — TUPC37

Yujong Kim, Hans-Heinrich Braun, Terence Garvey, Marco Pedrozzi, Jean-Yves Raguin, Volker Schlott (PSI, Villigen)

PSI is preparing an ultra-compact XFEL facility to generate coherent XFEL photon beams at 0.1 nm with a 5.8 GeV linac and a 60 m long undulator. To supply different photon pulse length, bandwidth, and photon intensity, we selected two nominal operation modes with 10 pC and 200 pC and one upgrade mode with 10 pC. To demonstrate challenging technologies such as ultra-tight RF jitter tolerances and high resolution beam diagnostics, PSI is constructing a 250 MeV injector test facility. In this paper, we describe design concepts and beam dynamics of the ultra-compact 5.8 GeV linac for the SwissFEL project.

250 MeV Injector Test Facility for the SwissFEL Project — TUPC38

Marco Pedrozzi, Yujong Kim (PSI, Villigen)

The x-ray FEL project at PSI involves the development of an injector complex that enables operation of a SASE FEL at 0.1 nm with permanent-magnet undulator and minimum beam energy. In order to extensively study the generation, transport and time compression of high brightness beams and to support the component developments necessary for the XFEL project, PSI is presently constructing a 250 MeV injector test facility. In the low energy region enough space has been reserved to accommodate complex electron source configurations while at high energy a 16 m diagnostic line will be used for projected and slice parameter characterization. The first installed electron source will be a 2.5 cell S-band RF-Photo injector, previously developed at CERN within the CTF program, which should provide a projected emittance below 0.4 mm mrad at 200 pC. Four S-band travelling wave cavities will boost the energy up to 270 MeV and a fourth harmonic X-band cavity will be used to linearize the longitudinal phasespace distribution in front of the magnetic compression chicane. In this paper we describe the overall accelerator facility with its main components and we discuss the expected beam performances.

Technical Design Studies of TAC SASE FEL Proposal — TUPC39

Bora Ketenoglu (Ankara University, Tandogan, Ankara)

A SASE FEL facility was first proposed in Feasibility Report of the TAC (Turkish Accelerator Center) project in 2000. Conceptual Design Report (CDR) of the project was completed in 2005. Technical Design Report (TDR) studies of TAC were started in 2006 in frame of an inter universities project with support of State Planning Organization (SPO) of Turkey. Main goal of the SASE FEL proposal is to cover VUV and soft x-rays region of the spectrum besides IR-FEL, Bremsstrahlung and Synchrotron Radiation proposals of TAC. Up to now, optimization studies based on a special RF linac or an Energy Recovery Linac (ERL) for the SASE FEL facility were completed. Today, ERLs provide a powerful broad range of applications like: electron cooling devices, high average brightness, high power FELs, short-pulse radiation sources and high luminosity colliders. In this study, main parameters for two linac options and SASE FEL are given.

Secondary Emission Magnetron Injection Gun as High-Brightness High-Current Electron Source — TUPC40

Sergiy Cherenshchykov (NSC/KIPT, Kharkov)

Secondary Emission Magnetron Injection Gun (SEMIG) is a simple cold-cathode electron source with high current density. Recently the achievement of a multi-kiloampere current level was reported in conference. Simultaneously we find a method of conversion from annular beam to pencil (solid) beam. Therefore, angular divergence of the beam may be low too. These two factors define brightness of electron sources. By the path increasing of electric and magnetic fields may be increasing beam current density and brightness up to several orders of magnitude. Moreover, the gun has many other advantages in the case of its application as injector for linacs. That is: existence of self-modulated mode, robustness for electron back bombardment, good repeatable of pulses, possibility of high repetition rate and long pulse duration, long lifetime. The gun was successfully tested in multi-MeV linac. Prospects of the gun improvements are discussed.

High Repetition Rate Photoinjector Design — TUPC41

Julian William McKenzie, Boris Leonidovich Militsyn (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

Future FEL-based light sources require high brightness electron beams delivered in short bunches at high repetition rates. The design of a photoinjector able to operate at a repetition rate of 1 MHz and above is presented. Beam dynamic simulations are presented for bunch charges ranging from 1 pC up to 1 nC, optimised for low slice emittance and high peak current. This injector is a suitable candidate for the UK‟s New Light Source project.

The Current Status of the ALICE (Accelerators and Lasers In Combined Experiments) Facility — TUPC42

Yuri Saveliev, Susan Louise Smith (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

ALICE (Accelerators and Lasers In Combined Experiments), a 35 MeV energy recovery linac based light source, is being commissioned and developed as an experimental R&D facility for a wide range of projects that could employ synchronized ultra-short (<1 ps) electron bunches and light pulses. A suit of light sources includes an IR FEL, Compton backscattering (CBS) x-ray source, high power THz source and a multi-TW femtosecond laser. The full energy recovery and coherently enhanced, due to shortness of the electron bunches, THz radiation have been already demonstrated on ALICE. Completion of the first phase of the CBS x-ray source experiment and first lasing of the IR FEL are expected during summer 2009. Status of ALICE experimental facility and latest results on FEL, THz, and CBS development are reported in this paper.

A Recirculating Linac as a Candidate for the UK New Light Source Project — TUPC43

Peter Williams (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

A design for a free electron laser driver which utilises 1.3 GHz superconducting CW accelerating structures is studied. The machine will deliver longitudinally compressed electron bunches with repetition rates of 1 kHz with a possibility to increase up to 1 MHz. Tracking is performed from an NC RF photocathode gun, accelerating and compressing in three stages to obtain peak current greater than 1 kA at 2.2 GeV. This is achieved through injection at ~200 MeV, then recirculating twice in a 1 GeV main linac. The optics design, optimisation procedures and start to end modelling of this system are presented.

Design of Baseline Injector for UK's New Light Source Project — TUPC44

Jang Hui Han, Hou-Cheng Huang, Morten Jensen, Ian Martin, Shivaji Apparao Pande (Diamond, Oxfordshire), Riccardo Bartolini (Diamond, Oxfordshire; JAI, Oxford)

The proposed New Light Source for the UK has the baseline specification of an FEL photon energy ranging up to 1 keV and a repetition rate of 1 kHz. In order to fulfil this specification, an injector with a normal conducting L-band photocathode gun and a superconducting L-band cavity module has been designed. To allow the implementation of a second stage injector with even higher repetition rate, a merging system with a dog leg is being considered. The beam parameter optimisation for several operation modes has been carried out using the ASTRA code. Technical issues of the RF design and thermal behaviour of the gun are also discussed.

Jitter and Tolerance Study of FEL Injectors — TUPC45

Jang Hui Han, James Rowland (Diamond, Oxfordshire), Klaus Floettmann, Siegfried Schreiber (DESY, Hamburg)

Linac based free electron lasers require very high quality and stable electron beams both for the lasing process, and for use of the FEL beams in experiments. Various kinds of jitter in the injector may sensitively affect the FEL operation. In this paper, we study the jitter sources in the FEL injector and simulate how much they impact on the beam dynamics. Then, we discuss the required jitter tolerances to maintain good machine performance. Measurements have been carried out at the FLASH free electron laser at DESY and beam dynamics simulations are applied to the UK's New Light Source facility.

Spatial Resolution Limits of YAG:Ce Powder Beam-Profile Monitors for Photoinjectors

TUPC46

Alex Lumpkin, Amber Sabrina Johnson, Jinhao Ruan, James Santucci, Randy Michael Thurman-Keup (Fermilab, Batavia, Illinois), Yin-E Sun (Fermilab, Batavia), Philippe Regis-Guy Piot (Northern Illinois University, DeKalb, Illinois)

The A0 photoinjector (A0PI) facility at Fermilab has an ongoing proof-of-principle experiment to demonstrate the exchange of the transverse horizontal and longitudinal emittances*. This experiment relies on measurements of the transverse emittances and longitudinal emittance upstream and downstream of an emittance-exchanger beamline. At several locations along the accelerator beamline, YAG:Ce powder scintillator screens are used to determine beam size, divergence, and energy spread when used in an electron beam spectrometer. The screens have ~5 micron grain size and are deposited on a metal substrate as provided by DESY**. We have recently performed direct comparisons of beam image and slit image sizes using both the OTR screens and the YAG:Ce screens. For micropulse charges of 250 pC and with beam energies of 15 MeV, we systematically observed larger beam image sizes with the YAG:Ce screens than with the OTR screens. We deduced a YAG:Ce screen spatial resolution limit of Σ=140 to 180 microns. Results at both the beam profile stations at different drift lengths from the slits and in the electron spectrometer will be reported as well as the needed corrections to the emittances.
** T.W. Koeth et al., Proceedings of PAC09, Vancouver, Canada. ** The YAG:Ce samples were manufactured at DESY and the associated specifications were provided by Klaus Floettmann, DESY.*

Observations on COTR Due to the Microbunching Instability in Compressed Beams

TUPC47

Alex Lumpkin (Fermilab, Batavia, Illinois), Yuelin Li, Stanley Joseph Pasky, Nicholas Sereno (ANL, Argonne, Illinois)

The observations of the strong enhancements of the optical transition radiation (OTR) signal observed after bunch compression of photocathode beams in the Advanced Photon Source (APS) linac chicane and at the Linac Coherent Light Source (LCLS) continue to be of interest. Spectral-dependence measurements of the coherent OTR (COTR) were done at APS initially at the 375 MeV station using a series of band pass filters inserted before the CCD camera, but recent tests with an Oriel spectrometer with ICCD readout have extended those studies. In this case we used a microchannel plate image intensifier with a GaAs photocathode to explore the NIR regime out to 880 nm. We report for the first time a ~40% intensity modulation of ~20 nm period throughout the observed broadband COTR spectra for some localized spatial structures. This effect was observed at full electron beam compression as determined from the CTR monitor located after the chicane, and it persisted with two different grating dispersions and for different spectrometer offsets. In addition, the observation of a ring-like COTR image structure in x-y space for a mismatched beam at 355 MeV will be presented and discussed.

Mode Analysis of the 500 MHz NPS Electron Source

TUPC48

Peter Stoltz, Kevin Paul (Tech-X, Boulder, Colorado), John Wesley Lewellen (NPS, Monterey, California), Andrew Eric Bogle, Terry Grimm (Niowave, Inc., Lansing, Michigan)

Researchers are designing a new 500 MHz quarter-wave electron source for the free electron laser facility at the Naval Postgraduate School (NPS). Important to designing this source are the higher-order modes, as researchers would like to understand how any such modes may affect the beam dynamics. In this work, the modes of the current design of the NPS source are analyzed using the filter diagonalization method of a time-domain field simulation. These modes are characterized and compared with results from Superfish. We also present results of higher-order mode excitation due to propagation of a 3 mm radius, 40 ps, 1 nC beam. We show the dependence of the higher-order mode excitation on beam misalignment, beam non-uniformity, and various geometry misalignments.

Simulation of Coherent Optical Transition Radiation in Linac Based Free Electron Lasers

TUPC49

Ralph Fiorito, Max Cornacchia, Anatoly Shkvarunets, Jayakar Charles Tobin Thangaraj (UMD, College Park, Maryland), Simone Di Mitri (ELETTRA, Basovizza), Henrik Loos, Juhao Wu (SLAC, Menlo Park, California)

Recent observations of coherent optical transition radiation (COTR) at LCLS and other laboratories have been recognized as a signature of the micro bunching instability, which affects the longitudinal phase space of the electron beam and ultimately the performance of the Free Electron Laser. In addition, the COTR emission limits the utility of OTR screens as beam profiling diagnostics. In an effort to understand and predict the extent of COTR emission and to help specify required instrumentation for new FELs, we have developed codes at UMD and SLAC-LCLS that use the output from the ELEGANT particle tracking code to predict the emission of COTR at specific wavelengths or within a band width. The COTR code provides plots of the intensity patterns in the transverse plane, simulating a virtual OTR screen. Both incoherent and coherent intensities are produced thus providing an estimate of the micro bunching gain at the observed wavelengths. Since the ELEGANT simulation of micro bunching strongly depends on the number of particles, efforts have been carried out to speed up the COTR code analysis. The results of these codes applied to the LCLS and FERMI@Elettra linac FELs are presented.

Wisconsin FEL Injector Simulations

TUPC50

Terry Grimm (Niowave, Inc., Lansing, Michigan), Robert Legg, Kevin J Kleman (UW-Madison/SRC, Madison, Wisconsin), Michaela Allen (Xavier University of Louisiana, New Orleans)

Seeded FELs will require exceptional beam quality. The Wisconsin FEL (WiFEL) requires peak currents of 1 kA ± 10% with <1 mm mrad transverse slice emittance and 10-4 slice dp / p at the undulator. To perform bunch compression after the injector without allowing micro-bunching or density modulations will require very smooth initial bunch energy and density profiles. An injector which uses a low frequency, superconducting, quarter wave resonator gun combined with self-inflating, ellipsoidal bunches to meet those requirements is described. The superconducting radio frequency TEM-class cavities have been in use for more than 25 years and because of their potential for flat field profiles, are desirable as electron gun structures.

Microbunching from Shot Noise Simulated with Fewer Particles than the Bunch

TUPC51

Robert Arthur Bosch, Kevin J Kleman (UW-Madison/SRC, Madison, Wisconsin), Juhao Wu (SLAC, Menlo Park, California)

In high-current magnetic bunch compression, shot-noise-induced energy and current fluctuations at the chicane entrance may cause microbunching. For the case where the energy fluctuations are the primary cause of microbunching, we perform approximate simulations with fewer particles than the bunch population by using a reduced value of the space-charge impedance upstream of the chicane. This method is applied to bunch-compressor designs for the Wisconsin Free Electron Laser (WiFEL).

Towards A Multialkali Dispenser Photocathode: Experiment and Theory — TUPC52

Joachim Vollaire (SLAC, Menlo Park, California), Eric J. Montgomery, Donald Feldman, Patrick Gerard O'Shea, Peter Zhigang Pan, Noah Sennett, Claire Stortstrom (UMD, College Park, Maryland), Kevin L. Jensen (NRL, Washington, DC)

High performance FELs demand photocathodes with high quantum efficiencies (QE), kHr life, kA / cm^2 peak and A / cm^2 average current, and ps response. In harsh accelerator vacuum conditions, having delicate cesium-based coatings, efficient photocathodes face shortened life. The UMD dispenser photocathode extends lifetime by resupplying cesium from a subsurface reservoir through a porous substrate*, and recesiation can rejuvenate cesiated cathodes (Cs:Ag) after contamination**. These studies have validated theory that can presently treat both coated metals and semiconductors***. Other alkali metals (Na, K) may also be deposited singly or together for better QE (e.g., Cs2KSb and other high QE multi-alkalis). Towards that end and to refine theory, we here report fabrication and testing of K:Ag and Na:Ag complementing the previously cited Cs:Ag work. Models of coating-dependent QE analyze the K and Na data on metal (e.g., silver) polycrystalline surfaces. The status of an effort to incorporate these models into PIC beam simulation codes such as MICHELLE**** shall also be indicated.
** Moody et al, APL 90, 114108 (2007). ** Montgomery et al,AIP Proc.1086, 599 (2009). *** Jensen et al, JAP104, 044907 (2008): Jensen et al,JAP102, 074902 (2007). **** Jensen et al, JVSTB26 (2), 831 (2008).*

LCLS Undulator Magnet Temperature Control — TUPC53

James Welch, Heinz-Dieter Nuhn, Javier A. Sevilla (SLAC, Menlo Park, California)

Undulator magnets for the LCLS need to be maintained at a very stable and accurate temperature in order to stay within the tolerance required for the FEL. At the LCLS the temperature of the undulator magnets is mainly determined by the temperature of the surrounding air. Furthermore, the climate control system which controls the temperature of the air must never accidentally go out of a safe operating range of ± 2.5 C or the magnets may lose calibration and have to be removed and remeasured. This was one motivation for the sighting the Unduator Hall underground in a tunnel where the thermal inertia of the surrounding earth provides stability. In this paper we describe the technical solution adapted by the LCLS for controlling the air temperature in the Undulator Hall and its initial performance. We also discuss thermal issues of heat balance and steady state and transient temperature behavior of the undulators system and the surrounding earth.

Bunch Compression Using Velocity Bunching and a Magnetic Chicane — TUPC54

Juhao Wu, Dao Xiang, James Welch, (SLAC, Menlo Park, California), Ji Qiang (LBNL, Berkeley, California), Robert Arthur Bosch (UW-Madison/SRC, Madison, Wisconsin)

A single-pass x-ray Free Electron Laser (FEL) requires a high-quality electron bunch that is compressed to a length of several microns or tens of microns. During the bunch compression and transport, collective effects can degrade the bunch quality, which also introduces difficulties for diagnostics such as optical transition radiation. We study a two-stage compression scheme that achieves kiloampere peak currents by using velocity bunching at low energy and a magnetic chicane at higher energy. Emittance compensation is considered with overall optimization. The quality of the compressed bunch and its effect upon FEL performance are modeled with analytic formulas and simulations.

Space Charge Effect in a Free Electron Laser Injector for an Electron Bunch with Granularity

TUPC55

Juhao Wu, Cecile Limborg-Deprey (SLAC, Menlo Park, California), Ji Qiang (LBNL, Berkeley, California)

For a single-pass high-gain X-ray Free Electron Laser (XFEL), electrons are born with very high density in the 6-dimensional phase space. Space charge effects are very important in the electron beam dynamics, especially, at the early stage of machine. Furthermore, there can be transverse and longitudinal granularities in the electron bunch. These granularities can affect the electron beam properties, which are studied with a full 3-dimensional space charge code, IMPACT, and with measurements at the LINAC Coherent Light Source.

Optimization of the Two Bunch Compressors for the Free Electron Laser Performance at Linac Coherent Light Source

TUPC56

Juhao Wu, Axel Brachmann, Franz-Josef Decker, Yuantao Ding, David Dowell, Steve A. Edstrom, Paul J. Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Richard Iverson, Henrik Loos, Alan Miahnahri, Heinz-Dieter Nuhn, Daniel Ratner, James Leslie Turner, James Welch, William White, Dao Xiang (SLAC, Menlo Park, California)

The LINAC Coherent Light Source (LCLS) Free Electron Laser (FEL) performance is determined by multiple-optimization on the peak current, the slice energy spread and the slice emittance over a large number of parameters in the accelerator system. The LCLS electron bunch is compressed by two bunch compressors and of particular importance is the partition of the compression factors and the resulting difference in the collective effects in the entire accelerator system and undulator system. Under-compression and over-compression configurations may result in electron bunches having similar peak current and emittances, thus leading to similar FEL performances, but with subtle differences as a frequency chirped FEL pulse with an over-compressed electron bunch. The Laser Heater effects in these under- and over-compression schemes are also addressed with respect to the horns in the electron bunch current profile and other microstructure that is manifested on the final FEL performance.

Novel Quarter-Wave Booster / Gun Cavity

TUPC57

Sean P. Niles, William B. Colson, Ken Ferguson, John Wesley Lewellen, Brian Rusnak (NPS, Monterey, California), William Graves (MIT, Cambridge, Massachusetts), Andrew Eric Bogle, Terry Grimm (Niowave, Inc., Lansing, Michigan)

The Naval Postgraduate School Beam Physics Lab and Niowave, Inc. are fabricating a novel quarter-wave resonant cavity that can be put to dual use as either a booster or electron gun. Fabrication of the 500 MHz superconducting cavity is nearing completion and is undergoing characterization at Niowave in Lansing, MI. Expected gradients may allow for use as a standalone injector without the need for additional acceleration prior to merging with the primary electron accelerator. The cavity design allows for insertion / retraction of the cathode stalk enabling easy cathode changes. Additionally, a novel power coupling design is used providing fewer penetrations of the primary cavity. Experimental results, beam dynamics, and future experiments are discussed.

Photoelectric Augmentation of a Thermionic Cathode with the NPS DC Electron Gun — TUPC58

Sean P. Niles, William B. Colson, John R. Harris, John Wesley Lewellen, Brian Rusnak, Todd Iversen Smith, Richard Swent (NPS, Monterey, California), Kevin Jordan (JLAB, Newport News, Virginia)

The Naval Postgraduate School Beam Physics Lab has been rebuilding the former Stanford Superconducting Accelerator – Free Electron Laser (SCAFEL). The first experiments using the SCAFEL DC injector in a combined thermionic / photoelectric mode are discussed and data regarding the attributes of this design for an FEL electron source are presented. Additionally, lessons learned on the revitalization of an operating high vacuum system after extended storage at atmospheric pressure and transport are presented.

Adsorbate Modification of Emission from Diamond Field Emitters and Carbon Nanotubes — TUPC59

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau, Joseph A. Driscoll, Kalman Varga (Vanderbilt University, Nashville, TN), Bo Kyoung Choi, Jimmy Davidson, Weng Kang, Yong Mui Wong (Vanderbilt University, Nashville)

We present new results in the measured electron energy spectrum from diamond field emitters. The energy spectrum from a clean diamond surface has been measured and is comparable in shape and width to that of metal emitters. The results suggest that the emitted spectrum is sensitive to the presence of adsorbed species on the emitter surface. Electrons significantly below the cathode‟s Fermi level are emitted by resonant tunnelling. Furthermore, these resonant surface states can increase the total emitted current by more than an order of magnitude while maintaining a narrow spectral width (~0.5 eV). Experiments are also being performed with individual multiwall carbon nanotubes (MWCNTs). We have observed beams emitted from individual residual gas molecules that approach the quantum-degenerate limit of electron-beam brightness. This limit has profound consequences for the behavior of an electron. Tightly bound designer adsorbates may greatly enhance the emission properties and improve performance in electron injector systems.

Fabrication of Self-Aligned-Gate Diamond Field-Emitter-Array Triodes for Free Electron Lasers — TUPC60

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau (Vanderbilt University, Nashville, TN), Bo Kyoung Choi, Jimmy Davidson, Weng Kang, Yong Mui Wong (Vanderbilt University, Nashville)

Diamond field-emitter arrays (DFEAs) possess several advantages over photocathodes: high brightness, ruggedness, no drive laser requirement, and minimal heating. A gated DFEA with micron-scale cathode-gate spacing has the added benefits of direct e-beam modulation and low operating voltages < 100 V. A second gate can be integrated, creating built-in focusing capability. We have developed two types of self-aligning gate fabrication methods. First, pyramidal molds are formed on a SOI (silicon on insulator) substrate then coated with CVD nanodiamond. The bulk layer of silicon is thinned, followed by oxide etching and opening the diamond tip isolating the gate electrode and insulating layer from the cathode. The second method uses additive physical evaporation depositions of insulating and gate electrode layers on top of the DFEAs. Chemical etching of the insulating layer separates and opens cathode tip due to „lift off" type step coverage of the evaporation technique. A 2-mask fabrication process has been used to pattern the gate to optimize active gate area and increase yield. Fabrication techniques and electrical behavior of the gated DFEAs will be discussed.

Pulsed Uniformity Conditioning and Emittance Measurements of Diamond Field-Emitter Arrays

TUPC61

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau (Vanderbilt University, Nashville, TN), Bo Kyoung Choi, Jimmy Davidson, Weng Kang (Vanderbilt University, Nashville)

We present recent advances in the uniformity conditioning of diamond field-emitter arrays (DFEAs), and new results from emittance measurements of their emitted electron beams. DFEAs have shown considerable promise as potential cathodes for free electron lasers. They have demonstrated their rugged nature by providing high per-tip currents, excellent temporal stability, and significant resistance to back-bombardment damage during poor vacuum, close-diode DC operation. Until now, the successful conditioning of high-density arrays has been precluded by thermal damage to the anode. We report successful uniformity conditioning of densely packed DFEAs using microsecond-pulsed high-current conditioning (HCC). A high degree of spatial uniformity was confirmed in low-current DC testing following these HCC procedures. The conditioned arrays will be used to refine previous measurements of the normalized transverse emittance of the emitted electron beams.

An Inverted Ceramic DC Electron Gun for the Jefferson Laboratory FEL

TUPC62

Fay Elizabeth Hannon, Stephen Vincent Benson, George Herman Biallas, Don Bullard, Forrest Kent Ellingsworth, Pavel Evtushenko, Carlos Hernandez-Garcia, Kevin Jordan, Matt Marchlik (JLAB, Newport News, Virginia)

A new 500 kV DC photocathode electron gun is being developed at Jefferson Laboratory (JLab) with the aim of improving on the performance of the present FEL injector. The design benefits from the use of two inverted ceramic insulators to allow for a photocathode preparation chamber and load-lock system to be placed directly behind the gun. The electrostatic design emphasises the requirement to minimise the electric field gradients on the internal surfaces and incorporates shaped electrodes to provide some transverse focusing to the electron beam. Finally, provisions have been made to maintain ultra high vacuum conditions inside the gun chamber to prolong cathode lifetime during CW operation. This paper presents an overview of the electron gun and load-lock design.

High-Brightness Electron Beam Generation at the NSLS SDL

TUPC64

Xijie Wang (BNL, Upton, Long Island, New York), Houjun Qian (BNL, Upton, Long Island, New York; TUB, Beijing), Yoshiteru Hidaka, James Murphy, Boris Podobedov, Sergei Seletskiy, Yuzhen Shen, Xi Yang

There is a growing interest in optimizing the electron beam for X-ray FEL (XFEL) and other applications. In the earlier design studies of the XFEL, electron beam with a charge on the order of 1 nC was adopted for the base line operation. The experimental results from both earlier beam studies* and FEL saturation** show that an electron beam with a charge ranging from 40 - 200 pC possess much higher brightness and leads to a better FEL performance. This paper presents the latest experimental effort in optimizing the electron beam for the future FEL applications at the NSLS SDL. For a 50 pC beam, measured normalized transverse and longitudinal RMS emittance are 0.6 mm-mrd and 5.2 ps-keV respectively. The smallest projected transverse emittance observed for a 20 pC charge is 0.15 ± 0.02 mm-mrad.

** X.J. Wang, et al, Phys. Rev. E, 54, R3121 -3124 (1996). ** A. Tremaine et al, Phys. Rev.Lett. 88, 204801 (2002).*

Observation of Coherent Smith-Purcell Radiation Using an Initially Continuous Flat Beam

TUPC65

John Thomas Donohue (CENBG, Gradignan), Laurent Courtois, Jacques Gardelle, Patrick Modin (CESTA, Le Barp)

A few years ago, a new theory for producing coherent Smith-Purcell (SP) radiation from an initially continuous electron beam was proposed. It was two-dimensional (2D), and it has been supported by 2-D particle-in-code simulations. We report here the results of an experiment using an intense continuous flat beam that confirms the theory. A maximum voltage of 200 kV was supplied by a single-shot pulsed-power source. The beam was typically 10 cm wide and a few mm thick, with a peak current of 200 A. The laminar grating had twenty 2 cm periods, and radiation was observed at the predicted fundamental grating mode frequency near 4 GHz. The second and third harmonics were also observed at the angles predicted by the SP formula. Direct evidence for beam bunching was obtained using both a current monitor and a pick-up loop placed at the end of a groove. In general, good agreement between this experiment and theory is found.

The IR-FEL Project at the Fritz-Haber-Institut Berlin

TUPC66

Wieland Schöllkopf, Sandy Gewinner, Gerard Meijer, Gert von Helden (FHI, Berlin), Ulf Lehnert, Peter Michel, Wolfgang Seidel, Rudi Wuensch (FZD, Dresden)

At the Fritz-Haber-Institut in Berlin, Germany, we plan to set up an IR-FEL tunable in the wavelength range from 5 to 300 micron for applications in molecular and cluster spectroscopy as well as surface science. It is planned to use a normal-conducting S-band electron linac with variable energy between 20 and 50 MeV. The pulse structure will consist of about 10 micro-second long macro-pulses repeated at 10 Hz containing micro-pulses of 200 pC charge at 1 GHz, or of more than 100 pC at 3 GHz. This corresponds to a beam power of up to about 2 kW. The electrons will be steered through either one of two oscillator FELs each consisting of a planar hybrid-magnet undulator placed within an IR cavity. The bandwidth of the IR-output will be Fourier limited. Its energy will be more than 10 micro-joule per micro-pulse and a few tens of milli-joule per macro-pulse. This corresponds to an optimized output in terms of milli-joule per micro-second, which is the figure of merit for many spectroscopy experiments. The design of the system and its calculated performance will be described, and the current status of the project will be presented.

Design of a Terahertz Source at CBS

TUPC67

Tushima Basak, Srinivas Krishnagopal, Sushil Arun Samant (CBS, Mumbai)

The Centre for Excellence in Basic Sciences (CBS) is proposing to build a terahertz source for applications in the basic and applied sciences. This source would provide radiation tunable from 30 to 100 microns, using a 25 MeV electron beam and 2.5 m long undulator. In this paper, we present details of the design.

Slippage Effect on the Table-Top THz FEL Amplifier Project in Kyoto University — TUPC68

Toshiteru Kii, Mahmoud Abdel Aziem Bakr, Keisuke Higashimura, Ryota Kinjo, Kai Masuda, Hideaki Ohgaki, Taro Sonobe, Satoshi Ueda, Kyohei Yoshida (Kyoto IAE, Kyoto), Heishun Zen (UVSOR, Okazaki)

We proposed a table-top seeded THz FEL amplifier using a multi-bunch photocathode RF gun and injection-seeded terahertz parametric generator (IS-TPG)*. Although the first numerical study was carried out under simplified conditions**, a slippage effect, which has a prominent effect on the long wavelength FEL, was not taken into account. In order to discuss feasibility and expected THz output power, start-to-end simulation of the FEL was performed by simulation code Parmela*** and 3D time-dependent FET simulation code GENESIS 1.3****. The peak output power of about 10 kW at 185 micro m was expected from the design scheme.
** K. Kawase, et al., Applied Physic Letters 80 (2002), p.195. ** T. Kii, et al., Proc. of FEL2008, in press. *** L.M. Young, et al., PARMELA, LA-UR-96-1835, (2001). **** S. Reiche, NIM A429 (1999) p.242.*

Consideration on Terahertz FEL Using Pre-Bunched Electrons Shorter than the Wavelength — TUPC69

Hiroyuki Hama, Mafuyu Yasuda (Tohoku University, Sendai)

To evaluate fundamental characteristics of conventional FELs with oscillator configuration, we assume an electron pulse sufficiently longer than the FEL wavelength in general (long pulse approximation). In the process of microbunching, the optical pulse gains the power exponentially. Taking finite bunch length into account, the head of the optical pulse does not grow more than the tail due to slippage. Consequently if there is no detuning for an optical cavity, the electrons are no longer able to be microbunched because of no power growth at the head of the optical pulse, which is well known as the lethargy effect. Meanwhile recent progress of the linac technology enables us to have high brilliant beam in 6-dimensional phase space; accordingly the electron bunch length reaches much shorter than the wavelength of THz radiation. We have studied THz FEL employing such pre-bunched beam by applying 1D FEL equations*. Since bunching factor of the electrons is already close to unity, non-linear power amplification is expected to occur. Bunching factor is resulted from long pulse approximation basically, so that we have to discuss the pre-bunched FEL carefully. The paper will describe the considerations on it.
** M. Yasuda et al., "Development of the THz Light Source Using Pre-Bunched FEL", Proc. 30th Int. FEL Conf., Gyeongju, Korea (2008).*

Analysis of a Compact Cherenkov Free Electron Laser — TUPC70

Dazhi Li, Kazuo Imasaki (ILT, Suita, Osaka), Makoto R. Asakawa (Kansai University, Osaka)

The interest in the terahertz radiation sources keeps growing in recent years because this frequency provides applications in medical, industrial and material science. The Cherenkov free electron lasers have an advantage over the usual undulator free electron lasers, and they can generate terahertz radiation with a low energy electron beam. We plan to construct a compact terahertz Cherenkov free electron laser with moderate (~10 mW) average power. To achieve this goal, a compact electron beam source is in development, and a double-slab Cherenkov free-electron laser resonator is studied. To perform a preliminary lasing experiment, this resonator is designed to generate the millimeter wave. In this paper, we aim at the analysis of the gain for the double-slab Cherenkov device. The dispersion equation is derived and solved numerically, and the single-pass gain is worked out for the parameters of our experiment.

Development of Compact THz-FEL Based on Laser Photocathode RF Gun System

TUPC71

Ryunosuke Kuroda, Masaki Koike, Kawakatsu Yamada (AIST, Tsukuba, Ibaraki)

A compact THz-FEL has been developed based on a laser photocathode RF gun system at AIST. The RF gun has been improved using a Cs2Te photocathode with a compact load-lock system. The multi-bunch electron generation has been performed with the RF gun and the multi-pulse UV laser system. The undulator has been designed to generate THz-FEL. The preliminary experiment of THz applications has been carried out using a coherent synchrotron radiation in the THz region with 40 MeV electron beam. In this conference, we will report a present status and results of the experiment.

The Simulations Studies of the SDUV FEL Facility

TUPC72

Dong Wang (SINAP, Shanghai)

The Shanghai Deep UV FEL is a new FEL facility working at Deep UV wavelength. Based on a newly upgraded 160 MeV linac with photo-injectors, the SDUV is capable of providing an intense FEL beam at 262 nm with 9 meters of undulators. Both SASE and HGHG modes are going to be tested. This paper shows the s3e simulation studies of typical working modes of the SDUV.

The First Experiments at the SDUV FEL Facility

TUPC73

Dong Wang (SINAP, Shanghai)

The Shanghai Deep UV (SDUV) FEL is expected to start its first experiments this summer. This paper will report the latest progress on beam commissioning and hopefully the early results of FEL experiments.

Design of a High-Power Table-Top THz Free Electron Laser

TUPC74

Young Uk Jeong, Yong-Ho Cha, Byung Cheol Lee, Kitae Lee, Seong Hee Park (KAERI, Daejon), Grigory Kazakevich (BINP SB RAS, Novosibirsk)

We have designed a high-power table-top terahertz (THz) Free Electron Laser (FEL). The size of the system is estimated to be 1x2 m^2 by using a 600 mm-long helical undulator and a compact 4 MeV Microtron accelerator. The condition for low-loss and high-gain oscillator of the table-top FEL has been studied by using a 2D FEL code. Simple injection scheme of the electron beam to the undulator was optimized by calculating beam trajectories with a 3D PIC code. The average THz power is calculated to be 1 W with the tunable wavelength range from 200 to 600 μm (0.5 to 1.5 THz). The FEL is expected to be used for the real-time imaging of security inspection.

Intense THz Radiation Generation from a Compact Electron Linac — TUPC75

Heung-Sik Kang (PAL, Pohang, Kyungbuk)

A femto-second THz radiation (fs-THz) facility is under commission at the Pohang Accelerator Laboratory (PAL), which uses a 60 MeV electron linac that consists of an S-band photocathode RF gun with 1.6 cell cavity, two S-band accelerating structures, and two chicane-type bunch compressors. The linac is designed to generate THz pulse with energy up to 10 μJ by transition radiation from a metal target hit by sub-picosecond electron beam. The linac takes advantage of the advanced technologies such as an inverter-type klystron modulator with stability below 100 ppm and a high precision synchronization timing system with a laser oscillator. The THz radiation energy measured with a Golay cell is 0.5 μJ / pulse from the electron beam with charge of 0.1 nC. We will present the properties of THz radiation as well as the electron beam parameters.

Powerful 30 GHz JINR-IAP FEM: Recent Results, Prospects and Applications — TUPC76

Nikolay Peskov, Naum Ginzburg, Sergey Vladimirovich Kuzikov, Andrey Vladimirovich Savilov, Alexander Sergeev (IAP/RAS, Nizhny Novgorod), Alim Kaminsky, Elkuno Perelstein, Sergey Sedykh (JINR, Dubna, Moscow Region)

The JINR-IAP FEM-oscillator was elaborated during the last few years based on 0.8 MeV / 200 A / 250 ns linac LIU-3000 (Dubna). This 30 GHz FEM generates currently 20 MW / 200 ns pulses with spectrum width of ~6 MHz and repetition rate of up to 1 Hz. The high efficiency and stability of the FEM was achieved by using reversed guide magnetic field regime and advanced type of Bragg resonator, i.e. a resonator with a step of phase of corrugation. The parameters achieved allow the FEM to be used in several applications. Test facility to study the life time of the metals in strong RF-fields was constructed based on the FEM. This information would be beneficial, in particular, when designing high-gradient accelerating structures for future linear colliders. Degradation of the copper surface was studied at different temperature rise during each pulse (from 50 to 250 C) in consequence of up to ~100,000 pulses. Investigation of possibility to use JINR-IAP FEM in medical and biological applications was also started. The effect of the powerful 30 GHz pulses on the biological tissue including the cancer cells was studied. Project to advance JINR-IAP FEM into sub-mm wavelengths is developed.

Terahertz Electron Masers with Frequency Multiplication — TUPC77

Andrey Vladimirovich Savilov, Ilya Vladimirovich Bandurkin, Vladimir Bratman, Nikolay Peskov (IAP/RAS, Nizhny Novgorod), Alim Kaminsky, Sergey Sedykh (JINR, Dubna, Moscow Region)

Various schemes of THz electron masers operating in the regime of frequency multiplication are discussed. The use of this approach makes possible the realization of high-harmonic cyclotron masers operating at low (tens kV) accelerating voltages in long-pulse and CW regimes with the relatively low (1 W – 1 kW) output power. Our first modeling experiment has demonstrated co-generation of second and fourth cyclotron harmonics in a simple microwave system. As for realization of pulsed high-power THz masers, it is attractive to use the regime of frequency multiplication in moderately-relativistic (hundreds kV) high-current FEMs and Smith-Purcell autooscillators. In our experiment based on a 0.8 MeV / 200 A e-beam, a two-wave FEM was realized. In this experiment, the low-frequency (30 GHz) wave was excited in the ubitron regime, and a feedback system partially reflected this wave back to the operating cavity. This backward low-frequency wave was scattered on the electrons into the forward high-frequency (360 GHz) wave. The use of the regime of frequency multiplication provided the stimulated character of this process, and, therefore, a quite high power (~100 kW) of the high-frequency wave.

Terahertz Band FEL with Advanced Bragg Reflectors — TUPC78

Vladislav Zaslavsky, Naum Ginzburg, Andrey Malkin, Nikolay Peskov, Alexander Sergeev (IAP/RAS, Nizhny Novgorod), Keiichi Kamada, Yukihiro Soga (Kanazawa University, Kanazawa)

Periodical Bragg structures may be considered as an effective way of controlling the electromagnetic energy fluxes and provision of spatially coherent radiation in the free electron lasers with oversized interaction space. A new scheme of terahertz band FEL with hybrid Bragg resonator consisting of advanced input Bragg mirror and traditional output Bragg mirror is proposed. Advanced Bragg mirror exploits coupling between two counter-propagating waves and the quasi cutoff wave and provides mode selection over the transverse index. Main amplification of the synchronous wave by the electron beam takes place in the regular section of the resonator. Small reflections from the output traditional Bragg mirror are sufficient for the oscillator self-excitation. Results of simulation of nonlinear dynamics of the FEL with a hybrid Bragg resonator is presented and demonstrate its operability in the terahertz frequency band with high (megawatt level) radiation power. In difference with the existing terahertz band FELs*, the above scheme would be driven by a long pulse (microsecond) electron beam from Induction linear accelerators or Electrostatic accelerators.
** V.P.Bolotin, e.a., Nucl. Instr. & Meth. Phys. Res. A, 2005, v.543, p.81; Y.U.Jeong, e.a., Nucl. Instr. & Meth. Phys. Res. A, 2004, v.528, p.88.*

Microstructured Optical Elements for High-Power Terahertz Applications — TUPC79

Sergey Alexandrovich Kuznetsov, Vitaly V. Kubarev (BINP SB RAS, Novosibirsk), Vladimir Petrovich Nazmov (IMT, Karlsruhe, Eggenstein-Leopoldshafen)

We present the results of development of passive quasi-optical selective elements based on 2D and 1D microstructures intended for polarization and frequency control of powerful terahertz radiation from the coherent light sources. The main emphasis is made on the optimization of electrodynamical behaviors and an experimental implementation of high-pass and band-pass harmonics filters, as well as high-performance polarization beam-splitters for application at the Novosibirsk THz-FEL (Siberian Photochemical Center), which first-stage generation wavelengths overlap the range 110-235 microns at a peak and average radiation power up to 1 MW and 500 W, respectively. The discussed structures are represented mainly by periodic arrays of the shaped micro-apertures made in self-supporting copper membranes with typical topological sizes from two units up to several tens of microns, and aspect ratio up to 100. Fabrication of such thick microstructures by deep x-ray lithography is considered, and the results of low- and high-power testing for a set of first manufactured prototypes are presented. A scaling of the obtained results onto radiation parameters of other THz-sources is discussed.

First Lasing of FEL at the Two-Orbit ERL — TUPC80

Nikolay Vinokurov, Evgeny Dementyev, Boris Dovzhenko, Yaroslav V. Getmanov, Boris Aleksandrovich Knyazev, Evegeniy I. Kolobanov, Vitaly V. Kubarev, Gennady N. Kulipanov, Lev E. Medvedev, Sergey Vladimirovich Miginsky, Leontii Mironenko, Vladimir Ovchar, Boris Z. Persov, Vasiliy M. Popik, Tatiana V. Salikova, Mikhail A. Scheglov, Stanislav S. Serednyakov, Oleg A. Shevchenko, Alexander Skrinsky, Vladimir G. Tcheskidov, Yury Tokarev, Pavel Vobly, Nataliya Zaigraeva (BINP SB RAS, Novosibirsk), Alexander N. Matveenko (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin)

Novosibirsk ERL has a rather complicated magnetic system. One orbit for 11 MeV energy with terahertz FEL lies in the vertical plane; the other four orbits lie in the horizontal plane. The beam is directed to these orbits by switching on two round magnets. In this case electrons pass four times through accelerating RF cavities, obtaining 40 MeV energy. Then (at the fourth orbit) the beam is used in the FEL, and is then decelerated four times. At the second orbit (20 MeV) we have bypass with a third FEL. When magnets of bypass are switched on, the beam passes through this FEL. The length of bypass is chosen to provide the delay, which is necessary to have deceleration instead of acceleration at the third passage through accelerating cavities. Last year, two of the four horizontal orbits were assembled and commissioned. The electron beam was accelerated twice and then decelerated down to low injection energy. The first multi-orbit ERL operation was demonstrated successfully. In 2009 the first lasing at the second FEL, installed on the bypass of the second track, was achieved. The wavelength tunability range lies near 50 microns. Energy recovery of a high energy spread used electron beam was optimized.

Thermionic Cathode-Grid RF Gun Simulations for L-Band FEL Injectors — TUPC81

Vladimir Volkov, Sergey Alexandrovich Krutikhin, Grigory Yakovlevich Kurkin, Ivan Makarov, Sergey Vladimirovich Miginsky, Victor Petrov, Michael A. Tiunov, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

The projected electron RF gun of 10 MeV L-band injector for FEL employs a commercial thermionic cathode-grid assembly with 0.08 mm gap that conventionally used in metal-ceramic RF tubes. Three-dimensional (3D) computer simulations have been performed that use the mesh refinement capability of the both Microwave Studio (MWS) and 2D SAM codes to examine the whole region of the real cathode-grid assembly in static fields in order to illustrate the beam quality that can result from such a gridded structure. These simulations have been found to reproduce the beam current dependency on applied potentials that are observed experimentally. Based on it ASTRA RF beam simulations also predict a complicated time-dependent response to the waveform applied to the grid during the current turn-on, calculation of the dissipated power by electrons at the grid, and particle tracking downstream of the grid into RF gun cavity and further on. These simulations may be representative in other sources, such as BINP Microtron-Recuperator 180 MHz injector and other RF injectors for industrial and scientific applications.

Experimental Design of a Single Beam Photonic Free Electron Laser — TUPC82

Thomas Denis, Klaus Boller, Peter van der Slot (Mesa+, Enschede)

The photonic Free Electron Laser (pFEL) aims to realize a compact terahertz source that emits Watt-level and tuneable radiation. For this purpose it uses a photonic structure, which coherently couples the Cerenkov radiation from a set of individual electron beams streaming through this structure. The resulting transverse coherence of the radiation allows a power scaling of the device by extending its cross-section and the number of electron beams. To study the fundamental physics of such devices, and to compare single beam with multi-beam performance, we first designed a single electron beam pFEL operating at a low frequency of around 22 GHz. Choosing such low operating frequency facilitates pumping of the pFEL by a single electron beam. This electron beam possesses a relatively high current of 2 A and its acceleration voltage is tuneable between 7 kV and 15 kV. It is guided by a solenoid through a metal photonic structure of 30 cm length. The general design of the single beam pFEL will be presented.

Interaction Structures for a Photonic Free Electron Laser — TUPC83

Thomas Denis, Klaus Boller, Peter van der Slot (Mesa+, Enschede)

Recently, we started research on photonic Free Electron Lasers (pFEL) to realize a handheld terahertz source, which emits Watt-level and tuneable radiation. In a pFEL a photonic structure couples the emission of several electron beams streaming through this structure. The structure provides transverse coherence between several co-propagating electron beams through transverse scattering. This property allows a power scaling of the device by extending its cross-section and number of electron beams. We will present a design for a pFEL structure, which allows the use of a compact electron gun with a beam energy of less than 20 keV. This structure consists of a square lattice of metal posts, which are embedded in a rectangular waveguide. Its dispersion relation and the transmission of rectangular waveguide modes through it are numerically and experimentally investigated. Additionally, we will show how the dimensions of this photonic structure affect its dispersion relation and through this the characteristics of the device (e.g., tuning range and operating frequency).

Realization of the Nijmegen THz-FEL — TUPC84

Rienk Jongma, Arno Engels, Ruurd Lof, Pieter van Dael, Wim J. van der Zande, Andre van Roij, Arjan van Vliet, Frans Wijnen, Gerben Wulterkens, Vitali Zhaunerchyk (Radboud University, Nijmegen), Alexander van der Meer (FOM Rijnhuizen, Nieuwegein), Ulf Lehnert, Peter Michel, Wolfgang Seidel, Rudi Wuensch (FZD, Dresden), Kai Dunkel, Christian Piel (RI Research Instruments GmbH, Bergisch Gladbach)

The Radboud University in Nijmegen received funding to realize a narrow-band THz laser system and a 45 T hybrid magnet system. Based on results of predesign studies*, all review committees agreed to continue the project and enter the realization phase. In this paper we present the technical solutions for realization of the main system components. We present the details of the RI Research Instruments GmbH (a former ACCEL Instruments GmbH activity) LINAC system. Operation of the full system (including the electron source) at 3 GHz is desirable and deemed feasible after first experimental studies. As the Nijmegen FEL will operate at wavelength up to 1.5 mm, the cavity will be fully waveguided, complicating the incorporation of an intra-cavity Fox-Smith interferometer required to induce coherence between micropulses and a Michelson interferometer as most ideal outcoupler. The optical distribution system comprises 150 m of vacuum tubing with 25 cm effective diameter (planar and refocusing) mirrors. A robust yet cost efficient realization taking boundary conditions on optical beam parameters at diagnostics station and user stations into account is foreseen.
** Design of the Nijmegen high-resolution THz-FEL, R.T. Jongma, et al. Proc. FEL 2008.*

Spontaneous and Induced Inter-Pulse Coherence in the Nijmegen THz FEL — TUPC85

Vitali Zhaunerchyk, Rienk Jongma, Wim J. van der Zande (Radboud University, Nijmegen)

The THz region of the spectrum does not know versatile powerful light sources. FEL technology clearly is well suited for the generation of THz radiation. The Nijmegen THz-FEL oscillator is scheduled to be in operation early 2011 and will produce THz light in the 0.1 mm (3 THz) - 1.5 mm (0.2 THz) spectral range. Electron bunches will be generated by an RF LINAC at a rate of 3 GHz such that 150 optical pulses will propagate simultaneously through a 7.5 m long optical cavity. A relatively short length of the electron bunches and the high Q-factor of the RF LINAC will give rise to strong coherent spontaneous emission. All micro pulses will tend to be coherent. Our aim is to induce full inter-pulse coherence by means of an intra-cavity Fox-Smith interferometer. The present study is devoted to the investigation into competition between spontaneous and induced inter-pulse coherence which is foreseen to be relevant for the most ambitious aim of the Nijmegen FEL project: generation of single mode THz radiation with pulse lengths of 7 microseconds, based on a RF type electron accelerator.

Mode Competition and Evolution in an FEM with 2D Distributed Feedback TUPC86

Ivan Vasilyevich Konoplev, Adrian William Cross, Lorna Fisher, Wenlong He, Philip MacInnes, Alan Phelps, Craig Robertson, Kevin Ronald, Colin Whyte (USTRAT/SUPA, Glasgow)

The demand for high power radiation sources operating in the millimetre and sub-millimetre wave regions is steadily increasing. Such sources are important for a number of applications including remote sensing, spectroscopy, material science and security. In order to achieve the desired high power radiation a large diameter high current but low density beam can be used. This has two distinct advantages; firstly the low space charge density avoids the formation of beam instabilities; secondly the electromagnetic power density inside the cavity can be maintained at a level which circumvents electromagnetic field breakdown inside the interaction space. Two dimensional distributed feedback can be used to synchronise the radiation from the oversized electron beam. The effect of the electron beam current density on the operation of the FEM based on 2D distributed feedback will be discussed. The evolution and competition of the modes when the FEM is driven with the high current density (1kA / cm^2) electron beam will be presented and compared with numerical modelling. The results will also be contrasted with experimental data obtained for a lower current density (0.3 kA / cm^2) electron beam.

Further Observations of Evanescent Waves in a Free Electron Laser TUPC87

Heather L. Andrews, Charles A. Brau, Jonathan D. Jarvis (Vanderbilt University, Nashville, TN), Robert Durant, Christian Guertin, Thomas Lowell, Michael R. Mross, Aidan O'Donnell (Vermont Photonics, Bellows Falls)

We present further experimental observations of evanescent waves in a Smith-Purcell Free Electron Laser (FEL) with vertical conducting walls bounding the sides of the grating. Evanescent waves are the basis of oscillator operation of the Smith-Purcell FEL. They have group velocity anti-parallel to the electron beam and for sufficiently high current, provide feedback to bunch the electron beam. A grating with side walls supports multiple transverse modes; we have observed emission from the two lowest such modes. The observed wavelengths and wavelength shift with changing operating voltage agree with theoretical predictions. Additionally, strong radiation from the upstream end of the grating confirms the negative group velocity.

Long Wavelength FELs

Chair: Young Uk Jeong

Novosibirsk Free Electron Laser Facility: Two-Orbit ERL Operation and Second FEL Commissioning (Invited) — TUOD01

Nikolay Vinokurov, Evgeny Dementyev, Boris Dovzhenko, Yaroslav V. Getmanov, Boris Aleksandrovich Knyazev, Evegeniy I. Kolobanov, Vitaly V. Kubarev, Gennady N. Kulipanov, Lev E. Medvedev, Sergey Vladimirovich Miginsky, Leontii Mironenko, Vladimir Ovchar, Boris Z. Persov, Vasiliy M. Popik, Tatiana V. Salikova, Mikhail A. Scheglov, Stanislav S. Serednyakov, Oleg A. Shevchenko, Alexander Skrinsky, Vladimir G. Tcheskidov, Yury Tokarev, Pavel Vobly, Nataliya Zaigraeva (BINP SB RAS, Novosibirsk), Alexander N. Matveenko (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin)

The first stage of Novosibirsk high power free electron laser (FEL) provides electromagnetic radiation in the wavelength range 120 - 230 micron. The maximum average power is 500 W. Five user stations are in operation now. Novosibirsk ERL has a rather complicated magnetic system. One orbit for 11 MeV energy with terahertz FEL lies in the vertical plane; the other four orbits lie in the horizontal plane. The beam is directed to these orbits by switching on two round magnets. In this case electrons pass four times through accelerating RF cavities, obtaining 40 MeV energy. Then (at the fourth orbit) the beam is used in the FEL, and is then decelerated four times. At the second orbit (20 MeV) we have bypass with third FEL. Last year, two of the four horizontal orbits were assembled and commissioned. The electron beam was accelerated twice and then decelerated down to low injection energy. The first multi-orbit ERL operation was demonstrated successfully. In 2009 the first lasing at the second FEL, installed on the bypass of the second track, was achieved. The wavelength tunability range lies near 50 microns. Energy recovery of a high energy spread used electron beam was optimized.

Time-Dependent, Three-Dimensional Simulation of Free Electron Laser Oscillators (Invited) — TUOD02

Henry Freund, William Miner (SAIC, McLean), Stephen Vincent Benson, Michelle Diane Shinn (JLAB, Newport News, Virginia), Klaus Boller, Peter van der Slot (Mesa+, Enschede)

We describe a procedure for the simulation of free electron laser oscillators. The simulation uses a combination of the MEDUSA simulation code for the FEL and the OPC code to model the resonator. The simulations are compared with recent observations of the oscillator at the Thomas Jefferson National Accelerator Facility and are in substantial agreement with the experiment.

The FEL-THz Facility Driven by a Photo-Cathode Injector — TUOD03

Xingfan Yang, Ming Li, Weihua Li (CAEP/IAE, Mianyang, Sichuan), Xiaojian Shu (IAP, Beijing)

After the first lasing in March 2005 in CAEP, the FEL-THz facility is now updated; the former thermionic cathode injector was replaced using a high brightness photo-cathode injector. The facility mainly consists of a 4.5 cells photo-cathode RF gun injector, a hybrid undulator and the optical oscillator cavity. The number of undulator periods is 44, the peak value of the undulator is 4900 Gs, and the good aperture is 6 mm. The cathode material is Cs2Te and the quadruple light is used, the width of the driving laser is 12 ps, and the quantum efficiency is about 1%. The commissioning of the injector is finished, the electron energy of the injector was measured and it is approximately 8 MeV, the energy spread is about 1% and the electron beam normalized emittance is about mm. mrad. The charge is about 100 pC and up to 1 nC per micro-pulse, the π9 repetition rate is 54.167 MHz. The calculated wavelength of the light is about 125 microns. At present, the spontaneous emission experiment is being undertaken.

Production of Powerful Spatially-Coherent Radiation in Free Electron Lasers Based on Two-Dimensional Distributed Feedback

TUOD04

Naum Ginzburg, Nikolay Peskov, Alexander Sergeev, Vladislav Zaslavsky (IAP/RAS, Nizhny Novgorod), Andrey Vasil'evich Arzhannikov, Peter Kalinin, Stanislav L. Sinitsky (BINP SB RAS, Novosibirsk), Manfred Thumm (FZ Karlsruhe, Karlsruhe), Adrian William Cross, Ivan Vasilyevich Konoplev, Alan Phelps (USTRAT/SUPA, Glasgow)

For intense oversize relativistic electron beams with sheet and annular geometry the use of two-dimensional (2D) distributed feedback is beneficial for providing spatial coherence of the radiation and increasing the total radiation power*. Such feedback can be realized in planar and co-axial 2D Bragg resonators having double-periodic corrugations of the metallic side walls. High selectivity of such resonators has been demonstrated for large Fresnel parameters in the frame of coupled-wave model and in direct 3D simulations. Results of theoretical analysis are validated by data obtained in “cold” microwave measurements. Modeling of nonlinear dynamics of FEL with 2D distributed feedback also demonstrates advantages of novel feedback mechanism for production of spatial coherent radiation from large size electron beams. Simulation results are confirmed by recent experimental results where narrow frequency radiation was obtained at Ka-band co-axial and W-band planar 2D Bragg FELs which were realized at Strathclyde University** and Budker INP***. To advance 2D Bragg FEL in terahertz band the methods for extension of microwave systems over second transverse coordinate are discussed.
* *N.S.Ginzburg, e.a. Opt. Comm., 1993, v.96, p.254.* ** *I.V.Konoplev, e.a. PRL, 2006, v.96, p.035002.*
*** *A.V.Arzhannikov, e.a. JETF Lett., 2008, v.87, p.715.*

FEL Technology I: Accelerators

Chair: Massimo Ferrario

Measurements of the LCLS Laser Heater and its Impact on the LCLS FEL Performance (Invited)

WEOA01

Zhirong Huang, Axel Brachmann, Franz-Josef Decker, Yuantao Ding, David Dowell, Paul J. Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Richard Iverson, Henrik Loos, Alan Miahnahri, Heinz-Dieter Nuhn, Daniel Ratner, James Leslie Turner, James Welch, William White, Juhao Wu, Dao Xiang (SLAC, Menlo Park, California)

The very bright electron beam required for an x-ray Free Electron Laser (FEL), such as the LCLS, is susceptible to a microbunching instability in the magnetic bunch compressors, prior to the FEL undulator. Using a 'laser heater', the uncorrelated electron energy spread in the LCLS can be increased by an order of magnitude to provide strong Landau damping against the instability without degrading the FEL performance. In this paper, we report the commissioning experience with the LCLS laser heater. We present detailed measurements of laser heater-induced energy spread, including the unexpected self-heating phenomenon when the laser energy is very low. We discuss the suppression of microbunching instability with the laser heater and its impact on the LCLS x-ray FEL performance. The experimental results are compared with theory and simulations where possible.

FLASH Status and Upgrade (Invited)

WEOA02

Bart Faatz, Josef Feldhaus, Katja Honkavaara, Siegfried Schreiber, Rolf Treusch (DESY, Hamburg), Jörg Rossbach (DESY, Hamburg; Uni HH, Hamburg)

The free electron laser user facility FLASH at DESY, Germany is world-wide the only SASE-FEL operating in the VUV and the soft x-ray wavelengths range. Since summer 2005, FLASH operates as a user facility providing almost fully coherent, 10 femtosecond long laser radiation in the wavelength range from 47 nm to 6.5 nm with an unprecedented brilliance - many orders of magnitude higher than conventional facilities. The SASE radiation contains also higher harmonics. Several experiments have successfully used the third and fifth harmonics, in the latter case down to a wavelength of 1.59 nm. Starting autumn 2009, FLASH will be upgraded with an additional superconducting TESLA type accelerating module boosting its beam energy to 1.2 GeV. This will allow lasing below 5 nm. In addition, a 3rd harmonic accelerating module will be installed, which improves the longitudinal phase space and the overall performance of the facility.

LCLS Drive Laser Shaping Experiments — WEOA03

David Dowell, Axel Brachmann, Ryan Neal Coffee, Steve A. Edstrom, Paul J. Emma, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Alan Miahnahri, Heinz-Dieter Nuhn, Daniel Ratner, David A. Reis, William White, Juhao Wu, Dao Xiang (SLAC, Menlo Park, California)

The effect of the drive laser transverse shape upon the electron beam emittance and FEL performance at 1.5 Ångströms was studied at 250 pC for the Linac Coherent Light Source x-ray FEL. Rectangular grids and cylindrically symmetric shapes were imaged onto the cathode and the emittance and FEL output were measured. Each pattern was truncated by a 1.2 mm diameter iris. The projected and time-sliced emittances as well as the electron bunch shape were measured at 135 MeV using a one micron thick optical transition radiation foil and a transverse RF deflecting cavity. The beam was then compressed and accelerated to 13.7 GeV and transported through the undulator. In our initial measurements, the 1.5 Ångström FEL pulse energy was determined from the energy loss of the electron beam. Future experiments will use an x-ray calorimeter. The gain length was obtained by measuring the FEL output along the undulator by deflecting the electron beam off the optical axis. These emittances and the FEL performance are compared with the nominal uniform transverse shape.

Field-Emission Cathodes for Free Electron Lasers — WEOA04

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau, Joseph A. Driscoll, Kalman Varga, Bo Kyoung Choi, Jimmy Davidson, Weng Kang, Yong Mui Wong (Vanderbilt University, Nashville)

High-quantum-efficiency photocathodes used for free electron lasers tend to be fragile and demand complex drive lasers. Field-emitter arrays eliminate both of these problems, but introduce other problems along with interesting new physics. Diamond field-emitter arrays are rugged and forgiving of poor vacuum. They are easily conditioned to give uniform emission, current density on the order of 100 A / cm^2 before phase compression, and emittance smaller than 10 μm-radians. In gated versions the emission can be phased to the RF drive and the emittance can be reduced by the focusing effect of the gate. Experimental evidence from diamond pyramids and carbon nanotubes suggests that field emission is enhanced by resonant tunneling through molecules adsorbed on the surface. The emission from individual molecules appears to reach the fundamental limits imposed by the Heisenberg uncertainty principle and by the Pauli exclusion principle.

Status and Plans for the LBNL Normal-Conducting CW VHF Photoinjector — WEOA05

Fernando Sannibale, Kenneth Michael Baptiste, John Corlett, Rick Kraft, Slawomir Kwiatkowski, Derun Li, Ji Qiang, John William Staples, Russell Wells, Lingyun Yang, Alexander Zholents (LBNL, Berkeley, California)

At the Lawrence Berkeley National Laboratory, a high-brightness high-repetition rate photo-injector is under fabrication. The scheme is based on a normal conducting 187 MHz RF cavity operating in CW mode and capable of generating an electric field at the cathode plane of ~20 MV / m. The electron bunches will be accelerated to ~750 keV with peak current, energy spread and transverse emittance suitable for FEL and ERL applications. At the same time, the presence of a vacuum load-lock mechanism jointly with a vacuum system designed to operate in the 10 picoTorr range, will make of this injector a flexible cathode test facility. In particular, it will allow to use "delicate" high quantum efficiency cathodes to generate nC bunches at MHz repetition rate with present laser technology. Construction status and future plans are presented.

FEL Technology I: Accelerators

Chair: Hywel Owen

Velocity Bunching Experiment at SPARC (Invited) WEOB01

Daniele Filippetto, David Alesini, Marco Bellaveglia, Roberto Boni, Manuela Boscolo, Enrica Chiadroni, Luca Cultrera, Giampiero Di Pirro, Massimo Ferrario, Luca Ficcadenti, Valeria Fusco, Alessandro Gallo, Giancarlo Gatti, Chiara Marrelli, Mauro Migliorati, Andrea Mostacci, Elisabetta Pace, Luigi Palumbo, Bruno Spataro, Cristina Vaccarezza, Carlo Vicario (INFN/LNF, Frascati (Roma)), Luca Giannessi, Marie Labat, Marcello Quattromini, Concetta Ronsivalle (ENEA C.R. Frascati, Frascati (Roma)), Barbara Marchetti (INFN-Roma II, Roma), Maurizio Serluca (INFN-Roma, Roma), Alberto Bacci, Vittoria Petrillo, Andrea Renato Rossi, Luca Serafini (Istituto Nazionale di Fisica Nucleare, Milano), Gerard Andonian, Gabriel Marcus, James Rosenzweig (UCLA, Los Angeles, California), Masoud Rezvani Jalal (University of Tehran, Tehran), Alessandro Cianchi (Università di Roma II Tor Vergata, Roma)

The optimization of the beam brightness is one of the main objectives of the research and development efforts in RF-photoinjectors devoted to short wavelength FELs. The velocity bunching experiment at SPARC has recently demonstrated the possibility of increasing the beam current via RF compression at low energies, while compensating the self-fields induced emittance degradation by means of continuous magnetic focusing. The result is an increase of the beam brightness by about one order of magnitude. Stable compression ratio up to a factor of 12 has been observed. Characterization of longitudinal phase spaces a measure of projected and slice emittances, as a function of the injection phase in the first accelerating structure and for different solenoids field values are presented. Comparisons with simulations are also reported.

Optimisation of a Single-Pass Superconducting Linac as a FEL Driver for the NLS Project (Invited) WEOB02

Riccardo Bartolini, Chris Christou, Jang Hui Han, Ian Martin, James Rowland (Diamond, Oxfordshire), Marco Venturini (LBNL, Berkeley, California), Deepa Angal-Kalinin, Frank Jackson, Bruno Muratori, Peter Williams (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

The New Light Source (NLS) project was launched in April 2008 by the UK Science and Technology Facilities Council (STFC) to consider the scientific case and develop a conceptual design for a possible next generation light source based on a combination of advanced conventional laser and free electron laser sources. In this paper we present the results of the optimisation of a single pass superconducting linac as a driver for the the NLS FELs. The optimisation process requires the analysis of complicated electron beam dynamics in the presence of CSR, wakefields and space charge and has specifically taken into account the requirements for FEL operation in a seeded harmonic cascade scheme.

Molecular Dynamics Simulation of Longitudinal Space-Charge Induced Optical Microbunching — WEOB03

James Rosenzweig, Agostino Marinelli (UCLA, Los Angeles, California)

Recent observation of coherent optical transition radiation in FEL injectors has provoked considerable theoretical activity. As this phenomenon is provoked by microbunching at or near the level of the mean interparticle spacing in the beam, any description of it should resolve the beam at the particle level. Here we present the first simulations that fulfil this requirement, based on a three-dimensional code in which fields are found in the beam frame using Fourier methods. The simulations take into account acceleration, which serves to freeze relative longitudinal motion, transverse focusing, and downstream bending motion. Comparisons are made between code predictions and experimental results, as well as with theoretical models.

Running Experience of the Superconducting RF Photoinjector at ELBE — WEOB04

Rong Xiang, Andre Arnold, Hartmut Buettig, Dietmar Janssen, Matthias Justus, Ulf Lehnert, Peter Michel, Petr Murcek, Arndt Schamlott, Christof Schneider, Rico Schurig, Jochen Teichert (FZD, Dresden), Thorsten Kamps, Jeniffa Rudolph, Mario Schenk (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Guido Klemz, Ingo Will (MBI, Berlin)

More and more electron accelerator projects for FELs, ERLs or 4th generation light sources require a “super” electron beam with high brightness, low emittance, and high average current. Under this background, much attention is paid to the research and development of new electron sources. The superconducting RF photoinjector was designed within a collaboration of BESSY, DESY, FZD, and MBI to improve the beam quality for ELBE IR-FEL users, and at the same time to test this kind of promising injector concept. The main design parameters of this gun are the final electron energy of 9.5 MeV, 1 mA average current, and transverse normalized emittances (rms) of 1 mm mrad at 77 pC and 2.5 mm mrad at 1 nC bunch charge. In this paper the results of the RF and beam parameter measurements with Cs2Te photo cathodes will be presented, and the experience for the gun running gained at the first experiments will be concluded, including the life time and compatibility of the normal conducting photocathode in SC cavity, the coupling of high average power into the gun, and the excitation of higher-order modes in the cavity.

ERL-FEL Study Activities at IHEP, Beijing — WEOB05

Xiongwei Zhu (IHEP Beijing, Beijing)

In this report, we summarise the ERL study activities at IHEP, Bejing. Since 2003, We began to enter the x-ray FEL field, and have finished two conceptual designs of soft x-ray FEL operating in the mode of HGHG: BTF, and CTF. In early 2008, there was a proposal for one machine which would fulfil two purposes: using a common SC linac for XFEL and XERL simultaneously at IHEP. Since then, we have undertaken a series of preliminary design studies on some topics: DC / RF photoinjector, merger (merging three beams), big bore SC cavity, the interactions between FEL and ERL beams via accelerating structure, et al. Furthermore, we have preliminarily designed the 100 MeV ERL test facility used for THz radiation, and given the parameters of the four kinds of THz sources (SASE FEL, FEL oscillator, CSR from bend and SR from ID) in the test facility.

Wednesday Poster Session

SUPA Tutorial by Jon Marangos

The New On-Line Photoionization Spectrometer at FLASH — WEPC01

Pavle Juranic, Susanne Bonfigt, Markus Ilchen, Kai I. Tiedtke, Jens Viefhaus (DESY, Hamburg), Lorenz Jahn, Stephan Klumpp, Michael Martins (Uni HH, Hamburg)

Due to the stochastic nature of the Self Amplifying Spontaneous Emission (SASE) process and the resulting pulse-to-pulse fluctuations of the Free Electron Laser (FEL) photon energies, experimenters working with FELs need to get real-time feedback for their experiments. Investigations of narrow atomic or molecular resonances, phase transitions, or any other kind of effect heavily dependent on photon energy would need to know the precise FEL photon energy for each individual photon bunch. Furthermore, any spectrometer developed to deliver this feedback would need to not significantly interfere or degrade the FEL beam. To that end, the group at the Free electron LASer in Hamburg (FLASH) has developed an on-line photoionization spectrometer that uses ion time of flight (I-TOF) measurement methods on noble gases to measure the photon pulse energy. This paper presents the first test results for the viability of this online photoionization spectrometer (OPS) and discusses its future use.

Theory of Edge Radiation Part II: Advanced Applications and Impact on XFEL Setups — WEPC02

Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

In this paper we exploit a formalism to describe Edge Radiation, which relies on Fourier Optics techniques, described in another contribution to this conference. First, we apply our method to develop an analytical model to describe Edge Radiation in the presence of a vacuum chamber. Such a model is based on the solution of the field equation with a tensor Green's function technique. In particular, explicit calculations for a circular vacuum chamber are reported. Second, we consider the use of Edge Radiation as a tool for electron beam diagnostics. We discuss coherent Edge Radiation, extraction of Edge Radiation by a mirror, and other issues becoming important at high electron energy and long radiation wavelength. Based on this work we also study the impact of Edge Radiation on XFEL setups and we discuss recent results.

Design Study of an Isochronous Bend for a Helical Radiator at the European XFEL — WEPC03

Yuhui Li, Vladimir Balandin, Winfried Decking, Bart Faatz, Nina Golubeva, Joachim Pflueger (DESY, Hamburg)

At the European XFEL circular polarized radiation in the wavelength range 0.4 - 1.6 nm is highly desired. An economically and technically convenient method is to utilize a long planar undulator to pre-bunch electron beam first and then pass it through a shorter and specially designed undulator to generate arbitrary polarized radiation. Between these two parts, the electrons and the radiation from the long undulator must be spatially separated by a bend. In this paper, a solution for an isochronous bend is presented considering nonlinear aberrations, which preserves the micro bunching even for the 0.4 nm case.

Status of the sFLASH Undulator System — WEPC04

Hossein Delsim-Hashemi, Jörg Rossbach (Uni HH, Hamburg), Isaac Vasserman (ANL, Argonne, Illinois), Yorck Holler, Andreas Schoeps, Markus Tischer (DESY, Hamburg)

A seeded Free Electron Laser (FEL) experiment at VUV wavelengths, called sFLASH will be installed at the existing SASE-FEL user facility FLASH until Spring 2010. Seed pulses at wavelengths around 30 nm and 13 nm from high harmonic generation (HHG) will interact with the electron beam in sFLASH undulators upstream of the existing SASE undulator section. In this paper, status of the sFLASH undulators are described.

Technical Design of the XUV Seeding Experiment at FLASH — WEPC05

Velizar Miltchev, Armin Azima, Joern Boedewadt, Francesca Curbis, Hossein Delsim-Hashemi, Markus Drescher, Theophilos Maltezopoulos, Manuel Mittenzwey, Jörg Rossbach, Roxana Tarkeshian, Marek Wieland (Uni HH, Hamburg), Shaukat Khan (DELTA, Dortmund), Stefan Düsterer, Josef Feldhaus, Tim Laarmann, Holger Schlarb (DESY, Hamburg), Atoosa Meseck (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Rasmus Ischebeck (PSI, Villigen)

The Free electron LASer at Hamburg (FLASH) operates in the Self-Amplified Spontaneous Emission (SASE) mode, delivering to users photons in the XUV wavelength range. The FEL seeding schemes promise to improve the properties of the generated radiation in terms of stability in intensity and time. Such an experiment using higher harmonics of an optical laser as a seed is currently under construction at FLASH. The installation of the XUV seeding experiment (sFLASH) is going to take place in fall 2009. This includes mounting of new variable-gap undulators upstream of the existing SASE-undulators, building the XUV-seed source as well as installation of additional photon diagnostics and electron beam instrumentation. In this contribution the layout of sFLASH will be discussed together with the technical design of its major components.

New Superconductive Undulator Designs for Use with Laser Wakefield Accelerators — WEPC06

Golo Fuchert, Tilo Baumbach, Axel Bernhard, Sandra Ehlers, Peter Peiffer, Daniel Wollmann (University of Karlsruhe, Karlsruhe), Robert Rossmanith (FZK, Karlsruhe)

In addition to large synchrotron radiation and FEL facilities smaller and cheaper intense UV and x-ray facilities are needed (so-called table-top sources). The electron beam for such a table-top source could be provided by a laser wakefield accelerator. Despite dramatic improvements during the last years on stability and intensity of those devices, one disadvantage remained: the energy spread of the electron beam is in the range of several percent, leading to an energy spread of the photon beam emitted by a conventional undulator. In this paper ideas for new designs of superconductive undulators are presented, which can produce an almost monochromatic photon beam out of an electron beam with a relatively large energy spread.

Performance and Parameters of a Novel Talbot Effect Confocal Resonator for mm-Wave FEL — WEPC07

Harry Saul Marks, Jeremy Dadoun, Oleg (Alon) Faingersh, Khona Garb, Avraham Gover (University of Tel-Aviv, Tel-Aviv), Boris Kapilevich, Boris Litvak (Ariel University Center of Samaria, Ariel)

The design, operating principles and results of characterization for a novel resonator are outlined. Measurements were conducted prior to insertion into the Wiggler cavity for future testing under lasing. The W-band (75-110 GHz) resonator consists of two Talbot splitters and two confocal cylindrical mirrors for decoupling the electron beam from the radiation, a corrugated waveguide, and an adjustable three grid reflector system. Two degrees of freedom have been built into the grid system; firstly, the central grid can be rotated via remote control to alter the out-coupling coefficient, and secondly, also using a motor it is possible to remotely move the grid system back and forth altering the length of the resonator, allowing continuous tuning of the longitudinal mode resonant frequencies (spaced about 100 MHz apart). The radiation pattern of the resonator mode is nearly a Gaussian. The round trip reflectivity and its Q factors where measured by matching the S parameters of the device (measured with a Scalar VNA) to the theoretical Fabry-Perot resonator reflection and transmission curves. Based on this estimate the roundtrip losses of the tunable resonator are less than 35%.

Improvement of a Wiggler by Single Axis Magnetic Measurement, Virtual Synthesis, and Relocation of Magnets — WEPC08

Harry Saul Marks, Egor Dyunin, Avraham Gover, Nimrod Rospsha, Mark Volshonok (University of Tel-Aviv, Tel-Aviv), Michael Kanter, Yoram Lasser, Roman Shereshevsky, Asher Yahalom (Ariel University Center of Samaria, Ariel)

Deviations in the electron beam trajectory through the planar wiggler of the Israeli Electrostatic Accelerator FEL were found to be primarily caused by small variations in the strength and angle of polarisation of lateral focussing bar magnets which are positioned on both sides of the wiggler, and provide a quadrupole guiding field on axis. The field of the wiggler on axis was measured using a Labview controlled automated system built in our lab, based on a 2-axis Hall Effect magnetic sensor driven by a stepper motor. Polarisation field components of the individual focussing magnets were measured separately. Then, using an algorithm, the focussing magnets were paired, such that their non-uniformities were utilised to not only cancel out each other's error, but also to cancel out the field errors on axis due to a variation in the strength and polarisation angle of the wiggler magnets. The quality of the predicted electron beam transport was evaluated by 3D simulation with the General Particle Tracer code which allowed the input of all the measured fields.

On-Line Beam Loss Position Monitors for SPARC — WEPC09

Luciano Catani, Alessandro Cianchi, Domenico Di Giovenale (INFN-Roma II, Roma), Francesco Broggi (INFN/LASA, Segrate (MI)), Giampiero Di Pirro (INFN/LNF, Frascati (Roma))

Beam Loss Position Monitors (BLPM) are diagnostic systems that, by detecting anomalies in the quantity of particles in proximity of the beam pipe, can give hints of accidental interaction between the beam and the vacuum pipe caused by beam lost particles also providing information on the position where the loss originated. This paper describes the design and characterization of the BLPM system proposed for the SPARC accelerator providing real-time information on the intensity and position of beam losses that might occur along the undulator section. The BLPM system will consist of optic fibers aligned to the undulator hanging a few centimeters from the beam pipe. Solid state MPPC from Hamamatsu will be used to convert the Cerenkov light produced by electrons traversing the fiber into a proportional time dependent signal. By analyzing its temporal structure and by comparing the intensities between the signals from different fibers information about the sources of the beam losses can be obtained.

Measurement of the Timing Jitter Between a Time Reference Signal and EUV-FEL Pulses at XFEL/SPring-8 — WEPC10

Shin-ichi Matsubara, Atsushi Higashiya, Naoyasu Hosoda, Shinobu Inoue, Hirokazu Maesaka, Mitsuru Nagasono, Takashi Ohshima, Yuji Otake, Kenji Tamasaku, Makina Yabashi (RIKEN/SPring-8, Hyogo), Tadashi Togashi (JASRI/SPring-8, Hyogo-ken)

The SCSS test accelerator was constructed and user experiments using SASE-FEL light in an extreme-ultraviolet (EUV) region have been performed at SPring-8. It is necessary to distribute an accurate timing signal both to accelerator components and experimental instruments. We developed a trigger system targeted as a timing jitter of less than 100 fs. The jitter of the time difference between the reference timing signal and a beam-induced signal from an RF BPM cavity was measured. The jitter value was nearly 50 fs in rms. However, this value was measured with electron beams after C-band accelerator cavities and not measured with the SASE light pulses at the experimental end station. Therefore, we employed an in-vacuum fast photo diode in order to directly observe EUV light at a 60 nm and to detect the arrival timing at the end station. The measured time jitter was 2.5 ps in rms, which was limited by the photo diode. Even though the resolution of the time jitter did not reach to 50 fs, the system is still usable to verify trigger delay values for user experiments. This fast timing measurement using the in-vacuum photo diode is still a pioneer of optical technology in an FEL field.

Undulator Commissioning Strategy for SPring-8 XFEL — WEPC11

Takashi Tanaka (RIKEN/SPring-8, Hyogo)

In order to achieve FEL lasing in an x-ray region, the undulator should be long enough for saturation and thus consist of a large number of segments. Such segmentation can cause non-negligible errors degrading the FEL gain, such as the phase mismatching, K-value discrepancy between segments and trajectory error. The undulator commissioning, i.e., tuning of the components in the undulator system to correct these errors, is crucially important. In the SPring-8 XFEL, the undulator commissioning is to be made in two steps. Firstly, optical properties of spontaneous radiation from two adjacent undulator segments are measured to specify the error sources between the two segments, which will be corrected accordingly. Secondly, the intensity of FEL radiation is monitored to adjust the components more accurately. In this paper, results of calculation and simulation for spontaneous and FEL radiation with possible error sources in SPring-8 XFEL are reported together with consideration on the correction accuracy.

A Compact Cryogenic ERL-FEL and Laser Cleaning in Nuclear Reactors — WEPC12

Eisuke John Minehara (WERC, Tsuruga , Fukui)

A compact cryogenic ERL-FEL (Energy-Recovery Linac-based Free Electron Laser) should be usable for laser cleaning applications in radio-isotope contaminated nuclear power reactors in the world. A new compact zero-boil off (ZBO) superconducting accelerating cavity module like the JAEA FEL machines will be discussed and optimized to realize the easy operation and free-maintenance for nuclear power and other industries. We will firstly make such a high peak and high average power ERL-FEL to realize all of them. The ERL-FEL will be used in the near future for decommissioning nuclear power plants and other purposes in heavy metal industries.

A 4-Dipole and 2-Quadrupole Bunch Compressor Chicane for SDUV-FEL — WEPC13

Lianhua Ouyang (SINAP, Shanghai)

This paper describes a 4-dipole and 2-quadrupole bunch compressor chicane for SDUV-FEL, and its magnetic field measurements and simulations.

Development of IVU20 at Pohang Accelerator Laboratory — WEPC14

Dong Eon Kim, Chang-Kyun Kim, Kyung-Ryul Kim, Sang Hoon Nam, Chong-Do Park (PAL, Pohang, Kyungbuk)

Pohang Accelerator Laboratory (PAL) is developing the In Vacuum Undulator (IVU) with Shanghai Synchrotron Radiation Facility (SSRF) for USAXS (Ultra Small Angle X-ray Scattering) beamline. The undulator design will be also utilized for the x-ray SASE based FEL which is now seeking funding. The first IVU has 20.0 mm magnetic period with an operating gap of 5.0 mm. The magnetic length will be approximately 1.8 m with 2.2 m flange to flange distance which is the maximum allowable length in the shorter straight section of the upgraded PLS-II storage ring. The effective peak field is greater than 0.97 T and the optical phase error should be less than 5 degrees for the operating gap range of 5 - 16 mm. The controller should be able to resolve the 1 μm gap. In this report, the design issues related to the vacuum system, measurement system, and other engineering problems of the IVU will be discussed.

Characterization and Fiducialization of the XFEL Undulator Quadrupoles — WEPC15

Fredrik Hellberg, Håkan Danared, Anders Hedqvist (MSL, Stockholm), Yorck Holler, Bernward Krause, Alexander Petrov, Joachim Pflueger (DESY, Hamburg

A rotating coil system has been set up at the Manne-Siegbahn Laboratory to characterize the XFEL undulator quadrupoles with respect to magnetic center stability. In combination with a coordinate measuring machine the position of the magnetic center with respect to fiducials is measured. The rotating coil system has previously been used to measure the magnetic center stability with respect to magnet excitation for two prototype magnets with yokes of different materials*. That work has now been extended to a third material for the yoke. Here the results from measurements of the prototype magnets are presented together with results from test measurements performed to determine the accuracy of the fiducialization process.
** FEL08, Gyeongju, Korea, 2008, to be published.*

Investigating the Effect of Mirror Imperfections in Photon Transport Systems for FELs — WEPC16

Marion Bowler (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Frank Siewert (BESSY GmbH, Berlin), Bart Faatz, Kai I. Tiedtke (DESY, Hamburg)

Imperfections on the surfaces of the optical components of photon transport systems can degrade the quality of the radiation, causing amongst other effects structure in the transverse beam profile. This effect is being investigated for one of the beamlines at FLASH. The FEL mirror surfaces have been measured in the metrology laboratory at Helmholtz Zentrum Berlin / BESSY-II, and these data are input into wavefront propagation calculations, which model the transport of the radiation field from the exit of the FEL across the optics to the experiment. The input fields for the propagation were generated using the Genesis1.3 code. This work is part of collaboration in the IRUVX-PP consortium.

Post-Linac Beam Transport and Collimation for a New UK Light Source — WEPC17

Frank Jackson, Deepa Angal-Kalinin, Juan Luis Fernandez-Hernando, Bruno Muratori (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

The next generation light source for the UK requires transport, collimation and dumping of high power, high quality beams. The accelerated beam must be transported to several different FELs. A design for the post-linac beam collimation, spreader (including diagnostics), and dump is presented.

Soft X-Ray Monochromators for the UK New Light Source (NLS) WEPC18

Mark David Roper (STFC/DL, Daresbury, Warrington, Cheshire)

The initial three FELs for the proposed UK NLS facility will cover the soft x-ray range 50 to 1000 eV in the fundamental and up to 5000 eV in the 3rd to 5th harmonics. The FELs will be seeded to produce pulse lengths of ~20 fs FWHM, equivalent to a transform limited bandwidth of ~0.1 eV. Whilst spectral filtering of the FEL pulses will not always be necessary, reasons for passing the FEL beam through a monochromator include: removing unwanted spectral content produced by SASE or spontaneous emission but without lengthening the pulse, improving the spectral resolving power from the inherent pulse bandwidth, and removing the fundamental radiation when using the harmonics. In this paper, a grating based monochromator is described that fulfills all three roles. It is based on the SX700 type of monochromator that uses a variable-included-angle plane-grating operating in collimated light. This flexible design allows different modes of operation optimised for minimising temporal stretch of the pulse or for achieving high spectral resolving power. The performance of a beamline operating over the fundamental range of NLS FEL2 (250 to 850 eV) and the harmonics to 2000 eV is calculated.

Design, Modeling, and Optimization of Precision Bent Refocus Optics WEPC20

Nicholas Kelez, Yi-De Chuang, Robert M. Duarte, Dae-Eun Lee, Wayne Richard McKinney, Valeriy Yashchuk (LBNL, Berkeley, California)

There is an increasing demand for highly de-magnified and well-focused beams with high quality imaging of the full field to further explore the potential of novel instruments. For beamlines operating at a focal point, mechanical benders have often been used to shape the refocusing mirror into an ideal elliptical cylinder. However, the limited number of couplings for these mechanisms requires specific substrate side-shaping, often calculated using beam bending theory, to meet demanding figure requirements. Here, we use finite element analysis (FEA) to both validate the side-shaping algorithm and then couple the output with SHADOW and a bender couple optimization algorithm to evaluate the resulting mirror figure and ultimately improve the mechanical design. Finally, the metrology results of the Long Trace Profiler (LTP) are used to both set the final shape of the completed assembly and validate the model and analysis methods.

Longitudinal Diagnostic for Single-Spike SASE Operation at the SPARC FEL WEPC21

Gabriel Marcus, Gerard Andonian, Atsushi Fukasawa, Pietro Musumeci, James Rosenzweig (UCLA, Los Angeles, California), Luca Giannessi (ENEA C.R. Frascati, Frascati (Roma)), Massimo Ferrario, Luigi Palumbo (INFN/LNF, Frascati (Roma)), Sven Reiche (PSI, Villigen)

Low charge electron beams have been used to drive single-spike operation at the SPARC Free Electron Laser (FEL). A longitudinal diagnostic based on the Frequency-Resolved Optical Gating (FROG) technique has been used to characterize the spectral and temporal structure of the radiation. This paper presents the analysis of data obtained from the diagnostic as well as a comparison to simulations.

Calculating the Loss Factor of the LCLS Beam Line Elements for Ultra Short Bunches

WEPC22

Alexander Novokhatski (SLAC, Menlo Park, California)

An ultra short bunch is used in the LCLS operation. The bunch is prepared, compressed and accelerated in the main part of the machine, which includes an injector, two bunch compressors and a linac. A feedback system precisely controls the bunch energy before it enters a 300 m long beam transport beam line (LTU). In this line and later in the undulator section (132 m long) the bunch may lose energy due to wake field radiation. Additionally, wake fields may add a significant linear energy spread to the bunch which has to be compensated at an early stage in the linac. The energy loss has to be compensated by varying the K-parameter of the undulators. This means that a precise knowledge of the wake fields in this part of the machine is very important. Resistive wake fields are known and well calculated. We discuss an additional part of the wake fields, which comes from the different vacuum elements like bellows, BPMs, transitions, vacuum ports, vacuum valves and other elements. We use the code NOVO and include analytical estimations for the wake potential calculations. We show that the bunch energy losses due to these elements are about 20% of the total wake field losses.

Radiation Protection Aspects of the Linac Coherent Light Source Front End Enclosure

WEPC23

Joachim Vollaire (SLAC, Menlo Park, California)

The Front End Enclosure (FEE) of the Linac Coherent Light Source (LCLS) is a shielding housing located between the electron dump area and the first experimental hutch. The upstream part of the FEE hosts the commissioning diagnostic for the FEL beam. In the downstream part of the FEE, two sets of grazing incidence mirror and several collimators are used to direct the beam to one of the experimental station and reduce the bremsstrahlung background and the hard component of the spontaneous radiation spectrum. This paper addresses beam loss assumption, the design limits and the simulations performed using the Monte-Carlo code FLUKA for the design of the shielding necessary to attenuate secondary radiations (including muons) induced by the bremsstrahlung photons. Other Radiation Safety Systems associated to the containment of the FEL beam and an overview of the Personnel Protection system is provided for completeness.

Measurements and Analysis of the Electron Bunch Energy Loss and Spread and Transverse Kicks in the LCLS Undulators

WEPC24

Juhao Wu, Karl Leopold Freitag Bane, Axel Brachmann, Alex Chao, Franz-Josef Decker, Yuantao Ding, David Dowell, Steve A. Edstrom, Paul J. Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Richard Iverson, Henrik Loos, Alan Miahnahri, Alexander Novokhatski, Heinz-Dieter Nuhn, Daniel Ratner, Gennady Stupakov, James Leslie Turner, James Welch, William White, Dao Xiang (SLAC, Menlo Park, California)

To ensure Free Electron Laser (FEL) saturation in the Linac Coherent Light Source (LCLS), the relative energy variation induced within the bunch in the undulator region must be kept to within a few times the FEL Pierce parameter. Inside the undulator, the longitudinal resistive wall wakefield, as well as other contributors like surface roughness wakefield of the beam pipe can induce an energy variation along the electron bunch. Furthermore, the undulator spontaneous radiation and FEL itself will induce energy loss. We report measurements in the LCLS undualtors about the electron bunch centroid energy loss and the energy spread, and compare to calculations. In the post saturation region, the energy loss due to coherent emission from the microbunched electron beam is used to model the undulator taper. Besides this, we study the transverse kick due to the transverse wakefield inside the undulator. The energy loss induced transverse dispersive kick is compared to the transverse wakefield effect. The transverse effects set a limit on the random displacements of the resistive-wall segments and the focusing elements.

Experiment on Iodine Transmutation Through High-Energy Gamma Ray — WEPC26

Dazhi Li, Kazuo Imasaki (ILT, Suita, Osaka), Sho Amano, Ken Horikawa, Shuji Miyamoto, Takayasu Mochizuki (NewSUBARU/SPring-8, Hyogo)

Transmutation is considered as an approach to reducing the radioactive life of the nuclear waste through converting the nuclei of long-lived activity to its corresponding isotope of short-lived activity. High-energy photons can induce a nuclear reaction, which is regarded as an approach to make transmutation. Laser Compton Scattering (LCS) gamma ray seems a good photon source. The LCS gamma ray is generated from the collision of a laser light to a high-energy electron beam, and it holds a peak in the energy spectrum, which can well overlap the peak of nuclear giant resonance and hence realize a good coupling. I-129 has a very long life of more than 16 million years and a high chemical activity. Besides these, Iodine is hard to include in the normal reposing container due to its low temperature boiling point. So Iodine is recognized as discrete waste for transmutation. The reaction rate of transmutation plays an important role in this proposal of deposing nuclear waste; therefore, the aim of this paper is to experimentally investigate the reaction rate of Iodine.

Visible FEL Irradiation Experiments on Carbonmonoxy Hemoglobin — WEPC27

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The Free Electron Laser (FEL) of LEBRA* produces near infrared FELs (IR FELs) including tunable wavelength from 1 to 6 microns. The higher harmonics generated by means of the nonlinear optical crystals are also available with output energy of about 0.5 mJ / micro-pulse. The IR FELs of LEBRA are of significant interest because these tunable wavelengths covered with visible and near infrared regions (350 - 6000 nm) expect to unveil photochemical reactions of bio-macromolecules even in living organisms. We use LEBRA IR FELs for macromolecules such as caronmonoxy hemoglobin (COHb), whose maximum absorption spectra are known as Soret band (418 nm) and two weaker bands (538 nm and 568 nm). We first selected three of the visible wavelengths. After irradiation (up to about 10 J), the effect of each of the three wavelengths on COHb was separately investigated by several methods including visible scanning absorption spectroscopy and Raman microscopy. We report the present results on the measurements.

** Laboratory for Electron Beam Research and Application, Institute of Quantum Science, Nihon University.*

XUV Fluorescence from XUV-FEL Interaction with Metals — WEPC28

Thomas Whitcher, Gianluca Gregori, William J. Murphy, Bob Nagler, Sam M Vinko, J. S. Wark (University of Oxford, Oxford), Tomas Burian, Jaromir Chalupsky, Jaroslav Cihelka, Vera Hajkova, Libor Juha (Czech Republic Academy of Sciences, Prague), Sasa Bajt, Henry Chapman, Stefan Düsterer, Roland Faustlin, Tim Laarmann, Sven Toleikis (DESY, Hamburg), Thomas Tschentscher (European X-ray Free Electron Laser Project Team, Hamburg), Ali Reza Khorsand (FOM Rijnhuizen, Nieuwegein), Marta Fajardo, Michaela Kozlova (GoLP, Lisbon), Eckhart Foerster, Ingo Uschmann, Ulf Zastrau (IOQ, Jena), Marek Jurek, Dorota Klinger, Ryszard Sobierajski (IP PAS, Warsaw), Fida Younus Khattak (Kohat University of Science and Technology, Kohat), Philip Heimann (LBNL, Berkeley, California), Tilo Doeppner, Siegfried Glenzer, Richard Lee, Art James Nelson, Hubert Joachim Vollmer (LLNL, Livermore, California), Thomas Dzelzainis, David Riley (Queen's University of Belfast, Belfast, Northern Ireland), Thomas Bornath, Carsten Fortmann, Sebastian Goede, Karl Heinz Meiwes-Broer, Andreas Przystawik, Ronald Redmer, Heidi Reinholz, Gerd Roepke, Robert Thiele, Josef Tiggesbaumker (Rostock University, Rostock), Jacek Krzywinski (SLAC, Menlo Park, California), Pascal Mercere (SOLEIL, Gif-sur-Yvette), Hae Ja Lee (UCB, Berkeley, California), Eric Galtier, Frank Rosmej, Romain Schott (UPMC, Paris)

Using the XUV Free electron LASer in Hamburg, FLASH, focussed to intensities exceeding 10^{17} W / cm^2, we have been able to create and probe highly exotic states of matter. Under such irradiances, electrons within the L-shell in metals such as Aluminium and Magnesium are excited and XUV absorption undergoes saturation due to the high photon-to-atom ratio. These electrons will subsequently recombine, mainly through Auger processes, heating the metals further. However, about 2.5×10^{-3} of the electrons will decay radiatively, providing information on the localised density of states. While this has been observed in many metals at room temperature, this is the first time that we have been able to get information on the density of states of a Warm Ionized Crystalline Matter. Using an XUV spectrometer, we obtain information on the temperature history as the metal evolves from a warm dense solid to a lower-density plasma.

Search for Dark Matter Particles with Jefferson Lab's FEL — WEPC29

Michelle Diane Shinn, George Herman Biallas, James R. Boyce (JLAB, Newport News, Virginia), Andrei Afanasev (Hampton University, Hampton, Virginia), Kevin Beard (Muons, Inc, Batavia), Minarni Minarni (UNRI, Riau), Oliver Keith Baker, Penny Slocum (Yale University, New Haven, CT)

Cosmology provides evidence that most of the mass of the observable universe cannot be associated with any of the known Standard-Model elementary particles. Evidence of this „dark matter' was also obtained in the recent data from space telescopes. Axions - hypothetical particles proposed to solve a strong CP problem in Quantum Chromodynamics - are dark matter candidates. Although they carry zero electric charge, they can be produced via Primakoff mechanism, resulting in predictable effects in the laboratory. We present first results from an ongoing LIPSS experiment to search for axion-like particles with Jefferson Lab's free electron laser.

FEL Amplifier Simulation of Coherent Electron Cooling — WEPC30

Yue Hao, Vladimir N. Litvinenko, Eduard Pozdeyev (BNL, Upton, Long Island, New York)

Coherent electron cooling (CEC) has a potential to significantly boost luminosity of high-energy, high-intensity hadron-hadron and electron-hadron colliders such as LHC and eRHIC*. The advantage of CEC over other cooling scheme is the micro bunching effect in FEL linear region that provides very high frequency amplifier. The nonliearity of the FEL process and the diffraction effect degrade the amplification quality and need to be evaluated the guarantee the effectiveness. We carried out simulation and analysis to investigate these effects.
** Vladimir N. Litvinenko, Yaroslav S. Derbenev, Physical Review Letters 102, 114801.*

Proof-of-Principle Experiment for FEL-Based Coherent Electron Cooling — WEPC31

Vladimir N. Litvinenko, Ilan Ben-Zvi, Michael Blaskiewicz, Alexei V. Fedotov, Yue Hao, Dmitry Kayran, Eduard Pozdeyev, Gang Wang, Stephen Davis Webb (BNL, Upton, Long Island, New York), George I. Bell, David Leslie Bruhwiler, Andrey V. Sobol (Tech-X, Boulder, Colorado)

Coherent electron cooling (CEC) has a potential to significantly boost luminosity of high-energy, high-intensity hadron-hadron and electron-hadron colliders such as LHC and eRHIC*. In a CEC system, a hadron beam interacts with a cooling electron beam. A perturbation of the electron density caused by ions is amplified and fed back to the ions to reduce the energy spread and the emittance of the ion beam. To demonstrate feasibility of CEC we plan a proof-of-principle experiment at RHIC. In this experiment, the RHIC ion beam will be cooled at an energy lower than the typical operational RHIC energy. In this paper, we describe the experimental setup for CeC installed into one of RHIC interaction region. We present results of analytical estimates and results of initial simulations of cooling gold-ion beam at 40 GeV / u energy via CeC.
** Vladimir N. Litvinenko, Yaroslav S. Derbenev, Physical Review Letters 102, 114801.*

Extraction of Single FELBE Radiation Pulses Using a Laser-Activated Plasma Switch — WEPC32

Wolfgang Seidel, Stephan Winnerl, Dietrich Wohlfarth (FZD, Dresden)

In order to decrease the average radiation power of the Rossendorf free electron laser FELBE, as required for certain experiments (high pulse energies but moderate or low average power), the FEL repetition rate can be reduced from 13 MHz to 1 kHz. To this end, plasma switching of FEL radiation pulses was demonstrated for cw operation. The plasma switch is based on the principle of photo-induced reflectivity by an optically excited electron-hole plasma. Germanium or silicon serves as semiconductor material for the switch. The semiconductor was illuminated by a Nd:YAG laser amplifier system (1 kHz, wavelength 1064 nm, pulse duration 16 ps, 1 W) or a Ti:S amplifier (1 kHz, wavelength 800 nm, pulse duration 22 fs, 1 W) respectively, generating an electron-hole plasma on the front surface of the semiconductor. To integrate this plasma-switch into the existing diagnostic station we build an additional by-pass to the Germanium or Silicon slab which is under Brewster‟s angle. The selected micro pulse will be refocused to the waist parameters outside of the by-pass line and transported to the user stations. We will report on first results at different wavelengths.

A Study of the Stability of FEL Resonators — WEPC33

Srinivas Krishnagopal (BARC, Mumbai), Tushima Basak, Sushil Arun Samant (CBS, Mumbai)

The presence of an FEL interaction perturbs the stability of an optical resonator. We use the FEL oscillator code TDAOSC to study this effect, and map out the modified stability diagram in two dimensions. In particular we study the phenomenon of mode-beating, and parameterization of the FEL interaction in terms of a lens model.

Simulation of an X-Ray FEL Oscillator for the Multi-GeV ERL in Japan — WEPC34

Ryoichi Hajima, Nobuyuki Nishimori (JAEA/ERL, Ibaraki)

In Japan, we have organized the ERL collaboration initiative towards future ERL light sources. Construction of an x-ray synchrotron light source, a multi-GeV ERL, is one of the targets of our collaboration. As an option of the multi-GeV ERL, we consider an X-ray FEL Oscillator (XFEL-O) to produce hard x-ray pulses with excellent temporal coherence*. In this study, we present simulation results of the XFEL-O such as FEL lasing including spectral narrowing and nonlinear phase shift at Bragg reflectors, possible energy-doubling configuration to enhance the single-pass gain and so on.
** R. Hajima, N. Nishimori, Proc. FEL 2008.*

Status of the MIR-FEL Facility in Kyoto University — WEPC35

Hideaki Ohgaki, Mahmoud Abdel Aziem Bakr, Keisuke Higashimura, Toshiteru Kii, Ryota Kinjo, Kai Masuda, Taro Sonobe, Satoshi Ueda, Kyohei Yoshida (Kyoto IAE, Kyoto), Young Uk Jeong (KAERI, Daejon), Heishun Zen (UVSOR, Okazaki)

A mid-infrared free electron laser facility has been constructed for developing energy materials in the Institute of Advanced Energy, Kyoto University. The accelerator has been installed and FEL gain saturation at 13.2 μm was achieved in May 2008. The FEL power of about 3 MW has been observed at the accelerator room. We have constructed the FEL transport system from the accelerator room to the user room. The beam characterization at the user room and preparation of the application of MIR-FEL will be introduced in the conference.

Present Status and Upgrade Plan of the UVSOR-II Free Electron Laser — WEPC36

Heishun Zen, Masahiro Adachi, Kenji Hayashi, Masahiro Katoh, Jun-ichiro Yamazaki (UVSOR, Okazaki), Masahito Hosaka, Masashi Koike, Yoshitaka Taira, Yasuyuki Uno, Naoto Yamamoto (Nagoya University, Nagoya), Takanori Tanikawa (Sokendai, Okazaki, Aichi)

At the UVSOR storage ring, Free Electron Lasers (FELs) have been studied for more than a decade. After the upgrade of accelerator components in 2003, FEL lasing around 199 nm* has been achieved. In these years, several application experiments of the FEL in the deep UV region have been carried out. A feedback alignment system of the optical resonator has been developed to improve long term stability of the laser power for user experiments. To promote application experiments more extensively, now we have two upgrade plans. One is FEL lasing with a top-up operation in order to maintain a high beam current and then a high out-coupled power. The other is upgrade of the optical klystron to have higher gain at deep UV region. These two upgrades will allow us to attract more users to our FEL.

** M. Hosaka, “Lasing below 200 nm at the UVSOR-II FEL,” UVSOR Activity Report 2007.*

Commissioning of Infrared FEL and its First Lasing at the Storage Ring NIJI-IV — WEPC37

Hiroshi Ogawa, Norihiro Sei, Kawakatsu Yamada (AIST, Tsukuba, Ibaraki)

At AIST, we are developing a FEL with wide wavelength range from the vacuum ultraviolet (VUV) to the far-infrared (FIR) based on a compact storage ring NIJI-IV. In the infrared region, a 3.6 m optical klystron ETLOK-III is used for an insertion device, which has been installed in the other side of a 6.3 m optical klystron ETLOK-II for UV / VUV FEL. All components installation for IR FEL oscillation was completed last year and beam commissioning was started. After tuning both beam and optical parameters, first lasing of the near-IR FEL at NIJI-IV was achieved on February 12, 2009*. Furthermore intensive quasi-monochromatic gamma-ray by the FEL Compton backscattering was successfully observed. In this paper, we will report on measured lasing characteristic and status of commissioning of FEL-X project**.

** N. Sei, H. Ogawa, K.Yamada, accepted in Optics Letters. ** T. Yamazaki et al., Nucl. Instr. and Meth. B144 (1998) 83.*

The TAC IR FEL Oscillator Facility Project

WEPC38

Bora Ketenoglu (Ankara University, Tandogan, Ankara)

The TAC (Turkish Accelerator Center) IR FEL Oscillator facility, which has been supported by the Turkish State Planning Organization (SPO) since 2006, will be based on a 15 - 40 MeV electron linac accompanying two different undulators with 2.5 cm and 9 cm periods in order to obtain IR FEL ranging between 2 - 250 microns. The electron linac will consist of two sequenced modules, each housing two 9-cell superconducting TESLA cavities for cw operation. It is planned that the TAC IR FEL facility will be completed in 2012 at Golbasi campus of Ankara University. This facility will give an opportunity to the scientists and industry to use FEL in research and development in Turkey and our region. In this study, the results of optimization studies and present plans about construction process of the facility are presented.

Overview and Status of the ALICE IR-FEL

WEPC39

David Dunning, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), James Clarke (Cockcroft Institute, Warrington, Cheshire; STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Ian Burrows (STFC/DL, Daresbury, Warrington, Cheshire)

The ALICE (Accelerators and Lasers in Combined Experiments) facility (formerly known as ERLP) is currently being commissioned at Daresbury Laboratory. It serves as a test facility for novel accelerator and photon science applications. As part of this facility, an oscillator-type FEL will be commissioned later in 2009. The FEL will be used to test energy recovery with a disrupted beam and to provide output for a select experimental programme. The FEL output will be measured and used to determine the accuracy of FEL modelling techniques. The facility could also potentially be used as a testbed for novel FEL concepts. In this paper, an overview of the FEL design is presented, together with an update of the status of commissioning preparations, including time-dependent modelling using the expected electron beam parameters.

Simulation Studies of the X-Ray Free Electron Laser Oscillator

WEPC40

Ryan Roger Lindberg, Kwang-Je Kim, Yuri Shvyd'ko (ANL, Argonne, Illinois), William M. Fawley (LBNL, Berkeley, California)

Simulations of the x-ray Free Electron Laser (FEL) oscillator are presented that include transverse effects and realistic Bragg mirror properties with the two-dimensional FEL code GINGER. In the present cases considered, the radiation divergence is much narrower than the mirror acceptance, and the numerical algorithm can be simplified by ignoring the finite angular bandwidth of the mirror. In this regime GINGER shows that the saturated x-ray pulses have ~109 photons and are nearly Fourier limited with peak powers in excess of 10 MW. We also include preliminary results for a four-mirror cavity that can be tuned in wavelength over a few percent, with future plans to incorporate the full transverse response of the Bragg mirrors into GINGER to more accurately model this tunable source.

Experimental Study and Simulation of Storage Ring FEL Output Power Scaling with Electron Beam Energy Spread

WEPC41

Ying K. Wu, Botao Jia, Jingyi Li (FEL/Duke University, Durham, North Carolina), Juhao Wu (SLAC, Menlo Park, California)

Accurate simultaneous measurements of Storage Ring Free Electron Laser (SRFEL) average power output and electron beam energy spread has been achieved at the Duke FEL Laboratory. This relationship is also simulated by a software package we developed based on Genesis. It is well known that the SRFEL power is limited by the electron beam synchrotron radiation power and the induced energy spread of the electron beam. The two-wiggler spectrum of an optical klystron can be used to determine the energy spread of the electron beam. Measuring the interference pattern of the modulated spontaneous spectrum with the FEL turned on, we are able to study the FEL power output as a function of electron beam energy spread. As the energy spread increases, the modulation in the two-wiggler spectrum reduces, resulting in a smaller FEL gain. During this process, the operation of an optical klystron degrades back to that of a conventional FEL. This paper reports our recent experiment study of transition of the FEL operation from an optical klystron to a conventional FEL. We also show the numerical simulation results.

FEL Gain Manipulation Using an In-Cavity Aperture System

WEPC42

Ying K. Wu, Jingyi Li, Botao Jia, Stepan F. Mikhailov, Victor Popov (FEL/Duke University, Durham, North Carolina), Senlin Huang (FEL/Duke University, Durham, North Carolina; PKU/IHIP, Beijing)

The Duke Free Electron Laser (FEL) is a storage ring based oscillator FEL (SRFEL). It has been used as the photon source for the High Intensity gamma-ray Source (HIgS) at Duke University. The 54 m long FEL cavity consists of two concave mirrors with the same radius of curvature. The downstream mirror receives not only the fundamental radiation but also higher harmonic radiation emitted by relativistic electrons in the wiggler magnetic field. The ultraviolet (UV) and vacuum-ultraviolet (VUV) power load of harmonic radiation on this mirror can deform or even seriously damage multi-layer coating of the mirror, and hence limit the maximum power for FEL operation. To mitigate these problems, a water-cooled aperture system has been installed inside the cavity. This aperture system can also be used to manipulate transverse modes of the FEL beam. In particular, they can be used to reduce the wiggler radiation power in the fundamental mode, thus as an independent FEL gain control device. This paper reports our study of the FEL gain manipulation using the water-cooled in-cavity apertures.

Free Electron Lasers in 2009

WEPC43

William B. Colson, Joseph Blau, Samuel Hallock, Jimenez Justin, Aaron Zimmer (NPS, Monterey, California)

Thirty-three years after the first operation of the short wavelength Free Electron Laser (FEL) at Stanford University, there continue to be many important experiments, proposed experiments, and user facilities around the world. Properties of FELs in the infrared, visible, UV, and x-ray wavelength regimes are tabulated and discussed.

The European XFEL Study with Weaker Undulator Focusing Lattice — WEPC44

Vahe Sahakyan, Vitali Khachatryan, Artur Tarloyan, Vasili Mkrtich Tsakanov (CANDLE, Yerevan), Winfried Decking (DESY, Hamburg)

Time-dependent simulations of the SASE process for two special arrangements with weak focusing lattice in European XFEL undulator section are presented. The radiation main parameters, saturation lengths and saturation power, are compared with the case based on design focusing lattice. The impact of the quadrupole misalignments, beta mismatch and the beam main parameters on the SASE FEL performance is discussed.

Numerical Performance Studies on the New Sliced-Beam-Parameter Measurement Section for FLASH — WEPC45

Christopher Behrens, Christopher Gerth, Igor Zagorodnov (DESY, Hamburg)

The Free Electron Laser (FEL) user facility FLASH at DESY operates a high-gain FEL and provides radiation in the vacuum-ultraviolet and soft x-ray regime. In order to improve the capability and performance of the facility, FLASH will be upgraded with a third harmonic (3.9 GHz) RF system to linearise the longitudinal phase space in front of the bunch compressors. For the study of the phase space linearisation, a new diagnostic and matching section located directly in front of the FEL undulators was designed, which makes it possible to determine sliced beam parameters with high temporal resolution. In this paper, we describe the design considerations for this diagnostic section and demonstrate the expected performance by means of sophisticated particle tracking simulations.

Integration of the Optical Replica Ultrashort Electron Bunch Diagnostics with the High-Resolution Coherent Optical Transition Radiation Imager — WEPC46

Gianluca Geloni, Petr Ilinski, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

Electron bunch imagers based on incoherent OTR constitute the main device presently available for the characterization of ultrashort electron bunches in the transverse direction. One difficulty to obtain high-resolution images is related with the very peculiar particle-spread function of OTR radiation, which has a large width compared to the usual point-spread function of a point-like source. In this contribution we explore the possibility of using coherent OTR instead of incoherent OTR radiation, by integrating an ORS setup with a high-resolution coherent optical transition radiation imager. Electron bunches are modulated at optical wavelengths in the ORS setup. When these electron bunches pass through a metal foil target, coherent radiation pulses of tens MW power are generated. It is thereafter possible to exploit the large number of available coherent photons. In particular we manipulate the particle spread function of the system, so that the imaging problem can be reduced to the usual (coherent or incoherent) imaging theory for point-like radiators.

Method for the Determination of the Three-Dimensional structure of Ultrashort Relativistic Electron Bunches — WEPC47

Evgeny Saldin, Gianluca Geloni, Petr Ilinski, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We describe a novel technique to characterize ultrashort electron bunches in x-ray free electron lasers. Namely, we propose to use coherent Optical Transition Radiation to measure three-dimensional (3D) electron density distributions. Our method relies on the combination of two known diagnostics setups, an Optical Replica Synthesizer (ORS) and an Optical Transition Radiation (OTR) imager. Electron bunches are modulated at optical wavelengths in the ORS setup. When these electron bunches pass through a metal foil target, coherent radiation pulses of tens MW power are generated. It is thereafter possible to exploit advantages of coherent imaging techniques, such as diffractive imaging, Fourier holography and their combinations. The proposed method opens up the possibility of real-time, wavelength-limited, single-shot 3D imaging of an ultrashort electron bunch.

A Scheme for Pump-Probe Experiments at an X-Ray SASE FEL — WEPC48

Evgeny Schneidmiller, Evgeny Saldin, Mikhail Yurkov (DESY, Hamburg)

We propose a new scheme for two-color operation of an FEL where an electron bunch generates an x-ray pulse and a long wavelength (VUV to infrared) radiation pulse. The scheme is very simple, cheap and robust, and therefore can be easily realized in facilities like FLASH, European XFEL, LCLS, and SCSS.

Limitations on the Operation of a Soft X-Ray FEL (SASE3) at the European XFEL — WEPC49

Evgeny Schneidmiller, Evgeny Saldin, Mikhail Yurkov (DESY, Hamburg)

The FEL process leads to energy loss by electrons and an increase of the energy spread. Further use of the electron beam for generation of the FEL radiation is possible, but only for longer wavelengths. This technical solution is implemented in the design of the European XFEL. Two undulators, SASE1 and SASE3, are installed in a raw. SASE 1 is designed to operate at fixed photon wavelength of 0.1 nm. The SASE 3 undulator has been placed behind SASE1, and will produce radiation in the wavelength range of 0.4 - 1.6 nm. Degradation of the electron beam quality after SASE1 is not completely negligible, and its influence on SASE3 performance is the subject of the present study.

Observation of Coherent Optical Transition Radiation and Evidence for Microbunching in Magnetic Chicanes — WEPC50

Stephan Wesch, Christopher Behrens, Bernhard Schmidt (DESY, Hamburg), Peter Schmüser (Uni HH, Hamburg)

The observation of coherent optical transition radiation (COTR) has recently attracted a lot of attention because of its detrimental influence on OTR based diagnostic techniques, and also as evidence for a microbunching instability in magnetic bunch compressors. At FLASH, we have observed coherent visible and infrared radiation from bunches having passed the magnetic bunch compressor chicanes. The spectral distribution was measured from 400 nm to 1600 nm with high resolution for various settings of the magnet currents in the chicanes. Remarkably, the coherent visible radiation was found to be stronger for uncompressed bunches than for the compressed bunches needed for FEL operation. Additionally, images of the bunches using narrow band filters from 950 nm to 1650 nm have been recorded.

Expected Properties of the Radiation from a Soft X-Ray SASE FEL (SASE3) at the European XFEL

WEPC51

Mikhail Yurkov, Evgeny Saldin, Evgeny Schneidmiller, (DESY, Hamburg)

This report deals with an update of parameters of a soft x-ray SASE FEL (SASE3) at the European XFEL. Two scenarios of SASE3 operation are considered: nominal mode of operation (fixed energy of 17.5 GeV, and operating wavelength range 0.4 - 1.6 nm), and long wavelength mode of operation (fixed energy of 8.75 GeV, and operating wavelength range 1.6 - 6.4 nm). Perspectives for obtaining ultimate intensity of the radiation are discussed as well.

Using a Ytterbium Fiber Laser-Based Electro-Optic Experiment for Electron Bunch Diagnostic at FLASH

WEPC52

Laurens-Georg Wissmann, Sebastian Schulz (Uni HH, Hamburg), Marie Kristin Bock, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Johann Zemella (DESY, Hamburg), Vladimir Arsov (PSI, Villigen)

FLASH (the Free electron LASer at Hamburg) is a high-gain SASE-FEL providing ultrashort pulses with a central wavelength of 6 to 40 nm. Measuring and controlling the longitudinal shape of the electron bunches can dramatically improve the stability of the lasing process. Non-destructive electro-optical bunch profile diagnostics have proved to work with resolutions down to 100 fs. The electro-optical (EO) setup at FLASH relies on a standard Ti:Sapphire laser delivering 80 fs pulses with 4 nJ pulse energy. For practical and physical reasons (i.e., space, costs, maintenance, performance) a new, ytterbium fiber laser system has been developed. This laser system supports pulse energies of 4.5 nJ and a bandwidth of 100 nm at a center wavelength of 1030 nm. Active repetition rate control allows the laser to be locked to the RF based synchronisation system. A better EO signal-to-noise ratio is expected due to the improved group velocity matching in the EO crystal. First results from the prototype Yb laser system and comparison with the Ti:Sa based data will be presented. Furthermore, a structurally engineered version, promising enhanced stability and reliability will be introduced.
** F. Loehl now at Cornell University, Ithaca, USA. ** A. Winter now at ITER, Cadarache, France.*

The Second Stage of FERMI@ELETTRA: a Seeded FEL in the Soft X-Ray Spectral Range

WEPC53

Enrico Allaria (ELETTRA, Basovizza), Giovanni De Ninno (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica)

The second stage of the FERMI FEL, named FEL-2, is based on the principle of high-gain harmonic generation and relies on a double-seeded cascade. Recent developments stimulated a revision of the original setup, which was designed to cover the spectral range between 40 and 10 nm. According to the numerical simulations we present here, the nominal (expected) electron-beam performance allows to extend the FEL spectral range down to 3 nm. A significant amount of power can be also expected at about 1 nm. We also show that the proposed setup is flexible enough for exploiting future developments of new seed sources, e.g., high harmonic generation in gases.

The ELETTRA Storage-Ring FEL: a VUV Source for the Investigation of Ultra-Fast Phenomena

WEPC54

Giovanni De Ninno (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica), David Garzella (CEA, Gif-sur-Yvette), Marcello Coreno (CNR - IMIP, Trieste), Enrico Allaria, Miltcho B. Danailov, Emanuel Karantzoulis, Carlo Spezzani, Mauro Trovo (ELETTRA, Basovizza), Jurij Urbancic (University of Nova Gorica, Nova Gorica)

The Elettra Storage-Ring FEL operated in single-pass configuration allows us to obtain coherent radiation in the UV-VUV range, with pulse duration of 100 - 200 fs. The setup relies on the frequency up-conversion of a high-power external signal (provided by a Ti:Sapphire laser) that seeds the electron beam circulating into the storage ring. A significant fraction of the seeding laser is transmitted together with the emitted CHG pulse at the exit of the source and is naturally synchronized with the latter. We present here the recent development of such a source (generation of coherent light at 87 nm), as well as the most relevant scientific opportunities offered by this facility to investigate ultra-fast phenomena.

FEL Commissioning of the First Stage of FERMI@ELETTRA

WEPC55

Carlo Spezzani, Enrico Allaria, Bruno Diviacco, Mauro Trovo (ELETTRA, Basovizza), Giovanni De Ninno (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica)

The commissioning of the first stage of FERMI@Elettra will start during the summer of 2009. During the first year of operation, efforts will concentrate on the optimization of the gun performance, as well as of the electron-beam acceleration and transport through the linac. By fall 2010, it is our aim to generate out of the linac an electron beam as similar as possible to the one needed for obtaining the nominal (i.e., user-required) FEL performance*. Such a beam will be then injected into the undulator chain and used to get the first FEL light. In this paper, we present our strategy for the commissioning of the FEL process, both in SASE and seeded configurations. On the basis of start-to-end simulations, we also discuss the expected FEL performance for day-one operation.
** See, e.g., S. Di Mitri et al., this conference.*

Seeding Experiments at SPARC

WEPC56

Marie Labat, Franco Ciocci, Giuseppe Dattoli, Mario Del Franco, Andrea Doria, Gian Piero Gallerano, Luca Giannessi, Emilio Giovenale, Alberto Maria Antonio Petralia, Marcello Quattromini, Concetta Ronsivalle, Elio Sabia, Ivan Panov Spassovsky, Vincenzo Surrenti (ENEA C.R. Frascati, Frascati (Roma)), Bertrand Carré, David Garzella (CEA, Gif-sur-Yvette), Alessandro Cianchi, Barbara Marchetti (INFN-Roma II, Roma), Mario Mattioli, Maurizio Serluca (INFN-Roma, Roma), David Alesini, Marco Bellaveglia, Roberto Boni, Manuela Boscolo, Michele Castellano, Enrica Chiadroni, Alberto Clozza, Luca Cultrera, Giampiero Di Pirro, Alessandro Drago, Massimo Ferrario, Luca Ficcadenti, Daniele Filippetto, Valeria Fusco, Alessandro Gallo, Giancarlo Gatti, Andrea Mostacci, Elisabetta Pace, Luigi Palumbo, Bruno Spataro, Cristina Vaccarezza (INFN/LNF, Frascati (Roma)), Alberto Bacci, Vittoria Petrillo, Andrea Renato Rossi, Luca Serafini (Istituto Nazionale di Fisica Nucleare, Milano), Fabien Briquez, Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Gabriel Marcus, James Rosenzweig (UCLA, Los Angeles, California)

The SPARC FEL can be operated in both SASE and seeded modes. A major part of the second stage of the commissioning, currently in progress, is dedicated to the characterization of the SASE radiation. Simultaneously, we are finalizing the experimental setup for seeding. We present an in-situ characterization of the two input seeds that are foreseen: both are obtained via harmonic generation, the first one in crystal (400 and 266 nm) and the second in rare gas (Argon). We also describe the specific diagnostics implemented for the electron-seed overlap in the undulator, together with the diagnostics for radiation analysis (2D spectrometer and FROG). The seeding will enable the operation of the SPARC FEL in original cascaded configurations.

Parameter Study for FEL Project at INFLPR — WEPC57

Florea Scarlat, Eugenia Simona Badita, Ecaterina Mitru, Anca Mariana Scarisoreanu (INFLPR, Bucharest - Magurele), Minola Rodica Leonovici (Bucharest University, Bucharest-Magurele), Vasile Babin, Sorin Miclos, Dan Savastru (INOE 2000, Magurele), Valerica Gheorghe Cimpoca, Calin Oros, Ion Popescu (Valahia University, Targoviste)

This paper is a presentation of a parameter study for the FEL Project at INFLPR considering recent advances of technologies in the domain of accelerators, lasers, undulators and seeded operation with HHG which in their turn allow the construction of a national user facility based on an intense FEL at VUV wavelengths. The calculations also considered the possibilities for the facility to be upgraded for EUV regime, in a second stage. In the first stage, results were obtained for the FEL subsystem parameters starting from the 1 GeV beam electron energy, a 500 A electron current, a single stage HGHG FEL and VUV regime. Also, the status of the project is briefly sketched herein.

Tolerance Studies for the Hard X-Ray Beamline of the SwissFEL — WEPC58

Sven Reiche (PSI, Villigen)

The currently planned x-ray facility at the Paul Scherrer Institut will span a wavelength range between 1 Ångström and 7 nm, distributed over 2 beamlines. The design aims for a compact layout with low electron beam energies and short undulator periods for the hard x-ray beamline. The resulting tolerances are the most stringent for the operation at the shortest wavelength of 1 Å. The tolerance study, presented here, distinguishes the error sources between those of components within the undulator beam line (e.g. undulator field errors) and jitter in the electron beam parameters. The latter can be used as the figure of merits for defining the tolerance budget of the injector and linac, the discussion of which is beyond the scope of this presentation.

Single Spike Operation for the Generation of Sub-fs Pulses in the NLS — WEPC59

Riccardo Bartolini, Ian Martin (Diamond, Oxfordshire)

We discuss the possible operation of the UK New Light Source in the single spike regime with photon energies ranging from 50 eV to 1 keV. The optimisation process of the beam dynamics in the single spike regime is outlined and we present the results of full start-to-end simulations to show that few-fs to sub-fs pulses can be obtained, depending on the photon energy, with an interesting power level. The analysis of the jitter of the SASE output characteristic is also reported.

The Potential of Chirped-Pulse X-Rays for Ultrafast Time-Resolved Experiments at LCLS

WEPC60

Ryan Roger Lindberg, Kwang-Je Kim (ANL, Argonne, Illinois), Tim Graber (Consortium for Advanced Radiation Sources, Argonne, IL)

We discuss the viability of time-resolved x-ray crystallography using an energy-chirped electron beam at the Linac Coherent Light Source (LCLS). The correlation of time and energy in the produced radiation can be used for time-resolved Laue diffraction experiments. In a Laue pattern, each spot is diffracted by a known x-ray energy and is therefore directly related to time according to the energy chirp*. Although the method is applicable to any chirped source, we focus on SASE x-rays in general and the LCLS in particular. Previous authors have proposed producing temporally short pulses using a monochromater**. The advantage of our method is that it can resolve molecular dynamics over the full duration of the x-ray pulse, effectively making several pump-probe measurements at once on a single crystal. Since the interaction region of the crystal will suffer severe radiation damage after one LCLS pulse, this technique maximizes the amount of time-resolved data collected on a single sample. We present some of the LCLS user requirements regarding the beam chirp magnitude and dynamic range, and begin to address the impact of the fluctuating SASE spectrum on experimental resolution.
** K. Moffat, Royal Soc. Chem. 122, 65 (2002). ** C. Pelligrini, Nucl. Instrum. Methods Phys. Res. A 445, 124 (2000).*

WiFEL: The Wisconsin Free Electron Laser

WEPC61

Robert Arthur Bosch, Ken Jacobs, Joseph Bisognano, Mark Bissen, Michael Green, Hartmut Hoechst, Kevin J Kleman, Robert Legg, Ruben Reininger, Ralf Wehlitz (UW-Madison/SRC, Madison, Wisconsin), William Graves, Franz Xaver Kaertner, David Moncton (MIT, Cambridge, Massachusetts)

The University of Wisconsin-Madison / Synchrotron Radiation Center and MIT are developing a design for a seeded VUV / soft x-ray free electron laser serving multiple simultaneous users. The present design uses an L-band CW superconducting 2.2 GeV electron linac to deliver 200 pC bunches to multiple FELs operating at repetition rates from kHz to MHz. The FEL output will be fully coherent both longitudinally and transversely, with tunable pulse energy, cover the 5 - 900 eV photon range, and have variable polarization. Bunch seeding at higher photon energies will be done with HHG laser pulses to avoid the need for fresh electron bunches. This unique facility is expected to enable new science through ultrahigh resolution in the time and frequency domains, as well as coherent imaging and nano-fabrication. We have proposed a program of R&D to address the most critical aspects of the project, including prototyping of a CW superconducting RF photoinjector, and development of conventional laser systems for MHz seeding of the FEL. We present an overview of the facility and our proposed R&D plan.

Efficiency Enhancement in Seeded and SASE Free Electron Lasers by Means of a Tapered Wiggler

WEPC62

Henry Freund, William Miner (SAIC, McLean)

Efficiency enhancement in Free Electron Lasers (FELs) using a tapered wiggler is well known. The physics of the tapered wigglers has been studied in theory and simulation, and large enhancements have been observed in oscillator and amplifier experiments. In this paper, we study the differences in the tapered wiggler interaction between seeded amplifiers and in Self-Amplified Spontaneous Emission (SASE) FELs. In comparison with seeded amplifiers, SASE FELs exhibit shot-to-shot fluctuations due to random phase noise in the electron bunch, and our purpose is to determine the effect of this phase noise on the tapered wiggler interaction. To this end, we study the interaction numerically using the MEDUSA simulation code for seeded and SASE FELs operating in the infrared regime. The results of the simulations indicate that the overall efficiencies of the seeded and SASE FELs are comparable for a uniform wiggler but that the output spectrum for the SASE FEL is much broader than for the seeded case. For a tapered wiggler, the efficiency enhancement in the SASE FEL is less than that found in the seeded example due to the broader excited spectrum that detunes the tapered wiggler interaction.

A Soft X-Ray FEL Design at the SLAC A-Line — WEPC63

Zhirong Huang, Huiping Geng, Yuantao Ding, Paul J. Emma, John Nicolas Galayda, Yuri Nosochkov (SLAC, Menlo Park, California)

LCLS capabilities can be significantly extended with a second undulator aiming at the soft x-ray spectrum (0.5 - 5 nm). To allow for simultaneous hard and soft x-ray operations, 14 GeV beams at the end of the LCLS accelerator can be intermittently switched into the SLAC A-line (the beam transport line to End Station A) where the second undulator may be located. Recently, a new optics has been designed to transport the LCLS beam through the A-Line while preserving the beam brightness. In this paper, we discuss the A-line soft x-ray FEL design - parameter selections and performance expectations with an energy-chirped LCLS beam as required by the A-Line optics. Start-to-end simulations using realistic LCLS beams show that it is possible to generate ~100 GW FEL power with the pulse duration as short as 1 fs.

Characterize the Electron Bunch Longitudinal Imperfectness on a Seeded Free Electron Laser Performance with Start-to-End Simulation — WEPC64

Juhao Wu, Alex Chao (SLAC, Menlo Park, California), Joseph Bisognano, Robert Arthur Bosch, Kevin J Kleman, Robert Legg (UW-Madison/SRC, Madison, Wisconsin)

A single-pass cascaded high-gain x-ray seeded Free Electron Laser (FEL) imposes stringent requirements on the high qualities of the electron bunch. Due to the collective effects and high-order effects from RF and lattice, the electron bunch has imperfectness, particularly, in the longitudinal phase space variables entering the undulator. Start-to-end numerical simulation together with analytical estimate is used to characterize such imperfectness on the seeded FEL performance such as coherence and stability. Study is carried out for concrete seeded FEL projects.

X-Ray Free Electron Laser Seeded by IR Laser Driven High-Order Harmonic Generation — WEPC65

Juhao Wu (SLAC, Menlo Park, California), Paul Robert Bolton (JAEA, Kyoto), Koichi Yamakawa (JAEA/Kansai, Kizu-machi Souraku-gun Kyoto-fu), Hiromitsu Tomizawa (JASRI/SPring-8, Hyogo-ken), Makina Yabashi (RIKEN/SPring-8, Hyogo), Kaoru Yamanouchi (University of Tokyo, Tokyo)

The X-ray Free Electron Laser (XFEL) is perceived as a fourth generation synchrotron light source. The cascaded Harmonic Generation FEL (HGFEL) that started from a coherent laser seed is being actively studied with the aim of generating an x-ray source, for a wide variety of applications, that is highly stable and with good coherence, both spatially and temporally. High-order Harmonic Generation (HHG) from a gas source irradiated by an intense conventional IR laser can provide highly coherent VUV and soft x-ray source. The HHG seed combined with a high quality electron beam makes a high-power, ultra-short coherent soft or hard x-ray source feasible using either a single stage or a cascaded HGFEL scheme. In this paper, we study HGFEL scheme with HHG seed around 13 nm and a direct seeding FEL amplifier with HHG seed at water window. FEL performance is compared for these two cases. Requirement on the HHG seed is characterized based on the FEL properties such as coherence and stability. Furthermore, by manipulating the electron beam, this scheme makes attosecond x-ray sources possible.

Beam Arrival Time Monitors Used in a Time-of-Flight Beam Energy Measurement

WEPC66

Marie Kristin Bock, Vladimir Arsov, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Laurens-Georg Wissmann (DESY, Hamburg), Sebastian Schulz, Johann Zemella (Uni HH, Hamburg)

At FLASH an optical synchronisation system with femtosecond stability is now being installed and commissioned. The pulses from an erbium-doped fibre laser being distributed in length-stabilised fibres to various endstations are used to detect the electron bunch arrival time using electro-optical modulators. To determine variations of the arrival time caused by phase changes of the RF gun or by timing changes of the photoinjector laser a beam arrival time monitor has been installed after the first acceleration section, prior to the bunch compressor BC2. A second bunch arrival time monitor installed after the bunch compressor allows for measuring the beam energy with high precision through a time-of-flight detection. Both monitors provide further insight into the accelerator subsystem stability and opens up the opportunity for a robust fast feedback stabilisation.

Timing Drift and Jitter Characterisation of EDFAs

WEPC67

Marie Kristin Bock, Vladimir Arsov, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Johann Zemella (DESY, Hamburg), Sebastian Schulz, Laurens-Georg Wissmann (Uni HH, Hamburg)

In next-generation FEL light sources like the European XFEL, it is crucial to achieve a timing stability of sub-10 fs of certain subsystems. In an optical synchronisation system now installed at FLASH the timing information is distributed across the facilities via length-stabilised optical fibres. Sub-picosecond laser pulses generated by a master laser oscillator (MLO) are distributed in a free space section and traverse an unstabilised fibre section while being amplified to various length-stabilised fibre links. To reach the aspired timing stability of the optical synchronisation system it is crucial that the fibre distribution section's erbium-doped fibre amplifiers (EDFAs) contribute less than 2 fs timing jitter. Temporal drift and jitter were measured through optical cross-correlation. The design and characterisation of the EDFAs are described.

Beam Arrival-Time Feedback for FLASH

WEPC68

Patrick Gessler, Vladimir Arsov, Marie Kristin Bock, Matthias Felber, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Johann Zemella (DESY, Hamburg), Sebastian Schulz, Laurens-Georg Wissmann (Uni HH, Hamburg), Jaroslaw Szewinski (Warsaw University of Technology, Warsaw)

Electron-bunches at the free electron laser FLASH at DESY have a temporal length of about 100 fs and an arrival-time jitter of about 200 fs (rms). It is anticipated that newly installed optical synchronisation system will stabilize the seed and pump-probe lasers n the level of 10 fs. In order to perform a reliable and stable seeding, the electron-bunch jitter needs to be reduced. A beam arrival monitor, which measures the arrival-time fluctuations and changes the gradient of the accelerating field accordingly in a feedback loop is able to improve the stability significantly. Previous measurements with test setups had already shown that an intra bunch jitter down to 40 fs (rms) could be achieved. We present long term measurements and design principles of the beam arrival-time feedback implemented at FLASH.

Master Laser Oscillator RF-Lock Characterization — WEPC69

Kirsten Elaine Hacker (DESY, Hamburg)

The master laser oscillator (MLO) at FLASH is locked to the master RF oscillator (MO) by mixing a 1.3 GHz signal from an MLO-based photodetector and a 1.3 GHz signal from the MO. The baseband output of the mixer is sent to an ADC-DSP-DAC regulation system that feeds back on a piezo controlled mirror position in the laser. The rms jitter and long term drift stability of the RF-lock circuit alone can be less than 5 fs in the temperature controlled chassis, but it can jump 10 to 15 fs when the temperature regulation of the room is disturbed by people working inside. Out-of-loop and in-loop measurements were also conducted under various environmental conditions.

Large Horizontal Aperture BPM Measurements with RF Mixing and EOM Sampling Schemes — WEPC70

Kirsten Elaine Hacker (DESY, Hamburg)

A unique, perpendicularly-mounted stripline BPM pickup is installed in the dispersive sections of the FLASH bunch compressors. For 4 - 5 μm resolution, it requires a front-end that can measure the difference between the phases of the beam transient pulses with a resolution that is better than 10 - 15 fs. Two front-ends have been tested with the pickup: a 10.4 GHz down-mixing scheme and an electro-optical modulator (EOM) based scheme that uses the optical synchronization system. The EOM scheme typically produces 6 to 12 fs resolution. It is, however, expensive, complex, and dependent on an optical infrastructure that is still in a development phase. It was not anticipated that an RF-mixing scheme could deliver the required, sub-15 fs resolution and drift stability, but with a temperature stabilized chassis in a climatized room and sufficiently high frequencies, an RF mixing scheme can deliver resolution that is comparable to that of the EOM scheme for this particular application, the measurement of the relative arrival-times of two ~ps pulses. A direct comparison of beam arrival time measurements with 10.4 GHz down-mixing and EOM sampling is also presented.

Locking Ti:Sapphire Lasers to the FLASH Optical Synchronization System — WEPC71

Sebastian Schulz, Laurens-Georg Wissmann (Uni HH, Hamburg), Vladimir Arsov, Marie Kristin Bock, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Johann Zemella (DESY, Hamburg)

The free electron laser FLASH and the planned European XFEL generate x-ray light pulses with durations in the order of a few ten femtoseconds. Consequently, time-resolved pump-probe experiments, special diagnostics and the seeded operation mode of the FEL crucially depend on the synchronization of various laser systems on the femtosecond time-scale. For this purpose, an optical synchronization system is being installed at FLASH. A commercial Ti:sapphire oscillator has been synchronized to the optical reference with sub-10 femtosecond timing jitter. The phase detector is based on a novel optical cross-correlation scheme which directly uses the pulse trains of the two individual mode-locked lasers and it is adaptable to different center wavelengths and repetition rates. The performance of the digitally controlled phase-locked loop was characterized and optimized by analyzing the phase noise and the drift behavior. We were able to achieve a stable and nearly drift-free operation of the loop for hours at a time, which is sufficient for most accelerator-based measurements.

Progress Towards a Permanent Optical Synchronization Infrastructure at FLASH

WEPC72

Sebastian Schulz, Laurens-Georg Wissmann (Uni HH, Hamburg), Vladimir Arsov, Marie Kristin Bock, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter, Johann Zemella (DESY, Hamburg)

Free electron lasers like FLASH and the planned European XFEL generate x-ray light pulses with durations in the order of a few ten femtoseconds. For these next-generation light sources, an optical synchronization system has been proposed to enable time-resolved measurements with sub-10 fs resolution and the laser-driven seeded operation mode of the FEL. The system is based on the timing-stabilized distribution of an optical pulse train, from which RF signals can be generated or to which other laser systems can be synchronized. Furthermore, it facilitates several special diagnostic measurements on the sub-10 fs time-scale. The optical synchronization system at FLASH has recently progressed from a bread-board / test-bench implementation to a more permanent engineered infrastructure. We report on the master laser oscillator, the lock to the master RF oscillator, the free-space distribution unit, three installed fiber links, two bunch arrival-time monitors, one optical cross-correlator and the controls development. A slow bunch arrival-time feedback has allowed for characterization and the long-term reliability of the system and identification of several design issues.

Conceptual Idea for the Temporal Overlap of the Electron Beam and the Seed Laser for sFLASH

WEPC73

Roxana Tarkeshian, Joern Boedewadt, Velizar Miltchev, Jörg Rossbach (Uni HH, Hamburg), Holger Schlarb, Siegfried Schreiber (DESY, Hamburg), Rasmus Ischebeck (PSI, Villigen)

SFLASH is a seeding FEL experiment at FLASH / DESY to introduce a 30 nm HHG-based XUV-beam laser to the electron bunches of FLASH at the entrance of a 10 m variable-gap undulator. The temporal overlap between the electron beam and HHG is important for the seeding process. The installation of a 3rd harmonic cavity at FLASH will provide a long high current electron beam (kA level) over ~600 fs (FWHM) bunch duration. The duration of the HHG laser pulse will be about 30 fs (FWHM). The desired overlap can be achieved in steps. One approach will be to synchronize the drive laser (Ti:Sapphire, 800 nm) of HHG and the incoherent spontaneous synchrotron radiation of the undulator at a sub-picosecond precision. In a following step the overlap can be improved by scanning within the sub-picosecond uncertainty. The possibility of using a streak camera to detect both the 800 nm laser and the spontaneous undulator radiation pulses without perturbing FLASH user operation is investigated. To match the power levels, the laser beam has to be attenuated by several orders in magnitude. The layout of the experiment and preliminary simulation results of generation and transport of both light pulses are presented.

Electromagnetic Wave Propagation in an Electron Ring with Ion Channel Guiding

WEPC74

Farzin Mojtaba Aghamir (University of Tehran, Tehran)

The dispersion characteristics of electrostatic and electromagnetic modes of a cylindrical waveguide in an electron ring, with ion channel guiding, are presented. The analysis takes into account a relativistic hollow electron beam guided by an ion channel. Dispersion relations are derived, and solved numerically, to study the waveguide modes, betatron modes, and space charge modes. The effect of the annular electron beam thickness on frequencies of the electrostatic and electromagnetic waves is investigated. The study reveals the strong dependence of the electromagnetic and electrostatic wave‟s frequencies on the electron ring radius. The results of this study are compared with previous works where an electron ring is guided with an axial magnetic field.

Analysis on Variation Factors of Optical Power at the LEBRA FEL — WEPC75

Keisuke Nakao, Ken Hayakawa, Yasushi Hayakawa, Manabu Inagaki, Kyoko Nogami, Takeshi Sakai, Isamu Sato, Toshinari Tanaka (LEBRA, Funabashi)

The near-infrared Free Electron Laser (FEL) has been provided for scientific studies in various fields since 2003 at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University. The behaviour of the LEBRA electron linac system has been monitored using various diagnostic devices such as beam position monitors, vacuum gauges, thermocouples, optical power monitors and so on. The results obtained during operation of the linac have been routinely stored in databases or files. This paper discusses the analysis on the factors of fluctuation for the electron beam energy / position and the FEL optical power on the basis of the linac diagnostic results. Intentional change in the linac cooling water temperature, introduced periodically with 0.1 °C peak-to-peak, has resulted in negligibly small fluctuation of the FEL output power. This suggests that the LEBRA linac cooling water system offering the temperature regulation within 0.02 °C has sufficient performance for stable FEL lasing.

Laser Driven RF Signal Generation with an Amplitude Stabilization Technique — WEPC76

Akihiko Mizuno, Hideki Dewa, Takao Asaka, Hirofumi Hanaki, Toshiaki Kobayashi, Shinsuke Suzuki, Tsutomu Taniuchi, Hiromitsu Tomizawa, Kenichi Yanagida (JASRI/SPring-8, Hyogo-ken)

The synchronous technologies of RF signal and laser pulse is important for the photo-cathode RF gun system, because it determines the beam stability in phase and energy. For a time jitter as small as 300 fs between RF signal and laser pulse, laser driven RF generation has been developed for our synchronization system since 2002. In the system, RF signal is directly generated from the laser pulse of 89.25 MHz by filtering the output of the photo detector with a band pass filter of 2856 MHz. The remaining problem was that the amplitude of the RF signal linearly depended on the laser pulse amplitude. For this reason, there was some amplitude jitter in the generated RF signal, which might also cause time jitter. To reduce the amplitude jitter, we developed a new laser driven RF generation system with amplitude stabilization realized by saturation amplifiers. The RMS deviation of the RF amplitude could be decreased to 0.173% from 1.18%. The RMS time jitter measured with a sampling oscilloscope was so small that it could not be correctly measured. The whole triggering and RF system of Spring-8 RF gun is also presented.

Preliminary Experiment of Terahertz Coherent Transition Radiation Generated from an Ultrashort Electron Beam Performed at Tsinghua University — WEPC77

Wenhui Huang, Qiang Du, Ying-Chao Du, Renkai Li, Wenxin Liu, Chuanxiang Tang, Dai Wu, Lixin Yan (TUB, Beijing)

Terahertz radiation, a currently active research area, is of importance for applications to medical imaging, biomedical research, surface chemistry and material sciences. The comprehensive applications of THz waves can be realized for the development of high performance THz sources and advanced detectors. Among the varieties of THz source, the coherent transition radiation is an important one for which has a unique broad bandwidth. In this paper, the preliminary experiments and particle-in-cell (PIC) simulations of terahertz (THz) coherent transition radiation (CTR) performed at the Accelerator Laboratory of Tsinghua University are reported. THz radiation is generated from the interactions of Titanium foil with the ultrashort electron beam produced by the photocathode RF gun. The frequency and power of radiation are measured with the Martin-Pupllet interferometer and Gollay Cell detector, respectively. The radiation characteristics depending on the foil properties are preliminarily studied. On the other hand, the distribution of radiation field pattern and energy are studied by numerical calculated. The optimum experiment is under performance.

Real Time FPGA Signal Processing for Libera Brilliance Single Pass — WEPC78

Matjaz Znidarcic, Andrej Kosicek, Matej Oblak (Instrumentation Technologies, Solkan)

Libera Brilliance is already a standard device for beam position monitoring, while Libera Brilliance Single Pass, as its variant, is optimized for single pass position measurement. Complete signal processing on it has now been moved from the embedded computer to FPGA. This enables complete hard real time data processing. Together with already implemented fast communication protocols (e.g. Gb Ethernet) it represents a reliable and deterministic building block for building of fast feedback or fast forward loops. The motivation, processing principles and first results are presented.

An Electro-Optical System for MAX-Lab Test-FEL Facility — WEPC79

Nino Cutic, Filip Lindau, Sara Thorin, Sverker Werin (MAX-lab, Lund), Christian Erny (Lund Laser Centre, Lund)

To get information about the arrival of the electron bunch relative to the laser pulse, an electro-optic detection scheme in a crossed polarizer configuration was set up and tested. Electron bunch induced birefringence in a ZnTe crystal leaves a polarization footprint in a chirped infrared pulse. The IR pulse is sampled before the third harmonic generation from the amplifier, then stretched and synchronized to the ultraviolet beam that is used for seeding. We report details of this setup and preliminary jitter measurements.

Longitudinal Electron Beam Diagnostics via Upconversion of THz to Visible Radiation — WEPC80

Giel Berden, Alexander van der Meer (FOM Rijnhuizen, Nieuwegein), Steven Jamison (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Allan MacLeod (UAD, Dundee), William Allan Gillespie, Paul Jonathan Phillips (University of Dundee, Nethergate, Dundee, Scotland)

Longitudinal electro-optic electron bunch diagnostics has been successfully applied at several accelerators. The electro-optic effect can be seen as an upconversion of the Coulomb field of the relativistic electron bunch (THz radiation) to the visible spectral range, where a variety of standard diagnostic tools are available. Standard techniques to characterise femtosecond optical laser pulses (auto- and cross-correlators) have led to the schemes that can measure electron bunch profiles with femtosecond resolution*. These techniques require, however, well-synchronized femtosecond laser pulses, in order to obtain the desired temporal resolution. Currently, we are exploring other EO variants which require less advanced laser systems. The first results will be presented in our contribution.

** Berden et al. Phys. Rev. Lett. 99, 164801 (2007), B. Steffen et al. Phys. Rev. ST - Acc. Beams, 12, 032802 (2009).*

The Preliminary Design of the TAC SASE-FEL Photon Diagnostics System — WEPC81

Ozkan Sahin, Ilhan Tapan (UU, Bursa), Omer Yavas (Ankara University, Tandogan, Ankara)

According to the Turkish Accelerator Center (TAC) project, the Self-Amplification of Spontaneous Emission Free Electron Laser (SASE-FEL) facility will be proposed. Here, the SASE-FEL photons in the wavelength region of 1 - 100 nm will be generated by using a 1 GeV electron linac. The Technical Design Report (TDR) will be completed in 2012. According to this report, the photon diagnostics were designed to measure and provide maximum information on the generated photons. In this work, the performance of the preliminary designed SASE-FEL photon diagnostics system for the TAC test facility has been discussed.

Electro-Optic Bunch Diagnostic on ALICE — WEPC82

Paul Jonathan Phillips, Allan MacLeod (UAD, Dundee), Steven Jamison (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), William Allan Gillespie (University of Dundee, Nethergate, Dundee, Scotland)

Electro-optic longitudinal bunch profile monitors are being implemented on ALICE (Accelerators and Lasers In Combined Experiments) at Daresbury Laboratories and have been used to characterise the electron bunch and to provide a testbed for electro-optic diagnostic techniques. ALICE is a 20 MeV energy recovery linac-based light source with a bunch length of approximately 0.4 ps and a bunch charge of 80 pC. It is being developed as an experimental test bed for a broad suite of science and technology activities that make use of electron acceleration and ultra-short pulse laser techniques. At ALICE the electro-optic station is located immediately after the bunch compressor. This location allows nearby OTR beam profile monitors and Coherent Synchrotron Radiation (CSR) diagnostics to be used for calibration and benchmarking. This range of diagnostics will be evaluated for suitability on the Next Light Source (NLS) under development in the UK. We present data for both spectral decoding and temporal decoding of the electron bunch at different bunch compression ratios, plus a measurement of the timing jitter of the electron bunch.

Remote Synchronization of Laser Systems for the LCLS — WEPC83

John Byrd, Lawrence Doolittle, Gang Huang, John William Staples, Russell Wilcox (LBNL, Berkeley, California), John Arthur, Josef Frisch, Gregory R. Hays, William White (SLAC, Menlo Park, California)

FELs require an unprecedented level of remote synchronization between lasers and accelerator systems. We present the design and initial results of a high precision timing distribution system installed at the LCLS for the purpose of synchronizing lasers with a time-arrival diagnostic. Timing signals are distributed on optical fiber links stabilized using interferometric delay sensing.

Optimization of Two-Stage Compression with a New Nonlinear Program — WEPC85

Juhao Wu, Martin J. Lee (SLAC, Menlo Park, California)

An x-ray Free Electron Laser (FEL) requires a high brightness electron beam. Generically, such a beam needs to be accelerated to high energy on the GeV level and compressed down to tens or a few microns. The very bright electron beam required for the FEL has to be stable and the high quality of the electron beam has to be preserved during the acceleration and bunch compression. With a newly developed global optimizer*, here we report study for the optimization of such a generic machine. Single particle dynamics, collective effects, and RF cavity phase and amplitude jitter are considered for the optimization of such a generic two-stage compression scheme. Applications are detailed for both SASE FEL and seeded FEL which have difference tolerances on the electron bunch parameters.

** M.J. Lee, SLAC-R-758 (2009).*

Coherence & Pulse Length Control

Chair: Henry Freund

Short Pulse Low Charge Operation of the LCLS (Invited) WEOD01

Josef Frisch, Axel Brachmann, Franz-Josef Decker, Yuantao Ding, David Dowell, Paul J. Emma, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Richard Iverson, Henrik Loos, Alan Miahnah Heinz-Dieter Nuhn, Daniel Ratner, James Leslie Turner, James Welch, William White, Juhao Wu (SLAC, Menlo Park, California)

Recent experiments on the LCLS accelerator have demonstrated low emittances for 20 pC bunches, with evidence for few-femtosecond electron bunch lengths, although the existing beam diagnostics do not allow a direct measurement of the bunch length. Simulations confirm that the LCLS accelerator can be operated at low charge (20 pC) while maintaining the nominal 3 kA peak current and with transverse emittances below 0.4 microns. An x-ray pulse duration of 2 femtoseconds with 3×1011 photons is predicted, and nearly a single longitudinal spike may be obtained for soft x-ray wavelengths. We report on the operation of the accelerator and undulator with short electron bunches and present supporting simulation results.

Study of an HHG-Seeded Harmonic Cascade FEL for the UK's New Light Source Project (Invited) WEOD02

Neil Thompson, David Dunning (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Riccardo Bartolini (Diamond, Oxfordshire; JAI, Oxford), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

The New Light Source (NLS) project was launched in April 2008 by the UK Science and Technology Facilities Council (STFC) to consider the scientific case and develop a conceptual design for a possible next generation light source based on a combination of synchronised conventional laser and free electron laser sources. The requirement identified for the FELs was continuous coverage of the photon energy range 50 – 1000 eV with variable polarisation, 20 fs pulse widths and good temporal coherence to as high a photon energy as possible. This paper presents a design study of three separate FELs which in combination satisfy these requirements. It is proposed to use an HHG seed source tunable from 50 – 100 eV giving direct seeding at the fundamental FEL wavelength up to 100 eV, then one or two stages of harmonic upconversion within the FEL to reach the higher photon energies. FEL simulations using realistic electron beam distributions tracked from the gun to the FEL will be presented, illustrating the predicted coherence properties of the FEL output at different photon energies.

Spatial Characterization of FEL Self-Amplified Spontaneous Emission — WEOD03

Pascal Mercere, Romain Bachelard, Marie-Emmanuelle Couprie, Mourad Idir (SOLEIL, Gif-sur-Yvette), Oleg Chubar (BNL, Upton, Long Island, New York), Samuel Bucourt, Guillaume Dovillaire, Xavier Levecq (Imagine Optic, Orsay), Hiroaki Kimura, Haruhiko Ohashi (JASRI/SPring-8, Hyogo-ken), Julien Gautier, Guillaume Lambert, Philippe Zeitoun (LOA, Palaiseau), Toru Hara, Atsushi Higashiya, Tetsuya Ishikawa, Mitsuru Nagasono, Makina Yabashi (RIKEN/SPring-8, Hyogo)

The VUV Self-Amplified Spontaneous Emission of the SPring-8 Compact SASE Source (SCSS) Test Accelerator is characterized at different stages of amplification up to saturation*. Experimental measurements are performed by use of a VUV Hartmann wavefront sensor. This kind of sensor gives access to both intensity and phase profiles of the incoming beam. We characterize the mode selection when approaching the saturation regime of the FEL. Optical quality of the saturated SASE radiation is measured to be better than λ / 5 PV and λ / 22 rms (λ = 61.5 nm) depending on the machine optimization. Moreover, pointing of the beam as well as spatial structure, size and position of the source are retrieved and their shot-to-shot fluctuations investigated. Analytical** and numerical*** calculations, using SRW and GENESIS codes, show good agreement with the experimental measurements. All these elements are of crucial importance for a better understanding and optimization of the FEL and of course for user applications requiring a stable focused beam on their samples. We are grateful to the SCSS Test Accelerator Operation Group at RIKEN for continuous support in the course of the studies.

** R. Bachelard et al., "Wavefront and transverse structure of the FEL Self-Amplified Spontaneous Emission", to be submitted. ** M. Xie, NIMA 445, 59 (2000). *** O. Chubar et al., Proc. EPAC-98, 1177 (1998).*

Efficiency and Spectrum Enhancement in a Tapered Free Electron Laser Amplifier — WEOD04

James Murphy, Xijie Wang, David Harder, Houjun Qian, Yuzhen Shen, Xi Yang (BNL, Upton, Long Island, New York), Henry Freund, William Miner (SAIC, McLean)

We report the first experimental characterization of efficiency and spectrum enhancement in a laser-seeded Free Electron Laser (FEL) using a tapered undulator. Output and spectra in the fundamental and 3rd harmonic were measured versus distance for uniform and tapered undulators. With a 4% field taper over 3 m, a 300% (50%) increase in the fundamental (3rd harmonic) output was observed. A significant improvement in the spectra with the elimination of side-bands was observed using a tapered undulator. The experiment is in good agreement with predictions using the MEDUSA simulation code.

FEL Technology II: Post-Accelerator

Chair: Bettina Kuske

Undulators for the SwissFEL (Invited) — THOA01

Thomas Schmidt, Sven Reiche (PSI, Villigen)

The proposed SwissFEL will provide both hard x-rays down to 1 Å and soft x-rays with full polarization control with a rather small electron energy of 5.8 GeV. This continues the strategy of the medium energy synchrotron facilities, namely the SLS. The U15 and UE40 undulators are based on the experience with small period, small gap in-vacuum undulators and of APPLE II type respectively but are optimized for FEL operation. The undulator design including room temperature versus cryogenic principle, field optimization, materials and the demands for a series production will be discussed.

LCLS Undulator Commissioning, Alignment and Performance (Invited) — THOA02

Heinz-Dieter Nuhn (SLAC, Menlo Park, California)

The LCLS x-ray FEL has recently achieved its 1.5 Ångström lasing and saturation goals upon first trial. This was achieved with an extensive effort of pre-beam checkout, both traditional and beam-based component alignment techniques, and a high electron beam brightness. The x-ray FEL process demands very tight tolerances on the straightness of the electron beam trajectory (<5 μm) through the LCLS undulator system. Tight, but less stringent tolerances of ~100 μm rms were met for the transverse placement of the individual undulator segments with respect to the beam axis. The tolerances for electron beam straightness can only be met through a beam-based alignment (BBA) method, which is implemented using large electron energy variations and sub-micron cavity beam position monitors (BPM), with precise conventional alignment used to set the starting conditions. Precision-fiducialization of components mounted on remotely adjustable girders, and the use of special beam-finder wires (BFW) at each girder have been used to achieve these challenging alignment tolerances.

Selection of the Optimum Undulator Parameters for the NLS: A Holistic Approach — THOA03

James Clarke, David Dunning, Barry David Fell, Kiril Marinov, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Neil Bliss (STFC/DL, Daresbury, Warrington, Cheshire)

The choice of undulator design and minimum magnet gap is crucial in the definition of every short wavelength FEL and is ultimately a cost driver for that project. The magnet gap selection is a compromise between wanting to minimise harmful wakefield effects whilst at the same time generating high magnetic fields with short periods. The NLS project has tried to take a holistic approach in the definition of the undulators. This has been carried out by first assessing the impact of resistive wall wakefields in general on the FEL performance and then selecting the maximum level of wakefield which has a just tolerable impact on the FEL. This wakefield is then translated into equivalent circular and elliptical vessel geometries. Suitable vessel thickness and mechanical tolerances are then added to define the undulator magnet gap for the case of a circular vessel (Delta undulator) and an elliptical vessel (APPLE-2 undulator). Finally, the two types of undulator have been modelled, their parameters compared, and a selection made. This paper summarises this global self-consistent approach to undulator definition and reports on the result for the NLS.

Undulator Options for Soft X-Ray Free Electron Lasers

THOA04

Soren Prestemon, Ross Schlueter (LBNL, Berkeley, California)

Soft x-ray free electron laser sources require significant photon energy tuning and ideally provide variable polarization to users. The LBNL proposed facility, BLASER, will provide multiple FEL lines with varying spectral characteristics to satisfy a broad array of soft x-ray physics. A variety of undulator technologies are being investigated to satisfy these requirements. We evaluate the performance characteristics of the key competing technologies, including superconducting options, and outline the impact of technology choice on overall facility design and cost. We review the key R&D issues that must be addressed to validate the different technologies for soft x-ray FEL application.

Undulator K-Parameter Measurements at LCLS

THOA05

James Welch, Axel Brachmann, Franz-Josef Decker, Yuantao Ding, Paul J. Emma, Alan Stephen Fisher, Josef Frisch, Zhirong Huang, Richard Iverson, Henrik Loos, Heinz-Dieter Nuhn, Peter Stefan, James Leslie Turner, Juhao Wu, Dao Xiang (SLAC, Menlo Park, California), Richard M. Bionta (LLNL, Livermore, California), Daniel Ratner (Stanford University, Stanford, Califormia)

Precision in-situ measurements of relative undulator segment K parameters were made at the LCLS and are reported here. We describe the methods used, systematics errors, and signal levels. A method for determining the central ray from each undulator segment was developed to control the effect of angle-energy correlation of the spontaneous radiation on the photon energy spectrum. A variety of photon-energy sensitive detectors were employed, including: Ni foil, the yttrium component in a YAG screen, and a narrow band monochromator followed by either a photodiode or a YAG screen. Different harmonics of the spontaneous radiation were also used.

FEL Technology II: Post-Accelerator

Chair: Holger Schlarb

Commissioning Results of the SPARC FEL (Invited) — THOB01

Massimo Ferrario (INFN/LNF, Frascati (Roma))

The SPARC project foresees the realization of a high brightness photo-injector to produce a 150 - 200 MeV electron beam to drive 500 nm FEL experiments in SASE, Seeding and Single Spike configurations. The present stage of the commissioning foresees a detailed analysis of the beam matching with the linac in order to confirm the theoretically prediction of emittance compensation based on the “invariant envelope” matching and the characterisation of the spontaneous and stimulated radiation in the SPARC undulators. In this talk we report the experimental results obtained so far. The future energy upgrade of the SPARC facility to produce UV radiation and its possible applications will be also discussed.

Results from the Optical Replica Synthesizer at FLASH (Invited) — THOB02

Peter Salen, Mats Larsson, Peter van der Meulen (FYSIKUM, AlbaNova, Stockholm), Florian Loehl (Cornell University, Ithaca, New York), Shaukat Khan (DELTA, Dortmund), Evgeny Saldin, Holger Schlarb, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg), Atoosa Meseck (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Axel Winter (ITER, St Paul lez Durance), Joern Boedewadt (Uni HH, Hamburg), Gergana Angelova Hamberg, Volker Ziemann (Uppsala University, Uppsala)

We present results from the new electron bunch diagnostic tool, Optical Replica Synthesizer* (ORS), installed at FLASH. The ORS produces an optical replica of the electron bunch profile, which is analyzed with a Grenouille, a device based on the Frequency Resolved Optical Gating (FROG) technique. This optical replica is generated by inducing a microbunching in the electron bunch and letting it pass through an undulator, called a radiator. The radiator emits coherently at the wavelength of microbunching, 772 nm. In order to create the microbunching a laser pulse is spatially and temporally overlapped with the electron bunch in another undulator, placed before the radiator. This introduces an electron energy modulation which is transformed into a density modulation in a chicane before the microbunched electron bunch is sent into the radiator. We observed an optical replica pulse of approximately 5 μJ corresponding to an electron bunch-spike of about 150 fs FWHM when the accelerators were set at optimal FEL conditions. We also showed that the ORS can run parasitically while maintaining SASE by steering the electron beam around the outcoupling mirror for the radiation.

** E. Saldin, E. Schneidmiller, M. Yurkov, “A simple method for the determination of the structure of ultrashort relativistic electron bunches,” Nucl. Inst. and Methods A 539 (2005) 499.*

Numerical Evaluation of Bulk HTSC Staggered Array Undulator by Bean Model THOB03

Ryota Kinjo, Mahmoud Abdel Aziem Bakr, Keisuke Higashimura, Toshiteru Kii, Kai Masuda, Kazunobu Nagasaki, Hideaki Ohgaki, Taro Sonobe, Satoshi Ueda, Kyohei Yoshida (Kyoto IAE, Kyoto), Heishun Zen (UVSOR, Okazaki)

A new type of undulator which consists of high-temperature superconductor bulk magnets in the staggered array configuration inside a solenoid is being developed, aimed at short period, high undulator field and controllability by the solenoid current*. In order to develop a numerical model, the field calculations were performed and comparisons were made with prototype measurements at the liquid nitrogen temperature. The field in the bulk magnet was modeled by loop currents of which amounts were determined by the critical current density which follow Bean model**. In the unsaturated condition, which is decided by the critical current density and the dimension of the bulk magnets, the field distributions and the dependence on the solenoid field were reproduced well. We then estimated the unsaturated performance at the liquid helium temperature, where increment of the critical current density is known*** and significant improvement of the undulator performance is expected accordingly. In the conference, the experimental results, the detail of modeling and numerical results will be shown and also the performance estimation will be discussed.
** T.Kii, et al. FEL 2006, THPPH035 (2006) R.Kinjo, et al., FEL 2008, THAAU03 (2008). ** C. P. Bean,Phys. Rev. Lett. 8, 250 (1962). *** M. Morita, et al. NIPPON STEEL TECHNICAL REPORT No. 93 (2006).*

Theory of Edge Radiation, Part I: Foundations and Basic Applications THOB04

Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We formulate a complete theory of Edge Radiation based on a novel method relying on Fourier Optics techniques. Special attention is paid in discussing the validity of approximations upon which the theory is built. Our study makes consistent use of both similarity techniques and comparisons with numerical results from simulation. We discuss both near and far zone. Physical understanding of many asymptotes is discussed. As an example of application we discuss the case of Transition Undulator Radiation, which can be conveniently treated with our formalism. This work forms the theoretical basis for understanding the impact of Edge radiation on XFEL setups, which is discussed in another contribution to this conference.

Photon Diagnostics for the Seeding Experiment at FLASH THOB05

Francesca Curbis, Armin Azima, Joern Boedewadt, Hossein Delsim-Hashemi, Markus Drescher, Theophilos Maltezopoulos, Velizar Miltchev, Manuel Mittenzwey, Jörg Rossbach, Roxana Tarkeshian, Marek Wieland (Uni HH, Hamburg), Shaukat Khan (DELTA, Dortmund), Stefan Düsterer, Josef Feldhaus, Tim Laarmann, Holger Schlarb (DESY, Hamburg), Atoosa Meseck (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin), Rasmus Ischebeck (PSI, Villigen)

Starting from next year, the technical feasibility of a direct seeding scheme at 30 and 13 nm will be studied at the free electron laser FLASH at DESY. During a major shutdown in order to upgrade the SASE-FEL facility, it has been planned to install an HHG source, a new chain of 10 m variable gap undulators and a dedicated commissioning beamline for photon diagnostics and pilot time-resolved pump-probe experiments. Besides demonstrating successful seeding at short wavelength, the project aims for time resolution in the 10 fs range to study ultrafast processes by combining the naturally synchronized FEL and seed laser pulses. After the extraction of the radiation in a magnetic chicane, a short branch will accommodate intensity and beam monitors and a spectrometer. The intensity monitor detects scattered photons from a gold mesh on a shot-to-shot basis using micro-channel plates and XUV diodes. It is designed to detect photons several orders of magnitude apart in flux, i.e. spanning the wide range from the spontaneous emission up to the seeded FEL radiation at gigawatt power level. Simulations of this device are presented as well as test and calibration measurements carried out at FLASH.

Stability & Synchronism

Chair: William Graves

High Performance SASE FEL Achieved by Stability-Oriented Accelerator System and Operation (Invited)

FROA01

Hitoshi Tanaka, Toru Fukui, Toru Hara, Naoyasu Hosoda, Takahiro Inagaki, Shinobu Inoue, Tetsuya Ishikawa, Hideo Kitamura, Noritaka Kumagai, Hirokazu Maesaka, Mitsuru Nagasono, Takashi Ohshima, Yuji Otake, Tsumoru Shintake, Katsutoshi Shirasawa, Takashi Tanaka, Kazuaki Togawa, Kensuke Tono, Makina Yabashi (RIKEN/SPring-8, Hyogo), Haruhiko Ohashi, Sunao Takahashi, Tadashi Togashi, Mitsuhiro Yamaga (JASRI/SPring-8, Hyogo-ken)

Stable SASE FEL has been routinely used for user experiments since May 2008 at the SCSS test accelerator, which was constructed to perform a proof-of-principle experiment towards realization of a compact and high performance XFEL facility. In FY2008, a beam time of 840 hrs (95 days) was provided to 11 research groups with a downtime rate of ~4%, a pulse energy of ~30 μJ and an intensity fluctuation of ~10% in STD. A feature of our stable operation is power-saturated SASE FEL kept over a full operation period (1) in spite of a day-by-day operation, (2) without a complicated beam feedback control, and (3) without hard maintenance. In this talk we will try to review key points much contributing to this stable SASE FEL operation from the viewpoint of accelerator design, hardware and operation together with achieved SASE FEL performance and some experimental results reflecting the FEL performance.

Electron Beam Stabilisation Test Results Using a Neural Network Hybrid Controller at the Australian Synchrotron and Linac Coherent Light Source Projects (Invited)

FROA02

Evelyne Meier (ASCo, Clayton, Victoria), Juhao Wu (SLAC, Menlo Park, California)

This paper describes the implementation of a neural network hybrid controller for energy and bunch length stabilization. The structure of the controller consists of a neural network (NNET) feed forward control, augmented by a conventional Proportional-Integral (PI) feedback controller to ensure stability of the system. The system is provided with past states of the machine in order to predict its future state, and therefore apply appropriate feed forward control. Experiments performed at the Australian Synchrotron showed the ability of the NNET to cancel multiple frequency energy jitter and the successful augmentation of the system by a PI algorithm. The LCLS experiments showed that the system can be expended to predict and correct coupled energy-bunch length deviations, and showed the improved jitter attenuation by the NNET system in comparison to the PI algorithm alone. Focus is also made on the machine response that needs to be accurately known to best operate the correction. When machine settings are modified, the response is re-calculated with the help of a model, and slight adjustments are made to optimize the energy jitter reduction as the control is operating.

Femtosecond Electro-Optical Synchronization System over Distance up to 300 m

FROA03

Jurij Tratnik, Bostjan Batagelj, Luka Naglic, Leon Pavlovic, Patrik Ritosa, Matjaz Vidmar (University of Ljubljana, Ljubljana), Mario Ferianis (ELETTRA, Basovizza), Silvan Bucik, Primoz Lemut, Borut Repic, Sebastjan Zorzut (Instrumentation Technologies, Solkan)

This paper presents a good solution for timing distribution and RF synchronization of multiple events at multiple remote locations in the accelerator facility with femtosecond precision. The proposed electro-optical synchronization system makes use of commercial telecom single-mode optical fibre operating at 1550 nm. Such fibre is subject to change in phase and group velocity correlated to temperature variations and is sensitive to acoustic perturbations. The synchronization system described makes use of stabilization of the fibre link which transports low-jitter microwave signal over a distance of 300 m. It consists of a transmitter, located at the place of low-jitter master oscillator, and receiver, located at the remote location. Both units are connected by a pair of optical single-mode fibres. Using a fibre pair instead of a single fibre allows for compensation of fibre-length changes. The added timing jitter of 20 fs at 100 Hz - 20 MHz is measured on the first experimental synchronization system. Even lower jitter is expected by some planned improvements in the transfer system and the industrialization of it.

Timing and Synchronisation Considerations for the NLS Project

FROA04

Graeme Hirst (STFC/RAL, Chilton, Didcot, Oxon), Steven Jamison, Lee Jones, Andrew Moss (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Paul Jonathan Phillips (University of Dundee, Nethergate, Dundee, Scotland)

The NLS project team is designing a UK-based ultrashort light pulse facility covering the whole spectrum from the terahertz to the soft x-ray. It will be based on a suite of sources including seeded FELs, conventional lasers and undulators. Experiments will frequently be multi-beam and will often depend on precise management of the pulse timings. With pulse durations of ~20 fs or less the aim will be to reduce timing jitter to the 10 – 20 fs level. In addition to the needs of the NLS"s users, stable operation of the machine itself will also require adequate timing control. In particular reproducible FEL operation will depend on good temporal overlap between the seed photons and the electron bunches. This paper covers both the underlying issues, (e.g. choice of pulse rates, passive and active timing management, requirements specification) and also the approaches taken in specific NLS areas (e.g. choice of clock and distribution system, management of electron bunch timing, management of fluctuations in beam transport paths). An overall jitter budget is presented.

RF-Based Detector for Measuring Fiber Length Changes with Sub-5 Femtosecond Long-Term Stability

FROA05

Johann Zemella, Vladimir Arsov, Marie Kristin Bock, Matthias Felber, Patrick Gessler, Kirsten Elaine Hacker, Florian Loehl, Frank Ludwig, Holger Schlarb, Bernhard Schmidt, Axel Winter (DESY, Hamburg), Sebastian Schulz, Laurens-Georg Wissmann (Uni HH, Hamburg)

At the Free electron LASer in Hamburg (FLASH), an optical synchronization system is being installed with a projected point-to-point stability of 10 fs. The system is based on the distribution of reference laser pulses over actively stabilized fiber links using optical cross-correlators. As an alternative to the complex cross-correlation scheme, which can achieve sub fs long-term stability and works well over several 100 m long fiber links, an RF-based technique which is much less complex and expensive could be used. It is based on the power detection of high harmonic frequencies in a balanced arrangement to reduce amplitude noise. For a 20 m long fiber link, it was demonstrated that a sub-5 fs rms long-term stability over 30 hours can be achieved. The system and the most recent measurements are presented here.

New Science from FELs & Closing Remarks

Chair: Jim Clarke

Achieving Microfocus of the 13.5 nm FLASH Beam for Exploring Matter Under Extreme Conditions (Invited)

FROB01

Art James Nelson, Richard Lee (LLNL, Livermore, California), Jaromir Chalupsky, Vera Hajkova, Libor Juha (Czech Republic Academy of Sciences, Prague), Sasa Bajt, Henry Chapman, Roland Faustlin, Sven Toleikis (DESY, Hamburg), Thomas Tschentscher (European X-ray Free Electron Laser Project Team, Hamburg), Marta Fajardo (GoLP, Lisbon), Karl Saksl (IMR SAS, Kosice), Marek Jurek, Ryszard Sobierajski (IP PAS, Warsaw), Thomas Dzelzainis, David Riley (Queen's University of Belfast, Belfast, Northern Ireland), Jacek Krzywinski (SLAC, Menlo Park, California), Bob Nagler (STFC/RAL, Chilton, Didcot, Oxon), Sam M Vinko, J. S. Wark, Thomas Whitcher (University of Oxford, Oxford), Jakob Andreasson, Janos Hajdu, Nicusor Timneanu (Uppsala University, Uppsala)

We have focused a beam (BL3) of FLASH (Free electron LASer in Hamburg: 13.5 nm, 15 fs, 10 µJ, 5 Hz) using a fine polished off-axis parabola which has a focal length of 270 mm and was coated with a Mo / Si-ML giving a reflectivity of 67% at 13.5 nm. The OAP was mounted and aligned with a picomotor control six-axis gimbel. Beam imprints on PMMA were used to measure focus and the focused beam was used to create isochoric heating of various slab targets. Results show the focal spot has a diameter of <1 µm producing intensities greater than 1E16 W cm^{-2}. Observations were correlated with simulations of best focus to provide further relevant information. This focused XUV laser beam now allows us to begin exploring matter under extreme conditions. Future experimental efforts at "4th generation" light sources will be outlined.

Evidence for Position Based Electron Entanglement in Resonant Auger Electron Emission from Dissociating O2 Molecules (Invited)

FROB02

Uwe Becker (FHI, Berlin)

The proof of entanglement on the basis of the variable"s position and momentum was the primary suggestion by Einstein, Rosen and Podolsky to distinguish between a quantum mechanical versus a local realistic description of our world. This paper reports on an effort to realize this proposal by employing dichotomic variables g, u and f, b for position and momentum, respectively. The result is a proof of quantum mechanics as in all former, mostly photon polarization, based studies. Our experiments regarding the entanglement of these variables reveal that Bell type measurements of spatial variables, such as position and momentum, are a transformation between two complementary representations of them, the coherent and localized representations into each other. This process emerges along a transformation angle Θ connecting the two systems which is experimentally varied by the correlation-angle of coincident electron-ion detection.

Studying the Secret of Life with FELs — FROB03

Peter Weightman (The University of Liverpool, Liverpool)

This talk will explore the contribution that research with Free Electron Lasers (FELs) can make to the understanding of living things. Physicists can play an important part in establishing the essential characteristics of life as demonstrated by Schrödinger‟s book "What is Life?" (1944). While there has been considerable progress in the determination of the structures of biological molecules using x-ray diffraction there has been very little progress in studying the conformational changes that are the key to understanding the mechanisms by which biological systems self-organise and maintain their functions. We lack methods of making real time observations of conformational change in proteins and exciting biological systems with the long wavelength radiation that is made available to biological systems at room temperature through the release of free energy from chemical processes. An outline will be given of the crucial role that FELs can play in this field and results will be presented on the real time observation of conformational change in proteins.

Saturable Absorption with VUV FEL Radiation — FROB04

Sam M. Vinko, Gianluca Gregori, William J. Murphy, Bob Nagler, J. S. Wark, Thomas Whitcher (University of Oxford, Oxford), Tomas Burian, Jaromir Chalupsky, Jaroslav Cihelka, Vera Hajkova, Libor Juha (Czech Republic Academy of Sciences, Prague), Sasa Bajt, Henry Chapman, Stefan Düsterer, Roland Faustlin, Tim Laarmann, Sven Toleikis (DESY, Hamburg), Thomas Tschentscher (European X-ray Free Electron Laser Project Team, Hamburg), Ali Reza Khorsand (FOM Rijnhuizen, Nieuwegein), Ulf Zastrau (FSU Jena, Jena), Marta Fajardo, Michaela Kozlova (GoLP, Lisbon), Eckhart Foerster, Ingo Uschmann (IOQ, Jena), Marek Jurek, Dorota Klinger, Ryszard Sobierajski (IP PAS, Warsaw), Fida Younus Khattak (Kohat University of Science and Technology, Kohat), Philip Heimann (LBNL, Berkeley, California), Tilo Doeppner, Siegfried Glenzer, Richard Lee, Art James Nelson, Hubert Joachim Vollmer (LLNL, Livermore, California), Thomas Dzelzainis, David Riley (Queen's University of Belfast, Belfast, Northern Ireland), Thomas Bornath, Carsten Fortmann, Sebastian Goede, Karl Heinz Meiwes-Broer, Andreas Przystawik, Ronald Redmer, Heidi Reinholz, Gerd Roepke, Robert Thiele, Josef Tiggesbaumker (Rostock University, Rostock), Jacek Krzywinski (SLAC, Menlo Park, California), Pascal Mercere (SOLEIL, Gif-sur-Yvette), Hae Ja Lee (UCB, Berkeley, California), Eric Galtier, Frank Rosmej, Romain Schott (UPMC, Paris)

We report for the first time saturable absorption in the soft x-ray regime: by photoionizing L-shell core electrons we observed on a 15 fs timescale a multifold increase of transmission through an aluminium foil. While saturable absorption is a phenomenon readily seen in the optical and infrared wavelengths, it has never been observed in a core electron transition due to the short lifetimes of the created excited states and the high intensities of the soft x-rays that are needed. The experiments were performed at the XUV free electron laser FLASH and used record high intensities. After the FEL pulse has passed, the aluminum sample is in an exotic state in which all the aluminium atoms have an L-shell hole, and the conduction band has a 9 eV temperature, while the atoms are still on their crystallographic positions. Subsequently, Auger decay heats the material to the Warm Dense Matter condition, at 20 eV temperatures. The saturable absorption allows for a very homogeneous and efficient heating. Therefore the method is an ideal candidate to study homogeneous Warm Dense Matter, highly relevant to planetary science, astrophysics and inertial confinement fusion.

Local Infrared Microspectroscopy with 100 nm Spatial Resolution and Application to Cell Imaging

FROB05

Jean-Michel Ortega, Alexandre Dazzi, Francois Glotin, Celine Mayet, Rui Prazeres, (LCP/CLIO, Orsay, Cedex)

Performing "chemical mapping" of various objects with sub-wavelength lateral resolution, by using the infrared vibrational signature characterizing different molecular species, is an old dream. We have recently demonstrated such a method of doing this, called AFMIR*. We use the photo-thermal expansion effect, detected by an atomic force microscope tip, probing the local transient deformation induced by an infrared pulsed laser tuned at a sample absorbing wavelength. This method records directly the local infrared absorption without interference due to the medium real index of refraction (i.e. sample topography and inhomogeneities) contrary to near-field optical methods. The pulsed character of the FEL, together with the small size of the AFM tip, allows a spatial resolution better than 100 nm. Local spectroscopy and imaging can be performed. We show different examples; in particular, we have imaged single viruses embedded into a cell** and living cells (in water). In this case, discrimination of the cell signal against water broadband absorption is made by selecting proper modes after Fourier analysis of the AFM cantilever modes of vibration***.

** A. Dazzi et al, Optics Letters, 30 (18), 2388 (2005). **A. Dazzi et al, Ultramicroscopy, 108/7, 635 (2008).*
**** C. Mayet et al, Optics Letters, 33(14), 1611 (2008).*

Chair: Jim Clarke

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09:00 – 10:45	Opening, New Lasing & FEL Prize Lectures (MOOA) Chairs: Mike Poole & Vladimir Litvinenko	Short Wavelength Amplifier FELs (TUOA) Chair: Jianping Dai	FEL Technology I: Accelerators (WEOA) Chair: Massimo Ferrario	FEL Technology II: Post-Accelerator (THOA) Chair: Bettina Kuske	Stability & Synchronism (FROA) Chair: William Graves
10:45 – 11:15	Refreshments				
11:15 – 13:00	FEL Theory (MOOB) Chair: Sven Reiche	New & Emerging Concepts (TUOB) Chair: Ingolf Lindau	FEL Technology I: Accelerators (WEOB) Chair: Hywel Owen	FEL Technology II: Post-Accelerator (THOB) Chair: Holger Schlarb	New Science from FELs & Closing Remarks (FROB) Chair: Jim Clarke
13:00 – 14:30	Lunch Break				
14:30 – 16:30	Poster Session (MOPC) & Refreshments SUPA Tutorial by Rodolfo Bonifacio	Poster Session (TUPC) & Refreshments SUPA Tutorial by Paul Emma	Poster Session (WEPC) & Refreshments SUPA Tutorial by Marangos	(Leaving at 14:00) STFC Daresbury Laboratory Visit (Returning at 18:30)	
16:30 – 18:00	Oscillator FELs (MOOD) Chair: Stephen Benson	Long Wavelength FELS (TUOD) Chair: Young Uk Jeong	Coherence & Pulse Length Control (WEOD) Chair: Henry Freund		
Evening	Reception (19:00 onwards)		Conference Dinner (19:30 onwards)