FEL 2012 NARA

34th International Free Electron Laser Conference

26-31 August 2012

Nara Prefectural New Public Hall,
Nara Japan

Conference Program & Abstracts

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FEL2012

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http://fel2012.spring8.or.jp

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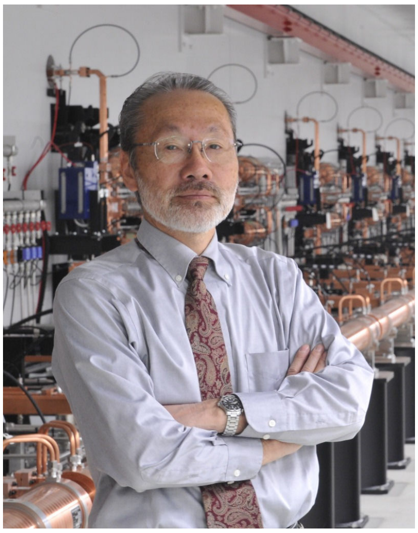
Welcome



We are pleased to announce the 34th International Free Electron Laser Conference, FEL2012, to be held in Nara, Japan from 26 to 31 August 2012. Nara is Japan's first permanent capital during the year of 710-784, therefore, it remains full of historic treasure, including Todaiji Temple (UNESCO World Heritage), one of Japan's largest temples located right next to the FEL2012 conference site. We chose Daibutsu (giant Buddha of Todaiji, National Treasure) as our FEL2012 symbol image, as it reminds us of the history of Buddhism, and also advanced ancient technology that made the creation of the giant Buddha statue possible. Today, one of the most advanced technologies is our FEL.

Recently, we have experienced dramatic achievement of FEL lasing of X-ray laser at LCLS-SLAC in 2009, followed by SACLA SPring-8 in 2011. Furthermore, there are extensive R&Ds to extend coherency by seeding technology or expanding wavelength to the THz region. In this conference FEL2012, I look forward to hearing exciting reports from new lasing FELs, beautiful theories, amazing technical achievements, and surprising new ideas.

Before we start, let me express my gratitude to friends around the world. Right after the earthquake occurred in the Tohoku Region in March 2011, we received many heart-warming messages and encouraging words from many in this community. Most of research accelerator facilities in the region have recovered after one year. Cities and towns affected by the earthquake are now recovering, while it will require a long period to put an end to the Fukushima nuclear power plants. My personal hope is to stop the use of nuclear power in future. I believe FEL can contribute to solving this problem through various researches.

Tsumoru Shintake
FEL2012 Conference Chair
Professor at OIST: Okinawa Institute of Science and Technology

General Information

Sponsors

SPring-8/ RIKEN, JASRI
The Kyoto University Foundation
Foundation for High Energy Accelerator Science
Nara Visitors Bureau
Kyoto University GCOE Program, "Energy Science in the AGE of Global Warming"

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E. J. Minehara (JAEA & WERC)
N. Nishimori (JAEA)
A. Shirakawa (KEK)
T. Tanaka (Nihon University)
H. Zen (Kyoto University)

Useful Information

Time Zone

The time zone in Japan is UTC/GMT + 9 hour.

Electricity

Japanese electrical standards in Western Japan are 60Hz, 100 Volt. Appliances set up for 240V will require a transformer if they don't already have built-in voltage adjustment. Mains sockets require a Type A plug and you are advised to obtain an adaptor before departure if needed. Type A plugs have two flat blades and are used in the US and Canada too.

Weather

The weather in Japan is very hot and humid in August. Nara has an average maximum temperature of 32°C and average minimum temperature of 25°C. The possibility to have rain is 25% in late August.

Currency and Credit Cards

Japanese Yen (¥) is Japanese currency. Most hotels, restaurants and shops accept major credit cards. Travelers' cheques are only accepted for exchange in banks and post offices, and, in general cannot be used to purchase goods and services. Foreign exchange can be performed in banks (look for sign in English), larger post offices, limited number of hotels: there is no street-side foreign money exchange in Nara. Bank counters are open 9 am to 3 pm, post offices financial services from 9 am to 4 pm on weekdays only. You can draw cash on your credit card or debit card at certain ATM cash machines: all post offices (found in every neighborhood; not 24 hr) and Seven Bank (in all 7-Eleven stores; 24 hr) ATMs accept overseas credit cards with PIN, and some debit card systems.

Taxis

The most common way to pay for taxi is cash. If you want to pay by credit card, you should ask the driver in any case before using the taxi. Many taxis accept Japanese but no foreign cards, so that the stickers with the logos of the credit cards on the windows of the taxi can be misleading. Please be aware that it is not common to tip the taxi driver – they will decline it in most cases.

Hours of Business

Around Nara station, restaurants and many shops are close at 9 pm except for several bars and first food restaurants. 7-Eleven stores offer beverages and foods.

Internet Access

Free wireless internet will be available at the Reception Hall and rooms for Poster Session and Industrial Exhibition. A password will be required and will be issued at registration. There will also be an internet café available.

In Japan you can not buy prepaid SIM card for your cell phone. Instead you can rent a WiFi device at the airport for mobile internet. Major hotels offer internet access with enough connection speed.

Insurance & Liability

The organizers of FEL2012 do not accept liability for medical, travel or personal insurance. Participants are strongly recommended to arrange their own personal insurance.

Emergency

Emergency call numbers are: 110 for police and 119 for fire/rescue.

Outline of Scientific Programme

	Monday 27th	Tuesday 28th	Wednesday 29th	Thursday 30th	Friday 31st
09:00	Opening	Seeding and Seeded FELs Chair : S. Reiche	FEL Technology -1- Chair: H.H. Braun	FEL Technology -2- Chair: H. Maesaka	Progress and Projects Chair : D. Nguyen
09:30	FEL Prize Lecture -1- Chair : H. Hama				
10:00	Coffee break				
10:30	New Lasing and Status Report Chair : H. Tanaka	Coffee break	Coffee break	Coffee break	Coffee break FEL Prize Lecture -2- Chair : H. Hama
11:00		XFELs Chair : T. Hara	Beam Physics for FEL Chair : M. Ferrario	New Concepts Chair : S. Biedron	
11:30					Closing
12:00	Announcement & Photo				Lab Tour SACLA
12:30	Lunch break	Lunch break	Lunch break	Lunch break	
14:00	FEL Theory Chair : L. Giannessi	Oscillator FELs and Storage Ring FELs Chair : R. Hajima	THz and Long Wavelength FELs Chair : U. Lehnert	FEL Technology -3- Chair : D.E. Kim	
14:30					
15:00					
15:30	Coffee break	Coffee break	Coffee break	Coffee break	
16:00	Poster Session	Poster Session	Poster Session	Poster Session	
17:30	Coffee break	Special Lecture -1- Chair : T. Shintake	Special Lecture -2- Chair : H. Hama	FEL Applications Chair : J. Hastings	
18:00	Japanese traditional theatre "Kyogen"				
18:30			Move to Conference Dinner		
19:00					

FEL Prize Lectures

FEL Prize Lecture -1- (9:15 – 10:00, Monday 27th August)

Tsumoru Shintake : Winner of 2012 FEL Prize

"Future Perspective on X-ray Laser and Electron Microscopy based on High Performance Particle Beams"

FEL Prize Lecture -2- (10:45 – 11:30, Friday 31st August)

Marie Labat : Winner of 2012 Young Scientist FEL Award

"Towards Compact Short FEL Sources : Seeding and LWFA based FEL"

Poster Session Topics

Monday 27th August	Tuesday 28th August
Status Report	XFELs
FEL Theory	Seeding and Seeded FELs
FEL Technology I:	FEL Technology II:
(Gun, Injector, Accelerator)	(Stability, Optics, Beamline)

Wednesday 29th August	Thursday 30th August
Oscillator and Ring FELs	FEL Technology III:
THz and Long Wavelength FELs	(Undulators, Monitors, Beam diagnostics)
Beam Physics for FEL	New Concepts
Progress and Projects	FEL Applications

Special Lectures

Special Lecture -1- (17:30 – 18:30, Tuesday 28th August)

Kiyoshi Ueda, Tohoku University

"FEL Experiments for Atoms and Atomic Clusters: From EUV to X Rays"

Special Lecture -2- (17:30 – 18:30, Wednesday 29th August)

Koichiro Tanaka, Kyoto University

"High-Power Terahertz Generation and Terahertz Nonlinear Spectroscopy"

Conference Venue

Nara was the capital of Japan from 710 to 784, so, it has many historical shrines and temples containing national treasures. The Conference will take place at Nara Prefectural New Public Hall, which was constructed in 1987 and is located in the center of Nara National Park, which is famous for its beauty and 1,200 tame deer. Famous tourist spots such as Kofukuji Temple, Todaiji Temple, Kasuga Shrine are within walking distance from the hall.

Directions

The address of the Conference venue is as follows:

Nara Prefectural New Public Hall, 101 Kasugano-cho, Nara-shi, 630-8212, Nara, Japan

奈良県奈良市春日野町 101 奈良県新公会堂 **(in Chinese character)**

The venue website is as follows:

http://www.shinkokaido.jp/english/index.html

Arrival by Limousine Bus from Kansai International Airport (Recommended)

The easiest way to come to Nara from Kansai International Airport is to use a limousine bus. We recommend using the limousine bus because it brings you to JR Nara station without a transfer. It takes about 90 min. and the fare is JPY 2,000 per person. You can also buy Round Trip Ticket to go and back with JPY 3,800 per person, which valid 14 days from the date of purchase. You should buy the ticket before boarding your bus.

The bus departs Kansai International Airport at 7:40, 8:40, 10:40, 12:40, 13:40, 14:40, 15:40, 16:40, 17:40, 18:40, 19:40 and 20:40. At the bus stop [9], you can catch the limousine bus to Nara. You can purchase the bus ticket using a ticket vending machine in front of the bus stop. The limousine bus stops at "Nara Hotel", "Kintetsu Nara Station" and "JR Nara Station".

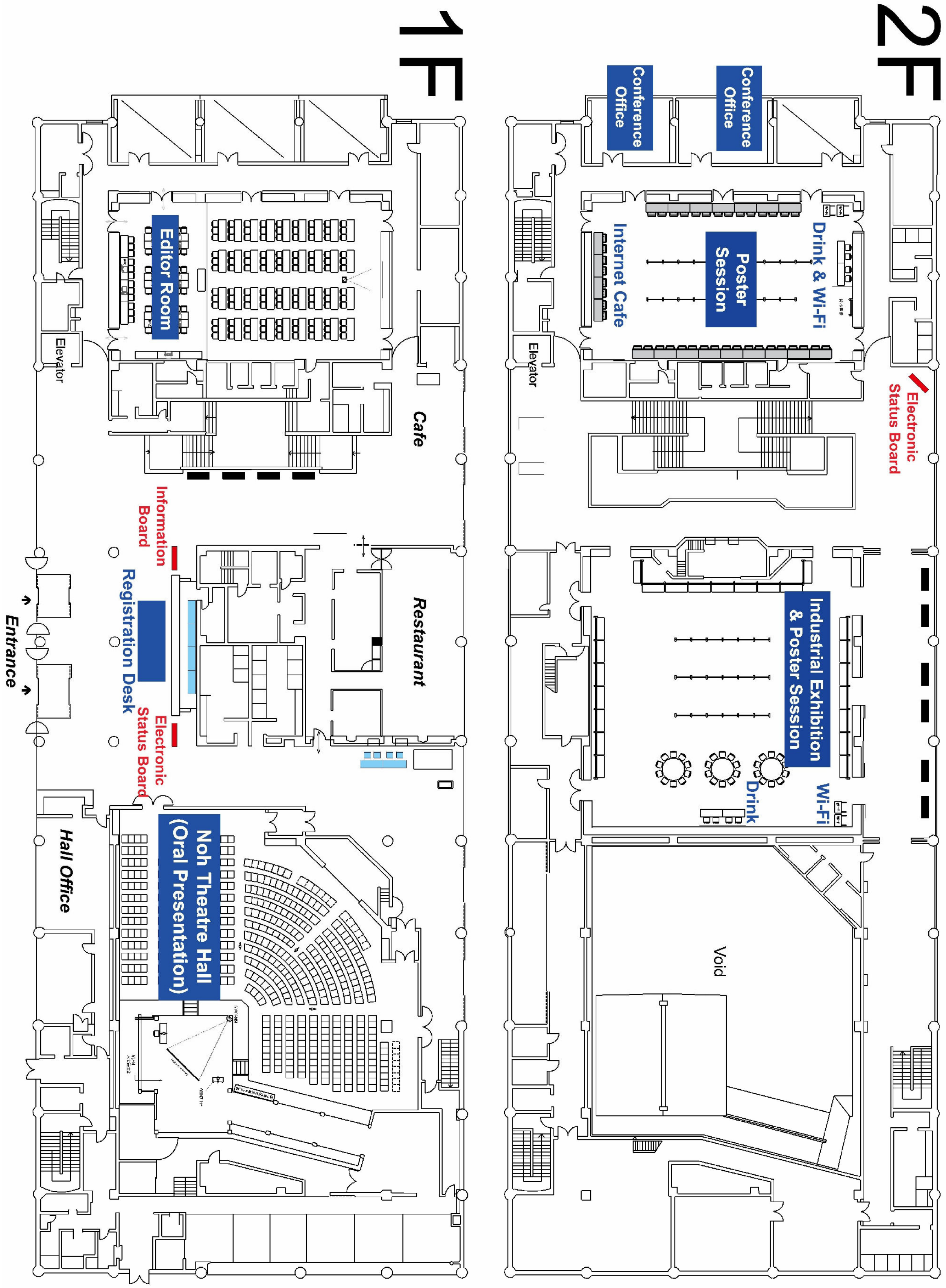
Arrival by Train from Kansai Airport

JR line services from Kansai Airport Station (neighboring the Kansai International Airport) to Nara Station. You once needed to change the train at Tennoji Station. You may arrive at plat home #18 if you take limited express "Haruka". The train going to Nara will depart from plat home #16 and its line name is "Yamatoji line". You must choose trains bound for "Nara" and are recommended to take a train operated as Yamatoji Rapid Service (Yamatoji Kaisoku in Japanese). The transportation fare is JPY 1,660 for one way trip. If you take limited express "Haruka", you need to buy a special ticket for the limited express, JPY 730.

About Local Bus Transportation between Nara Station and Conference Venue

At the east entrance of the JR Nara Station, you can find several bus stops. You should wait at the bus stop #1 and take a #2 bus which is circulating bus around Nara city. In day time, you can have one bus per 10 minute. The nearest bus stop of Conference venue is "Daibutsu-den Kasuga-Taisha Mae" (大仏殿春日大社前). The bus fee is JPY 200 and you should pay by coin. In the bus, there is an exchanger from JPY1000 bill to coins. But you are recommended to prepare coins before taking on the bus. It will take 3 minutes by walk from the bus stop to the Conference venue.

Conference Venue Layout



Registration

Registration is open from 16:00 to 20:00 on Sunday 26th August. Registration will take place in the entrance hall of the Conference Venue. A welcome reception will also be held during this time at the garden of Conference venue.

Registration continues on Monday 27th August from 08:30.

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 pay the fee at the registration desk. **Please note that you will only be able to pay by credit card (VISA, Master Card, AMEX, DINERS and JCB) or in cash (JPY)**.

Japanese Traditional Theatre "Kyogen"

After the poster session on Monday 27th August, Japanese Traditional Theatre "Kyogen" will be performed on the stage of main hall of the Conference. At the beginning, short lecture (20 min.) on "Kyogen" will be made. A Kyogen play, Kaminari (= Thunder), will be performed (20 min.) after the lecture

Conference Dinner

The Conference dinner will take place on Wednesday 29th August at 19:30, in Hotel Nikko Nara.

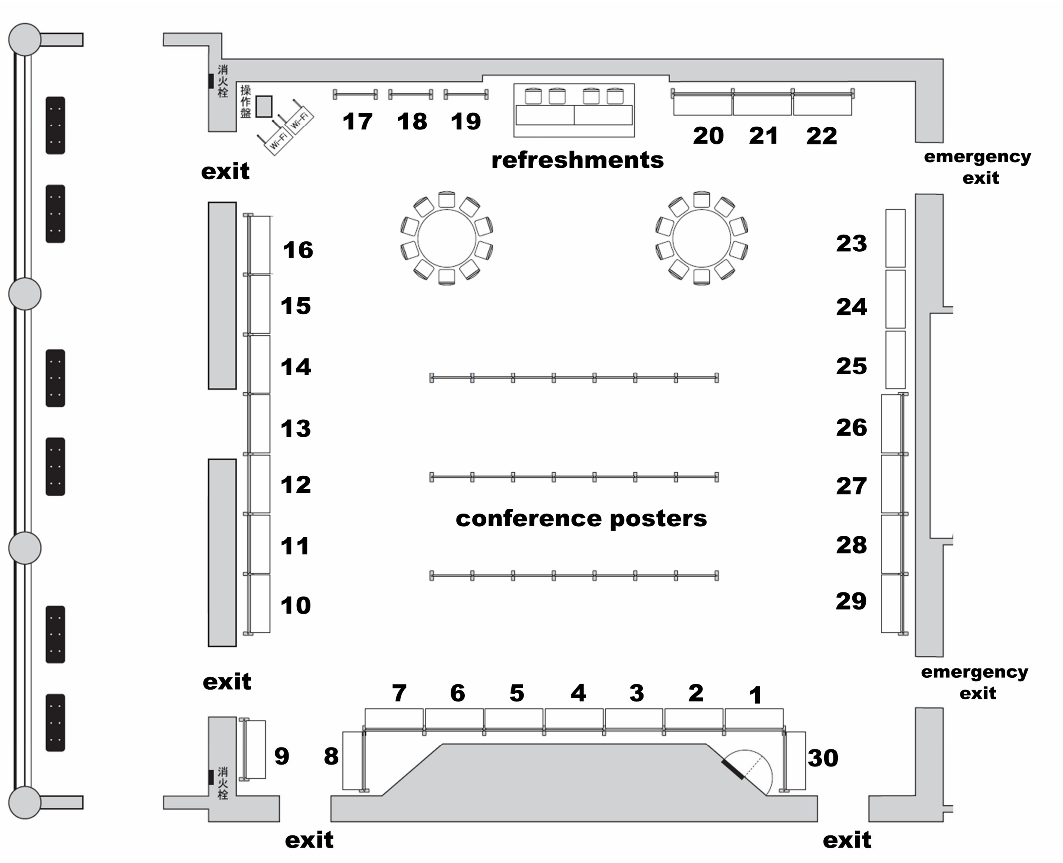
Lab. Tour to SACLA (XFEL)

As part of the FEL conference 2012, there will be a scientific excursion to SACLA on the afternoon of Friday August 31, 2012. The last session of the conference will be closed at 11:30, and the buses will depart from the conference venue at **12:00-13:00 (4 buses at intervals of 20 min)**. A lunch box is included in the excursion fee (3,000 JPY). The returning time is scheduled as **19:00-20:00**. In the return trip, the buses will also stop at JR Nara station.

All participants are kindly requested to fill in your information at the conference registration desk by Tuesday.

Industrial Exhibition

The industrial exhibition will be held on Monday through Thursday from 09:00 until 18:00 and on Friday from 09:00 until 11:00. The exhibition will take place in 2nd floor of Conference Venue (see page XIV). Advertisements of Exhibitors are attached on the last part of this abstract.



1	Instrumentation Technologies, d. d.
2	MTT Corp.
3	NEOMAX Engineering Co., Ltd.
4	Niki Glass Co., Ltd.
5	ScandiNova System AB
6&7	Mitsubishi Heavy Industries, Ltd.
8	Toyama Co. Ltd.
9	SAES Getters S.p.A.
10	Hakuto Co., Ltd.
11	AET, Inc.
12	Glassman Japan High Voltage Ltd.
13	Toshiba Corp.
14	Advanced Energy Systems, Inc.
15	Nihon Koshuha Co., Ltd.
16	Edwards Japan Ltd.
17	STI Optronics, Inc.
18	Nippon Roper, K.K.
19	Hitachi Zosen Corp.
20	VacLab, Inc.
21	R&K Company Ltd. & Cornes Tech. Ltd.
22	KOBELCO Research Institute, Inc.
23&24	Toshiba Electron Tubes & Devices Co., Ltd.
25	Japan Laser Corp.
26	Mitsubishi Electric Corp.
27	SII NanoTechnology Inc.
28	Fujikin Inc.
29	Osaka Vacuum, Ltd.
30	Okinawa Inst. Sci. Tech. Graduate Univ.

Exhibitors & Supporting Companies (arranged in alphabetical order)

Advanced Energy Systems, Inc.
27 Industrial Blvd. Medford, NY 11763, USA
Phone: +1-631-345-6264 Fax: +1-631-345-0458
http://www.aesys.net

AET, Inc.
2-7-6 Kurigi, Asao-ku, Kawasaki-city, Kanagawa, Japan
Phone: +81-44-980-0505 Fax: +81-44-980-1515
info@aetjapan.com http://www.aetjapan.com/english/

AIDEN Co., Ltd.
2-3 2-Choume Mitsugaoka, Nishi-ku, Kobe, Hyogo, Japan
Phone: +81-78-994-1400 Fax: +81-78-994-1462
info@aiden.com http://www.aiden.com

ARGO Corp.
Interplanet Esaka Building 9th floor, 1-13-48 Esaka-cho, Suita, Osaka 564-0063, Japan
Phone: +81-6-6339-3366 Fax: +81-6-6339-3365
argo@argocorp.com http://www.argocorp.com

Cornes Technologies Ltd.
http://www.cornestech.co.jp/en/

Edwards Japan Ltd.
1078-1, Yoshihashi, Yachiyo-shi, Chiba, 276-8523, Japan
Phone: +81-47-458-8831 Fax: +81-47-458-8835
EJ-hp@edwardsvacuum.com http://www.edwardsvacuum.co.jp

Fujikin Inc.
Kita Hankyu Bldg., 1-4-8 Shibata, Kita-ku, Osaka 530-0012, Japan
Phone: +81-6-6372-7141 Fax: +81-6-6375-0697
http://www-ng.fujikin.co.jp/

General Bussan Co., Ltd.
2-18-2 Nakano, Nakano-ku, Tokyo 164-0001, Japan
Phone: +81-3-3383-1711 Fax: +81-3-3383-1719
info@general-bussan.co.jp http://www.general-bussan.co.jp

Glassman Japan High Voltage Ltd.
Green City Building, 2-17, Utsukushigaoka 5-Chome, Aoba-ku, Yokohama 225-0002, Japan
Phone: +81-45-902-9988 Fax: +81-45-902-2268
glassman@yha.att.ne.jp http://www.kagaku.com/glassman

Hakuto Co., Ltd.
1-13, Shinjuku 1-Chome, Shinjuku-Ku, Tokyo 160-8910, Japan
Phone: +81-3-3225-8939 Fax: +81-3-3225-9011
pfeiffer@hakuto.co.jp http://www.hakuto-vacuum.jp

Hitachi Zosen Corp.
7-89 Nanko-Kita A-Chome, Suminoe-Ku, Osaka 559-8559, JAPAN
Phone: +81-6-6569-0082 Fax: +81-6-6569-7058
serino@hitachizosen.co.jp http://www.hitachizosen.co.jp

IDX Co., Ltd.
568-113 Ishizuka-cho, Sano city, Tochigi 327-0103, Japan
Phone: +81-283-25-1576 Fax: +81-283-25-2731
kowada@idx-net.co.jp http://english.idx-net.co.jp/

Instrumentation Technologies, d. d.
Velika pot 22, SI-5250 Solkan, Slovenia
Phone: +386-5-33-52-600 Fax: +386-5-33-52-601
info@i-tech.si http://www.i-tech.si/

Japan Laser Corp.
2-14-1 Nishiwaseda, Shinjyuku-ku, Tokyo 169-0051, Japan
Phone: +81-3-5285-0861 Fax: +81-3-5285-0860
jlc@japanlaser.jp http://www.japanlaser.jp

Katsukitarousukesyoten Co., Ltd.
67 Shimenomachinishi, Kanazawa city, Ishikawa, Japan
Phone: +81-76-268-2880 Fax: +81-76-268-2880
info@katuki.jp http://www.katuki.jp/

Kinokuniya Company Ltd.
3-7-10 Shimomeguro, Meguro-ku, Tokyo 153-8504, Japan
Phone: +81-3-6910-0502 Fax: +81-3-6420-1350
http://www.kinokuniya.co.jp/

KOBELCO Research Institute, Inc.
5-9-12 Kita-Shinagawa, Shinagawa-ku, Tokyo 141-8688 Japan
Phone: +81-3-5739-5030 Fax: +81-3-5739-5037
eigyo@kki.kobelco.com http://www.kobelcokaken.co.jp/

Material Technology Trading Corp.
103-0001 YusMediaBldg., 17-16 Kodenma-cho, Nihonbashi, Chuo-ku, Tokyo, Japan
Phone: +81-3-3667-6801 Fax: +81-3-3667-5835
matt@athena.ocn.ne.jp http://www.matt-tech.co.jp/

Mitsubishi Electric Corp.
Advanced Magnetic & Medical Systems Marketing Department
2-7-3, Marunouchi Chiyoda-ku Tokyo 100-8310, Japan
Phone: +81-3-3218-2607 Fax: +81-3-3218-9027
Sato.Fumitake@db.MitsubishiElectric.co.jp
http://www.mitsubishielectric.com/

Mitsubishi Heavy Industries, Ltd.
<Shinagawa>
16-5 Konan 2-chome, Minato-ku, Tokyo 108-8215, Japan
<Mihara>
1-1, Itosakiminami 1-chome, Mihara, Hiroshima 729-0393, Japan
http://www.mhi.co.jp/en/products/category/accelerating_device.html

MTT Corp.
2-7-12 Murotani, Nishi-ku, Kobe City 651-2241, Japan
Phone: +81-78-996-8414 Fax: +81-78-991-8210
umeda@mtt.co.jp http://www.mtt.co.jp/

NEC TOKIN Corp.
1-1 Asahicho 7-chome, Shiroishi-shi, Miyagi 989-0223, Japan
http://www.nec-tokin.com/english/

NEOMAX Engineering Co., Ltd.
Seavans North 2-1, Shibaura 1-chome Minato-ku, Tokyo
105-8614, Japan
Phone: +81-3-5765-4250 Fax: ＋81-3-5765-4457
Sachio_Hirano@hitachi-metals.co.jp http://www.nxe.co.jp/

Nihon Koshuha Co., Ltd.
1119 Nakayama-cho, Midori-ku, Yokohama, 226-0011, Japan
sales@nikoha.co.jp http://www.nikoha.co.jp

Niki Glass Co., Ltd.
Tokyo Branch:
3-9-7 Mita Minato-ku, Tokyo 108-0073, Japan
Phone: +81-3-3456-4700 Fax: +81-3-3456-3423
Oasaka Sales Office:
6-2-16 Nishinakajima Yodogawa-ku Osaka 532-0011, Japan
Phone: +81-6-4805-4155 Fax: +81-6-4805-0211
info@nikiglass.com http://www.nikiglass.co.jp

Nippon Roper, K.K.
3F Sakurai Building, 2-8-19, Fukagawa, Koto-ku, Tokyo
135-0033, Japan
Phone: +81-3-5639-2741 Fax: +81-3-5639-2775
webmaster2@roper.co.jp http://www.pi-j.jp/index.shtml

Okinawa Institute of Science and Technology Graduate University
1919-1 Tancha, Onna-son, Okinawa 904-0495, Japan
Phone: +81-98-966-2195 Fax: +81-98-966-1065
stu-rcrt@oist.jp http://www.oist.jp/

Ophir Optronics Solutions Ltd.
4-384 Sakuragi, Omiya, Saitama 330-0854, Japan
Phone: +81-48-646-4150 Fax: +81-46-253-1412
info@ophirjapan.co.jp http://www.ophiropt.com/jp

Osaka Vacuum, Ltd.
3-5-29 Kitahama, Chuo-ku, Osaka 541-0041, Japan
Osaka: +81-6-6203-3981 Tokyo: +81-3-3546-3731
Nagoya: +81-52-950-3051 Shanghai: +86-21-5031-1522
Seoul: +82-31-707-0002
http://www.osakavacuum.co.jp/

RAD Device Co., Ltd.
URBANPLAZA IZUMI 7F 2-26-4 Myojin-Cho, Hachioji-Shi, Tokyo 192-0046, Japan
Phone: +81-42-642-0889 Fax: +81-42-642-0896
info@rad-dvc.co.jp http://www.rad-dvc.co.jp/

R&K Company Ltd.
721-1 Maeda, Fuji-City, Shizuoka 416-8577, Japan
Phone: +81-545-31-2600 Fax: +81-545-31-1600
info@rkco.jp http://www.rk-microwave.com

SAES Getters S.p.A.
2nd Gotanda Fujikoshi Bldg., 23-1 Higashi-Gotanda 5-chome, Shinagawaku-ku, Tokyo 141-0022, Japan
Phone: +81-3-5420-0431 Fax: +81-3-5420-0438
saesjapan-cs@saes-group.com http://www.saesgetters.jp

ScandiNova System AB
Ultunaallén 2A, 756 51 UPPSALA, Sweden
Phone: +46-18-480-5900 Fax: +46-18 480-5999
info@sc-nova.com http://www.sc-nova.com

Setec, Inc.
5-2-3,Asakusabasi, Taito-ku, Tokyo 111-0053, Japan

SII NanoTechnology Inc.
Shintomi2-15-5,Chuo-ku Tokyo 104-0041,Japan

Spectra-Physics K.K.
Daiwa-Nakameguro Bldg., 4-6-1, Nakameguro, Meguro-ku, Tokyo 135-0061, Japan
Phone: +81-3-3794-5511 Fax: +81-3-3794-5510
spectra-physics@splasers.co.jp http://www.spectra-physics.jp

Spectronix Corp.
5F Kunisato Bldg., 8-8 Eidai-cho, Ibaraki, Osaka, 567-0816 Japan
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Oral Presentation Instructions

All the oral sessions will take place at the Noh Theatre Hall (see page XIV).
Each **Contributed Oral is allotted 15** or **20 minutes** depending on the session program.
Each **Invited Oral is allotted 30 minutes**.
All the oral presenters should arrange their talk so that we keep time of **5 minutes available for question and discussion**.

For the oral session, a Windows PC with Microsoft PowerPoint 2010 and Adobe Acrobat 10 is prepared on the stage. We recommend all the oral presenters to use the PC.
In the Editor Room (see page XIV), we prepare another PC with the same configuration for checking the slide operation.
All the oral presenters are requested to check the slide operation before the session.

Presentation files should be uploaded to the JACoW SPMS server and/or supplied on disc or memory stick and taken well in advance (>1 hour) of your Session to the conference secretariat where your presentation will be uploaded and tested.
The presentation files will be posted on the Conference Web. The authors are kindly asked to check if their presentations can be posted as it is. If the authors prefer revised versions to be posted, please upload the revised files to the SPMS server or bring them directly to the conference secretariat, but only after the Session.

It is prohibited to step up on the stage with your shoes on. You are kindly requested to change into indoor shoes at the downstage.

Poster Session Information

Poster sessions are scheduled for Monday, Tuesday, Wednesday and Thursday afternoons from 16:00 to 17:30, in **2nd floor of Conference Venue (see page XIV)**. Please refer to the conference programme on **page XI** of this booklet for the topics to be presented on each day. Refreshments will be available 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. Mounting material will be provided.

The maximum poster format is ISO A0 size (84.1 cm × 118.9 cm) in portrait orientation.

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 and posters should be manned for approximately one hour at least, allowing time for delegates to visit other posters.

Papers for posters that are not displayed for the full poster session will not be published in the proceedings.

Paper Preparation and Submission

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. Authors are required to abide to the specifications outlined in "Preparation of Papers for JACoW Conferences". This document not only provides precise instructions for preparing the manuscript, but its source file (available in Word, Latex and Open Office) also serves as a template for authors.

Use of the template and careful attention to the specifications will help the Editors to quickly process papers and enable a speedy delivery of the Conference Proceedings. Instructions for downloading templates are given below. **Papers should be submitted (i.e. uploaded) by the deadline of Wednesday, August 22, 2012 at Midnight, Japan Standard Time.** This deadline will allow the Editors to make an early start on paper processing, enabling any outstanding problems to be resolved during the Conference. Papers passed through the editorial process will be sent in sequence to referees and refereed before the end of the Conference.

Authors will be kept informed of the status of their papers by viewing the electronic status board at the Conference and or by logging in to their FEL2012 SPMS account.

Electronic File Submission

Authors are required to create a Portable Document Format (PDF) file of the paper. Each author should submit the PDF and all of source files (text and figures), to enable the paper to be reconstructed if there are processing difficulties. Authors are advised to follow the guidelines for the creation of PDF files (follow the links "JACoW.org Home" -> "Information and help" -> "About electronic processing"). Be sure to check that the PDF file prints correctly.

Checking the Editing and Refereeing Status

Authors can check the editing and refereeing status of their manuscripts by logging in to their FEL2012 SPMS account and electronic status board in the Conference Venue (see page XIV). **Note that, before the paper is completely ready to be published in the Proceedings, the author must have two green dots; one of these is given by an Editor, and the other by a Referee. If the paper is being presented as a poster, this must also be additionally approved by the 'poster police'.**

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FEL Prize Lecture -1-

Chair: Hiroyuki Hama

Future Perspective on X-ray Laser and Electron Microscopy based on High Performance Particle Beams	MOOAI01

Tsumoru Shintake (RIKEN/SPring-8, Hyogo)

Leaning from X-ray laser technology development, now we know of the high performance electron beams; its generation and handling. Using X-ray FEL beams, now we start developing new technologies matching with such a high coherent intensity X-ray shot. Among them, imaging of atomic level structure is common target with electron microscopy. Learning between two communities will be very important and I personally believe it become more creative for us. I will present personal perspective on interdisciplinary science along with this direction.

New Lasing and Status Report

Chair: Hitoshi Tanaka

First Lasing of the IR FEL at the Fritz-Haber-Institut Berlin — MOOB01

Wieland Schöllkopf, Wolfgang Erlebach, Sandy Gewinner, Heinz Junkes, Andreas Liedke, Gerard Meijer, Gert von Helden, Weiqing Zhang (FHI, Berlin), Kevin Jordan, John Rathke, Alan Murray Melville Todd, Lloyd Martin Young (AES, Medford, NY), Hans Bluem, David Dowell, Ralph Lange, Jangho Park (AES, Princeton, New Jersey), Michael Davidsaver (BNL, Upton, New York), Ulf Lehnert, Peter Michel, Wolfgang Seidel, Rudi Wuensch (HZDR, Dresden), Henrik Loos (SLAC, Menlo Park, California), Stephen C. Gottschalk (STI, Washington)

An IR and THz FEL with a design wavelength range from 4 to 500 µm has been commissioned at the Fritz-Haber-Institut (FHI) in Berlin, Germany, for applications in, i.a., molecular and cluster spectroscopy as well as surface science.* The linac** comprises two S-band standing-wave copper structures. The first one operates at near fixed field to accelerate the electrons to 20 MeV, while the second one is designed to accelerate (or decelerate) to any final energy between 15 and 50 MeV. A key aspect of the system is low longitudinal emittance, < 50 keV-psec, at more than 200 pC bunch charge with a max. micro pulse rep. rate of 1 GHz. The up to 15 µs long macro pulses come at a rate of up to 20 Hz. The electrons are steered through either one of two FELs. A single-plane-focusing, 40 mm period wedged-pole hybrid undulator*** combined with a 5.4 m long cavity has been commissioned for the mid-IR (< 50 µm). In addition, a two-plane-focusing undulator in combination with a 7.2 m long cavity with a 1-d waveguide for the optical mode is planned for the far-IR. In February 2012 we observed 'first lasing' at 28 MeV and 18 µm wavelength. We will present first results characterizing the system.

** W. Schollkopf et al., "Status of the Fritz Haber Institute THz FEL", Paper TUPB30, Proc. FEL 2011.*

*** Advanced Energy Systems, Inc., Medford, NY, USA *** STI Optronics, Inc., Bellevue, WA, USA*

First Lasing of the Terahertz FEL FLARE — MOOB02

Rienk Jongma, Roy Bakker, Chris Berkhout, Arno Engels, Ruurd Lof, Cor Sikkens, Pieter van Dael, Alexander van der Meer, Wim J. van der Zande, Andre van Roij, Arjan van Vliet, Frans Wijnen, Bryan Willemsen, Gerben Wulterkens (Radboud University, Nijmegen), Ulf Lehnert (HZDR, Dresden), Kai Dunkel, Aron Metz, Christian Piel (RI Research Instruments GmbH, Bergisch Gladbach)

Early 2011 we commenced the assembly of FLARE, the Free-electron Laser for Advanced spectroscopy and high-Resolution Experiments, in its dedicated, new building. FLARE will operate as a pulsed FEL in the 100-1500 micron range and is, amongst others, intended for spectroscopy in very high magnetic fields and (bio) molecular spectroscopy *,**. After completion of the move of FELIX and FELICE to the Radboud University, FLARE will operate as part of the FELIX facility Nijmegen. Challenging in the design, assembly and operation of the FLARE cavity are the parallel plate waveguide that extends over the full cavity length and the outcoupling slit. In June 2011 the commissioning of the accelerator and optical cavity of FLARE was started, resulting in first lasing on September 26 of 2011. Since then, FLARE demonstrated lasing between 100 micron and 1400 micron at output powers meeting the design values. Until the end of 2012, the optical distribution system serving all the user-stations as well as the high field magnets in the neighboring HFML will be assembled, after which FLARE will come on-line as part of the new user facility in Nijmegen.

**W.J. van der Zande, et. Al. Proc. FEL 2006, Berlin, Germany, (2006) 485.*

***R.T. Jongma, et al., Proc. FEL-2008, Gyeongju, South Korea, (2008) 200.*

The Nijmegen THz-FEL is funded via the 'Big Facilities' programme of the Netherlands Organisation for Scientific Research (NWO).

First Lasing of FERMI FEL-2 – 1st stage and FERMI FEL-1 Recent Results — MOOB06

Luca Giannessi (CSU, Fort Collins, Colorado; ELETTRA, Basovizza; ENEA C.R. Frascati, Frascati (Roma))

The FERMI@Elettra seeded Free Electron Laser (FEL) is based on two complementary FEL lines, FEL-1 and FEL-2. FEL-1 is a single stage cascaded FEL delivering light in the 80-20nm wavelength range, while FEL-2 is a double stage cascaded FEL where the additional stage should extend the frequency up-conversion to the spectral range of 20-4nm. The FEL-1 beam line is in operation since the end of 2010, with user experiments carried on in 2011 and 2012. During 2012 the commissioning of the FEL-2 beam line has started and the first observation of coherent light from the first stage of the cascade has been demonstrated. In the meanwhile the commissioning of a number of key components of FERMI, as the laser heater, the X-Band cavity for the longitudinal phase space linearization and the high energy RF deflector has been completed. The additional control on the longitudinal phase space and a progressive improvement in the machine optics optimization had a significant impact of FEL-1 performances, which has reached the expected specifications. In addition, emission of radiation at very high order conversion factors (up to 29th) has been observed and double stage cascades have been preliminarily tested with the observation of coherent radiation in the water window, up to the 65th harmonic of the seed laser, at about 4 nm.

Progress in SACLA Operation

MOOB03

Toru Hara, Hitoshi Tanaka, Kazuaki Togawa,
(RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo)

In March 2012, SACLA is open as a public user facility. Currently, 100-400 micro-J laser pulses ranging from 5 to 15 keV are provided to the user experiments. During the user time, the user can freely change the undulator gap to finely adjust the photon energy. While the first lasing was achieved at 10 keV after several months of machine commissioning, the pulse energy was about 30 micro-J, which is lower than the design value. In the autumn of 2011, we intensively worked on the reduction of a projected emittance, then 150 micro-J was finally obtained at 10 keV. After the cathode replacement in the winter shutdown, we re-tuned the accelerator and further increased the pulse energy to 250 micro-J. At the same time, the stability of the accelerator, particularly the injector section, has been improved, and an intensity fluctuation of 10-20 % (RMS) is currently achieved during day-to-day operation. Since the floor of the undulator hall still moves by 0.1 mm in 3 months, the beam orbit at the undulator section is re-aligned every 2 weeks to maintain the FEL performance. In this presentation, we will report the recent progress of the SACLA laser performance and operation.

SwissFEL, the X-ray Free Electron Laser at PSI

MOOB04

Hans-Heinrich Braun (Paul Scherrer Institut, Villigen)

PSI prepares the construction of an X-ray free electron laser, SwissFEL, as its next major research facility. The baseline design consists of a 5.8 GeV linear accelerator and two FEL lines covering the wavelength range from 0.1-0.7nm and 0.7-70nm, respectively. SwissFEL features a linear accelerator in C-band technology, a novel design of variable gap in-vacuum undulators for the hard X-ray FEL and Apple II undulators with full polarization control for the soft X-ray FEL. The two FELs are operated independently and simultaneously with 100 Hz pulse rate each. In addition to the FEL performance goals SwissFEL aims for a low overall energy consumption. Linac parameters as well as the cooling systems are optimized towards this goal. For the whole facility a staged construction is planned, with groundbreaking in spring 2013 and the commissioning of the linear accelerator and the hard X-ray FEL starting in 2016. An overview of SwissFEL goals, status and plans is given and the SwissFEL R&D activities are reviewed.

The European XFEL Project: Current Status and Future Development

MOOB05

Tobias Haas (European XFEL GmbH, Hamburg)

The European XFEL is currently under construction in Hamburg, Germany. After completion in 2015 it will provide a highly versatile X-Ray FEL user facility covering the wavelength range from 300 eV to over 25 keV with a wide range of operating conditions. At the moment in time, the civil construction for the project is almost complete and the installation phase is starting. In this talk we review the state of the project and outline the steps that are foreseen from now until completion. We shall also discuss the plans for technical and machine commissioning. Finally we shall touch upon a number of future extensions and upgrades that are currently under discussion.

Funding Agency : European XFEL GmbH

FEL Theory

Chair: Luca Giannessi

Laser Phase Errors in Seeded Free Electron Lasers — MOOCI01

Daniel Ratner, Alan Fry, Gennady Stupakov, William White (SLAC, Menlo Park, California)

Harmonic seeding is a promising method for producing transform-limited FEL pulses in the soft x-ray region. While harmonic multiplication schemes extend seeding to shorter wavelengths, they also amplify the spectral phase errors of the initial seed laser, degrading the final pulse quality and decreasing longitudinal coherence. Here we consider the effect of seed laser phase errors on longitudinal coherence for high gain harmonic generation and echo-enabled harmonic generation. We develop simulations to confirm analytical results for the case of linearly chirped seed lasers, and extend the results for arbitrary seed laser envelope and phase.

Growth Rates and Coherence Properties of FODO-lattice based X-ray Free Electron Lasers — MOOC02

Sven Reiche, Eduard Prat (Paul Scherrer Institut, Villigen)

Most hard X-ray Free Electron Lasers are designed with a super-imposed FODO lattice to focus the electron beam for optimum performance of the FEL. Theory predicts an optimum value of the beta-function, where the induced axial velocity spread starts to counteract the increased rho-parameter due to higher electron density. However in a FODO lattice the electron beam envelope varies significantly and disrupts the coupling of the electron beam to the radiation field. This is particularly relevant for hard X-ray FELs, where the radiation mode is smaller than the electron beam size. In this presentation we study the impact of the FODO cell length and the beta-function variation on the FEL gain length and growth of the coherence properties for SASE FELs

On Quantum Effects in Spontaneous Emission by a Relativistic Electron Beam in an Undulator — MOOC03

Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin (DESY, Hamburg)

Robb and Bonifacio (2011) claimed that a previously neglected quantum effect results in noticeable changes in the evolution of the energy distribution associated with spontaneous emission in long undulators. They revisited theoretical models used to describe the emission of radiation by relativistic electrons, and claimed that in the asymptotic limit for a large number of undulator periods the evolution of the electron energy distribution occurs as discrete energy groups according to Poisson distribution. These novel results are based on a one-dimensional model of spontaneous emission and assume that electrons are sheets of charge. However, electrons are point-like particles and the bandwidth of the angular-integrated spectrum of undulator radiation is independent of the number of undulator periods. The evolution of the energy distribution studied with a three-dimensional theory is consistent with a continuous diffusive process. We also review how quantum diffusion of electron energy in an undulator with small undulator parameter can be analyzed using the Thomson cross-section expression, unlike the conventional treatment based on the expression for the Lienard-Wiechert fields.

Free-Electron Laser Growing Modes and their Bandwidth — MOOC04

Gang Wang, Vladimir N. Litvinenko (BNL, Upton, Long Island, New York),
Stephen Davis Webb (Tech-X, Boulder, Colorado)

Forty years after invention of FELs a number of fundamental questions remain unanswered. For example, it is known that for a beam with a Gaussian energy distribution an infinite number of modes exist. But it is unknown how many of these modes are growing, or what frequency cutoffs might exist for these growing modes? In this talk, for the first time, we present the proof that for typical bell-shape energy distribution in the electron beam there is no more that one growing mode - both without* and with space charge effects. We also present an analytical expression, which determines the bandwidth of the free-electron laser. Furthermore, we prove that for an energy distribution with N peaks, there is no more than N FEL growing modes. Finally, present a simple method of determining number of growing modes for the case of beam energy distributions with multiple peaks.

**On Free-Electron Laser Growing Modes and their Bandwidths, S. Webb, V.N. Litvinenko, G. Wang, Submitted to PR ST-AB*

Monday Poster Session

- **New Lasing and Status Report**
- **FEL Theory**
- **FEL Technology I : Gun, Injector, Accelerator**

Status of FLASH Facility — MOPD01

Siegfried Schreiber, Bart Faatz, Josef Feldhaus, Katja Honkavaara, Rolf Treusch, Mathias Vogt (DESY, Hamburg)

FLASH at DESY, Hamburg is a soft X-ray free-electron laser user facility. After a 3.5 months shutdown in autumn 2011 required for civil construction for a second undulator beamline, beam operation started as scheduled in January 2012. FLASH shows again an improvement in performance with even higher single and average photon pulse energies, better stability, and significant improvements in operation procedures. The 4th user period started end of March 2012. A 4 months shutdown is scheduled early 2013 to connect the second undulator beamline to the FLASH accelerator.

Pulse-front Tilt Caused by the Use of a Grating Monochromator and Self-seeding of Soft X-ray FELs — MOPD02

Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin (DESY, Hamburg)

Self-seeding is a promising approach to significantly narrow the SASE bandwidth of XFELs to produce nearly transform-limited pulses. The development of such schemes in the soft X-ray wavelength range necessarily involves gratings as dispersive elements. These introduce, in general, a pulse-front tilt, which is directly proportional to the angular dispersion. Pulse-front tilt may easily lead to a seed signal decrease by a factor two or more. Suggestions on how to minimize the pulse-front tilt effect in the self-seeding setup are given.

Harmonic Lasing in X-ray FELs — MOPD03

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

Contrary to nonlinear harmonic generation, harmonic lasing in a high-gain FEL can provide much more intense, stable,and narrow-band FEL beam which is easier to handle if the fundamental is suppressed. We propose efficient methods for suppression of the fundamental. We perform a parametrization of the solution of the eigenvalue equation for lasing at odd harmonics, and present explicit expression for FEL gain length, taking into account all essential effects. We conclude that harmonic lasing is much more robust than usually thought, and can be widely used in the existing or planned X-ray FEL facilities. LCLS after a minor modification can lase at the 3rd harmonic up to the photon energy of 25-30 keV providing multi-gigawatt power level. At the European XFEL the harmonic lasing would allow to extend operating range (ultimately up to 100 keV), to increase brilliance, to enable two-color operation for pump-probe experiments,and to provide more flexible operation at different electron energies. We discover that in a part of the parameter space, corresponding to the operating range of soft X-ray beamlines of X-ray FEL facilities, harmonics can grow faster than the fundamental.

Fitting Formulas for Harmonic Lasing in FEL Amplifiers — MOPD04

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

One of the most important subjects of the high-gain FEL engineering is the calculation of the gain length, and fitting formulas are frequently used for this purpose. Here we refer to Ming Xie fitting formulas* and fitting formulas for optimized FEL written down in an explicit form in terms of the electron beam and undulator parameters**. In this paper we perform generalization of these fitting formulas to the case of harmonic lasing.

** M. Xie, Nucl. Instrum. and Methods A445(2000)59*

*** E.L. Saldin, E.A. Schneidmiller and M.V. Yurkov, Opt. Commun. 235(2004)415*

Harmonic Lasing of Thin Electron Beam MOPD05

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

For a typical operating range of hard X-ray FELs the condition $2 \pi \varepsilon / \lambda \sim 1$ is usually a design goal for the shortest wavelength. In the case of the simultaneous lasing the fundamental mode has shorter gain length than harmonics. If the same electron beam is used to drive an FEL in a soft X-ray beamline, the regime with $2 \pi \varepsilon / \lambda << 1$ is realized which corresponds to the case of a small value of diffraction parameter. Here we present a detailed study of this regime. We discover that in a part of the parameter space, corresponding to the operating range of soft X-ray beamlines of X-ray FEL facilities (like SASE3 beamline of the European XFEL), harmonics can grow faster than the fundamental wavelength. This feature can be used in some experiments, but might also be an unwanted phenomenon, and we discuss possible measures to diminish it.

Spatial Properties of the Radiation from SASE FELs at the European XFEL MOPD06

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

Recently DESY and the European XFEL GmbH performed revision of the baseline parameters for the electron beam. Operating range of bunch charges has been extended from 20 pC to 1 nC. Different modes of FEL operation become possible with essentially different properties of the radiation. Radiation from SASE FEL with planar undulator contains visible contribution of higher odd harmonics. Knowledge of spatial properties of harmonics is of great practical interest for planning user experiments. In this report we present results of the studies of spatial properties of the radiation from SASE FELs at the European XFEL. We consider nonlinear mechanism of harmonic generation and trace spatial properties of the odd harmonics up to deep nonlinear regime.

On Disruption of the Fundamental Harmonic in SASE FEL with Phase Shifters MOPD07

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

A method to disrupt the fundamental harmonic with phase shifters installed between undulator modules (while keeping the lasing at the third harmonic undisturbed) was proposed in [*]. If phase shifters are tuned such that the phase delay is $2\pi/3$ (or $4\pi/3$) for the fundamental, then its amplification is disrupted. At the same time the phase shift is equal to 2π for the third harmonic, i.e. it continues to get amplified without being affected by phase shifters. We note that simulations in [*] were done for the case of a monochromatic seed, and the results cannot be applied for a SASE FEL. The reason is that in the latter case the amplified frequencies are defined self-consistently, i.e. there is frequency shift (red or blue) depending on positions and magnitudes of phase kicks. This leads to a significantly weaker suppression effect. In particular, we found out that a consecutive use of phase shifters with the same phase kicks $2\pi/3$ (as proposed in [*] is inefficient, i.e. it does not lead to a sufficiently strong suppression of the fundamental wavelength. In the present report we propose a modification of phase shifters method that can work in the case of a SASE FEL.
**B.W.J. McNeil et al., Phy. Rev. Lett. 96, 084801 (2006).*

Coherence Properties of the Odd Harmonics of the Radiation from SASE FEL with Planar Undulator MOPD08

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We present a comprehensive analysis of coherence properties of odd harmonics radiated from a SASE FEL with planar undulator. Nonlinear mechanism of harmonic generation is under study. Temporal and space correlation functions, coherence time and degree of transverse coherence are calculated by means of numerical simulations with the code FAST. Similarity techniques have been used to derive general coherence properties of the radiation in the saturation regime.

The Effects of Initial Electron Momentum on Quantum Free-Electron Laser with Ion Channel Guiding MOPD09

Masoud Alimohamadi, Hassan Mehdian (TMU, Tehran)

The Compton regime of a quantum free-electron laser with a helical wiggler in the presence ion-channel guiding in the Bambini-Renieri (BR) frame is considered. Regarding to Ref. [*] "Quantum statistical properties of free-electron laser with ion-channel guiding", A quantum approach has been used to get quantum statistical properties of the FEL and the photon gain formula for the small signal gain limit in term of initial electron momentum. It is found that the ion-channel guiding decreases the squeezing. Also, the conditions for positive (bunching) and negative (antibunching) gain have been studied numerically.
[*] H. Mehdian, M. Alimohamadi and A. Hasanbeigi, J. Plasma. Physics, (2012) doi: 10.1017/S0022377812000256.

Nonlinear Harmonic Selection in an FEL Undulator System — MOPD10

Sandra Biedron, Karen Horovitz, Stephen Milton (CSU, Fort Collins, Colorado),
Luca Giannessi (CSU, Fort Collins, Colorado; ELETTRA, Basovizza; ENEA C.R. Frascati, Frascati (Roma))

The area of harmonic selection in undulator magnets is an important area of free electron laser (FEL) research. Within the undulator section of an FEL system, a wiggling electron beam emits coherent radiation at multiple wavelengths (harmonics), but in some cases the output should only be in the desired region for application purposes. Dispersion sections and unique undulators can be tailored in order to select harmonics and control their power levels. GINGER and PERSEO code were used for simulations. This research will lead to a better understanding of the emission process as well as the interaction of beam density distribution, the frequency and phase relationship of emission, and the amplitude of the emission as a function of time. Furthermore, harmonic control has applications within oscillator or amplifier-based FEL systems.

A New 4D FEL Oscillator Model — MOPD11

Joseph Blau, Keith Cohn, William B. Colson, Adrian Laney, Ricardo Vigil
(NPS, Monterey, California)

At the Naval Postgraduate School, we have recently developed a new 4D (x,y,z,t) FEL oscillator model that is multimode in both transverse and longitudinal dimensions. It uses periodic boundary conditions to represent pulses that are long compared to the slippage distance. The model includes diffraction, betatron motion, and generalized electron beam distributions. The code is parallelized to run on a cluster computer, and all of the optics are self-contained, so no external optics program is necessary. The mirrors and the electron beam can be shifted or tilted off-axis to study misalignment effects. This new model is useful for studying longitudinal coherence evolution, transverse wavefront evolution, the trapped particle instability, and the development of sidebands. The program is currently being validated by comparison to analytic formulas and other FEL codes. Results of these studies and examples of various effects that this model can be used to understand are presented.
This work has been supported by the Office of Naval Research

Puffin: A 3D Parallel Unaveraged FEL Simulation Code — MOPD12

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

The broadband, 3D FEL code Puffin is presented. The analytical model is derived in absence of the Slowly Varying Envelope Approximation, and can model undulators of any polarization. Due to the enhanced resolution, the memory and processing requirements are greater than equivalent unaveraged codes. The numerical code to solve the system of equations is therefore written for a parallel computing environment utilizing MPI. Some example simulations are presented.

SASE FEL Operating with a Storage Ring — MOPD13

Giuseppe Dattoli, Emanuele DiPalma, Alberto Petralia (ENEA C.R. Frascati, Frascati (Roma)),
Julietta V. Rau (ISM-CNR, Rome), Vittoria Petrillo (Istituto Nazionale di Fisica Nucleare, Milano)

We explore the possibility of operating a SASE FEL with a Storage Ring. We use a semi-analytical model to obtain the evolution inside the undulator by taking into account the interplay on the laser dynamics due to the induced energy spread and to the radiation damping. We obtain the Renieri's limit for the stationary output power and discuss the possibility of including in our model the effect of the beam instabilities.
**A. Renieri, Nuovo Cimento B53 (1979) 160, **P. Elleaume, J. Physique 45, 997 (1984)*
****Z. Huang et al., Nucl. Instr. And Meth. A 593, 120 (2008)*
Funding Agency : ENEA Frascati Italy

Longitudinal Dynamics of High Gain Free Electron Laser Amplifiers — MOPD14

Giuseppe Dattoli, Elio Sabia (ENEA C.R. Frascati, Frascati (Roma)), Pier Luigi Ottaviani, Simonetta Pagnutti (ENEA-Bologna, Bologna), Vittoria Petrillo (Istituto Nazionale di Fisica Nucleare, Milano)

We consider the dynamics of a coherent seed undergoing a Free Electron Laser high gain amplification. We discuss the dispersion of the optical packet during the interaction and study the problem using different formalisms, including that of the Wigner distribution. The analysis we develop is mainly based on a 1 D procedure, the inclusion of transverse longitudinal interplay is also briefly discussed.

Electron Beam Transverse and Longitudinal Transport and SASE FEL Dynamics MOPD15

Giuseppe Dattoli, Emanuele Di Palma, Alberto Petralia (ENEA C.R. Frascati, Frascati (Roma)), Marcello Artioli (ENEA-Bologna, Bologna)

The electron beam transport dynamics in high-gain FEL is not a secondary issue for the optimization of the device*. We present a semi-analytical code** including either longitudinal and transverse effects. The analysis accounts for the longitudinal phase space manipulation along with mechanism of transverse-longitudinal emittance coupling through appropriate dogleg and cavity placed on the electron transport line. The analysis embeds beam degradation due to coherent synchrotron radiation emission and provides a useful tool for the optimization of the device.

** M.Cornacchia, P.Emma, Phys. Rev. STAB, 5, 084001 (2002)*
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Funding Agency : ENEA

On the Feasibility of SASE FEL Wave Undulators MOPD16

Giuseppe Dattoli (ENEA C.R. Frascati, Frascati (Roma)), Julietta V. Rau (ISM-CNR, Rome), Vittoria Petrillo (Istituto Nazionale di Fisica Nucleare, Milano)

We investigate the working conditions of Free Electron Lasers operating in the SASE regime with wave undulators. We provide general scaling criteria and corroborate them with appropriate numerical simulations.

** L. S. Brown et al. Phys. Rev. 133, A705 (1964)*
*** R. H. Pantell et al. IEEE J. Quantum Electron. 4, 905 (1968)*
**** J. M. Madey, J. Appl. Phys. 42:1906 (1971)*

On Maximum FEL Gain in Coherent Electron Cooling System MOPD17

Andrey Elizarov (SUNY SB, Stony Brook, New York), Yue Hao, Yichao Jing, Vladimir N. Litvinenko, Gang Wang (BNL, Upton, Long Island, New York), David Leslie Bruhwiler, Ilya V. Pogorelov, Brian T. Schwartz, Stephen Davis Webb (Tech-X, Boulder, Colorado)

Novel method of coherent electron cooing relies on amplification of the interaction between hadrons and electrons by an FEL. The linearity of the amplification process is essential for operation of such cooler. In this paper we explore, both numerically and analytically, the limits of the FEL gain with special attention of the smearing of the phase caused by nonlinear and saturation effects.

Stimulated Coherent Spontaneous Emission in an FEL with 'Quiet' Bunches MOPD18

Vitaliy Alexandrovich Goryashko, Volker Ziemann (Uppsala University, Uppsala)

For a planar FEL configuration we study stimulated coherent spontaneous emission driven by a gradient of the bunch current in the presence of different levels of noise in bunches. To perform a vast amount of simulations required for obtaining statistically valid results, we developed a memory and time efficient one-dimensional simulation code based on the integral solution to a Klein-Gordon equation describing the electric field evolution. The longitudinal granularity of the electron bunch density originating from shot noise is maintained throughout the analysis. Three-dimensional effects are taken into account via an effective FEL parameter calculated from Xie's fitting formula. Calculations are performed for an FEL model with the SwissFEL injector bunch parameters. It turns out that a reduction of noise by several orders of magnitude below the level of shot noise is required to mitigate the noise effect. We propose a scheme that allows for formation of electron bunches with a reduced level of noise and a high gradient of the current at the bunch tail to enhance coherent spontaneous emission.

This investigation has been produced during V.A.~Goryashko scholarship period at Uppsala University, thanks to the Swedish Institute for a VISBY scholarship.

Undulator Motion Excited by a Fixed Traveling Wave: Quasiperiodic Averaging, Pendulum Normal Forms and Low Gain FEL Theory

MOPD19

Klaus Albert Heinemann, James A. Ellison (UNM, Albuquerque, New Mexico), Mathias Vogt (DESY, Hamburg)

We present a mathematical analysis of the 6D electron phase space dynamics in helical and planar undulators excited by fixed circular and planar polarized plane wave Maxwell fields, with wave number k_l in the X-Ray FEL parameter range. Our main tool is the ODE Method of Averaging from asymptotic analysis. Introducing transformed and scaled variables and creating a small parameter (SP) by balancing two small SPs, we put the 6D initial value problem (IVP) in a form appropriate for the method. We introduce nonresonant and near to resonance (NtoR) normal forms, as a function of k_l, and derive true error bounds proportional to the SP. In contrast to the conventional derivation of the pendulum equations (*,**), our general IVP gives resonances at all harmonics. For special initial conditions the resonances appear only at the usual k_l values, however our normal forms have a new term. In light of our analysis this discrepancy needs study. Also new are our NtoR normal forms, which allow exploration of small neighborhoods of the resonances. The rigorous asymptotic analysis in this simple, low gain setting sets the stage for our mathematical investigation of high gain FEL theory.

** Section 3 in: P. Schmueser, et al, ``Ultraviolet and Soft X-Ray FELs'', Springer Tracts in Modern Physics 229, 2008.*
*** Section 1.2 in: E.L. Saldin et al, ``The Physics of FELs'', Springer, 2000.*

Funding Agency : DOE under DE-FG-99ER41104

An Analysis of Effects of Waveguide on the Free Electron Laser Gain

MOPD20

Qika Jia (USTC/NSRL, Hefei, Anhui)

The effects of waveguide on free electron laser gain are analysed for both low gain regime and high gain regime. The gain performances, such as the gain line-shape, the gain bandwidth and the slippage, and their dependences on the waveguide dimension are analysed. The analytic relations of them with the waveguide dimension and the radiation wave number are given. It is shown that for both the high gain and low gain, by choosing appropriate waveguide dimension a single wide flat top gain line-shape can be obtained and the slippage can be eliminated fully at a certain radiation frequence. It is also shown that the high order modes of the waveguide have more effect in the high gain than the low gain.

An Analysis of Pulse Slippage Effect

MOPD21

Qika Jia (USTC/NSRL, Hefei, Anhui)

The effect of relative slippage between the radiation and electron pulses in FEL is analyzed in a simple way. The low gain case is studied, the correction factor of the pulse slippage effect on the FEL gain is given for both long and short electron pulse, it agree well with the simulation result. For short electron pulse case, the analysis shown that the slippage effect can be partly compensated by heightening the electron energy.

A General Method for Analyzing 3-D Effects in FEL Amplifiers

MOPD22

Panagiotis Baxevanis, Zhirong Huang, Ronald Ruth (SLAC, Menlo Park, California)

FEL configurations in which the parameters of the electron beam vary along the undulator become relevant when considering new aspects of existing FELs or when exploring novel concepts. This paper describes a fully three-dimensional, analytical method suitable for studying such systems. As an example, we consider a seeded FEL driven by a beam with varying transverse sizes. In the context of the Vlasov-Maxwell formalism, a self-consistent equation governing the evolution of the radiation field amplitude is derived. An approximate solution to this equation is then obtained by employing an orthogonal expansion technique. This approach yields accurate estimates for both the amplified power and the radiation beam size. Specific numerical results are presented for two different sets of X-ray FEL parameters.

Multi-dimensional Optimization of a Tapered Free Electron Laser

MOPD23

Yi Jiao (IHEP, Beijing), Juhao Wu (SLAC, Menlo Park, California)

Energy extraction efficiency of a free electron laser (FEL) can be increased when the undulator is tapered. In this paper, we report a multi-dimensional optimizer to maximize the radiation power in a tapered FEL by searching for an optimal taper profile as well as a reasonable variation in electron beam radius. This code has the advantage that it is not necessary for the users to have strong background knowledge of the taperingrelated physics. Applications of the proposed multidimensional optimization to the terawatt-level, hard X-ray, tapered FELs with LCLS-II like electron beam parameters are presented.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515

Efficiency Enhancement in a Tapered Free Electron Laser — MOPD24

Yi Jiao (IHEP, Beijing), Juhao Wu (SLAC, Menlo Park, California)

Energy extraction efficiency of a free electron laser (FEL) can be greatly increased using a tapered undulator and self-seeding. An in-depth understanding of the tapering-related physics is required to explore the full potential of a tapered FEL, not only by tapering the undulator parameters in longitudinal dimension, but also optimizing the transverse effects. Based on the modified one-dimensional FEL model and GNESIS singlefrequency numerical simulations, we study the contribution of variation in electron beam radius and related transverse effects. Taking a terawatt-level, 120-m, hard X-ray, tapered FEL as example, we demonstrate that a reasonably varied, instead of a constant, electron beam radius along the undulator helps to improve the optical guiding and hence the radiation output.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515.

Saturation of a Tapered Free Electron Laser — MOPD25

Juhao Wu, William M. Fawley, Xiaobiao Huang, Zhirong Huang, Claudio Pellegrini, Tor Raubenheimer (SLAC, Menlo Park, California), Yi Jiao (IHEP, Beijing)

To extract more energy from the electron bunch so as to increase the FEL radiation power, tapering the undulator is an effective approach. Yet, this process stops due to various reasons, such as weakening of the optical guiding, the sideband instability, the enhanced SASE in a self-seeding scheme, etc. We study these effects with GENESIS simulation as well as analytical calculation. Schemes to delay the saturation are discussed.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515.

FEL Seeding in the Presence of Electron Beam Non-uniformities — MOPD26

Ryan Roger Lindberg (ANL, Argonne)

We discuss the physics of FEL seeding in the presence of electron beam non-uniformities, focusing on energy modulations but also mentioning modulations in current. We discuss how a long-wavelength, single-frequency modulation of the electron beam energy results in the development of sidebands of the seeded mode. For small modulation amplitudes the power in the sidebands scale quadratically with the modulation amplitude. We derive an analytic model describing the evolution dynamics in the linear regime that is complementary to those of Refs.*,**, and compare these predictions with simulation results. We then discuss extensions of the theory to nonuniformities comprised of many frequencies, and to the nonlinear regime including undulator tapering.

** A. Marinelli, C. Pellegrini, L. Gianessi, and S. Reiche. Phys. Rev. ST-AB 13, 070701 (2010).*
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Funding Agency: U.S. Dept. of Energy Office of Sciences under Contract No. DE-AC02-06CH11357

The Effect of Accelerator Frequency on Free Electron Laser Performance — MOPD27

Adrian Laney, Joseph Blau, Keith Cohn, William B. Colson (NPS, Monterey, California),
Todd Iversen Smith (Stanford University, Stanford, California), Matthew Stanton (UCSC, Santa Cruz)

Lowering accelerator frequency in free electron lasers (FELs) based on superconducting linacs has the potential to allow cryogenic operation at 4K, twice the temperature of many existing accelerator designs, which could significantly reduce the size and cost of refrigeration systems. It also enables the use of longer electron pulses, which would reduce longitudinal emittance and pulse slippage, thus potentially enhancing FEL performance. Using simulation codes developed at the Naval Postgraduate School, we have investigated the performance of FEL amplifiers and oscillators at several accelerator frequencies and electron beam energies. By utilizing dimensionless parameters in our simulations, we were able to reduce the number of variables searched to achieve peak performance for each beam energy and frequency. The results of our study show that both FEL amplifier and oscillator performance can be improved by lowering accelerator frequency.

This work has been supported by the Office of Naval Research.

Theoretical Study of Smith-Purcell Free-Electron Lasers — MOPD28

Dazhi Li, Kazuo Imasaki (ILT, Suita, Osaka), M Hangyo (ILE Osaka, Suita), Makoto R. Asakawa, Yoshiaki Tsunawaki (Kansai University, Osaka), Shuji Miyamoto (LASTI, Hyogo), Yanyu Wei, Ziqiang Yang (UESTC, Chengdu, Sichuan)

We report here a theory to calculate the growth rate and start current of a Smith-Purcell free-electron lase. The mechanism of the interaction between a sheet electron beam and the surface wave above a lamellar grating is well investigated. After deriving the growth rate from the dispersion equation, the start current is dexterously worked out by considering the energy flow above the grating. The predictions of our theory agree with the results from the particle-in-cell simulations.

Gain Enhancement and Growth Rate in Two-stream Free-Electron Laser with a Helical Wiggler Pump

MOPD29

Nader Mahdizadeh (Islamic Azad University, Sabzevar),
Farzin Mojtaba Aghamir (University of Tehran, Tehran)

In this paper we derive the dispersion relation and small signal gain of Two-Stream Free Electron Laser (TSFEL) with a helical wiggler pump. In this analysis, the dispersion relation is derived with the aid of fluid theory for thermal electron beams. The small signal gain was derived by employing kinetic theory. The slippage of the electromagnetic wave with respect to the electron beam is ignored. Numerical calculation show that there are three instabilities namely: Two-Stream,FEL and TS-FEL instabilities. The result show that the small signals gain in TSFEL is larger than common FEL.

Funding Agency: Islamic Azad University, Sabzevar Branch

The Physics of Regenerative Amplifier FEL

MOPD30

Dinh C. Nguyen, Henry P Freund (LANL, Los Alamos, New Mexico)

The physics of the Regenerative Amplifier free-electron laser (RAFEL) is explored through 4D MEDUSA simulations. Specifically, we show features unique to the RAFEL such as optical mode modifications (both transverse and longitudinal) and group velocity reduction due to the RAFEL's large single-pass gain. Another feature that is markedly different from the low-gain oscillator FEL is the cavity length detuning that exhibits higher power on both sides of the zero-detuning length (defined as an integer times the speed of light divided by twice the bunch repetition rate). This contrasts with the oscillator FEL that has its highest power near the zero detuning length. Compared to SASE, the RAFEL offers two main benefits: improved longitudinal coherence and narrower spectral linewidth. These benefits prompted Huang et al. to propose the RAFEL as an alternative x-ray FEL architecture to the current SASE-based x-ray FEL design.* Through 4D FEL simulations, we will show the evolution of an optical pulse starting from noise in the first pass and evolving into a single co-operation (coherence) length after a few passes through the RAFEL optical feedback cavity.

** Z. Huang and R.D. Ruth, Phys. Rev. Lett., 96 144801 (2006)*

Injector Optimization for a High-repetition Rate X-ray FEL

MOPD31

Christos Frantzis Papadopoulos, John Corlett, Paul J. Emma, Daniele Filippetto, Gregory Penn, Ji Qiang, Matthias Reinsch, Fernando Sannibale, Marco Venturini (LBNL, Berkeley, California)

In linac driven free electron lasers, the final electron beam quality is constrained by the low energy (<100 MeV) beam dynamics at the injector. In this paper, we present studies and the optimized design for a high-repetition (>1 MHz) injector in order to provide a high brightness electron beam. The design effort is also extended to multiple modes of operation, in particular different bunch charges. The effects of space charge and low energy compression on the electron beam brightness are also discussed for the different modes.

This work was supported by the Director of the Office of Science of the US Department of Energy under Contract no. DEAC02-05CH11231

Theory of the Quantum FEL at a Glance

MOPD32

Paul Preiss (HZDR, Dresden)

New developments in accelerator and laser physics raise hope for the so-called QFEL, a free-electron laser operating in the quantum mechanical regime.We develop a fully quantized single-particle theory describing the dynamics of the interaction between the electron, the wiggler and the laser field. In the quantum mechanical regime the dynamics are reminiscent of the standard laser theory with a two-level atom. Indeed, we find oscillations between two entangled states - where the entanglement appears between the electron momentum state and the Fock states of the laser and wiggler field. Compared to a two-level system with one internal degree of freedom (e.g. an atom with a ground and one excited state) the state of our system is mainly determined by the momentum of the electron in the co-moving Bambini-Renieri frame. In contrast to the classical regime here the electron propagating through the wiggler field can only emit or absorb a single laser photon. Transitions including the emission or absorption of many photons are substantially much suppressed.

Saturation in Free Electron Laser with Quadrupole Wiggler and Axial Magnetic Field

MOPD33

Parisa Yahyaee, Amirhossein Ahmadkhan Kordbacheh (IUST, Narmac, Tehran)

In this paper, we study the nonlinear evolution of a quadrupole wiggler free electron laser, in the presence of a helical wiggler, which increases adiabatically from zero to a constant level. To focus the electron beam, we apply an axial magnetic field. By using Maxwell equations and Lorentz force equation of motion for electrons, a set of coupled nonlinear equation is derived and solved numerically. The beam is cold and propagates with a relativistic velocity. Results are compared with dipole wiggler FEL.

Phase Noise Error Caused by Energy Modulation in HGHG Process — MOPD34

Li-Hua Yu (BNL, Upton, Long Island, New York)

In a high gain harmonic generation (HGHG) process, the phase noise error caused by energy modulation increases the output bandwidth. And the energy chirp jitter in the electron bunches causes the output wavelength to shift and jitter. In order to achieve Fourier transform limited output, we need to control these noise sources and the jitter. We estimate the required tolerances on these damaging effects, and assess the possibility to achieve fully coherent X-ray FEL based on these tolerances.

Funding Agency: DOE

Detailed Modeling of Seeded Free-electron Lasers — MOPD35

Sven Reiche (Paul Scherrer Institut, Villigen)

Seeding schemes for Free Electron Lasers have mostly a strong impact on the electron distribution by either a conversion of an energy modulation into a current modulation with high harmonic content (HGHG seeding) or an over-compression of this energy modulation to induce energy bands (EEHG seeding) or smear out any bunching in the electron beam (self-seeding). Most codes follow an approach to use thin electron slices, which are carefully generated to provide the correct shot-noise but which also prevents them from mixing and re-sorting the macro-particle distribution. The FEL code Genesis 1.3 has been modified to allow resolution of each individual electron. Using this approach the correct shot noise at all frequencies is provided and permits "re-binning" of the particles to the 3D radiation grid at any time. The results for self-seeding and HGHG seeding are discussed.

Dark Current Studies for SwissFEL — MOPD36

Frederic Le Pimpec, Andreas Adelmann, Sven Reiche, Riccardo Zennaro (Paul Scherrer Institut, Villigen), Bagrat Grigoryan (CANDLE, Yerevan)

Activation of the surrounding of an accelerator must be quantified and those data provided to the official agencies, This is a necessary step for obtaining the appropriate authorization to operate such accelerator. The SwissFEL, being a 4th generation light source, will produce more accelerated charges, which are dumped or lost, than any conventional 3rd generation light source, like the Swiss Light Source. We have simulated the propagation of a dark current beam produced in the photoelectron gun using tracking codes like ASTRA and Elegant for the current layout of the SwissFEL. Detailed experimental study have been carried out at the SwissFEL test facilities at PSI (C-Band RF Stand and SwissFEL Injector Test Facility), in order to provide necessary input data for detailed study of components using the simulation code OPAL. A summary of these studies are presented.

Switchyard Design: Athos — MOPD37

Natalia Milas (PSI, Villigen), Sven Reiche (Paul Scherrer Institut, Villigen)

The SwissFEL facility will produce coherent, ultrabright and ultra-short photon pulses covering a wavelength range from 0.1 nm to 7 nm, requiring an emittance of 0.43 mm mrad or better. In order to provide electrons to the soft X-ray beam line a switchyard is necessary. This beamline will switch the electron bunch coming from the SwissFEL linac, with an energy of 3.0 GeV, and transport it to Athos. The switchyard has to be designed in such a way to guarantee that beam properties like low emittance, high peak charge and small bunch length will not be spoiled. In order to keep the switchyard as versatile as possible it can work for a range of values of R56 from isochronous up to 6 mm, when the bunch is stretched by a factor two, and also be able to transport the beam in the so called "large bandwidth" mode. In this paper we present the schematics for the switchyard, discuss its many modes of operation, sextupole correction scheme and positioning of energy collimator for machine protection.

Investigation of Schottky and Back-bombardment Effects in Emitted Electron Current of Thermionic RF-gun at the Linac based THz Facility in Thailand — MOPD38

Kantaphon Damminsek, Sakhorn Rimjaem (Chiang Mai University, Chiang Mai)

An electron gun of a linac based THz source at the Plasma and Beam Physics (PBP) Research facility, Chiang Mai University in Thailand is a 1-1/2 cell S-band standing wave RF cavity with an Os/Ru coating dispenser cathode. The electron current density of a few amperes per square centimeter can be achieved from zero-field thermionic emission using this cathode type at a desired operating temperature. However, Schottky and back-bombardment effects have significant influence on the emitted electron current in a thermionic RF-gun. Numerical and experimental studies of the contribution of both effects have been carried out. Results of the investigation together with a proposed model to improve the performance of the thermionic RF-gun will be presented and discussed in this contribution.

Funding Agency : Department of Physics and Materials Science at Chiang Mai University, Thailand Center of Excellence in Physics and the Development and Promotion of Science and Technology talents project.

~~Commissioning of the APEX Photocathode Laser~~

~~MOPD39~~ withdrawn

Daniele Filippetto (LBNL, Berkeley, California), Conor Michael Pogue (NPS, Monterey, California)

The electron photo-gun of the Advanced Photo-injector EXperiment project (APEX) at the LBNL is driven by a compact Ytterbium doped fiber laser. It generate 1 picosecond pulses at 1 microJoule pulse at 1064 nm, with a repetition rate of 1MHz. The pulse is frequency doubled and quadrupled to deliver both UV and green light to the cathode, where different materials will be tested. Due to the requirement of small emittance for the electron beam, the laser pulse is shaped in space and time for 532nm and UV lights, Diagnostics of the laser beam itself and of the cathode will be integrated with techniques such as cross-correlation, streak camera, and virtual cathode imaging, not only to monitor the laser pulse but also to provide automated feedbacks. The present status and the plan for future activities of the drive laser system are presented.

Simulation for New Injector Test Facility of PAL-XFEL

MOPD40

MoonSik Chae, In Soo Ko (POSTECH, Pohang, Kyungbuk),
Jang Hui Han, Juho Hong, Sung-Ju Park (PAL, Pohang, Kyungbuk)

As a part of the preparation plan of PAL-XFEL, Injector Test Facility (ITF) has been constructed and now required beamline components are being installed for the test of injector system. ITF components includes RF gun, two accelerating columes, solenoids and basic diagnostic components such as spectrometers, quad scan system, BPMs, wire scanner, etc. Main diagnostics will be installed until October this year and deflecting cavity and laser heater will be installed next year. This facility will generate 135 MeV electron beam with the emittance under 0.5 mm-mrad. Simulation for the optimized operation of the ITF has been carried out with ASTRA code and its results are given in this paper.

Low Emittance Injector Development for the PAL-XFEL Project

MOPD41

Jang Hui Han, Juho Hong, Heung-Sik Kang, In Soo Ko, Sung-Ju Park (PAL, Pohang, Kyungbuk), MoonSik Chae (POSTECH, Pohang, Kyungbuk)

An injector designed for low emittance beam generation as well we high repetition rate and more reliable operation is under development at PAL. By adopting a coaxial high power RF coupler at the gun exit, the gun solenoid can be positioned at an optimum location for low emittance and the cooling water channels can fully surround the gun cavity cylinder for high cooling capacity. With an exchangeable photocathode plug, high quantum efficiency cathode can be used for reducing the drive-laser power requirement and a damaged cathode can be easily replaced with a fresh one. Injector beam dynamics optimization with this gun is presented.
Funding Agency: The Ministry of Education, Science and Technology of the Korean Government

Microbunching Instability Study for the PAL-XFEL Linac

MOPD42

Jang Hui Han, Ilmoon Hwang, Heung-Sik Kang (PAL, Pohang, Kyungbuk)

PAL-XFEL is designed to generate X-ray FEL radiation in a range of 0.1 and 10 nm for users. The machine consists of a 10 GeV linear accelerator and five undulator beamlines. An electron beam is generated at a low emittance S-band photocathode RF gun and accelerated through an S-band normal conducting linac. Microbunching instability may occur when the beam goes through magnetic bunch compressors and beam spreaders. We discuss microbunching instability issues at PAL-XFEL.
Funding Agency: The Ministry of Education, Science and Technology of the Korean Government

New RF-Gun for PAL-XFEL

MOPD43

Juho Hong, Kyehwan Gil, Jang Hui Han, Heung-Sik Kang, Sung-Ju Park (PAL, Pohang, Kyungbuk), MoonSik Chae, In Soo Ko (POSTECH, Pohang, Kyungbuk)

We are developing an S-band photocathode RF-gun for the X-ray free electron laser (XFEL) at the Pohang Accelerator Laboratory (PAL). This RF-gun is a 1.6-cell RF-gun with dual-feed waveguide ports and two pumping ports. We have done the complete RF and thermal analysis of a new gun. The new RF-gun is designed to operate at a maximum field gradient of 130MV/m with a RF pulse width of 2 μs, a repetition rate of 120Hz. In this paper we present features and RF simulation results and thermal analysis results.

Design of Magnets for PAL-XFEL — MOPD44

Hyung Suck Suh, Moo-Hyun Cho, Hong Sik Han, Jung Yun Huang, Sang Tae Jung, Young-Gyu Jung, Heung-Sik Kang, Dong Eon Kim, In Soo Ko, Hong-Gi Lee, Tae-Yeon Lee, Ki-Hyeon Park (PAL, Pohang, Kyungbuk)

Pohang Accelerator Laboratory (PAL) is starting the X-ray Free Electron Laser of 10 GeV. PAL-XFEL has the hard X-ray and soft X-ray branches. The linac contains dipole magnets, quadrupole magnets and corrector magnets. The kicker magnet followed by the septum magnet is needed to extract the beam from the linac to the soft X-ray undulator line. In this presentation, we describe the design and analysis of the magnets.

Present Status of Thermionic RF-Gun for Terahertz Source Project at Tohoku University — MOPD45

Fujio Hinode, Hiroyuki Hama, Nuan-Ya Huang, Shigeru Kashiwagi, Masayuki Kawai, Toshiya Muto, Ikurou Nagasawa, Ken-ichi Nanbu, Yoshinobu Shibasaki, Ken Takahashi (Tohoku University, Sendai), Xiangkun Li (TUB, Beijing)

A thermionic RF gun for an acceleratora-based terahertz source has been commissioned at Electron Light Science Centre, Tohoku University*. The RF gun consisting of two independently-tunable cells (ITC RF gun) can be operated so as to optimize the phase space distribution of the extracted electrons for the further manipulation in an alpha magnet and a 3 m accelerating structure for the short pulse generation. Tracking simulations show that very short electron pulse less than 100 fs with a bunch charge of about 20 pC can be obtained by means of the velocity bunching in the accelerating structure. In the early result of the gun commissioning, it was shown that the back-bombardment (B-B) effect was rather serious for the beam quality in spite of the operation with the short pulse length and slow repetition rate. The simulation study for the B-B effect with the 2D heat transfer model turned out that low energy electrons coming back in the cathode cell have the significant contribution for the additional cathode heating rather than the higher energy electrons**. We will show the recent results of beam commissioning of the ITC RF gun and the current status of t-ACTS project.

**H. Hama et al., New J. Phys. 8 (2006) 292,*

***X. Li et al., Proc. of FEL'11, (2011) THPA17*

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Design Study of the LINAC of the Shanghai Soft X-ray Free Electron Laser Facility — MOPD46

Dazhang Huang, Wencheng Fang, Duan Gu, Qiang Gu, Guoqiang Lin, Meng Zhang (SINAP, Shanghai)

Shanghai soft X-ray Free Electron Laser Facility (SXFEL), which is planned to start construction by the end of 2012, will be the first X-ray free electron laser facility in China. As of today, the physical design of it has been done and optimized. In this article, the design process and the key physical parameters will be discussed in details, including RF structures, microbunching instability, jitter analysis, etc. The goal and the expected performance of the LINAC will also be given.

Enhancement of the Electron Energy by using a Linearly Tapered Density in the Laser Wakefield Acceleration — MOPD47

Jaehoon Kim (KERI, Changwon)

Due to the capability of making a compact accelerator and the ability to generate an ultra-short bunch electron beam, a laser wakefield acceleration(LWFA) is widely studied. In LWFA, a dephasing effect is the main limitation of the electron energy. To overcome the dephasing effect and increase the electron energy, we studied the linearly tapered density. A 2D particle in cell simulation and the experimental results show that with linearly tapered density, we could increase the electron energy with the same laser power. The details of the work will be presented.

Overall Performance Comparison of S-band, C-band, and X-band Based XFEL Facilities

MOPD48

Yujong Kim (IAC, Pocatello, IDAHO)

After successful demonstration of XFEL lasing from C-band based XFEL facility at SPring-8, demand on compact XFEL facilities becomes much stronger. Recently, there were several activities to build much more compact XFEL facilities, which are based on X-band RF linac technology. But up to now, there was no detailed research to compare the performance of S-band, C-band, and X-band RF linac based XFEL facilities. To compare the performance, recently, ISU accelerator and FEL physics group has designed three different XFEL facilities where the S-band, C-band, and X-band RF linac technologies are used for the main FEL driving linacs. In this paper, we describe layouts, start-to-end simulations, and comparison of overall performance of those three XFEL facilities. Finally, we also describe control of energy chirp, RF jitter tolerances, alignment and transverse wakefield issue, and bandwidth of XFEL photon beam in C-band or X-band based XFEL facilities.

Larger more Powerful Cyclotrons with more Electrons may Create more Powerful Beams

MOPD49

Richard Kriske (University of Minnesota, Minneapolis, Minnesota)

It may be possible to produce more Electrons at a higher velocity with the experience gained from the International Linear Collider. The bunching of the Electrons may also be more precisely controlled. This author would like to make some suggestions as to how to increase the strength of the beam, and have better beam control, which may result in a more powerful Free Electron Laser..

Quantum Efficiency and Emission Mechanisms of Electrons from Flat Metallic Cathodes under Varying Electric Fields and Tunable Laser Illumination

MOPD50

Stephan Mingels, Benjamin Bornmann, Dirk Lützenkirchen-Hecht, Guenter Mueller (Bergische Universitaet Wuppertal, Wuppertal)

Highly brilliant electron sources are crucial for the performance of future free electron lasers*. Photo-induced field emission (PFE) might combine the high peak currents of photo cathodes with the low emittance of field emitted electrons. Previous investigations of PFE were performed on tip cathodes and yielded a high brilliance B ≤ 1x10^13 A/m^2rad^2 but only low currents I ≤ 2.9 A and parasitic field emission**. We are investigating PFE from flat cathodes in an UHV system for PFE spectroscopy with a resolution of less than 50 meV***. Electric fields of up to 400 MV/m can be applied, and pulsed tunable laser illumination of the cathode (0.5 - 5.9 eV photon energy, 1-15 mJ in 3.5 ns pulses, 10 Hz repetition rate) are available. First indications of Schottky-induced photo emission and PFE on flat polycrystalline Au samples were obtained. Measurements of quantum efficiency at continuously varied photon energies revealed strong resonances, which hint for certain band structure transitions. Detailed measurements on single-crystalline Au and Ag samples including electron spectra are ongoing, and the results will be presented at the conference.

**D.H. Dowell et al., Nucl. Instr. And Meth. Phys. A 622, 685-697 (2010)*
***R. Ganter et al., PRL 100, 064801 (2008)*
****B. Bornmann et al., Rev. Sci. Instrum. 83, 013302 (2012)*

Funding Agency: German Federal Ministry of Education and Research BMBF (contract number 05K10PXA)

Developing S-band Accelerating Structures

MOPD51

Sadao Miura (MHI, Hiroshima)

We have supplied more than fifty high gradient S-band accelerating structures to KEK/ATF, SPring-8, PAL/Korea and INFN/Italy. Maximum accelerating garinent of these structures reaches in 30MV/m. Now we are developing new S-band accelerating structures. This time we report manufacturing of these structures.

Beam Dynamics Calculations for the SPring-8 RF Gun Injector System using the Multiple Beam Envelop Equations

MOPD52

Akihiko Mizuno (JASRI/SPring-8, Hyogo-ken)

A new semi-analytical method of investigating the beam dynamics for electron injectors was developed. In this method, a short bunched electron beam is assumed to be an ensemble of several segmentation pieces in both the longitudinal and transverse directions. The trajectory of each electron in the segmentation pieces is solved by the beam envelope equations. The shape of the entire bunch is consequently calculated, and thus the emittances can be obtained from weighted mean values of the solutions for the obtained electron trajectories. Using this method, dynamics calculation for the SPring-8 RF gun system was performed while taking into account the space charge fields, the image charge fields at a cathode surface,the electromagnetic fields of the RF gun cavity and the following accelerator structure, and the solenoidal coils. In this paper, we discuss applicable conditions for this method by comparing calculation results of this method and that of the particle simulation code.

Development of a Photoemission DC Gun at JAEA

MOPD53

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

The next generation light source such as X-ray FEL oscillator requires high brightness electron gun with megahertz repetition rate. We have developed a photoemission DC gun at JAEA. By employing a segmented insulator with rings which guard the ceramics from field emission, we successfully applied 500-kV on the ceramics with a center stem electrode for eight hours without any discharge in 2009. This high voltage testing was performed with a simple configuration without NEG pumps and electrodes. In 2011 we reached 526kV with NEG pumps and electrodes, before suffering another field emission problem from the cathode electrode. The problem may be attributed to small dust inside our gun chamber. We found wiping the cathode electrode with a lint free tissue could remove the field emission site effectively. Noble gas conditioning is also planned to remove the emission site without air exposure of the gun chamber.

This work is supported by MEXT Quantum Beam Technology Program and partially supported by JSPS Grants-in-Aid for Scientific Research in Japan (23540353).

Longitudinal Pulse Shaping of APEX Drive Laser

MOPD54

Conor Michael Pogue, Joseph Blau, Keith Cohn, William B. Colson (NPS, Monterey, California), Daniele Filippetto, Fernando Sannibale (LBNL, Berkeley, California)

The Advanced Photo-injector Experiment (APEX) is a high-brightness, high repetition rate injector designed for X-ray FEL applications that is currently being commissioned at LBNL. The desired longitudinal shape for the drive laser pulse is a trapezoid with a rise and fall time of less than ~2 ps and a flat-top of ~50 ps. This desired pulse length is the result of extensive optimization work using electron beam dynamics simulation codes, aiming to maximize beam current without transverse emittance dilution. To perform the pulse shaping, a set of 6 birefringent crystals are used to divide the initial Gaussian pulse (~1 ps FWHM) into 64 separate pulses properly shifted in time so that their combined fields assume the desired shape. Simulations were used to optimize the number of crystals, their lengths, and their angles with respect to the initial polarization and to predict the final pulse duration as well as intensity variations along the pulse. The parameters were chosen to create equidistant pulses that combine to generate an overall approximate flat top envelope. The results of such activity are presented.

This work has been supported by the Office of Naval Research.

High Power RF Tests and Emittance Studies of a New Tsinghua Photocathode RF Gun

MOPD55

Houjun Qian, Ying-Chao Du, Jianfei Hua, Wenhui Huang, Chen Li, Chuanxiang Tang, Lixin Yan (TUB, Beijing)

A new photocathode RF gun has been designed and fabricated to meet beam brightness requirements (0.5-1 nC, 1-2 mm mrad) of Tsinghua Thomson scattering project (TTX) and Shanghai soft X-ray free electron laser test facillity (SXFEL). The new gun features higher quality factor, 0-mode and multipole field suppression, and structure simplicity due to inner wall axisymmetry and single RF feed*. Emittance growth due to single RF feed are investigated theoretically, which is ~0.01 mm mrad at 120 MV/m, and supports the simplified design. The gun operates stably at ~112 MV/m with a RF pulse width of 1.5 μs, and max gun gradient is limited by RF input power. Components of copper cathode thermal emittace are experimentally studied, which reveal work function reduction (~4.16 eV) and roughness emittance growth (0.92 mm mrad/mm at 50 MV/m) for a damaged old copper cathode with surface roughness of ~650 nm**. A new fresh copper cathode was finished with better surface smoothness (~20 nm, rms), and the detailed characterization of the new copper cathode and beam emittance at photoinjector exit are still in process.

** Qian H, Chen H, Du Y-C, et al. IPAC'11; 2011. p 3170-3172.*

*** H. J. Qian, C. Li, Y. C. Du, L. X. Yan, J. F. Hua, W. H. Huang, and C. X. Tang, PRST-AB 15, 040102 (2012).*

Design and Commission of the Driven Laser System for Advanced Superconducting Test Accelerator — MOPD56

Jinhao Ruan, Michael Church, James Santucci (Fermilab, Batavia)

Currently an advanced superconducting test accelerator (ASTA) is being built at Fermilab. The accelerator will consist of an photo electron gun, injector, ILC-type cryomodules, multiple downstream beam lines for testing cryomodules and carrying advanced accelerator researches. In this paper we will describe the design and commissioning of the drive laser system for this facility. It consists of a fiber laser system properly locked to the master frequency, a regen-amplifier, several power amplifier and final wavelength conversion stage. We will also report the initial characterization of the fiber laser system and the current commissioning status of the laser system.

Development of Multi-bunch Laser System for Photocathode RF Gun in KU - FEL — MOPD57

Kyohei Shimahashi, Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Ryota Kinjo, Kai Masuda, Hani Hussein Negm, Hideaki Ohgaki, Kensuke Okumura, Mohamed Omer, Marie Shibata, Konstantin Torgasin, Kyohei Yoshida, Heishun Zen (Kyoto University, Kyoto)

We have been developing mid-infrared FEL (MIR-FEL) system, KU-FEL (Kyoto University-FEL), which utilizes a 4.5-cell S-band thermionic RF gun, in Institute of Advanced Energy, Kyoto University. We plan to introduce a BNL-type 1.6-cell photocathode RF gun to generate higher peak power MIR-FEL. The purpose of this work is to develop the multi-bunch laser system which excites the photocathode in the RF gun. The target values of the system are bunch number of 300 and pulse energy of 10 μJ per micro pulse in 266 nm. The laser system consists of a mode-locked Nd:YVO4 laser as the oscillator, an acousto-optic modulator, a laser beam pointing stabilization system, a flash lamp pumped amplifier and 4th harmonic generation crystals. We will report the current status of multi-bunch laser in this conference.

Commissioning of the FERMI@ELETTRA Laser Heater — MOPD58

Simone Spampinati, Enrico Allaria, Laura Badano, Silvano Bassanese, Davide Castronovo, Miltcho B. Danailov, Alexander Demidovich, Simone Di Mitri, Bruno Diviacco, William M. Fawley, Luca Giannessi, Giuseppe Penco, Carlo Spezzani, Mauro Trovo (ELETTRA, Basovizza), Giovanni De Ninno, Eugenio Ferrari (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica)

The linac of the FERMI seeded free electron laser includes a laser heater to control the longitudinal microbunching instability, which otherwise is expected to degrade the quality of high brightness electron beam sufficiently to reduce the FEL power. The laser heater consists of an short undulator located in a small magnetic chicane through which an external laser pulse enters to the electron beam both temporally and spatially. The resulting interaction within the undulator produces an energy modulation of the electron beam on the scale of the optical wavelength. This modulation together with the effective R52 transport term of the chicane increases the incoherent energy spread (i.e., e-beam heating). We present the first commissioning results of this system and its impact on the electron density and energy distribution.

PITZ Status, Recent Measurements and Tests — MOPD59

Mikhail Krasilnikov, Hans-Juergen Grabosch, Matthias Gross, Levon Hakobyan, Igor Isaev, Yevgeniy Ivanisenko, Martin Khojoyan, Guido Klemz, Georgios Kourkafas, Mahmoud Mahgoub, Dmitriy Malyutin, Barbara Marchetti, Anne Oppelt, Marek Otevrel, Bagrat Petrosyan, Andrey Shapovalov, Frank Stephan, Grygorii Vashchenko (DESY Zeuthen, Zeuthen), Keerati Kusoljariyakul (FNRF, Chiang Mai), Dieter Richter (HZB, Berlin), Ji Li (USTC/NSRL, Hefei, Anhui)

The photo injector test facility at DESY, Zeuthen site (PITZ) is dedicated to the development and optimization of a high-brightness electron source for the European XFEL. Recently a significant upgrade has been done at the facility. A new RF system has been installed for the PITZ gun, enabling higher attainable peak power in the cavity which is important for efficient LLRF regulation. First long-term tests for a stable gun operation at high duty cycle have been performed. Two major components for electron beam diagnostics - a transverse deflecting cavity for time resolved electron bunch characterization, and a second high energy dispersive arm for precise longitudinal phase space measurements - have been installed. First results of their commissioning will be reported.

Optimization of the Transverse Projected Emittance of the Electron Beam at PITZ — MOPD60

Grygorii Vashchenko, Matthias Gross, Levon Hakobyan, Igor Isaev, Yevgeniy Ivanisenko, Mikhail Krasilnikov, Mahmoud Mahgoub, Dmitriy Malyutin, Marek Otevrel, Bagrat Petrosyan, Andrey Shapovalov, Frank Stephan (DESY Zeuthen, Zeuthen), Martin Khojoyan (ANSL, Yerevan), Dieter Richter (HZB, Berlin), Galina Asova (INRNE, Sofia)

High brightness electron sources for linac based free-electron lasers operating at short wavelength such as FLASH at DESY, Hamburg Site and the European X-FEL are developed and optimized at the Photo Injector Test Facility at DESY, Zeuthen Site (PITZ). One of the most important parameters influencing the FEL process is the transverse projected emittance of the electron beam. The major part of the experimental program at PITZ is devoted to the optimization of the transverse projected emittance of the electron beam. Detailed simulations of the present facility setup are performed for the different electron bunch charges in order to optimize the transverse projected emittance of the electron beam. Cathode laser pulse length and transverse spot size at the photo cathode, gun and booster accelerating gradients and launching phases, solenoid current were optimized. Simulations results together with experimental data will be presented.

Laser Pulse Train Management with an Acousto-optic Modulator — MOPD61

Matthias Gross, Hans-Juergen Grabosch, Levon Hakobyan, Igor Isaev, Yevgeniy Ivanisenko, Martin Khojoyan, Guido Klemz, Georgios Kourkafas, Mikhail Krasilnikov, Keerati Kusoljariyakul, Ji Li, Mahmoud Mahgoub, Dmitriy Malyutin, Barbara Marchetti, Anne Oppelt, Marek Otevrel, Bagrat Petrosyan, Andrey Shapovalov, Frank Stephan, Grygorii Vashchenko (DESY Zeuthen, Zeuthen), Holger Schlarb, Siegfried Schreiber (DESY, Hamburg), Dieter Richter (HZB, Berlin)

Photo injector laser systems for linac based FELs often have the capability of generating pulse trains with an adjustable length. For example, the currently installed laser at the Photo Injector Test Facility at DESY, Zeuthen Site (PITZ) can generate pulse trains containing up to 800 pulses. Repetition frequencies are 10 Hz for the pulse trains and 1 MHz for the pulses within a train, respectively. Mostly due to thermal effects caused by absorption in amplifier and frequency doubling crystals, pulse properties are changing slightly within a pulse train and also shot-to-shot, depending on the pulse train length. To increase stability and repeatability of the laser it is desirable to run it under constant conditions. To achieve this while still being able to freely choose pulse patterns a pulse picker to sort the wanted from the unwanted pulses can be installed at the laser output. A promising candidate for this functionality is an acousto-optic modulator which currently is being tested at PITZ. First experimental results will be presented and discussed towards the possibility of including this device into an FEL photo injector.

High-brightness Electron Beam Evolution after Laser-Based Cleaning of the LCLS Photocathode — MOPD62

Feng Zhou, Axel Brachmann, Franz-Josef Decker, Paul J. Emma, Richard Iverson, James Leslie Turner (SLAC, Menlo Park, California)

Laser-based techniques have been widely used for cleaning metal photocathodes to increase quantum efficiency (QE). However, the impact of laser cleaning on the cathode uniformity and final quality of the electron beam is not understood. We are evaluating whether the technique can be applied to revive photocathodes used for electron beam sources of advanced x-ray free electron laser (FEL) facilities, such as the Linac Coherent Light Source (LCLS) at the SLAC. The laser-based cleaning was applied to two separate areas of the LCLS photocathode on July 4 and July 26, 2011, respectively. Since the cleaning performed, routine operation has shown a slow evolution of both the QE and the transverse emittance, with a significant improvement of both over 2-3 weeks. Currently, the LCLS photocathode QE is constant at about 1.2e-4 with a normalized injector emittance of about 0.3 μm for a 150-pC bunch charge. The laser cleaning technique becomes a viable tool to revive the LCLS photocathode. We present these observations of the QE and emittance evolution after laser-based cleaning of the LCLS photocathode,and the thermal emittance for different QE.
The work supported under DOE contract No. DE-AC02-76SF00515.

Seeding and Seeded FEL

Chair: Sven Reiche

sFLASH: Seeding at 38.1 nm — TUOAI01

Christoph Lechner, Sven Ackermann, Armin Azima, Joern Boedewadt, Hossein Delsim-Hashemi, Markus Drescher, Eugen Hass, Ulrich Hipp, Theophilos Maltezopoulos, Velizar Miltchev, Manuel Mittenzwey, Marie Rehders, Juliane Roensch, Jörg Rossbach, Roxana Tarkeshian, Marek Wieland (Uni HH, Hamburg), Shaukat Khan (DELTA, Dortmund), Sasa Bajt, Stefan Düsterer, Katja Honkavaara, Tim Laarmann, Holger Schlarb, Siegfried Schreiber, Markus Tischer (DESY, Hamburg), Francesca Curbis (MAX-lab, Lund), Rasmus Ischebeck (Paul Scherrer Institut, Villigen)

The free-electron laser FLASH has been in operation as an XUV FEL user facility since 2005. For pump-probe experiments a laser system generating the pump pulses has to be synchronized to the incoming FEL light pulses. Within present state of the art, the resulting jitter limits the temporal resolution to 100 fs. In addition, the SASE mode of operation introduces energetic and spectral fluctuations of the emitted FEL radiation pulses. The sFLASH experiment at DESY addresses these issues. We use the NIR laser for both driving the HHG (higher-harmonics generation) process and as a pump source. Thanks to the intrinsic synchronization of the pump source and the FEL light pulses leaving the undulator, we expect a reduction of the timing jitter down to 10 fs. We also anticipate stabilization of energy and spectrum of the emitted XUV FEL pulses. In this contribution we give a summary of the experimental setup and present recent results on seeding at sFLASH.
The project is supported by the Federal Ministry of Education and Research of Germany under contract No. 05 ES7GU1 and by the German Research Foundation programme graduate school 1355.

Hard X-ray Self-Seeding at the LCLS — TUOAI02

Ryan Roger Lindberg, William Berg, Deming Shu, Yuri Shvyd'ko, Stanislav Stoupin, Emil Trakhtenberg, Alexander Zholents (ANL, Argonne), Simone Spampinati (ELETTRA, Basovizza), Paul J. Emma (LBNL, Berkeley, California), John Wilfred Amann, Franz-Josef Decker, Yuantao Ding, Yiping Feng, Josef Frisch, David Fritz, Jerome Hastings, Zhirong Huang, Jacek Krzywinski, Henrik Loos, Alberto Andrea Lutman, Heinz-Dieter Nuhn, Daniel Ratner, Jeffrey Alan Rzepiela, Dieter Walz, James Welch, Juhao Wu, Diling Zhu (SLAC, Menlo Park, California), Vladimir Davidovich Blank, Sergey Terentiev (TISNCM, Troitsk)

The Linac Coherent Light Source (LCLS) has produced extremely bright hard x-ray pulses using self-amplified spontaneous emission (SASE) since 2009. In SASE, the electron beam shot noise initiates the FEL gain, resulting in output radiation characterized by poor temporal coherence and a fluctuating spectrum whose normalized width is given by the FEL bandwidth. Recently, colleagues at DESY suggested a self-seeding scheme for the LCLS to reduce the bandwidth*. Here, the SASE produced in the first half of the undulator line is put through a simple diamond-based monochromator; the resulting monochromatic light trailing the main SASE pulse is used to seed the FEL interaction in the downstream undulators. We report on the experimental results implementing such a scheme at the LCLS, in which we have measured a reduction in bandwidth by a factor of 40-50 from that of SASE at 8-9 keV. The self-seeded FEL operates close to saturation, with the maximum output energy approximately equal to that with no seeding for low charge. The observed level of power fluctuations in the seeded output is presently rather large, and future plans focus on discovering their origins and reducing their magnitude.
** Geloni, V. Kocharyan ,and E.L. Saldin, DESY 10-133, arXiv:1008.3036 (2010)*
Funding Agency: U.S. Dept. of Energy Office of Sciences under Contract No. DE-AC02-06CH11357.

Two Novel Laser-Based Seeding Schemes for X-ray FELs — TUOA03

Quinn Robert Marksteiner, Kip Bishofberger, Bruce Carlsten, Leanne Duffy, Cliff Fortgang, Peter Walstrom, Nikolai Yampolsky (LANL, Los Alamos, New Mexico)

The proposed Matter-Radiation Interactions in Extremes (MaRIE) hard X-ray facility at Los Alamos National Laboratory (LANL) has some user requirements that require longitudinal bandwidths that are an order of magnitude smaller than the bandwidths provided by a SASE FEL. We discuss two novel laser-based harmonic generation schemes for x-ray FELs which could be incorporated into x-ray FELs in order to achieve these bandwidths. The first scheme is a hybrid of Echo-Enabled Harmonic Generation (EEHG) and High-Gain Harmonic Generation (HGHG), which only requires a single laser with relatively low power, compared with EEHG. The second scheme uses a pair of Emittance Exchangers (EEX) after a laser modulator, in order to compress the modulation by a large factor. The strengths and design constraints of these schemes will be discussed, and a general formulism for studying the evolution of bandwidth and bunching factors in a complex seeding scheme will be presented [Yampolsky, arXiv:111.0553v1]. We will show how the hybrid EEHG-HGHG scheme can be incorporated into the NGLS for increased seeding performance.
We acknowledge the support of the LDRD program at Los Alamos National Laboratory.

Coherence Properties of FERMI@Elettra — TUOA04

Benoît Mahieu (CEA/DSM/DRECAM/SPAM, Gif-sur-Yvette; ELETTRA, Basovizza), Enrico Allaria, Giovanni De Ninno, Eugenio Ferrari, Fulvio Parmigiani, Lorenzo Raimondi, Simone Spampinati, Carlo Spezzani, Cristian Svetina, Marco Zangrando (ELETTRA, Basovizza)

We report the results of a campaign of measurements aimed at characterizing the spatial and temporal coherence of the FERMI@Elettra free-electron laser. The results (the first obtained on a high-gain seeded single-pass free-electron laser), are compared with those obtained on other (SASE-based) facilities.

XFELs

Chair: Toru Hara

System Design for Self-Seeding the LCLS at Soft X-ray Energies — TUOBI01

Yiping Feng, John Wilfred Amann, Daniele Cocco, Jerome Hastings, Philip Heimann, Zhirong Huang, Henrik Loos, James Welch, Juhao Wu (SLAC, Menlo Park, California), Ken Chow, Paul J. Emma, Robert W. Schoenlein (LBNL, Berkeley, California)

The complete design for self-seeding the LCLS at soft X-ray energies from 400 to 1000 eV based on a grating monochromator is described. The X-ray optics system consists of a toroidal variable-line-space (VLS) grating with a resolving power greater than 5000 for creating a nearly transform-limited seed pulse from the upstream SASE undulator for pulse durations of the order of 25 fs, and focusing mirrors for imaging the seed pulse onto the downstream seeding undulator. Diagnostics for ensuring overlap with the reentrant electron beam are included in the design. The optical system is sufficiently compact to fit within a single 3.4 m LCLS undulator segment. The electron chicane system which serves to delay the electron beam to match the less than 1 ps delay from the optical system is similar to the chicane used in the hard X-ray self-seeding at LCLS. The seeded FEL pulse is expected to be nearly transform-limited with a bandwidth in the 10-4 range, potentially increasing the low-charge FEL X-ray peak brightness by 1-2 orders of magnitude.

Portions of this research were carried out at the LCLS at the SLAC. LCLS is an Office of Science User Facility operated for the U.S. DOE Office of Science by Stanford University

Spectral Characterization of the FERMI Pulses in the Presence of Electron-beam Phase-space Modulations — TUOB02

Enrico Allaria, Simone Di Mitri, William M. Fawley, Eugenio Ferrari, Lars Froehlich, Giuseppe Penco, Carlo Spezzani, Mauro Trovo (ELETTRA, Basovizza), Luca Giannessi (ELETTRA, Basovizza; ENEA C.R. Frascati, Frascati (Roma)), Giovanni De Ninno, Benoît Mahieu (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica)

As a seeded FEL based on a single stage HGHG configuration, FERMI's FEL-1 has produced very narrow bandwidth FEL pulses in the XUV wavelength region relative to those typical of SASE devices. This important feature of seeded FELs relies however upon the capability to produce high quality electron beams and with clean longitudinal phase spaces. As has been predicted previously, the FEL output spectra can be modified from a simple, nearly transform-limited single spike by modulation and distortions of the longitudinal phase space of the electron beam. In this work we report a study of the FEL spectra recorded at FERMI for various situations showing the effects of phase-space modulation on the FEL properties.

Complete Ultrafast X-ray Pulse Characterization at FELs — TUOB03

Adrian L Cavalieri, Hubertus Bromberger, Ivanka Grguras, Sebastian Huber (CFEL, Hamburg), Gilles Doumy (ANL, Argonne), John Costello (DCU, Dublin), Christopher Behrens, Stefan Düsterer, Holger Schlarb (DESY, Hamburg), Nikolay Kabachnik, Tommaso Mazza, Michael Meyer, Thomas Tschentscher (European XFEL GmbH, Hamburg), Wolfram Helml, Reinhard Kienberger, Andreas Richard Maier, Wolfgang Schweinberger (MPQ, Garching, Munich), Louis DiMauro (Ohio State University,), Christoph Bostedt, John Bozek, Ryan Neal Coffee, Yuantao Ding, Jerome Hastings, Matthias Clemens Hoffmann, Sebastian Schorb (SLAC, Menlo Park, California), Andrey Kazansky (UPV-EHU, Leioa)

The ability to fully characterize X-ray pulses from free electron-lasers will underpin their exploitation in experiments ranging from single-molecule imaging to extreme timescale X-ray science. This issue is especially acute when confronted with the characteristics of current generation FELs operating on the principle of SASE, as most parameters fluctuate strongly from pulse to pulse. Here, we have extended the techniques of attosecond metrology with the use of single-cycle terahertz (THz) pulses, allowing for simultaneous, in-line, single-shot measurement of both the arrival time and temporal profile of FEL pulses on an absolute scale. The technique is non-invasive and could be incorporated in pump-probe experiments, eventually leading to characterization before and after interaction with most sample environments. Optical-laser-driven THz streaking measurements, revealing X-ray pulse structure shorter than 50 fs FWHM in the soft X-ray regime at FLASH and in the ~ keV range at LCLS will be discussed. With clear potential for improvement in resolution to the sub-10 fs regime, this method will ultimately allow for characterization of the shortest predicted few-femtosecond FEL pulses.

Comparison of Hard X-Ray Self-seeding with SASE after a Monochromator at LCLS — TUOB04

James Welch, Jerome Hastings, Zhirong Huang, Marc Messerschmidt, James Leslie Turner (SLAC, Menlo Park, California)

Self-seeding of a hard x-ray FEL was demonstrated at LCLS in January 2012 and produced a factor of 40-50 bandwidth reduction using a electron bunch charge of 20-40 pC*. For many hard x-ray users, the photon intensity after a monochromator is an important performance parameter. In this paper, we report results from a subsequent study of self-seeding performance using the Si (111) K-monochromator with a full bandwidth of 1.2 eV at 8.2 keV. These include a direct comparison of the average intensity of the monochromatized seeded beam with that of a monochromatized fully tuned-up SASE beam, in both cases using 150 pC bunch charge. The intensity distribution, fluctuations, and spatial profiles of the monochromatized radiation are studied and compared.

** J. Amann, et. al, Nature Photonics, to be published*

Work supported in part by the DOE Contract DE-AC02-76SF00515.

Oscillator FELs and Storage Ring FELs

Chair: Ryoichi Hajima

Progress Towards X-Ray Free Electron Laser Oscillator — TUOCI01

Kwang-Je Kim (ANL, Argonne)

The characteristics of X-ray free electron laser oscillators (XFELOs) [K.-J. Kim, et. al., Phys. Rev. Lett. 100, 244802 (2008)]--high-stability, high-spectral purity, and high-average brightness--will greatly enrich the era of x-ray FELs begun recently. If combined with a high-gain amplifier possibly with harmonic generation, an XFELO would constitute an ultimate x-ray machine. The drive accelerator can either be a straight SCRF linac or an ERL in energy gain mode. Sub-Angstrom stabilization of the output x-ray pulse spacing may be feasible by locking one of the longitudinal modes to a nuclear resonance such as 57Fe, opening up new opportunities for extreme x-ray metrology, with potential applications to technology and fundamental physics [B. Adams and K.-J. Kim, FEL2012]. A wide range of parameters is possible [R.R. Lindberg, FEL2012], optimized for particular accelerator or applications, such as ultra-low bunch charge for ERL [1], for short cavity length for nuclear resonance metrology, etc. The prospects for an XFELO are encouraging: Diamond as a Bragg reflector has been demonstrated for near 99% reflectivity [2] and high thermal diffusivity at cryogenic temperature [3].

[1] R. Hajima and N. Nishimori, Proc. of the FEL2009; R.R. Lindberg, FEL2012
[2] Y. Shvyd'ko, et al, Nat. Photonics 5, 539 (2011)
[3] S. Stoupin and Y. Shvyd'ko, Phys. Rev. Lett. 104, 085901(2010)

This work is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Contract No. DE-AC02-06CH11357

Start to End Simulations of Optics-free X-ray FEL Oscillator — TUOC02

Vladimir N. Litvinenko, Yue Hao, Yichao Jing, Dmitry Kayran, Dejan Trbojevic (BNL, Upton, Long Island, New York)

There is obvious need for an optics-free X-ray FEL oscillator. While self-seeded SASE FELs demonstrated the capability of providing very high gain and short pulses of radiation, the spectra of SASE FELs is still rather wide and can be significantly improved in an FEL-oscillators. Idea of optics-free X-ray FEL oscillator using is know for a decade [1]. In this talk, we present start-to-end simulation of this scheme including both incoherent and coherent SR effects. We discussed the projected performance of this scheme and its potentials limitations.

[1] Optics-Free FEL oscillators, V.N.Litvinenko, ICFA Advanced Accelerator and Beam Dynamics Workshop Chia Laguna, Sardinia, July 1-6, 2002

Use of the Projected Torus Knot Lattice for a Compact Storage Ring FEL — TUOC03

Shigemi Sasaki, Atsushi Miyamoto (HSRC, Higashi-Hiroshima)

We proposed a new scheme of lattice design for a compact storage ring in which a design orbit of electron beam closes after completing multiple turns.* This new lattice can be made by placing necessary accelerator components at certain positions on a projected torus knot in the horizontal orbit plane. In a storage ring having this type of lattice, the beam trajectory crosses in bending magnets, i.e. each bending magnet accepts two beam orbits. For example, in the ring having the (11, 3) torus knot lattice with 11 bending magnets, a bunch goes through bending magnets 22-times to complete its 3-turn closed orbit. Since the maximum output laser power is proportional to the synchrotron radiation loss in the complete turn round a closed orbit starting from the optical resonator section,** the maximum laser power from the projected torus knot storage ring FEL can be doubled for 2-turn lattice and tripled for 3-turn lattice compared with that from a conventional storage ring FEL. The new lattice scheme may contribute to more stable operation of a compact storage ring FEL. Some realistic parameters and achievable performance for UV-FEL are discussed in the presentation.

**S. Sasaki and A. Miyamoto, Proceedings of IPAC'11, San Sebastian, September 2011, TUPO010, p.1467 (2011).*
***R. Bartolini, et al, Phys. Rev. E 69, 036501 (2004).*

This work is partially supported by the KEK-Universities Collaborative Support Program for Accelerator Science.

Compact ERL FELs as High Rep Rate, High Intensity Driver Sources for High-Field Applications

TUOC04

Mufit Tecimer (University of Hawaii at Manoa, Honolulu)

100-200 MeV range ERL-FELs generating few cycle short, high intensity mid-IR pulses with tens of MHz repetition rates might become attractive tools in various strong field applications such as the recently considered up-frequency conversion processes in the x-ray region*. The presented coupled FEL oscillator employs a shorter undulator in the amplifier section than the one used in its master oscillator. The scheme achieves an exceptionally high overall extraction efficiency to tap on the high power deposited in the electron beam*. We elaborate on modified versions of this scheme and direct the attention towards a (seemingly far-fetched) major High-Field application**, the laser driven plasma-based electron accelerator and its parameter scalings***.

** M. Tecimer, PRST-AB 15,020703 (2012).*
*** M. Tecimer, HZB-BESSY,Nov 2010.*
**** C.B. Schroeder et al., PRST-AB 13, 101301 (2010).*

A New Approach to Improving the Efficiency of FEL Oscillator Simulations

TUOC05

Michelle Diane Shinn, Stephen Vincent Benson, Anne Watson (JLAB, Newport News, Virginia),
Henry P Freund, Dinh C. Nguyen (LANL, Los Alamos, New Mexico), Peter van der Slot (Mesa+, Enschede)

During the last year we have been benchmarking FEL oscillator simulation codes against the measured performance of the three Jefferson Lab oscillator FELs. While one might think that a full 4D simulation is de facto the best predictor of performance, the simulations are computationally intensive, even when analytical approximations to the electron bunch longitudinal distribution are used. In this presentation we compare the predictions of the 4D FEL interaction codes Genesis and Medusa, in combination with the optical code OPC, with those using a combination of the 2D & 3D versions of these codes, which can be run quickly on a single CPU core desktop computer.

This work was supported by the Commonwealth of Virginia and U.S. DOE Contract No. DE-AC05-84-ER40150.

Tuesday Poster Session

- **XFELs**
- **Seeding and Seeded FELs**
- **FEL Technology II: Stability, Optics, Beamline**

FERMI@Elettra Progress Report — TUPD01

Enrico Allaria, Laura Badano, Carlo Callegari, Davide Castronovo, Paolo Craievich, Ivan Cudin, Miltcho B. Danailov, Gerardo D'Auria, Simone Di Mitri, Bruno Diviacco, Alessandro Fabris, Riccardo Fabris, William M. Fawley, Mario Ferianis, Lars Froehlich, Paol Furlan Radivo, Giulio Gaio, Emanuel Karantzoulis, Maya Kiskinova, Marco Lonza, Claudio Masciovecchio, Giuseppe Penco, Luca Rumiz, Carlo Spezzani, Michele Svandrlik, Cristian Svetina, Mauro Trovo, Alessandro Vascotto, Marco Veronese, Roberto Visintini, Dino Zangrando (ELETTRA, Basovizza), Benoît Mahieu (CEA/DSM/DRECAM/SPAM, Gif-sur-Yvette; ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica), Marco Zangrando (ELETTRA, Basovizza; IOM-CNR, Trieste), Giovanni De Ninno, Eugenio Ferrari, Simone Spampinati (ELETTRA, Basovizza; University of Nova Gorica, Nova Gorica), Fulvio Parmigiani (ELETTRA, Basovizza; Università degli Studi di Trieste, Trieste)

FERMI@Elettra is progressing rapidly towards its first operation as user facility based on a seeded FEL in the soft X-ray range. More than thirty experiment proposals were submitted to the first call for external users. Significant performance improvement could be achieved on the first FEL line, FEL-1, covering the wavelength range between 80 and 20 nm, also thanks to the progress of the commissioning of some linac systems which have not yet been installed or commissioned, among them the X-band linearizing system and the laser heater. First results have been obtained also on the second FEL line, FEL-2, which will reach down to 4 nm wavelength. A general overview of the project progress is presented here.

Baseline Design for the MaRIE X-ray Free Electron Laser — TUPD02

Leanne Duffy, Kip Bishofberger, Bruce Carlsten, Patrick Colestock, Cynthia Heath, Quinn Robert Marksteiner, Nathan A. Moody, Dinh C. Nguyen, Steven Russell, Richard Sheffield, Evgenya I. Simakov, Nikolai Yampolsky (LANL, Los Alamos, New Mexico), Robert D. Ryne (LBNL, Berkeley, California)

A 42 keV X-ray free electron laser (XFEL) is a key part of Los Alamos National Laboratory's proposed Matter-Radiation Interactions in Extremes (MaRIE) Experimental Facility. We present the baseline design for the MaRIE XFEL, which will produce 1e10 longitudinally incoherent photons, simulation results and design considerations. Advanced design options to improve longitudinal coherency and reduce beam emittance will also be discussed.
We acknowledge the support of the LDRD program at Los Alamos National Laboratory.

FEL Simulation Study for PAL XFEL — TUPD03

Ilmoon Hwang, Jang Hui Han, Heung-Sik Kang (PAL, Pohang, Kyungbuk)

Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL XFEL) will provide X-ray FEL radiation in a range of 0.1 and 10nm with five undulator beamlines. A undulator section for hard X-ray is designed for 0.1nm SASE FEL. The wakefield effect and its cure by tapering are investigated by tracking simulation. We present FEL simulation study by using GENESIS.

Possible Upgrade of FLASH for Harmonic Lasing down to 1.4 nm — TUPD04

Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We propose the 3rd harmonic lasing in a new FLASH undulator as a way to produce intense, narrow-band, and stable SASE radiation down to 1.4 nm with the present accelerator energy of 1.25 GeV. We also show that a moderate upgrade of the FLASHII undulator system can allow for the 3rd harmonic lasing to saturation through the entire water window.

Sensitivities of FEL Parameters in LUNEX5 in France by GENESIS Simulation — TUPD05

Takanori Tanikawa, Marie-Emmanuelle Couprie, Marie Labat, Alexandre Loulergue (SOLEIL, Gif-sur-Yvette), Serge Bielawski, Clement Evain, Christophe Szwaj (PhLAM/CERCLA, Villeneuve d'Ascq Cedex)

LUNEX5 (free-electron Laser (FEL) Using a New accelerator for the Exploitation of X-ray radiation of 5th generation) aims at producing short and intense laser pulse in the soft x-ray region (target wavelength is 13 and 20 nm). This FEL comports either a conventional linear accelerator or a laser wakefield accelerator, and includes innovative schemes such an echo-enable harmonic generation and higher-order harmonics seeding generated in gases to obtain the high spatio-temporal coherent radiation. Sensitivities of FEL radiation property to parameter such as beam energy, energy spread, bunch length, input seed power have been studied by using GENESIS.

Optimization of a Terawatt Free Electron Laser — TUPD06

Xiaobiao Huang, Ajay Mandlekar, Tor Raubenheimer, Juhao Wu, George Yu (SLAC, Menlo Park, California), Yi Jiao (IHEP, Beijing), Simone Spampinati (University of Nova Gorica, Nova Gorica)

There is great interest in a terawatt (TW) hard X-ray free electron laser (FEL) that will enable coherent diffraction imaging of complex molecules like proteins. A feasibility study of producing such pulses was carried out employing a configuration beginning with an SASE amplifier, followed by a "self-seeding" crystal monochromator, and finishing with a long tapered undulator. The undulator tapering profile, the phase advance in the undulator break sections, the quadrupole focusing strength and the electron bunch peak current, etc. are parameters to be optimized. A genetic algorithm (GA) is adopted for this multi-dimensional optimization. The GA solution is compared to the solution found by a grid scan multi-dimensional optimization scheme. Concrete examples are given for LCLS and LCLS-II systems.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515.

Narrow Bandwidth High Power FEL with an Improved SASE Scheme — TUPD07

Juhao Wu, Claudio Pellegrini (SLAC, Menlo Park, California)

We study an improved-SASE (iSASE) scheme to generate narrow bandwidth Free Electron Laser (FEL) by introducing phase shifter between the undulator segments to speed up the slippage. Due to the shift of the FEL pulse with respect to the electron bunch, spikes with phase relation develop; therefore the coherent length increases faster. Furthermore, due to the similarity of these spikes in the temporal domain with respect to the spikes generated in the previous sections, the spectrum of such an FEL containing a regular temporal spike train is intrinsically narrower than that of a conventional SASE FEL. Here, we report study results for a soft x-ray FEL at 6 nm and a hard x-ray at 0.15 nm. With a narrower bandwidth, the FEL responds to a tapered undulator more efficiently than a conventional SASE FEL does. This then make it possible to reach high power. Analysis is carried out with GENESIS numerical simulation as well as 1-D analytical calculation.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515.

Tolerance of a Seeded Free Electron Laser — TUPD08

Juhao Wu, Tor Raubenheimer (SLAC, Menlo Park, California)

Tolerance and stability are important issues for designing and operating accelerator and FEL. Jitter can come from various sources. We identify and study well known sources as well as some particular ones, important for a seeded tapered high power FEL. Seed laser phase error, electron bunch current profile, self-seeding residual density bunching and energy modulation after the chicane, undulator wakefield, and phase errors in the undulator breaks are just a few important examples. Schemes to improve the stability of a seeded FEL are also discussed.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract DE-AC02-76SF00515.

~~Harmonic Lasing of X-ray Free Electron Laser: On the Way to Smaller and Cheaper~~ — ~~TUPD09~~ withdrawn

Haixiao Deng, Jinhua Dai, Zhimin Dai (SINAP, Shanghai)

Harmonic lasing of free electron laser (FEL) has been experimentally demonstrated in the terahertz, infrared and ultraviolet FEL oscillators. By using high order harmonics of undulator radiation, harmonic lasing is helpful in the simplification and reduction of x-ray FEL, i.e. costs and size. In this paper, an overview on harmonic lasing of x-ray free electron laser will be presented, including the recently proposed harmonic lasing of x-ray FEL oscillator * and further ideas on harmonic lasing of single pass x-ray FEL

** J. H. Dai, H. X. Deng, Z. M. Dai, PRL 108, 034802, 2012*

Status of Polarization Control Experiment at Shanghai Deep Ultraviolet Free Electron Laser — TUPD10

Haixiao Deng, Jianhui Chen, Zhimin Dai, Yong Fan, Chao Feng, Lie Feng, Yongzhou He, Taihe Lan, Bo Liu, Dong Wang, Xingtao Wang, Zhishan Wang, Jidong Zhang, Meng Zhang, Miao Zhang, Tong Zhang (SINAP, Shanghai), Lin Song (BUAA, Beijing)

A polarization control experiment using a pair of crossed undulators has bee proposed for the Shanghai deep ultraviolet free electron laser (FEL) test facility. Numerical simulation indicates that, with the phase-shifter between the two crossed undulators, Fourier-Transform-Limited output radiation with 100nJ order pulse energy, 5ps full pulse length and circular polarization degree above 90% could be achieved. The physical design study and the experimental setup status are presented in the paper.

Optimization of HHG Seeding between 10 nm to 40 nm — TUPD11

Sven Ackermann, Winfried Decking, Bart Faatz (DESY, Hamburg),
Velizar Miltchev, Jörg Rossbach (Uni HH, Hamburg)

FLASH* delivers coherent FEL radiation suitable for a variety of scientific purposes. In order to provide more beam time to the photon experiments, the FLASH II project, consisting of a second undulator branch and a new experimental Hall driven by the same superconducting modules as FLASH today has been started in 2008. While in the present undulator the kinetic energy of the electrons has to be changed in order to change the wavelength, the new beamline will benefit from variable gap undulators which will allow to have largely independent radiation wavelength; in the range of 10 to 40 nm an HHG seeding option is foreseen which will improve radiation quality for users beyond SASE. For experiments it is important to have the source point of the FEL radiation at the same position, close to the end of the undulator. However, one would like to keep the HHG focus at a fixed longitudinal position, such that wavelength changes will not require adjustments of the HHG focus. In this contribution, we will present the optimization of these conflicting requirements by opening undulator gaps at wavelength dependent positions, keeping both the seeding point and the source point for users fixed.

** The Free-Electron Laser in Hamburg*

Extension of Self-seeding to Hard X-rays > 10 keV as a Way to Increase User Access at the European XFEL — TUPD12

Gianluca Geloni (European XFEL GmbH, Hamburg), Vitali Kocharyan, Evgeny Saldin (DESY, Hamburg)

We propose to use a self-seeding scheme with single crystal monochromator at the European X-ray FEL to produce monochromatic, high-power radiation at 16 keV. The FEL power of the transform-limited pulses can reach about 100 GW by exploiting tapering in the tunable-gap baseline undulator. The combination of high photon energy, high peak power, and very narrow bandwidth opens a new range of applications, and allows to increase the user capacity and exploit the high repetition rate of the European XFEL. Dealing with monochromatic hard X-ray radiation one may use crystals as deflectors with minimum beam loss. To this end, a photon beam distribution system based on the use of crystals in the Bragg reflection geometry is proposed for future study and possible extension of the baseline facility. They can be repeated a number of times to form an almost complete (one meter scale) ring with an angle of 20 degrees between two neighboring lines. The reflectivity of crystal deflectors can be switched fast enough by flipping the crystals with piezo-electric devices. It is then possible to distribute monochromatic hard X-rays among 10 independent instruments.

Progress Towards EEHG and HGHG at FLASH — TUPD13

Kirsten Elaine Hacker, Holger Schlarb, Bernd Steffen (DESY, Hamburg), Shaukat Khan (DELTA, Dortmund), Peter Salen, Peter van der Meulen (FYSIKUM, AlbaNova, Stockholm), Gergana Angelova Hamberg (Uppsala University, Uppsala)

New infrastructure was built at FLASH to enable 30-100 fs long, milliJoule pulses of 270 nm light to seed the electron beam with HGHG and EEHG techniques, targeting wavelengths in the range from 10 nm to 40 nm. HGHG, or High Gain Harmonic Generation, and EEHG, or Echo-Enabled Harmonic Generation, utilize an external laser together with chicanes and undulators in order to generate a bunched beam which will radiate in a subsequent undulator. In the case of HGHG, the beam is bunched at the seed laser wavelength, radiating harmonics thereof in the radiator. In the case of EEHG, the beam is bunched at a harmonic of the seed wavelength, radiating that same harmonic in the radiator. The properties of the setup, commissioning difficulties and the inital attempts at HGHG seeding at 38.5 nm will be described.

Funding Agency : BMBF 05K10PE1 and DESY

Optical Replica Synthesizer to be Re-commissioned at FLASH with 270 nm Seed — TUPD14

Kirsten Elaine Hacker, Holger Schlarb (DESY, Hamburg), Shaukat Khan (DELTA, Dortmund), Peter Salen, Peter van der Meulen (FYSIKUM, AlbaNova, Stockholm),
Gergana Angelova Hamberg (Uppsala University, Uppsala)

The Optical Replica Synthesizer at FLASH was first commissioned in 2008 with an 800 nm seed. This wavelength proved to be problematic due to the fact that the COTR resulting from a microbunching instability at that wavelength was often as strong or stronger than the radiation from the seeded and bunched beam. It has since been observed that the microbunches which are responsible for the unwanted COTR can be smeared out in the dogleg if they are shorter than 600 nm. This opens the possibility to try the same experiment with a shorter wavelength and avoid the problems with the unwanted background signal from the microbunching instability. This is the motivation behind a new experimental design involving a new 270 nm seed laser and a new pulse length detection device to replace the old 800 nm seed and pulse length detection device. Details about the experiment design and commissioning plans will be described.
Funding Agency: BMBF 05K010PE1, grant 621-2009-2926 and DESY

Seeded Coherent Harmonic Generation with in-line Gas Target — TUPD15

Francesca Curbis, Nino Cutic, Olivia Karlberg, Filip Lindau, Erik Mansten, Sara Thorin, Sverker Werin (MAX-lab, Lund), Fernando Brizuela, Byunghoon Kim, David Kroon, Anne L'Huillier (Lund University, Lund), Mathieu Gisselbrecht (SLF, Lund)

The test-FEL at MAX-lab already demonstrated seeded coherent harmonic generation down to 40 nm*. As next step in the development of seeding techniques we plan to use a gas target to generate harmonics of the drive laser and seed the electron beam with them. In order to optimize the injection process, our aim is to place the gas target for harmonic generation as close as possible to the first undulator. In order to minimize the losses the transport of the drive laser is done with a minimal number of mirrors and there are neither focusing nor filtering elements between the harmonic chamber and the first undulator. This will be the first experiment that will imprint energy modulation to the electron beam by harmonics generated in gas. The wavelength range of the harmonics that will be used as seed is around 100 nm and we plan to detect the coherent harmonic signal of the second harmonic generated in the radiator. The flexibility of the set-up will allow to drive the HG process with the fundamental wavelength or the second harmonic or the combination of them. Adding the second harmonic will lead to the generation of even harmonics, thus increasing the range of seeding wavelength.
N. Cutic, et al., "Vacuum ultraviolet circularly polarized coherent femtosecond pulses from laser seeded relativistic electrons", Phys. Rev. Spec. Top. Accel. Beams 14, 030706 (2011)

An Analyse on Choice of the Undulator Length for Self-seeding FEL — TUPD16

Qika Jia (USTC/NSRL, Hefei, Anhui)

A simple analyse is given for the choice of the undulator length in self-seeding FEL. The obtained relations show the correlation between the undulators length and the system parameters. The power required for the seeding in the second part undulator and overall efficiency to monochromatizating the seeding settle on the length of the first part undulator; the magnitude of seeding power dominates the length of the second part undulator; the whole length of the undulators in self-seeding FEL is determined by the overall efficiency to get coherent seed, it is longer than that in SASE case.

Seeding of SPARC-FEL with a Tunable Fibre-based Source — TUPD17

Nicolas Yann Joly (University of Erlangen-Nuremberg, Erlangen-Nuremberg), Giovanni De Ninno, Benoît Mahieu (ELETTRA, Basovizza), Marcello Artioli, Luca Giannessi, Alberto Petralia, Marcello Quattromini, Vincenzo Surrenti (ENEA C.R. Frascati, Frascati (Roma)), Enrica Chiadroni, Alessandro Cianchi (INFN-Roma II, Roma), Marco Bellaveglia, Giampiero Di Pirro, Massimo Ferrario, Giancarlo Gatti, Andrea Mostacci (INFN/LNF, Frascati (Roma)), Julietta V. Rau (ISM-CNR, Rome), Vittoria Petrillo (Istituto Nazionale di Fisica Nucleare, Milano), KaFai Mak, Philip Russell, Francesco Tani, John Colin Travers (Max Planck Institute for the Science of Light, Erlangen), Serge Bielawski (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Marie-Emmanuelle Couprie, Marie Labat, Takanori Tanikawa (SOLEIL, Gif-sur-Yvette)

Instead of seeding a free electron laser in the UV-VUV with a frequency doubled or tripled laser or high order harmonics, here we investigate and present the first results on seeding SPARC-FEL with a fiber-based tunable ultraviolet source. The seed generation system consists of a kagomé hollow-core photonic crystal fiber filled with noble gas. Diffraction-limited DUV pulses of >50 nJ and fs-duration which are continuously tunable from below 200 nm to above 300 nm are generated. The process is based on soliton-effect self-compression of the pump pulse down to a few optical cycles, accompanied by the emission of a resonant dispersive wave in the DUV spectral region. The quality of the compression highly depends on the pump pulse duration, and ideally, pulses <60 fs should be used. Our experimental set-up and associated GENESIS simulations enable us to study the utility of the seed tunability, and the influence of the seed quality, on the performance of the SPARC-FEL in the 200-300 nm range.

Generation and Metrology of the 6th Harmonic Generated from Gas at 135 nm in View of Seeding VUV FELs — TUPD18

Guillaume Lambert, Julien Gautier, Victor Malka, Stephane Sebban, Boris Vodungbo, Philippe Zeitoun (LOA, Palaiseau), Luca Giannessi, Alberto Petralia (ENEA C.R. Frascati, Frascati (Roma))

FEL in single pass have been recently evolving very fast in the UV to soft X-ray region. Once seeded with high harmonics generated in gas, these light sources deliver amplified emissions with properties which are, for most of them, directly linked to the injected harmonic beam. Here we have developed and study a new source of harmonics at 135 nm, corresponding to the 6th harmonic of a kHz 40 fs Ti: Sa laser, in the two-color field cross-polarized configuration. We observed, what we think is of prime importance for the FEL community, that the spatial distribution can evolve from Gaussian distribution to annular distribution and most of all the polarization from linear to circular. Also the pulse energy has been measured in any case to be close to the microjoule level. Finally, the spatial coherence revealed to be very good. This opens great perspectives for applications and especially for seeding of SPARC FEL facility.

The Radiator-first HGHG Multi-MHz X-ray FEL Concept — TUPD19

Matthias Reinsch, Gregory Penn (LBNL, Berkeley, California), Jonathan Wurtele (LBNL, Berkeley, California; UCB, Berkeley, California), Punit R. Gandhi (UCB, Berkeley, California)

A novel configuration for a high repetition rate X-ray FEL is investigated. In this scheme longitudinally coherent FEL pulses are obtained using a high gain harmonic generation (HGHG) system in which the seed power is generated in an FEL oscillator downstream of the HGHG section. The oscillator is powered by the spent beams that leave the HGHG radiator. Radiation from the oscillator is sent to the modulator of the HGHG section. The dynamics and stability of the radiator-first scheme is explored analytically and numerically. A single-pass map is derived using a semi-analytic model for FEL gain and saturation. Iteration of the map is shown to be in good agreement with simulations. A numerical example is presented for a soft X-ray FEL in which the oscillator operates at 13.4 nm and HGHG radiation is generated at 1.34 nm. This radiator-first configuration potentially solves (i) the challenge of finding sources to seed future FELs driven by multi-MHz superconducting RF linacs and (ii) the difficulty of producing X-ray radiation with a bunch that exits an oscillator in the more "natural" configuration in which the oscillator precedes the radiator.

Soft X-ray SASE and Self-seeding Studies for a Next-generation Light Source — TUPD20

Gregory Penn, Paul J. Emma, Donald Prosnitz, Ji Qiang, Matthias Reinsch (LBNL, Berkeley, California)

In the self-seeding scheme, the longitudinal coherence and spectral density of an unseeded FEL can be improved [*] by placing a monochromator at a location before the radiation reaches saturation levels, followed by a second stage of amplification. The final output pulse properties are determined by a complex combination of the monochromator properties, undulator settings, variations in the electron beam, and wakefields. We perform simulations for the output of SASE and self-seeded configurations for a soft x-ray FEL using both idealized beams and realistic beams from start-to-end simulations. These studies include cross-planar undulators dedicated to polarization control [**].

[*] J. Feldhaus, E.L. Saldin, J.R. Schneider, E.A. Schneidmiller, and M.V. Yurkov, Optics Commun. 140 (1997) 341-352.
[**] K.-J. Kim, Nucl. Instrum. Methods A 445 (2000) 329-332.

This work was supported by the Director, Office of Science, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

TUPD21 Self-Seeding Design for SwissFEL — TUPD21

**Eduard Prat (PSI, Villigen), Sven Reiche (Paul Scherrer Institut, Villigen),
David Dunning (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)**

The SwissFEL facility, planned at the Paul Scherrer Institute, is based on the SASE operation of a hard (1-7 Å) and soft (7-70 Å) X-ray FEL beamline. In addition, seeding is foreseen for the soft X-ray beamline (down to a wavelength of 10 Å), and it is currently also under consideration for the hard X-ray beamline. We have investigated two methods, Echo-Enabled Harmonic Generation (EEHG) and self-seeding for each of the two FEL beamlines. Presently we consider self-seeding the most robust and lowest risk strategy for both lines. The paper discusses our considerations and presents the design of self-seeding implementation for the soft and the hard X-ray beamlines including the layout and simulation results.

Pulse Train Generation at a Deep Saturated Superradiant Free-Electron Laser Amplifier — TUPD22

Xi Yang, Jinhyuk Choi, Boris Podobedov, Yuzhen Shen (BNL, Upton, Long Island, New York)

We report the first numerical demonstration of a coherent radiation pulse train generation in a slippage-dominant deep-saturated superradiant free-electron laser (FEL) using an ultrafast seed-laser pulse. In the superradiant regime, some nonlinear effects have been developed. Especially when the FEL interaction is deeply saturated, the energy spread of the electrons become so large that the longitudinal phase space is broken from one rf bucket into several mini-buckets. Each bucket radiates with different gain, at slightly different wavelength, and also separates in time to form a pulse train. We numerically demonstrate that the temporal and spectral distribution of those FEL pulses can be controlled via the electron and seed laser parameters. It could be significant for the applications which require high spectral and temporal resolution.

Spatiotemporal Response of Crystals in Asymmetric X-ray Bragg Diffraction and Self-Seeding of XFELs — TUPD23

Yuri Shvyd'ko, Ryan Roger Lindberg (ANL, Argonne)

We are developing a theory of the spatiotemporal response of crystals to excitations by ultra-short, laterally confined x-ray pulses in the general case of asymmetric x-ray Bragg diffraction. The theory represents an extension of the analysis in symmetric reflection geometry [*] to a generic case of asymmetric Bragg diffraction, both in reflection (Bragg) and transmission (Laue) geometries. The spatiotemporal response is presented in the general case as a product of a crystal-intrinsic response function and an envelope function defined by the crystal-independent transverse profile of the incident beam and by the scattering geometry. Analytical expressions for the response functions are derived for non-absorbing crystals. The characteristic measure of the spatiotemporal response in Bragg diffraction is expressed in terms of a few parameters: the extinction length, crystal thickness, Bragg angle, asymmetry angle, and the speed of light. Applications to the self-seeding of hard x-ray free electron lasers are discussed, with particular emphasis on the relative advantages of using either the Bragg or Laue scattering geometries.

[*] R. R. Lindberg, Yu. V. Shvyd'ko ``Time dependence of Bragg forward scattering and self-seeding of hard x-ray free-electron lasers'' Phys. Rev. ST Accel. Beams, 15 (2012) 050706.

This work was supported by U.S. Department of Energy Office of Sciences under Contract No. DE-AC02-06CH11357.

Time Response of Bragg Diffraction from Temporally Short X-ray Pulses — TUPD25

Ryan Roger Lindberg, Yuri Shvyd'ko (ANL, Argonne)

X-ray optics based on perfect Bragg crystals is an important component of FEL facilities, particularly for high-resolution monochromators. We discuss the spatiotemporal response of Bragg scattering from temporally short incident pulses by framing the dynamical theory of x-ray diffraction as a set of coupled waves. We compute the profiles of both the reflected and forward scattered x-ray pulses from crystals in the symmetric geometry, showing that the time delay of the wave is proportional to the transverse spatial shift times the cotangent of the grazing incidence angle. Finally, we apply our findings to obtain an analytic description of Bragg forward scattering relevant to monochromatically seed hard x-ray FELs.

Funding Agency: U.S. Dept. of Energy Office of Sciences under Contract No. DE-AC02-06CH11357

Fast Beam-Based BPM Calibration — TUPD26

Kirk Bertsche, Henrik Loos, Heinz-Dieter Nuhn, Franz Peters (SLAC, Menlo Park, California)

The Alignment Diagnostic System (ADS) of the LCLS undulator system indicates that the 33 undulator quadrupoles have an extremely high position stability over many weeks. However, beam trajectory straightness and lasing efficiency degrade more quickly than this. A lengthy Beam Based Alignment (BBA) procedure must be executed every two to four weeks to re-optimize the X-ray beam parameters. The undulator system includes RF cavity Beam Position Monitors (RFBPMs), several of which are utilized by an automatic feedback system to align the incoming electron-beam trajectory to the undulator axis. The beam trajectory straightness degradation has been traced to electronic drifts of the gain and offset of the BPMs used in the beam feedback system. To quickly recover the trajectory straightness, we have developed a fast beam-based procedure to recalibrate the BPMs. This procedure takes advantage of the high-precision monitoring capability of the ADS, which allows highly repeatable positioning of undulator quadrupoles. This report describes the ADS, the position stability of the LCLS undulator quadrupoles, and some results of the new recovery procedure.

Work supported by the U.S. Department of Energy under contract number DE-AC02-76SF00515.

Beam based Alignment of X-FEL Undulator Section Utilizing Corrector Pattern — TUPD27

Masamitsu Aiba (Paul Scherrer Institut, Villigen)

Beam based alignment of the undulator section is one of the delicate issues in beam commissioning and regular beam tuning of X-FEL facilities since the tolerance on the electron beam orbit straightness is tight, typically a few micro-meters rms. A new approach based on the dipole corrector strengths is under investigation for the PSI future X-FEL facility, SwissFEL. The idea is to minimize the deviation of corrector strengths, required to steer the electron beam to the beam position monitor (BPM) centres, by varying BPM positions. The beam trajectory, if there is no dipolar error, must be fully straight with no corrector excitation, where the deviation is zero, i.e. minimized. Under dipolar errors, e.g. undulator imperfections, the minimization is performed w.r.t. their average value. The procedure requires precise BBA of quadrupoles to adjacent BPM beforehand and an orbit feedback in operation. Although these preparation works require some efforts, the method is rather simple and robust. The methodology together with expected performance from analytical estimation and simulations applied to the undulator section of SwissFEL is presented.

Bunch Compression Layout and Longitudinal Operation Modes for the SwissFEL Aramis Line — TUPD28

Bolko Beutner (Paul Scherrer Institut, Villigen)

The SwissFEL Aramis Undulator line will produce SASE photon pulses covering a wavelength range from 0.07 nm to 0.7 nm. The facility will consists of an S-band RF-gun and booster, an X-band lineariser, and a C-band main linac, which accelerates the beam up to 5.8 GeV. Two compression chicanes at about 330 MeV and 2.1 GeV will provide a nominal peak current up to 3 kA. It is foreseen to deliver electron pulses between 3 and 19 fs length to the undulator. This is done by adjusting the charge between 10 and 200 pC. Longitudinal wakes in the C-band linac are used to remove the chirp to deliver small bandwidth radiation. A special mode uses these wakes to increase the energy chirp to deliver a photon bandwidth an the percent level for special applications like single shot spectroscopy. In addition a fully compressed 10 pC beam is used as a source of sub femto-second pulses. An iterative semi-analytic procedure was used to setup and optimise the setup efficiently. In this paper these optimised operation modes are presented and discussed.

A Dynamic Feedback Model For High Repetition Rate Linac-driven FELs — TUPD29

John Byrd, Lawrence Doolittle, Paul J. Emma, Gang Huang, Marvin Mellado, Alessandro Ratti, Carlos Serrano (LBNL, Berkeley, California)

One of the concepts for the next generation of linac-driven FELs is a CW superconducting linac driving an electron beam with MHz repetition rates. One of the challenges for next generation FELs is improve the shot-to-shot stability of the energy, charge, peak current, and timing jitter of the electron beam. This class of machine presents an opportunity to use a variety of broadband feedbacks to stabilize the beam parameters. To understand the performance of such a feedback system, we are developing a dynamic model of the machine with a focus on the longitudinal beam properties. The model is being developed as an extension of the LITrack code and includes the dynamics of the beam-cavity interaction, RF feedback, beam-based feedback, and multibunch effects. In this paper, we present the status of this model along with results.

Work supported by U.S. Department of Energy under contracts DE-AC02-05CH11231.

In situ Alignment of Kirkpatrick-Baez Refocusing Optics at the PG1 Beamline of FLASH — TUPD30

Siarhei Dziarzhytski, Natalia Gerasimova, Holger Weigelt (DESY, Hamburg)

To enable in-situ alignment of Kirkpatrick-Baez (KB) refocusing optics at the PG1 beamline of FLASH a new motorized mirror mount has been designed, manufactured and tested at DESY. The compact mirror manipulators allow in-situ adjustment of the mirrors with required accuracy to focus FEL beam to a focal spot of below 5 µm size. To provide in-situ focal spot characterization a portable UHV compatible diagnostics port has been developed. Combining three techniques: focus imaging by luminescence crystal, in-situ analysis of photo ablation imprints on PMMA surfaces, and focus reconstruction from wavefront measurements,- this port appears to be a powerful instrument for fast and accurate refocusing optics alignment at FLASH beamlines.

Hartmann Wave Front and Caustic Measurements at FLASH

TUPD31

Barbara Keitel, Markus Braune, Günter Brenner, Svea Kreis, Marion Kuhlmann, Elke Plönjes, Kai I. Tiedtke (DESY, Hamburg), Bernhard Floeter, Klaus Mann, Tobias Mey, Bernd Schaefer (LLG, Goettingen)

We present Hartmann wave front measurements performed at FLASH in the focused and unfocused beam, employing a compact Hartmann sensor developed by DESY/Hasylab and the Laser-Laboratorium Goettingen. This detector is adapted to the special beam properties of FLASH. The Hartmann plate divides the incoming FEL into subrays and illuminates a phosphor coated CCD chip. From lateral deviations in the beam spot pattern, the wave front for single pulses is reconstructed using a modal approach. Second moment beam parameters (e.g. beam width, divergence, waist position, waist size,...) are calculated, as well as aberrations of the optical system (*,**). We characterized the FLASH beam also by a quantitative determination of the Wigner distribution function (***). The setup, comprising an ellipsoidal mirror, a phosphor screen and a moveable CCD detector, enables the mapping of two-dimensional phase spaces corresponding to the horizontal and vertical coordinate axes, respectively. For separable beams this yields the entire Wigner distribution, offering comprehensive information about the special coherence properties, wave front, beam profiles, as well as beam propagation parameters.

** B. Flöter et al., New J. Phys. 12, 083015 (2010) ** B. Flöter et al., NIM A 635, S108-S112 (2011) *** B. Schäfer et al., NIM A 654, 502-507 (2011)*

Simultaneous Operation of a Multi Beamline FEL Facility

TUPD32

**Bart Faatz, Sven Ackermann, Valeri Ayvazyan, Winfried Decking, Christian Gruen, Karsten Klose, Frank Obier, Sven Pfeiffer, Matthias Scholz, Jens Wortmann (DESY, Hamburg),
Eugen Hass (Uni HH, Hamburg)**

The FLASH II project will add an undulator beamline and a new experimental Hall to the existing FLASH Facility. In addition to improving the radiation properties of the FEL by using seeding, one of the main goals is to double the beamtime of the facility for users. At the moment, we deliver photon pulses in 10 Hz bursts with up to 800 bunches within each RF pulse. In order not to limit parameter ranges, we will have to give those same tuning possibilities within an RF pulse for each of the users independently. For this purpose, several tests have been performed to determine the limits of the difference in beam parameters which can be delivered. We will show to what extend we can switch fast between two beamlines, how we can change photon pulse length by allowing different charges, have different energy in the two beamlines simultaneously to allow for wavelength scans for the fixed-gap undulator presently built in FLASH, while not interfering with user operation of the new beamline.

Extraction Arc for FLASH II

TUPD33

Matthias Scholz, Winfried Decking, Bart Faatz, Torsten Limberg (DESY, Hamburg)

FLASH II is an extension of FLASH, an FEL user facility at DESY, Hamburg. It uses the same linear accelerator. A fast kicker and a septum will be installed behind the last superconducting acceleration module at the FLASH linac, providing the possibility to distribute beam to the FLASH undulator beamline and through the new extraction arc into the beamline FLASH2. It is foreseen that at the end of the FLASH II extraction arc the beam can be send into two separate beamlines: The main beamline hosting undulators for SASE and space for HHG seeding, the other might serve later another beamline. The FLASH2 extraction arc was designed to mitigate the effects from coherent synchrotron radiation (CSR) like emittance and energy spread growth. The extraction arc for FLASH2 places also demands on the existing FLASH beamline which are taken into account. The lattice optimization of the arc was done using the program ELEGANT. Start to end simulations for different bunch charges including FEL simulations with GENESIS were carried out to show the feasibility of the FLASH2 extraction arc design.

Beam Optics Design of PAL XFEL

TUPD34

Heung-Sik Kang (PAL, Pohang, Kyungbuk)

The PAL XFEL lattice is a three bunch compressor lattice (3-BC lattice) with a hard x-ray FEL line at the end of 10-GeV linac and a switch line at 3-GeV point for soft X-ray FEL line. The 3-BC lattice is chosen to minimize emittance growth due to CSR. Robustness of beam optics is verified with initial conditions far from ideal like asymmetric current profile, optics mismatch, nonlinear energy chirp.

Synchronization of a Linac based Coherent THz Facility for Femtosecond Pump Probe Experiments — TUPD35

Michael Kuntzsch, Michael Gensch, Venkatesh Mamidala, Fabian Roeser (HZDR, Dresden), Michael Bousonville, Holger Schlarb, Nikola Stojanovic (DESY, Hamburg)

The superconducting radiofrequency (SRF) electron accelerator ELBE at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) is currently upgraded with an SRF Gun and a femtosecond (fs) electron beamline to enable continuous wave operation with bunch charges of up to 1 nC and bunch durations down to 100 fs (RMS). The new femtosecond electron beamline will be used to drive two coherent THz sources and one X-ray source based on Thomson scattering. The two different THz sources, one narrow bandwidth undulator source and one broad bandwidth coherent transition/diffraction source, are guided into a dedicated THz Laboratory where they can be combined with various fs-laser systems. For the planned THz pump laser probe experiments, synchronization of the external pump-probe lasers on the fs- level is essential. Our approach is based on an optical synchronization system, adapted from a similar system installed at FLASH [*]. That system will be installed in collaboration between DESY and HZDR. In this contribution we will discuss the layout of the synchronization scheme and first ideas for measurements of the arrival time jitter of the THz pulses to evaluate the achieved degree of timing stability.

** F.Loehl, H.Schlarb et. al."Sub-10 femtosecond stabilization of a fiber-link using a balanced optical cross-correlator", proceedings of PAC2007, Albuquerque, USA, JUN 25-29 2007, FR0AC04.*

Variation of Beam Arrival Timing at SACLA — TUPD36

Takashi Ohshima, Shin-ichi Matsubara (JASRI/SPring-8, Hyogo), Hirokazu Maesaka, Yuji Otake (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo)

The user operation of SACLA was started on March 2012. In this machine, it is a key issue to deliver stable timing signals (better than 30 fs) to the beam monitor units and apparatus of XFEL users. Since the arrival timing change of the X-ray at an experimental station depends on that of the electron beam, we measured the arrival timing of the electron beam by comparing an rf reference signal and a beam induced signal from an rf beam position monitor (rf bpm). A standard deviation of the arrival timing of the bpm was around 70 fs averaged in 100 beam-shots. The timing signal also changes by a drift of the rf reference signal, and this change leads to the measurement error. To evaluate this contribution, we measured difference of the arrival timings between two bpms located at the entrance and the exit of a beamline which has 18 ID units having the rf bpm, each. The difference corresponding to the reference time drift was less than 100 fs p-p in a day. We can measure the arrival timing of the X-ray with a resolution of less than 100 fs which is acceptable level in the current stage.

Upgrade of a Precise Temperature Regulation System for the Injector at SACLA — TUPD37

Teruaki Hasegawa, Takao Asaka, Takahiro Inagaki, Hirokazu Maesaka, Yuji Otake, Kazuaki Togawa (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo), Sunao Takahashi, Toru Fukui (JASRI/SPring-8, Hyogo)

A precise temperature regulation system for the injector at SACLA is being upgraded. To make stable operation of the SACLA, it is indispensable to achieve extremely high stability of the accelerator's components. At the beam commissioning, it has become clear that even a tiny fluctuation in the cooling water temperature, such as 0.1 K, for RF cavities of the injector can significantly influence on lasing stability. Although the existing temperature control system has been able to keep temperature stability of the cavity less than 0.08 K by using an ON-OFF alternatively heating method with a pulse width modulation, a laser power fluctuation has been observed, which has a strong correlation with the cavity temperature. An improvement in temperature stability for this system is expected by replacing a PLC module to a temperature controller with an extremely high temperature resolution of 0.001 K. We will be applying continuous level control of a heater with the DC power supply. This system will dramatically improve our lasing stability. This paper describes the temperature control scheme and its performance in detail.

Stability Improvements of SACLA — TUPD38

Hirokazu Maesaka, Takao Asaka, Toru Hara, Teruaki Hasegawa, Takahiro Inagaki, Takashi Ohshima, Yuji Otake, Hitoshi Tanaka, Kazuaki Togawa (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo), Shin-ichi Matsubara (JASRI/SPring-8, Hyogo), Taichi Hasegawa, Yutaka Kano, Takuya Morinaga, Yasuyuki Tajiri, Shinichiro Tanaka, Ryo Yamamoto (SES, Hyogo-pref.)

The XFEL facility, SACLA, achieved first x-ray lasing in June 2011 and started public user operation in March 2012. In the early days after the first x-ray lasing, large drift of FEL intensity was observed and the period of FEL lasing condition to keep within acceptable intensity variation was only about an hour. We found that this short period mainly came from drifts of the rf phases and amplitudes of sub-harmonic buncher cavities and accelerator cavities in an injector section (238, 476, 1428, 5712 MHz). These rf drifts caused drifts of a peak current, a beam energy and a beam trajectory. As a result, the FEL gain was significantly degraded. Since the rf field in the cavity had a strong correlation with the cavity temperature, we improved a cavity temperature regulation system by a factor of 2 or 3 and the temperature stability was reduced to be 0.08 K peak-to-peak. In addition, we introduced an energy feedback loop for a C-band main accelerator and an orbit feedback loop for an undulator beamline. After these improvements, the FEL intensity was maintained within 10% for longer than a day.

Effect of Active Fibre Stabilization on Carrier Phase Stability — TUPD39

Trina Tsao-Tin Ng, Steven Jamison (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

An optical clock distribution system is being developed on the ALICE accelerator at Daresbury Laboratory. The system is based on a MLL fibre stabilization scheme* which delivers the clock signal with ultrashort optical pulses over an actively stabilized optical fibre. While these schemes stabilize the pulse transit time through fibre, they do not necessarily control the optical carrier. The ability to stabilize both the carrier and envelope phase in these systems could give higher resolution current envelope stabilized systems while continuing to deliver ultrashort pulses for use at delivery sites. We report here on a carrier phase detector to investigate the carrier-envelope phase walk-off in fibre distribution systems and how it is affected by active stabilization of the fibre. The phase monitor uses polarisation rotation associated with sub-wavelength delays in the fibre to detect changes in the carrier phase of ultrashort pulses. We present here studies of the carrier phase stability in an actively stabilized fibre link and its implications on the feasibility of stabilizing both carrier and envelope phase in pulsed synchronisation systems.

** S. Schulz et. al., Progress towards a permanent optical synchronization infrastructure at FLASH, Proc. of FEL 2009, Liverpool, UK, WEPC72 (2009).*

Beam Feedback System using BPM Readout for Improving FEL Power Stability in KU-FEL — TUPD40

Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Ryota Kinjo, Takuya Komai, Kai Masuda, Hani Hussein Negm, Hideaki Ohgaki, Mohamed Omer, Marie Shibata, Kyohei Shimahashi, Taro Sonobe, Konstantin Torgasin, Kyohei Yoshida, Heishun Zen (Kyoto University, Kyoto)

As improving the electron beam stability of KU-FEL linac, FEL power can be stabilized much more. In that reason, the electron beam parameters such as position, energy, current etc. should be monitored precisely by using at each part of KU-FEL by using Beam Position Monitor (BPM) readout system. Six BPMs have been installed at KU-FEL. Each two BPMs are located at low & high energy section in KU-FEL, respectively. The others are located before & after the undulator. We have already developed beam position monitoring system, which is consisted of 4-button type BPM, a super-heterodyne detector, and CAMAC-ADC controlled by Labview-based PC. We have already gotten basic information of electron beam position at each part in KU-FEL. Beam feedback system using this BPM readout system will be developed in near future to control electron beam parameters. In this conference, the BPM Readout System and Beam Feedback System in KU-FEL to improve the FEL power stability will be presented.

Strategies for Refinement of Cavity for Triode Type Thermionic RF Electron Gun — TUPD41

Konstantin Torgasin, Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Ryota Kinjo, Kai Masuda, Kazunobu Nagasaki, Hani Hussein Negm, Hideaki Ohgaki, Mohamed Omer, Marie Shibata, Kyohei Shimahashi, Kyohei Yoshida, Heishun Zen (Kyoto University, Kyoto)

The FEL radiation production requires temporal stability of electron beam energy. The latter depends directly on the quality of electron gun. The KUFEL(Kyoto University- FEL) facility uses a thermionic 4.5 cell S-band RF gun for electron beam generation. The main disadvantage of using a thermionic RF gun is the effect of backstreaming electrons, which heats up the cathode material during operation and causes energy drop. An additional cavity, triode cavity, for RF gun was designed and fabricated in order to control the electron injection and to mitigate the amount of backstreaming electrons*. The quality factor and the coupling coefficient of the triode cavity with the RF feed coaxial cable were designed to ensure the induction of the required cavity voltage and a wide frequency acceptance***. The corresponded simulations show the power reduction of back streaming electrons for 80% as well as peak current enhancement without emittance degradation**,***. However the fabricated prototype didn't match the designed parameters as tested at low power****. In this work we report the strategies for correction of deviation from simulated and tested parameters of triode cavity.

**K. Masuda et al. Prc. FEL 2009, Liverpool. **K. Masuda et al. Prc. FEL 2006, Berlin.*
****T. Shiiyama et al. Prc. FEL 2007, Novosibirsk. **** M.Takasaki et al. Prc. FEL 2010, Malmö.*

Special Lecture -1-

Chair: Tsumoru Shintake

FEL Experiments for Atoms and Atomic Clusters: From EUV to X Rays | TUOEI01

Kiyoshi Ueda (Tohoku University, Sendai)

Following FLASH operation in Germany [1], SPring-8 Compact SASE Source (SCSS) test accelerator in Japan [2] started user operation in 2008. These facilities provide EUVFEL pulses. In 2009, LCLS [3] started user operation providing the soft X-ray FEL pulses. Now it provides users with hard X-ray FEL pulses. SACLA, Japanese XFEL, lased in June 2011 in the hard X-ray regime and started user operation in March 2012. We have been studying multi-photon processes in atoms, molecules, and clusters at these FEL facilities, from EUV to X-rays, using electron and ion momentum spectroscopy [4-14]. I will describe some showcase examples at the conference, to illustrate how we users enjoy new opportunities to investigate unexplored new areas of science using these new light sources. First, I will discuss two examples for a few photon processes in atoms. The first example is the simplest nonlinear process, i.e., two photon single ionization of helium atoms by the EUV pulses at SCSS. Here, I will demonstrate that intense ultrashort pulses can be used to control the quantum processes [15]. The second example is a few photon absorption of xenon atoms by the X ray pulses at SACLA, where I will demonstrate that the xenon atom can absorb up to 4 photons in the x-ray regime of 5-5.5 keV. Second, I will discuss multi-photon processes in rare-gas atomic clusters. Namely, after frustration of the cluster photoionization and Auger decay by the increase of the ionization potential, the cluster still absorbs photons and forms nanoplasma. Then thermal emission takes place and then coulomb explosion and recombination take place. I will describe the fate of the multiply excited nanoclusters based on our ion and electron spectroscopy data both in the EUV and X-ray regimes. I am grateful to all the collaborators who are co-authors of Refs. [4-15] and who are on SACLA campaigns.

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The work is supported by X-ray Free Electron Laser Utilization Research Project of MEXT.

FEL Technology -1- : Gun, Injector, Accelerator

Chair: Hans-Heinrich Braun

APEX Initial Commissioning Results — WEOAI01

Daniele Filippetto, Fernando Sannibale, Barry Bailey, Kenneth Michael Baptiste, John Byrd, Carl William Cork, John Corlett, Stefano De Santis, Scott Dimaggio, Lawrence Doolittle, Jennifer Doyle, Paul J. Emma, Gang Huang, Hanjing Huang, Tobin Dean Kramasz, Richard Lellinger, Eric Norum, Howard A. Padmore, Christos Frantzis Papadopoulos, Chris Pappas, Gregory James Portmann, David Garcia Quintas, John William Staples, Massimiliano Vinco, Russell Wells, Max Zolotorev, Frank Zucca (LBNL, Berkeley, California), Conor Michael Pogue (NPS, Monterey, California)

APEX the Advanced Photo-injector EXperiment at LBNL is devoted to the development of a MHz-class repetition rate high-brightness electron injector for X-ray FELs. APEX is based on a novel room-temperature 186 MHz RF gun operating in CW mode in conjunction with high quantum efficiency photocathodes capable of the required repetition rates with commercial lasers. APEX is organized in 3 phases. Phase 0 includes the demonstration of several important milestones for the project. The gun must be conditioned at full RF power in CW mode; the vacuum performance, directly impacting the lifetime of photocathodes, needs to be characterized; and different photocathodes will be tested at full repetition rate at the nominal gun energy of 750 keV. In Phase I, a new suite of beam diagnostics will be added to characterize the electron beam at the gun energy and at full repetition rate. In Phase II, a pulsed linac will be added for accelerating the beam at ~30 MeV to reduce space charge effects and measure the brightness performance of the gun when integrated in an injector scheme. Phase 0 is presently under commissioning and the first experimental results from this phase are presented.

This work was supported by the Director of the Office of Science of the US Department of Energy under Contract no. DEAC02-05CH11231.

Photocathodes at FLASH — WEOA02

Siegfried Schreiber, Ingo Hansen, Sven Lederer, Hans-Hinrich Sahling (DESY, Hamburg), Paolo Michelato, Laura Monaco, Daniele Sertore (INFN/LASA, Segrate (MI))

Since several years, caesium telluride photocathodes are successfully used in the photoinjector of the Free-Electron-Laser FLASH at DESY, Germany. They show a high quantum efficiency and long lifetime and produce routinely thousands of bunches per second with a single bunch charge mostly in the range of 20 pC to 3 nC. Recent studies on lifetime, quantum efficiency, darkcurrent, and operating experience is reported.

Machine Protection for Single-Pass FELs — WEOA03

Lars Froehlich (ELETTRA, Basovizza)

The linacs driving modern single-pass FELs carry electron beams of unprecedented brightness. Their average power ranges from few watts to hundreds of kilowatts. At the same time, these machines are equipped with unusual amounts of instrumentation that need to be protected from beam losses. The FEL process itself depends crucially on the precision of the magnetic field inside undulator structures that are prone to demagnetization under radiation exposure. This combination makes machine protection for FELs both a necessity and a challenge. The talk gives an overview of typical hazards and of machine protection strategies adopted at FELs in various laboratories.

Time-Resolved Images of Coherent Synchrotron Radiation Effects in the LCLS First Bunch Compressor — WEOA04

**Christopher Behrens (DESY, Hamburg), Paul J. Emma (LBNL, Berkeley, California),
Zhirong Huang, Feng Zhou (SLAC, Menlo Park, California)**

The Linac Coherent Light Source (LCLS) is an x-ray Free-Electron Laser (FEL) facility now in operation at SLAC. One of the limiting effects on electron beam brightness is the coherent synchrotron radiation (CSR) generated in the bunch compressor chicanes, which can significantly dilute the bend-plane (horizontal) emittance. Since simple emittance measurements* do not tell the full story, we would like to see the time-dependent CSR-kicks along the length of the bunch. We present measured images and simulations of the effects of CSR seen on an intercepting beam screen just downstream of the LCLS BC1 chicane while powering a skew quadrupole magnet near the center of the chicane [ ]. The skew quadrupole maps the time coordinate of the pre-BC1 bunch onto the vertical axis of the screen, allowing the time-dependent CSR-induced horizontal effects to become clearly visible.

** K. Bane et al., Phys. Rev. ST Accel. Beams 12, 030704 (2009).*

*** K. Bertsche, P. Emma, O. Shevchenko, "A Simple, Low Cost Longitudinal Phase Space Diagnostic", PAC'09, Vancouver, BC, Canada, 2009.*

We thank the US Department of Energy under contract number DE-AC02-76SF00515.

Beam Physics for FEL

Chair: Massimo Ferrario

Single-shot Reconstruction of Beam Microbunching by Phase-retrieval of Coherent Transition Radiation images — WEOBI01

Agostino Marinelli, Gerard Andonian, Jianwei (John) Miao, Finn O'Shea, James Rosenzweig (UCLA, Los Angeles, California), Michael P. Dunning, Carsten Hast, Erik Hemsing, Stephen Weathersby, Dao Xiang (SLAC, Menlo Park, California)

We describe a technique for the reconstruction of the transverse spatial distribution of microbunching in a relativistic electron beam, and report on its experimental demonstration at the NLCTA test accelerator at SLAC. This technique relies on an oversampling phase retrieval method on a far field coherent optical transition radiation image. This method has a number of applications as an diagnostic for the FEL amplification process and in the imaging of compressed beams. We report on the experimental demonstration of this method in the case of microbunching generated by the interaction of an external laser pulse with an electron beam traversing an undulator.

Optical Diffraction Radiation Interference as a Non-intercepting Emittance Measurement for High Brightness and High Repetition Rate Electron Beam — WEOB02

Alessandro Cianchi, Luciano Catani, Enrica Chiadroni (INFN-Roma II, Roma),
Vladimir Balandin, Nina Golubeva, Katja Honkavaara, Gero Kube (DESY, Hamburg),
Michele Castellano (INFN/LNF, Frascati (Roma))

Conventional intercepting transverse electron beam diagnostics, as the one based on Optical Transition Radiation (OTR), cannot tolerate high power beams without significant mechanical damages of the diagnostics device. Optical Diffraction Radiation (ODR), instead, is an excellent candidate for the measurements of the transverse phase space parameters in a non-intercepting way. One of the main limitation of this method is the low signal to noise ratio, mainly due to the synchrotron radiation background. This problem can be overcome by using ODRI (ODR Interference). In this case the beam goes through slits opened in two metallic foils placed at a distance shorter than the radiation formation zone. Due to the shielding effect of the first screen a nearly background-free ODR interference pattern can be measured allowing the determination of the beam size and the angular divergence. We report here the result of the first measurements of the beam emittance using ODRI carried out at FLASH (DESY). Our result demonstrate the unique potential of this technique suitable to be used as not intercepting diagnostic in every machine with high brightness and high repetition rate electron beam.

Laser-induced CSR : Seeding of the Microbunching Instability in Storage Rings — WEOB03

Eléonore Roussel, Serge Bielawski, Clement Evain, Christophe Szwaj, Takanori Tanikawa (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Marc Le Parquier (CERLA, Villeneuve d'Ascq), Heishun Zen (Kyoto University, Kyoto), Masahito Hosaka, Naoto Yamamoto (Nagoya University, Nagoya), Masahiro Adachi, Masahiro Katoh (UVSOR, Okazaki)

Microbunching instability arises both in Linear Free Electron Laser and in storage rings due to the interaction of the electrons with their own radiation, mainly in dipoles (bending magnets in storage rings and chicanes in linear FEL). This instability leads to the formation of micro-structures in the longitudinal phase-space (typically in the mm range in the longitudinal profile) and limits the performances of these accelerator based ligth sources. We show that the interaction of the electron bunch with an external laser pulse, whose envelope is modulated at a Terahertz frequency (associated to mm wavelength), allows to investigate the dynamics of electron bunches in storage rings during the micro-bunching instability. Here, we achieve experiments at UVSOR-II* around the CSR instability threshold. We also perform numerical calculations using a one-dimensional Fokker-Planck-Vlasov modeling taking into account CSR wakefield. This seeding mechanism highlights that CSR depends on the wakefields for some ranges of excited wavenumber.

** C. Evain et al., Phys. Rev. ST Accel. Beams 13, 090703 (2010); S. Bielawski et al., Nature Physics 4, 390 (2008).*

First Demonstration of Optical Frequency Shot-Noise Suppression in Relativistic Electron-Beams and implications to FEL Coherence Enhancement — WEOB04

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

We report first demonstration of optical frequency current shot-noise suppression in a relativistic e-beam. The effect was demonstrated by measuring sub-linear growth of OTR Radiation as a function of current. This finding indicates that the beam charge homogenizes, and its distribution becomes sub-Poissonian. The effect is made possible by collective Coulomb interaction between the electrons of a cold intense beam during beam drift, and is essentially a process of longitudinal beam-plasma oscillation*. Suppression of beam current noise below the classical "shot-noise" level has been known in the microwave tubes art**. This is the first time that it is demonstrated in the optical regime. We predict that the scheme can be extended to the XUV and possibly to shorter wavelengths with further development of technology. The fundamental current shot-noise determines the level of incoherent spontaneous radiation emission from e-beam radiators and SASE-FELs. Suppressing shot-noise would make it possible to attain spontaneous emission sub-radiance *** and surpass the shot-noise coherence limits of seed-injected FELs, approaching fundamental (Schawlow-Towenes****) coherence limits of lasers.

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****A. Dicke, Phys. Rev. 93, 99 (1954). ****A.L.Schawlow and C.H.Townes, Phys.Rev., 112, 1940.*

We acknowledge support of the Israel Sciience Foundation grant

THz and Long Wavelength FELs

Chair: Ulf Lehnert

The Infrared and THz User Facility FELIX in Nijmegen | WEOCI01

Giel Berden, Britta Redlich (FOM Rijnhuizen, Nieuwegein), Alexander van der Meer (FOM Rijnhuizen, Nieuwegein; Radboud University, Nijmegen), Rienk Jongma, Wim J. van der Zande, Frans Wijnen (Radboud University, Nijmegen)

The infrared and THz user facility FELIX at the Radboud University Nijmegen will comprise two free electron lasers - namely FLARE, the recently commissioned THz laser at Nijmegen, as well as the FELIX and FELICE laser beam lines, currently relocated from the FOM Institute to Nijmegen. The FELIX (Free Electron Lasers for Infrared eXperiments) facility will offer the international user community a unique wavelength range covering the mid- and far-infrared as well as the THz range from 3 to 1500 micron (3300 - 6 cm^{-1} or 100 THz - 0.2 THz). We will discuss the layout of this new facility including the user laboratories as well as some of the special features offered to the users including: (i) the FLARE high spectral resolution mode, (ii) the FELICE intra-cavity configuration for extreme infrared intensities and (iii) the connection of the facility with the adjacent high magnetic field laboratory (HFML). The timeline for the integration of the facility foresees a start of operation in the summer of 2013 and full operation is expected for the beginning of 2014.

Status of the KAERI Table-Top THz Free-Electron Laser Development | WEOC02

Young Uk Jeong, Sangyoon Bae, Byung Heon Cha, Boris Gudkov, Kyu Ha Jang, Kyung Nam Kim, Kitae Lee, Sergey Vladimirovich Miginsky, Jungho Mun, Seong Hee Park, Nikolay Vinokurov (KAERI, Daejon), Sunjeong Park (Kyungpook National University, Daegu)

Korea Atomic Energy Research Institute is under development of a table-top terahertz (THz) free electron laser (FEL) driven by a conventional microtron accelerator. The THz FEL is composed of a compact variable-period helical undulator and a cylindrical-waveguide resonator with a mesh outcoupling mirror to achieve a small scale. The target wavelength and average power of the system are 400-600 um and 1 W. The energy and peak current of the microtron is designed to be 6.5 MeV and 1 A. We fabricated a compact microtron accelerator including a thermionic RF gun, a magnetron and a modulator having a maximum repetition rate of 200 Hz. We fabricated a variable-period helical undulator having tunable periods of 23-26 mm while keeping the on-axis field strength of 1 T, and total length of 700-800 mm. A compact beamline with two 45-degree bending magnets and 6 permanent-magnet quadrupoles has been designed to transport optimal electron beams to the variable-period helical undulator. A cylindrical-waveguide resonator having a mesh outcoupling mirror and a full mirror with the function of beam dump will decrease the size of the FEL. The size of the FEL is expected to be 2.3 m x 1.6 m.

This work was supported by the World Class Institute (WCI) Program of the NRF funded by the MEST (NRF Grant Number: WCI 2011-001).

The Novosibirsk Terahertz FEL Facility - Current Status and Future Prospects — WEOC03

Oleg A. Shevchenko, Vladimir Sergeevich Arbuzov, Konstantin Chernov, Evgeny Dementyev, Boris Dovzhenko, Yaroslav V. Getmanov, Eduard Iosifovich Gorniker, Boris Aleksandrovich Knyazev, Evegeniy I. Kolobanov, Alexey Anatolyevich Kondakov, Victor Kozak, Evgueni Kozyrev, Vitaly V. Kubarev, Gennady N. Kulipanov, Eduard Kuper, Igor Kuptsov, Grigory Yakovlevich Kurkin, Lev E. Medvedev, Leontii Mironenko, Vladimir Kirillovich Ovchar, Boris Z. Persov, Andrey Pilan, Vasiliy M. Popik, Vladimir Valeryevich Repkov, Tatiana V. Salikova, Mikhail A. Scheglov, Igor Sedlyarov, Gennady V. Serdobintsev, Stanislav S. Serednyakov, Alexander Skrinsky, Sergey Tararyshkin, Vladimir G. Tcheskidov, Nikolay Vinokurov, Maksim G. Vlasenko, Pavel Vobly, Vladimir Volkov (BINP SB RAS, Novosibirsk)

The Novosibirsk terahertz FEL facility is based on the normal conducting CW energy recovery linac (ERL) with rather complicated lattice. This is the only multiorbit ERL in the world. It can operate in three different modes providing electron beam for three different FELs. The first FEL works for users since 2003. This FEL radiation is used by several groups of scientists which include biologists, chemists and physicists. Its maximum average and peak powers are 500 W and 1MW and wavelength can be tuned from 110 up to 240 microns. The high peak and average powers are used in experiments on material ablation and biological objects modification. The second FEL is installed on the second orbit. The first lasing of this FEL was achieved in 2009. Its radiation has almost the same average and peak powers and is delivered to the same user stations as the first FEL one, but its tunability range lies between 35 and 80 microns. The third FEL will be installed on the fourth orbit. In this paper we report the latest results obtained from the operating FELs as well as our progress with the commissioning of the two remaining ERL orbits. We also discuss possible options for the future upgrade.

Accelerator Beamline Performance for the IR FEL at the Fritz-Haber-Institut Berlin — WEOC04

Hans Bluem, David Dowell, Jangho Park, Alan Murray Melville Todd (AES, Princeton, New Jersey), Lloyd Martin Young (AES, Medford, NY), Sandy Gewinner, Wieland Schöllkopf (FHI, Berlin)

An electron accelerator and beamline for an IR and THz FEL with a design wavelength range from 4 to 500 μm has been commissioned by Advanced Energy Systems at the Fritz-Haber-Institut (FHI) in Berlin, Germany, for applications in, i.a., molecular and cluster spectroscopy as well as surface science. The linac comprises two S-band standing-wave copper structures and was designed to meet challenging specifications, including a final energy adjustable in the range of 15 to 50 MeV, low longitudinal emittance (<50 keV-psec) and transverse emittance (<20 μm), at more than 200 pC bunch charge with a micro pulse repetition rate of 1 GHz. First lasing was achieved February 2012. Operational experience and measured electron beam performance will be presented.

Wednesday Poster Session

- **Oscillator and Ring FELs**
- **THz and Long Wavelength FELs**
- **Beam Physics for FEL**
- **Progress and Projects**

Free Electron Lasers in 2012 — WEPD01

Joseph Blau, Miguel Alvarez, Keith Cohn, William B. Colson, Adrian Laney, Jeffrey Wilcox (NPS, Monterey, California)

Thirty-six 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.
This work has been supported by the Office of Naval Research.

The CSU Accelerator Laboratory — WEPD03

Stephen Milton, Sandra Biedron, Theodore Burleson, Jonathan Edelen, Christopher Hall, Karen Horovitz, Auralee Morin (CSU, Fort Collins, Colorado), Luca Giannessi (CSU, Fort Collins, Colorado; ENEA C.R. Frascati, Frascati (Roma)), Peter van der Slot (CSU, Fort Collins, Colorado; Mesa+, Enschede; Twente University, Enschede)

The Department of Electrical and Computer Engineering recently received a donation of an L-band photocathode-gun and RF linear accelerator system from the University of Twente, the Netherlands. This system will be used for training and research and development of beam components. A description of the system configuration, estimated build-up schedule, and first experiments will be described.

Status of the SOLEIL Femtosecond X-ray Source — WEPD04

Olivier Marcouillé, Lodovico Cassinari, Marie-Emmanuelle Couprie, Christian Herbeaux, Philippe Hollander, Marie Labat, Claire Laulhe, Vincent Leroux, Jan Luning, Jean-Louis Marlats, Thierry Moreno, Paul Morin, Amor Nadji, Pascale Prigent, Jean-Baptiste Pruvost, Sylvain Ravy, Mathieu Gael Silly, Fausto Sirotti, Keihan Tavakoli, Daniel Zerbib (SOLEIL, Gif-sur-Yvette), Jianfeng Zhang (LAL, Orsay)

An electron bunch slicing setup is presently under construction on the SOLEIL storage ring. It is aimed to deliver 100 fs long photon pulses to two undulator-based beamlines operating with soft X-rays (TEMPO) and hard X-rays (CRISTAL). SOLEIL storage ring is equipped with a Ti:Sa laser which produces 30 fs pulses at 800 nm with a repetition rate of 2.5 kHz. The laser beam is splitted into two branches in order to provide 2 mJ to the modulator and 1 mJ as pump pulse for the CRISTAL and TEMPO end stations. Focusing optics and beam path, from the laser hutch to the inside of the storage ring tunnel are presently under finalization. The energy modulation will be done in a wiggler composed of 20 periods of 164 mm. It produces a magnetic field of 1.8 T at a minimum gap of 14.5 mm. The non-zero dispersion function present in all straight sections of the storage ring will enable to easily separate the sliced bunches from the core bunches at the beamlines' location. In this paper, we will report on the specificities of the SOLEIL setup, the status of its installation and the expected performances.

Beam Transfer Investigation from Laser Wake Field Accelerator to FEL Undulator Line — WEPD05

Alexandre Loulergue, Chamseddine Benabderrahmane, Marie-Emmanuelle Couprie, Marie Labat (SOLEIL, Gif-sur-Yvette)

Laser Wake Field Accelerator (LWFA) are able to produce high energy beams over a very short path. Just like this strong acceleration process, the beam exhibits a strong focusing (large divergence of about 1 mrad or more). The bunches are very short (typically a few fs) with a high peak current (few kA) but suffer from a large energy spread (typically 1% or more). Together, this large energy spread and large beam divergence make the matching, emittances and peak current preservation from LWFA source to FEL undulator line, very concerning. The FEL gain being very sensitive to these parameters, analytical and numerical investigations of different transfer line configurations are presented in this paper. In addition, preliminary simulations of FEL issues in the framework of LUNEX5 project are also presented.

Tsinghua Thomson Scattering X-ray Source — WEPD06

Ying-Chao Du, Huaibi Chen, Qiang Du, Jianfei Hua, Wenhui Huang, Houjun Qian, Chuanxiang Tang, Lixin Yan, Zhen Zhang (TUB, Beijing)

The Thomson scattering (or Inverse Compton scattering) of a TW ultra short laser pulse by a high brightness, relativistic electron beam has been demonstrated as a viable approach toward compact, sub-picosecond, polarized, tunable hard X-ray sources. There is a growing interest in it among scientists in various fields, due to its excellent performances. We have design, built, and tested such a source at Tsinghua University. We have produced the first light at 50keV by head-on collisions between the 800nm TW laser and the 50 MeV electron beam. The X-ray signals were captured and optimized with a microchannel plate detector. The maximum resultant yield was found to be 1X10^6/pulse with 200pC electron beam and 300mJ laser pulse. The angular distribution of intensity was measured with an EMCCD using a CsI scintillator, and the local spectrum was measured using various thickness Si absorbers. The observed angular distribution of intensity and energy spectrum were found to consistent with imulations. In addition, we preliminarily demonstrated the X-ray the imaging with the generated X-ray.

Status of the FLASH II Project — WEPD07

Katja Honkavaara (DESY, Hamburg)

The extension of the FLASH facility at DESY (Hamburg, Germany) - FLASH II Project - is under way. The extension includes a second undulator line with variable gap undulators to allow a more flexible operation, and a new experimental hall for photon experiments. The present FLASH linac will drive the both undulator beamlines. Civil construction of the new buildings has been started in autumn 2011 continuing in several steps until early 2013. The design of the new beamline including the extraction from the FLASH linac and the undulator is mostly finished, and the manufacturing of the components is under way. The mounting of the beamline will start in autumn 2012, and the commissioning with beam is scheduled for second half of 2013. We report here the design of the different phases of the project including the time schedule up to the first user operation.

Upgrades of the Photoinjector Laser System at FLASH — WEPD08

Siegfried Schreiber, Christian Gruen, Olaf Hensler, Karsten Klose, Torsten Schulz, Martin Staack (DESY, Hamburg), Matthias Gross, Guido Klemz, Gerald Koss (DESY Zeuthen, Zeuthen), Ingo Horst Templin, Ingo Will, Holger Willert (MBI, Berlin)

The photoinjector of FLASH uses an RF gun equipped with caesium telluride photocathodes illuminated by appropriate UV laser pulses as a source of ultra-bright electron beams. The superconducting accelerator of FLASH is able to accelerate a 0.8 ms long train of thousands of electron bunches in a burst mode. This puts special demands on the design of the electron source, especially the laser system. The construction of a second undulator beamline FLASH2 has started. The pulse train will be divided into two parts to serve both beamlines simultaneously. Since experiments with the FLASH soft X-ray beam need flexibility, we plan to use two laser systems each serving one beamline. This makes it possible to deliver two trains with different properties in charge, number of bunches, and bunch spacing in the same RF pulse. This also required an upgrades of the laser beamline design. We report on improvements of the laser beamline and first tests operating two lasers simultaneously at FLASH.

Scheme for Generating and Transporting THz Radiation to the X-ray Experimental Hall at the European XFEL — WEPD09

Winfried Decking, Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin, Igor Zagorodnov (DESY, Hamburg)

We consider generation of THz radiation from the spent electron beam downstream of the SASE2 undulator in the electron beam dump area. The THz output must propagate at least for 250 meters through the photon beam tunnel to the experimental hall to reach the SASE2 X-ray hutches. We propose to use an open beam waveguide such as an iris guide as transmission line. In order to efficiently couple radiation into the iris transmission line, generation of the THz radiation pulse can be performed directly within the iris guide. The line transporting the THz radiation to the SASE2 X-ray hutches introduces a path delay of about 20 m. Since THz pump/X-ray probe experiments should be enabled, we propose to exploit the European XFEL baseline multi-bunch mode of operation, with 222 ns electron bunch separation, in order to cope with the delay between THz and X-ray pulses. We present start-to-end simulations for 1 nC bunch operation-parameters, optimized for THz pump/X-ray probe experiments. Detailed characterization of the THz and SASE X-ray radiation pulses is performed. Highly focused THz beams will approach the high field limit of 1 V/atomic size.

Conceptual Design of an Undulator System for a Dedicated Bio-imaging Beamline at the European X-ray FEL — WEPD10

Gianluca Geloni, Vitali Kocharyan, Evgeny Saldin (DESY, Hamburg)

We describe a future possible upgrade of the European XFEL consisting in the construction of an undulator beamline dedicated coherent diffraction imaging of complex molecules. Crucial parameters are photon energy range, peak power, and pulse duration. The peak power is maximized in the photon energy range between 3 keV and 12 keV by the use of a very efficient combination of self-seeding, fresh bunch and tapered undulator techniques. The unique combination of ultra-high peak power of 1 TW in the entire energy range, and ultrashort pulse duration tunable from 2 fs to 10 fs, would allow for single shot coherent imaging of protein molecules with size larger than 10 nm. Also, the new beamline would enable ima ing of large biological structures in the water window, between 0.3 and 0.4 keV. In order to make use of standardized components, at present we favor the use of SASE3-type undulator segments. The number segments, 40, is determined by the tapered length for the design output power of 1 TW. The present plan assumes the use of a nominal electron bunch with charge of 0.1 nC. Experiments would be performed without interference with the other three undulator beamlines.

Dependence of FEL Intensity on the Available Number of Undulators for FERMI FEL-1 — WEPD11

Enrico Allaria (ELETTRA, Basovizza)

FERMI@Elettra is a free electron laser user facility based in Trieste Italy. The first FEL line (FEL-1), based on the high gain harmonic generation scheme, covers the spectral range from about 80nm down to 20nm with high quality FEL pulses and started producing FEL light for user operations in 2011. FERMI FEL-1 radiator is composed by six undulators 2.4meter long with the available space for additional two undulators. In this work we investigate the impact of additional undulators on the FEL performance in the case of FERMI FEL-1. We finally extend the work studying the dependence of the FEL power as a function of the length of the radiator for FELs based on the high gain harmonic generation scheme showing that for typical parameters there is a linear dependence.

Status of the DELTA Short-Pulse Facility — WEPD12

Holger Huck, Mohammed Bakr, Markus Höner, Shaukat Khan, Robert Molo, Andre Nowaczyk, Andreas Schick, Peter Ungelenk, Maryam Zeinalzadeh (DELTA, Dortmund)

Since 2011, a new Coherent Harmonic Generation (CHG) source* is under commissioning at the 1.5 GeV storage ring DELTA. Following first experiments using the fundamental wavelength of a Ti:sapphire laser for seeding a non-symmetrical optical klystron, 400 nm pulses from a second-harmonic conversion unit (SHG) are used since early 2012. With the radiator tuned to the second harmonic thereof, 200 nm CHG pulses are routinely observed. In order to detect higher harmonics and to proceed to a seed wavelength of 266 nm, an evacuated diagnostics beamline is under construction. Additionally, an existing VUV beamline is being upgraded to allow for the detection of the CHG pulses and their utilization in pump-probe experiments. Furthermore, a dedicated THz beamline provides valuable information about the laser-induced energy modulation of the electrons. In this paper, the status of the project and technical details will be presented.

** Huck et.al., FEL 2011*

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Beam Dynamics Design of the CLARA FEL Test Accelerator — WEPD13

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

CLARA (Compact Linear Advanced Research Accelerator) is a proposed FEL test facility at Daresbury Laboratory in the UK. This is proposed to be a 250 MeV normal-conducting linac capable of producing short, high brightness electron bunches which can be synchronised with an external source. CLARA will build upon the EBTF photinjector under construction at Daresbury, utilising the S-band RF photoinjector. Bunch compression will be achieved via two methods; a variable magnetic chicane with fourth harmonic cavity, or velocity bunching in the low energy regime. CLARA will be capable of providing beam for various novel FEL schemes.

FEL Performances of the French LUNEX5 Project — WEPD14

Clement Evain, Serge Bielawski (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Guillaume Lambert, Agustin Lifschitz, Victor Malka (LOA, Palaiseau), Chamseddine Benabderrahmane, Marie-Emmanuelle Couprie, Marie Labat, Alexandre Loulergue, Takanori Tanikawa (SOLEIL, Gif-sur-Yvette)

LUNEX5 is a French FEL test facility project based on two types of accelerators: a Conventional Linear Accelerator (CLA) and a Laser WakeField Accelerator (LWFA). The FEL performances will be presented at 20 nm, 17 nm and 12 nm, wavelengths of interest for the pilot experiments. Results are obtained with GENESIS simulations in time-dependent mode. With the CLA, two energies are considered. At 400 MeV, the nominal energy, the FEL performances are compared with two configurations : Echo Enabled Harmonic Generation (EEHG) and High Gain Harmonic Generation (HGHG) with High Harmonic in Gaz (HHG). As an intermediate step at 220 MeV, EEHG is also studied at 17 m using 800 nm laser seeds. In parallel, LWFA FEL performances are presented as a function of the electron bunch characteristics, in particular the bunch length and the energy-spread.

Beam Dynamics Simulation Studies of the Proposed Turkish Accelerator Center SASE-FEL Facility — WEPD15

Hatice Duran Yildiz (Ankara University, Tandogan/Ankara), Ayse Bat (Dumlupinar University, Kutahya), Osman Caglar Akin (Fatih University, Istanbul), Gokhan Coskun (Kahramanmaras Sutcu Imam University, Kahramanmaras), Ilker Yildiz (Metu, Ankara)

Beam dynamics simulations of the proposed Turkish Accelerator Center Self Amplified Spontaneous Emission Free Electron Laser Facility by using 1 GeV electron energy with 2 kA peak current and 1 nC bunch charge is studied. The codes Superfish and Astra are used to simulate electron bunch behaviour in the superconducting cavities in the gun and further beamline. 1.5 - cell superconducting cavity is used while we consider 40 MV/m for accelerating gradient and 0.178 T magnetic field for solenoid. Elegant Code is used to track particle distribution after bunch compressor through the undulator entrance. Magnetic design of the Undulator is done by using Radia-Mathematica magnetic design Code and Hybrid undulator is chosen with 12 mm gap and 15 mm undulator wavelenth. SASE free electron laser is modelled with the Genesis 1.3 Code with time dependency. In this study, electron beam, accelerator, and laser optimized are given. This laser can be used in many applications such as material sciences especially surface characterisations, magnetic material researches and biological and chemistry applications such as investigation of chemical analysis with coherent x-rays.

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Funding Agency: Ankara University

LCLSII Long-range CSR Cancellation to Optimize Transverse Emittance — WEPD16

Yipeng Sun, Zhirong Huang, Tor Raubenheimer (SLAC, Menlo Park, California)

In this paper, some possible cancellation of CSR impact on transverse emittance between different bending systems of LCLSII is studied. By tuning the phase advance between these bending systems, such as bunch compressors and dogleg beamlines, the final projected transverse emittance may be optimized.

Observation of Dispersive Shot Noise Suppression at Optical Wavelengths — WEPD17

**Daniel Ratner, Gennady Stupakov (SLAC, Menlo Park, California),
Ji Qiang (LBNL, Berkeley, California)**

Control of collective properties is an important aspect of FEL design. In particular, shot noise affects accelerator performance by driving instabilities or by competing with FEL seeding. We present experimental observations of dispersive shot noise suppression at the Linac Coherent Light Source. By adjusting the dispersive strength of the first bunch compressor chicane, we observe a decrease in the optical transition radiation emitted from a downstream foil. We show agreement between the experimental results, theoretical models, and 3D particle simulations.

Potential for Laser-induced Microbunching Studies at ASTA — WEPD18

Alex Lumpkin, Jinhao Ruan (Fermilab, Batavia), John Byrd, Russell Wilcox (LBNL, Berkeley, California)

Investigations of the laser-induced microbunching as it is related to time-sliced electron-beam diagnostics and high-gain-harmonic generation (HGHG) free-electron lasers using bright electron beams are proposed for the Advanced Superconducting Test Accelerator (ASTA) facility at Fermilab. Initial tests at 40-50 MeV with an amplified 800-nm seed laser beam co-propagating with the electron beam through a short undulator (or modulator) tuned for the third-harmonic resonance condition followed by transport through a subsequent chicane will result in energy modulation and z-density modulation (microbunching), respectively. The latter microbunching will result in generation of coherent optical or UV transition radiation (COTR, CUVTR) at a metal converter screen which can reveal slice beam size, centroid, and energy spread. Additionally, direct assessment of the microbunching factors related to HGHG by measurement of the COTR intensity and harmonic content after the chicane as a function of seed laser power and beam parameters will be done. These experiments will be performed using the ASTA 1-MHz-rate micropulse train for up to 1ms which is unique to test facilities in the USA.

Operated by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the United States Department of Energy.

Design of a Proof-of-principle Experiment Toward the Generation of Coherent Optical Radiation using a 4-MeV Electron Beam — WEPD19

Yin-E Sun (Fermilab, Batavia), Philippe Regis-Guy Piot (Fermilab, Batavia; Northern Illinois University, DeKalb, Illinois), William Graves (MIT, Cambridge, Massachusetts), Daniel Mihalcea (Northern Illinois University, DeKalb, Illinois)

Transverse-to-longitudinal phase space exchange techniques have open new possibilities toward shaping the temporal distribution of electron bunches. Recently, the combination of such exchange methods with structured, e.g. field-emission, cathodes was suggested as the backbone of compact coherent short-wavelength sources [W. S. Graves, *et al.*, ArXiv:1202.0318 (2012)]. In this paper, we present the design and numerical investigation of a proof-of-principle experiment to produce coherent optical transition radiation using a ~4-MeV electron bunch. The optically-modulated bunch is produced from a structured cathode combined with a transverse-to-longitudinal phase space exchanger. The current status of the experiment are also summarized.

This work was supported by DOE grants DE-AC02-07CH11359, DE-FG02-08ER41532, and DARPA grant N66001-11-1-4192.

Time-Sliced Emittance and Energy Spread Measurements at FERMI@Elettra — WEPD20

Giuseppe Penco (ELETTRA, Basovizza)

FERMI@Elettra is a single pass seeded FEL based on the high gain harmonic generation scheme, producing intense photon pulses at short wavelengths. For that, a high-brightness electron beam is required, with a small uncorrelated energy spread. In this paper, we present a detailed campaign of measurements aimed at characterizing the electron-beam time-sliced emittance and energy spread, both after the first magnetic compressor and at the end of the linac.

~~Start-to-end Simulation of a Next Generation X-ray FEL Light Source using the Real Number of Electrons~~ — ~~WEPD21~~ withdrawn

Ji Qiang, John Corlett, Paul J. Emma, Chad Eugene Mitchell, Christo Frantzis Papadopoulos, Gregory Penn, Matthias Reinsch, Robert D. Ryne, Marco Venturini (LBNL, Berkeley, California)

Start-to-end simulation plays an important role in design and optimization of next generation light sources. In this paper, we will present start-to-end (from the photocathode to the end of undulator) simulations of a high repetition rate next generation soft X-ray light source proposed at LBNL with the real number of electrons (300 pC) using the multi-physics parallel beam dynamics code IMPACT. We will discuss numerical methods and physical models used in the simulation. We will also present some preliminary simulation results of a beam transporting through photoinjector, beam delivery system, and final X-ray FEL radiation.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Simulation Study of Electron Response Amplification in Coherent Electron Cooling — WEPD22

Yue Hao, Vladimir N. Litvinenko (BNL, Upton, Long Island, New York),
Andrey Elizarov (SUNY SB, Stony Brook, New York)

In Coherent Electron Cooling (CEC), it is essential to study the amplification of the electron response to a single ion in the FEL process, in order to gain maximum efficiency of the cooling effects. In the test stage, viz., CEC Proof of Principle experiment, the economical setup requires more consideration since the ion beam travels along with the electron beam. In this paper, we use Genesis to simulate the amplified electron beam response of single ion in FEL amplification process, which acts as 'Green function' of the FEL amplifier for various electron beam longitudinal profiles.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE--AC02--98CH10886 with the U.S. Department of Energy.

Coupling of Particle Distributions into an FEL Amplifier for Coherent Electron Cooling — WEPD23

Ilya V. Pogorelov, George I. Bell, David Leslie Bruhwiler, Brian T. Schwartz, Stephen Davis Webb (Tech-X, Boulder, Colorado), Yue Hao, Vladimir N. Litvinenko, Gang Wang (BNL, Upton, Long Island, New York)

Next-generation ion colliders will require effective cooling of high-energy ion beams. Coherent electron cooling (CeC) can in principle cool relativistic ion beams on orders-of-magnitude shorter time scales than other techniques*. Particle-in-cell (PIC) simulations of a CeC modulator, performed with the VORPAL framework, generate macro-particle distributions with subtle but important phase space correlations. It is essential to couple these macro-particles into a 3D simulation code for the free-electron laser (FEL) amplifier stage of the CeC process, while retaining all details of the 6D phase space coordinates. For this purpose, we implemented an alternative approach based on particle-clone pairs**. This approach allows for self-consistent treatment of shot noise and spontaneous radiation, with no need for quiet-start initialization of the FEL macro-particles' ponderomotive phase. We present comparisons between fully 3D amplifier modeling based on the particle-clone approach and GENESIS simulations where distribution of bunching parameter was used as input.

** V.N. Litvinenko and Y.S. Derbenev, Phys. Rev. Lett. 102, 114801 (2009). ** V.N. Litvinenko, "Macro-particle FEL model with self-consistent spontaneous radiation" (2002), unpublished*

This work is funded by the US DOE Office of Science, Office of Nuclear Physics. Resources of the National Energy Research Scientific Computing (NERSC) center were used.

CSR in Dipoles Studied by using Floating Boundary FDTD — WEPD24

Hiroyuki Hama, Fujio Hinode, Nuan-Ya Huang, Shigeru Kashiwagi, Masayuki Kawai, Toshiya Muto, Ikurou Nagasawa, Ken-ichi Nanbu, Yoshinobu Shibasaki, Ken Takahashi (Tohoku University, Sendai)

A project, t-ACTS (test Accelerator as Coherent THz Source) has been developed at Tohoku University. Injecting bunch train consisted of femto-second short electron pulse from a thermionic RF gun into a compact isochronous ring, coherent synchrotron radiation (CSR) from bending magnets is expected to be intense broadband radiation in THz frequency region. Although the bunch charge will be not much higher than ~20 pC, because of thermionic RF gun, the effect of CSR wake on the circulating bunch may be significant. In addition, the CSR effect in 3-D space has to be well evaluated because the beam energy of less than 50 MeV in t-ACTS is much lower than other storage rings in which the CSR effect has been well studied so far. In order to simulate 3-D electromagnetic waves, we have developed a compact simulator code employing finite difference time domain (FDTD) method. The code cannot count for high frequency components in the radiation fields. However, longer wavelength such as THz - GHz region is observable, which are significant for CSR effect. Tentative simulation results for the beam will be reported.

Supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (S), Contract #20226003 and National Science Council, Taiwan, Contract # 101-2917-I-007-003.

Multi Objective Genetic Optimization of Beam Parameters for LINACs driven FELs — WEPD25

Riccardo Bartolini, Marco Apollonio, Ian Martin (Diamond, Oxfordshire)

The optimization of the beam dynamics in a Linac for free electron lasers (FELs) can be a very time consuming process, in which several parameters of the acceleration stage and of the compression system need to be varied simultaneously. Electron beam quality can also be a demanding task, and the optimization procedure is required to tackle different and often conflicting requirements. Multi-objective genetic algorithms consitute a powerful techinque potentially capable of targeting several conflicting objectives at a time. We propose an optimization strategy based on a combination of multi-objective optimization with a fast computation of the FEL performance. Specific examples for the seeded FEL of the UK New Light Source proejct will be presented.

Collective and Individual Aspects of Fluctuations in Relativistic Electron Beams for Free-Electron Lasers

WEPD26

Ryan Roger Lindberg, Kwang-Je Kim (ANL, Argonne)

Fluctuations in relativistic electron beams for free-electron lasers (FELs) exhibit both collective and individual particle aspects, similar to that seen in non-relativistic plasmas. We show that the density fluctuations are described by a linear combination of the collective plasma oscillation and the random individual motion of Debye-screened dressed particles. The relative importance of the individual to the collective motion is determined by comparing the fluctuation length scale divided by two pi with the relativistic beam Debye length. Taking into account the fact that the velocity spread is caused by both the energy spread and the angular divergence, we derive a simple formula for the minimum value of the Debye length using a solvable 1-D model. For electron beams used for x-ray self-amplified spontaneous emission (SASE) we find that the Debye length is comparable to the radiation wavelength, and that therefore the collective motion is not relevant.

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A Variety of Parameter Regimes for X-ray FEL Oscillators

WEPD27

Ryan Roger Lindberg, Kwang-Je Kim (ANL, Argonne)

The x-ray FEL oscillator (XFELO) calls for a low charge, low emittance beam at MHz repetition rate, which makes it a natural fit at energy recovery linac based facilities. After reviewing the 'canonical' XFELO parameters, we will show how using extremely low charge, low emittance beams (e.g., similar to that in **) may also be of interest to increase the repetition rate, reduce the emittance dilution in recirculation passes, or decrease the optical element radiation damage. Also interesting is the parameter set minimizing the length of the undulator and hence the pulse spacing, which makes it particularly attractive for applications to x-ray metrology with nuclear resonance***.

** K.-J. Kim, et al., 100, 244802 (2008)*
*** J.B. Rosenzweig, et al., NIMA 593, 39 (2008)*
**** B. Adams and K.-J. Kim, this conference*

Funding Agency: U.S. Dept. of Energy Office of Sciences under Contract No. DE-AC02-06CH11357

Electron Optics and Magnetic Chicane for Matching an XFEL-Oscillator Cavity into a Beamline at the European XFEL Laboratory

WEPD28

Christoph Paul Maag (DESY, Hamburg), Jörg Rossbach, Johann Zemella (Uni HH, Hamburg)

At DESY the European XFEL (X-Ray Free-Electron Laser) laboratory is currently under construction. Due to the time structure of its electron bunch trains it is in principle possible to run a FELO (Free-Electron Laser Oscillator) at the European XFEL. The major elements of a FELO are the cavity and the undulator. To couple the electron beam with the required beta functions into the cavity, a magnetic chicane and an appropriate focusing structure are considered. In this paper we discuss the lattice design of the magnetic chicane and the focusing section. We also present the results of the beam dynamics simulations performed.

Numerical Simulations of an XFELO for the European XFEL driven by a Spent Beam

WEPD29

Johann Zemella, Jörg Rossbach (Uni HH, Hamburg), Martin Tolkiehn (DESY, Hamburg), Christoph Paul Maag (DESY, Hamburg; Uni HH, Hamburg), Harald Sinn (European XFEL GmbH, Hamburg)

The European XFEL will be an X-ray free electron laser laboratory at DESY in Hamburg Germany. In the baseline design the light pulses will be generated in long undulators via the SASE process. The wavelengths of the light pulses will be between 5 nm and 0.05 nm. Since SASE pulses have a poor longitudinal coherence a lot of research is ongoing to overcome the statistical fluctuations of the SASE pulses. Some years ago Kim et al. proposed an FEL oscillator for light sources based on energy-recovery linacs (ERL), using Diamond Bragg crystals to perform a high reflective cavity in the X-ray regime (XFELO). Since the European XFEL will be based on superconducting accelerator structures it will deliver a long train of electron bunches which might be suitable to support an XFELO arrangement as well. In particular, the spent beam at the exit of a SASE FEL might be still qualified to drive an XFELO. Theoretical simulations of an oscillator based on Diamond crystals for the European XFEL will be presented using electron bunches of a spent beam.

Simulations of XFELO for the KEK ERL

WEPD30

Ryoichi Hajima, Nobuyuki Nishimori (JAEA, Ibaraki-ken), Norihiro Sei (AIST, Tsukuba, Ibaraki), Norio Nakamura, Miho Shimada (KEK, Ibaraki)

Following the recent development of high-brightness electron guns and high-reflectivity X-ray crystal optics, an FEL oscillator operated in a hard X-ray wavelength region (XFELO) has been considered as a possible extension of the 3-GeV ERL light source proposed at KEK. In order to deliver a 6-GeV electron beam to the XFELO, the ERL is operated at the energy-doubling mode with a low average current. In this paper, we present results of electron beam simulations and FEL simulations.

Sub-Angstrom Stabilization of X-ray Free Electron Laser Oscillator and Nuclear Resonance Metrology

WEPD31

Bernhard Werner Adams, Kwang-Je Kim (ANL, Argonne)

A scheme is described to length-stabilize the cavity of an x-ray free-electron-laser oscillator (XFELO) [1] by keeping one of its longitudinal modes in nuclear resonance at 14.4 keV with a sample of 57Fe. The mode spacing corresponding a 100 m XFELO cavity is about 12 neV, which can be resolved with the 5-neV linewidth of 57Fe, even with some inhomogeneous line broadening. With a cavity thus stabilized, a standing-wave pattern can be maintained over hours, to be probed by another sample of 57Fe in a meter-long scan to compare the nuclear-resonant wavelength with a known optical standard. This should improve the relative accuracy of this wavelength from 10^-7 [2] to 10^-11. Ensemble, or long-time averaging, as used in atomic clocks, can further increase the accuracy. Refining the scheme to other nuclear-resonant species with narrower resonances, such as 181 Ta (6.2 keV, 75 peV), will open up precision x-ray metrology for technological and fundamental applications.

[1] K.-J. Kim, Yu. Shvyd'ko, S. Reiche, Phys. Rev. Lett. 100, 244802 (2008);K.-J. Kim, Yu. Shvyd'ko, Phys. Rev. ST-AB, 030703 (2009) [2] M. Lucht, dissertation, Hamburg (2005)

This work was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No.¥ DE-AC02-06CH11357.

Injector System for Linac-based Infrared Free-electron Laser in Thailand

WEPD32

Sakhorn Rimjaem, Prach Boonpornprasert, Jatuporn Saisut, Sikharin Suphakul, Chitrlada Thongbai (Chiang Mai University, Chiang Mai)

A possibility to develop a compact linac-based Infrared Free-electron Laser (IR-FEL) facility has been studied at Chiang Mai University (CMU) in Thailand. Characteristics of the emitted FEL light and reliability in operation of the facility are determined by the properties of an electron injection system, an undulator, and an optical cavity. The proposed injector system for the future IR-FEL is based on the RF linear accelerator system at the Plasma and Beam Physics Research facility (PBP-linac) at CMU. However, the required electron beam properties for the IR-FEL are different from the current available electron beams from the PBP-linac. Numerical and experimental studies to modify the existing system to be able to drive the IR-FEL have been performed. The results of the studies and the proposed injector system parameters will be presented in this contribution.

This work has been supported by the Department of Physics and Materials Science at Chiang Mai University, the Thailand Center of Excellence in Physics, and the Thailand Research Fund.

Simulation and Optimization Studies of an IR Free-electron Laser based on RF-Linac

WEPD33

Somjai Chunjarean (ThEP Center, Bangkok), Prach Boonpornprasert, Sakhorn Rimjaem, Chitrlada Thongbai (Chiang Mai University, Chiang Mai)

A preliminary design of Infrared Free-electron Laser (IR-FEL) has been studied at the Thailand Center of Excellent in Physics (ThEP). The IR-FEL is composed of a thermionic radio frequency (RF) gun, an RF linear accelerator, a planar undulator and an optical cavity with symmetric spherical mirrors. To reach a high level of the IR-FEL power, the dynamics of electron bunches in the undulator and the interaction of electron beam and photon beam will be investigated. Microbunching processes and the IR-FEL amplification will be modeled and simulated with time-dependent FEL code, GENESIS 1.3. With optimization of the electron beam and undulator parameters as well as the optical cavity characteristics, a performance of the IR-FEL will be analyzed. Results of the simulations and optimization will be presented and discussed in this contribution.

Funding Agency: Thailand Center of Excellence in Physics (ThEP)

Beam Dynamics Simulation and Optimization of Electron Beam Properties for IR-FELs at Chiang Mai University — WEPD34

Sikharin Suphakul (Chiang Mai University, Chiang Mai)

The linear accelerator system at the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University (CMU), Thailand, has been under a plan to extend its function to be an injector system for the Infrared Free-electron Lasers (IR-FELs). The current system consists of an S-band thermionic cathode RF-gun, a bunch compressor in a form of alpha-magnet and a 3-m SLAC-type linear accelerator. The current system will be modified to generate the electron beam with the properties suitable for the IR-FELs. Numerical simulations have been performed to investigate and optimize the electron beam parameters. The planned modification of the system and optimization of the electron beam parameters will be presented in this contribution.

This work has been supported by the Department of Physics and Materials Science at Chiang Mai University, the Thailand Center of Excellence in Physics, and the Thailand Research Fund.

Free Electron Oscillator (FEO) Amplitude Fluctuations Caused by an Electron Beam Spontaneous Noise — WEPD35

Sergei Georgii Oganesyan (RAU, Yerevan), George S Oganesyan (LT CSC, Yerevan)

We have studied the problem of laser field amplitude fluctuations in the undulator FEO that operates in a nonlinear steady-state regime. Analysis is based on a set of semiclassical equations suggested in [1]. Namely, a density matrix of the second order and the matrix fluctuations have been used to describe the e-beam and a nonlinear equation (of the Van Der Pol type) employed for analysis of the electric field strength. In this approach fluctuations of the density matrix are responsible for the spontaneous noise of electrons [2], which leads, particularly, to fluctuations of the electric field amplitude. We derived an equation, which made it possible to calculate the amplitude fluctuations and a spectral density of their dispersion in terms of the density matrix. The latter was calculated employing a method of correlation functions. It is shown the spectral density is a product of electron energy Gaussian and Lorentz distributions. Both, an absolute value of the amplitude fluctuations and an expression for the amplitude correlation time have been estimated when a width of the second line is relatively small.

1. S.G. Oganesyan et al, Contr. ID: MOPB11. 32-nd FEL Conf., Sweden, 23-27 Aug-10. 2. S.G. Zager et al, Wave and fluctuation processes in lasers, Moscow, 1974.

Toward the Single-shot Measurement of Mid-infrared FEL Pulse Spectra — WEPD36

Takashi Nakajima, Toshiteru Kii, Hideaki Ohgaki, Yu Qin, Xiaolong Wang, Heishun Zen (Kyoto University, Kyoto)

For a laser pulse in the visible region one can conveniently use a Si-based CCD spectrometer to obtain the laser spectrum by the single-shot measurement. In contrast a similar measurement is not easy for a mid-infrared (mid-IR) laser pulse due to the lack of the cheap array-type photodetector in this wavelength range. To overcome this problem we propose to use a sum-frequency mixing (SFM) technique with an external ns laser pulse. For example, we obtain the 962 nm SFM pulse from the 10 micron FEL pulse and 1064nm external laser pulse. Once the SFM pulse spectrum is obtained by the single-shot measurement with a Si-based CCD spectrometer, we can easily convert it to the original mid-IR pulse spectrum. The advantage of this new technique is that we can obtain the entire mid-IR FEL spectrum by the single-shot measurement for the selected individual micropulse, and moreover we can choose a different micropulse of the mid-IR FEL simply by changing the synchronization timing between the mid-IR FEL and external near-IR pulses. The individual micropulse spectra measured this way would provide us with enormous amount of information than the statistically averaged FEL spectra.

Measurements of Pulse Duration and Second-harmonic Generation Efficiency of KUFEL — WEPD37

Yu Qin, Toshiteru Kii, Takashi Nakajima, Hideaki Ohgaki, Xiaolong Wang, Heishun Zen (Kyoto University, Kyoto)

Kyoto University free-electron laser (KUFEL) is an oscillator-type FEL working in the mid-infrared wavelength, 8-14 micron. We have carried out the pulse duration measurement of KUFEL with intensity autocorrelation and also fringe-resolved autocorrelation techniques at different lasing wavelengths, and compare them. For instance, the pulse duration of KUFEL at 12 micron has been found to be about 0.57 ps. We have also undertaken the second-harmonic generation at 12 micron with the AgGaSe2 crystals having three different crystal lengths, 1, 3, and 6 mm, and studied the conversion efficiency.

Improvement of KU-FEL Performance by Replacing Undulator and Optical Cavity — WEPD38

Heishun Zen, Mahmoud Abdel Aziem Bakr, Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Ryota Kinjo, Kai Masuda, Hani Hussein Negm, Hideaki Ohgaki, Kensuke Okumura, Mohamed Omer, Marie Shibata, Kyohei Shimahashi, Konstantin Torgasin, Kyohei Yoshida
(Kyoto University, Kyoto)

A mid-infrared FEL named as KU-FEL (Kyoto University FEL) has been developed for energy related sciences*. The FEL achieved first lasing and saturation in 2008**,***. However, the tunable range was limited from 10 to 13 micro-m because of insufficient macro-pulse duration of e-beam and FEL gain. The undulator of KU-FEL has been replaced with the undulator which was previously used for ERL-FEL in JAEA. The optical cavity has been replaced with optimized one. In addition the diameter of the coupling hole on the upstream cavity mirror has been reduced from 2 to 1 mm for reducing cavity loss. After installation, the tunable range of KU-FEL has been improved to 5-15 micro-m. Estimated FEL gain is greater than 30%, which was 1.5 times larger than original configuration.

**H. Zen, et al., Infrared Physics and Technology, Vol. 51, Issue 5, p.382 (2008) **H. Ohgaki, et al., Proc. of FEL08, p.4 (2008) ***H. Ohgaki, et al., Proc. of FEL09, p.572 (2009)*

Status of IR-FEL at Tokyo University of Science — WEPD39

Takayuki Imai, Jun Fujioka, Takayasu Kawasaki, Keisuke Komiya, Mitsutoshi Matsubara, Koichi Tsukiyama (Tokyo University of Science, Chiba), Tetsuo Shidara, Mitsuhiro Yoshida (KEK, Ibaraki), Keiichi Hisazumi, Testsuo Morotomi (MELCO SC, Tsukuba)

IR-FEL research center of Tokyo University of Science (FEL-TUS) is a facility for aiming at development of the high performance FEL device and promotion of photo-sciences using it. The main part of FEL-TUS involves a mid-infrared FEL (MIR-FEL) which provides continuously tunable radiation in the range of 5 -14 um and a variety of experiments are by the use of this photon energy corresponding to the various vibrational modes of molecules are now underway. We also are making effort to develop a far-infrared FEL (FIR-FEL) in order to realize FEL lasing in the THz region. The status of research activities at FEL-TUS will be presented.

Hole-coupling in IR-FELs: an Experimental Study — WEPD40

Alexander van der Meer (FOM Rijnhuizen, Nieuwegein)

Even though hole-coupling has been used for many years at several IR FEL facilities, its usefulness as outcoupling scheme has recently been questioned [1]. Also, it has been suggested that the output beam profile will inevitably show strong asymmetries at the short wavelength end of the tuning curve [2]. In this contribution, experimental results for the performance of hole coupling in terms of wavelength and bandwidth tunability, efficiency and beam profile as obtained at the FELIX facility will be presented.

[1] Modeling and operation of an edge-coupled free electron laser, M.D. Shin, TUOC3, FEL2010, Malmø
[2] R. Prazeres et al, Phys.Rev. S.T. A/B, 13 (2010) 090702

Present Status of Coherent Light Source Developments at UVSOR — WEPD41

Sei-ichi Tanaka, Masahiro Adachi, Kenji Hayashi, Masahiro Katoh, Shin-ichi Kimura, Jun-ichiro Yamazaki (UVSOR, Okazaki), Heishun Zen (Kyoto University, Kyoto), Toshiharu Takahashi (Kyoto University, Osaka), Masahito Hosaka, Yoshitaka Taira, Yoshifumi Takashima, Naoto Yamamoto (Nagoya University, Nagoya)

At UVSOR, Coherent light source technologies, such as resonator free electron laser, coherent harmonic generation and coherent synchrotron radiation via laser modulation, have been developed parasitically by using an undulator and a beam-line normally used for photo-electron spectroscopy. Under Quantum Beam Technology Program of MEXT in Japan, we started constructing a new experiment station dedicated for the coherent light source developments. We created a new straight section by moving the injection line. Two identical undulators 1m long were constructed and installed there. A buncher magnet was constructed and installed between the undulators to form an optical klystron. Two beam-lines, BL1U and BL1B, were constructed, the former of which is for free electron laser and coherent harmonic generation and the later for the coherent synchrotron radiation in the terahertz range. The laser system was reinforced and new laser transport line was constructed. The generation of coherent synchrotron radiation by laser modulation was already tested. The construction of the optical cavity for the free electron laser will start in this year.

Electron Beam Dynamics in the ALICE IR-FEL Facility — WEPD42

Frank Jackson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)

The ALICE facility at Darebury Laboratory is an energy recovery test accelerator which includes an infra-red oscillator-type free electron laser (IR-FEL). The longitudinal and transverse electron beam dynamics are discussed and their impact on the performance of the IR-FEL.

Dynamics of a Free Electron Laser Oscillator injected by an External Laser — WEPD43

Christophe Szwaj, Serge Bielawski, Takanori Tanikawa (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Heishun Zen (Kyoto University, Kyoto), Masahito Hosaka, Naoto Yamamoto (Nagoya University, Nagoya), Masahiro Adachi, Masahiro Katoh (UVSOR, Okazaki)

Noise (spontaneous emission) plays a fundamental role in the dynamics of the storage Free Electron Laser. Hence, outside perfect tuning, all the regimes are driven by the spontaneous emission noise. Here, we propose to inject the FEL oscillator with an external laser so that the emission builds up from a mastered seed instead of noise. The UVSOR-II storage ring FEL oscillator operating at 400nm has been injected by an external frequency doubled Ti-Sa laser and its dynamics investigated. In particular, in Q-Switch like regime, the laser injection induce the emission of a strong peak of Coherent Synchrotron radiation in the THz domain. Experimental results are interpreted with the help of numerical simulations.

FEL Research and Development at STFC Daresbury Laboratory — WEPD44

Neil Thompson, James Clarke, David Dunning (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Michele Ruth Fisher Siggel-King (Cockcroft Institute, Warrington, Cheshire; The University of Liverpool, Liverpool), Mark David Roper (STFC/DL, Daresbury, Warrington, Cheshire), Mark Surman (STFC/DL/SRD, Daresbury, Warrington, Cheshire), Gareth Michael Holder, Andrew Smith, Peter Weightman (The University of Liverpool, Liverpool), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

In this paper we present an overview of current and proposed FEL developments at STFC Daresbury Laboratory in the UK. We discuss progress on the ALICE IR-FEL since first lasing in October 2010, covering the optimisation of the FEL performance, progress on the demonstration of a single shot cross correlation experiment and the results obtained so far with a Scanning Near-Field Optical Microscopy beamline. We discuss a proposal for a 250 MeV single pass FEL test facility named CLARA to be built at Daresbury and dedicated to research for future light source applications. Finally we present a brief overview of other recent research highlights.

Study of a Compact ERL- FEL based Coherent Light Source combining NIR/MIR/THz and X-ray Regions — WEPD45

Mufit Tecimer (University of Hawaii at Manoa, Honolulu)

A 30 to 100 MeV, ~10mA average current compact ERL based NIR-MIR-THz FEL covering the wavelength region between 1-1200 microns is described. The proposed high peak and average brightness, ultrashort light source employs an open (NIR/MIR) and a parallel plate waveguide (MIR/THz) FEL oscillator in tandem configuration[1,2]. The latter arrangement allows a large flexibility in wavelength combinations within the targeted wide spectral range for the generation of well synchronized pump-probe pulses[2]. Based on the provided high rep rates, the system supports also the use of high finesse (IR- and THz-) pulse stacker cavities. This feature along with various internal (FEL) and external cavity dumping techniques eventually enable upfrequency conversion processes which allow the tunable spectral range of the system to incorporate soft/hard (upto ten keV) x-ray pulse trains with down to attosecond durations[3]. The FEL as well as pulse stacker cavities make use of the (tunable) high reflectivity characteristics of the 1D photonic crystal mirrors**. System components and the characteristics of the generated coherent pulses in the NIR/MIR/THz as well as in the x-ray regions will be presented.

[1] Scientific Case and Engineering Design for the BigLight THIR Laser, NHMFL, 2009. [2] M. Tecimer, Presentations BESSY, Nov. 2010 & Apr. 2011.Footnote

Pulse Structure Measurement of Near-Infrared FEL in Burst-Mode Operation of LEBRA Linac

WEPD46

Keisuke Nakao, Ken Hayakawa, Yasushi Hayakawa, Manabu Inagaki, Kyoko Nogami, Takeshi Sakai, Toshinari Tanaka (LEBRA, Funabashi), Heishun Zen (Kyoto University, Kyoto)

The near-infrared free electron laser (FEL) at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University has been provided for scientific studies in various fields since 2003. Improvement in the electron beam injector system for the LEBRA 125MeV electron linac made possible to accelerate the electron beam in three different modes, full-bunch mode, superimpose mode and burst mode. FEL lasing in the second and the third modes was achieved in 2011. The FEL pulse lengths in the full-bunch mode and the burst mode, measured at an FEL wavelength of 1600 nm with autocorrelation method using a Michelson interferometer, were approximately 100 fs and 180 fs, respectively. The FEL gain in the burst mode was apparently much higher than that in the full-bunch mode. Although the autocorrelation method provides only a rough estimate, the burst-mode FEL pulse structure was suggested to be different from the full bunch mode.

Development of Free-electron Lasers using Two "Higher Orders" with the Storage Ring NIJI-IV

WEPD47

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

In National Institute of Advanced Industrial Science and Technology (AIST), higher harmonic oscillations of free-electron lasers (FELs) have been developed with the storage ring NIJI-IV*. We have already achieved the seventh harmonic FEL at a wavelength of around 890 nm, which is the highest order in the harmonic FELs**. Using another "higher order", that is, higher diffraction orders of a target wavelength of dielectric multilayer mirrors, we realized the following results: + shortening a wavelength of the FEL oscillation in the NIJI-IV IR-FEL system, + lasing on the highest order in the harmonic FEL, + discovering differences between the fundamental harmonic FEL and higher harmonic FEL, + controlling the harmonic order in the same condition of the electron beam and insertion device. In the presentation, we will report the characteristics of the FEL oscillations using the two higher orders in the NIJI-IV IR-FEL system.

** N. Sei et al., J. Phys. Soc. Jpn., 79 (2010) 093501. ** N. Sei et al., Opt. Express, 20 (2012) 308.*

This work was supported by the Budget for Nuclear Research of the Ministry of Education, Culture, Sports, Science and Technology of Japan.

Development of Intense Terahertz-wave Coherent Synchrotron Radiations at LEBRA

WEPD48

Norihiro Sei, Hiroshi Ogawa (AIST, Tsukuba, Ibaraki), Ken Hayakawa, Yasushi Hayakawa, Manabu Inagaki, Keisuke Nakao, Kyoko Nogami, Toshinari Tanaka (LEBRA, Funabashi)

Nihon University and AIST have jointly developed intense terahertz-wave coherent synchrotron radiations at Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University. Because a bunch length is short and a charge is large in an electron beam of a linac to saturate free-electron laser (FEL) power, the electron beam of the linac in an FEL facility is suitable for generating intense coherent radiations generally. Therefore, we launched a development of a THz-wave source with using an upstream bending magnet located in the FEL beam line. Recently, Nihon University developed 'burst mode operation', in which two or three electron bunches were included at an interval of 22.4 or 44.8 ns [1]. The electric charge in the micropulse was high (several hundreds pC) in the burst mode, so generation and observation of the coherent synchrotron radiation became easy. We have already measured the intense THz-wave from LEBRA and confirmed it to be the coherent synchrotron radiation (CSR). It was also found that CSR might have serious influence on a high-energy electron beam. In the presentation, we will report the characteristics of the CSR at LEBRA.

[1] K. Nakao et al., Lasing of near infrared FEL with the burst-mode beam at LEBRA, Proceedings of FEL11, Shanghai, China, (2011).

This work was supported by JSPS Grant-in-Aid for Challenging Exploratory Research 2365696.

The Terahertz FEL Facility Project at CAEP

WEPD49

Xingfan Yang (CAEP/IAE, Mianyang, Sichuan)

To meet the requirement of material and biomedicine study, a terahertz FEL user facility project was proposed by China Academy of Engineering Physics(CAEP), at present the project has been approved and the facility will be constructed within 5 years. The facility will operate in the quasi CW mode and the average power is about 10W. The wavelength of the light can be regulated between 100μm/3THz to 300μm/1THz according to the user necessary by changing the electron energy and the magnetic field of the wiggler. In order to achieve the high brightness beam, the photocathode DC gun will be used as the electron source.The electron energy after a superconducting accelerator is about 8MeV, which is suitable to obtain the terahertz light. The facility will be a useful tool to the science.

A Comparison of Different Types of Coherent Radiation of MeV Electron Beam in THz Range — WEPD50

Ruixuan Huang (USTC/NSRL, Hefei, Anhui)

A comparison of different types of coherent radiation of MeV electron beam in THz range is described in the paper. It presents the theory and characteristics of Smith-Purcell radiation, Cherenkov radiation, and transition radiation. The analysis and conclusion are provided.

The Output Study of Terahertz Free-Electron Laser Oscillator based on Electrostatic Accelerator — WEPD51

Ailin Wu, Qika Jia (USTC/NSRL, Hefei, Anhui)

For the terahertz radiation sources provide wide applications in medical science, material science and industrial, a compact, wavelength tunable and high-power THz source attracted much attention in many laboratories. In this paper, we give a primary study of a compact electrostatic accelerator driven THz FEL (EA-THz) and its basic design parameters. The feasibility study is carried out using FELO code. The initial results show that such EA-FEL will be a promising compact and powerful THz source.

THz Radiation Sources based on RF-linac at Chiang Mai University — WEPD52

Chitrlada Thongbai, Prach Boonpornprasert, Keerati Kusoljariyakul, Sakhorn Rimjaem, Jatuporn Saisut, Sikharin Suphakul (Chiang Mai University, Chiang Mai)

A THz radiation source in a form of coherent radiation from short electron bunches has been constructed at the Plasma and Beam Physics (PBP) research facility, Chiang Mai University. The accelerator system consists of an RF-gun with a thermionic cathode, an alpha-magnet as a magnetic bunch compressor, and a SLAC-type linear accelerator. Coherent transition radiation emitted from short electron bunches passing through an Al-vacuum interface was used as the THz radiation source. This THz radiation can be used as a source of the THz imaging system and THz spectroscopy. Details of the accelerator system and THz radiation production will be presented. A plan for extension to accommodate Free Electron Lasers (FEL) optimized for mid-infrared and far-infrared/THz radiation will also be discussed.

Linac-based THz Imaging at Chiang Mai University — WEPD53

Jatuporn Saisut, Prach Boonpornprasert, Keerati Kusoljariyakul, Sakhorn Rimjaem, Chitrlada Thongbai (Chiang Mai University, Chiang Mai; ThEP Center, Bangkok), Michael W. Rhodes, Prissana Thamboon (IST, Chiang Mai; ThEP Center, Bangkok)

At the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University, intense THz radiation is generated in a form of coherent transition radiation from femtosecond electron bunches. The THz radiation is used as a source of THz imaging system which was successfully setup and tested. The radiation is focused onto a sample which will be scanned using an xy-translation stage. The transmission or reflection at different points of the sample are recorded to construct a THz image. Details of the setup and the experimental results from the system will be presented. The THz imaging to accommodate a future IR-THz Free Electron Laser (FEL) will also be discussed.

Funding Agency: The Thailand Center of Excellence in Physics (ThEP), the National Research Council of Thailand (NRCT) and the Thailand Research Fund (TRF)

Characterization of Single-cycle THz Pulses at the CTR Source at FLASH — WEPD54

Steffen Wunderlich, Sven Schefer, Bernhard Schmidt, Sebastian Schulz, Stephan Wesch (DESY, Hamburg), Matthias Clemens Hoffmann (SLAC, Menlo Park, California)

At the coherent transition radiation source at the free-electron laser in Hamburg (FLASH) at DESY, single-cycle THz pulses with electric field strengths exceeding one MV/cm are generated. We present the temporal and spatial characterization of this source with the technique of electro-optic sampling using a laser system synchronized with the accelerator to better than 100 fs. This method offers a quantitative detection of the electric field of the THz pulses in the time domain. Compared to other electron-accelerator driven sources like undulator radiation, the transition radiation source provides pulses with a high bandwidth and durations shorter than one picosecond. This enables time-resolving and non-destructive experiments with radiation in the THz regime including THz pump / THz probe experiments. Broadband and intense THz pulses are expected to be valuable tools for the study of dynamics of excitation of complex materials in transient electric and magnetic fields.

Tunable THz Source for Pump Probe Experiments at the European XFEL — WEPD55

Mikhail Krasilnikov, Frank Stephan (DESY Zeuthen, Zeuthen),
Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We present a concept of an accelerator based source of powerful, coherent THz radiation for pump-probe experiments at the European XFEL. The electron accelerator is similar to that operating at the PITZ facility. It consists of rf gun and warm accelerating section (energy up to 30 MeV). The radiation is generated in a 5 meter long APPLE-type undulator with a period length of 4 cm, thus providing polarization control. Radiation with wavelength below 200 micrometers is generated using the mechanism of SASE FEL. Powerful coherent radiation with wavelength above 200 micrometers is generated in the undulator by a tailored (compressed) electron beam. Properties of the radiation are: wavelength range is 10 to 1000 micrometers (30 THz - 0.3 THz), radiation pulse energy is up to a few hundreds microjoles, peak power is 10 to 100 MW, spectrum bandwidth is 2 - 3%. It is important to note that the time structure of the THZ source ideally matches with the time structure of the x-ray pulses since the THZ source is based on the same technology as the injector of the European XFEL. A similar scheme can be also realized at LCLS, SACLA, or SWISS FEL with S-band rf accelerator technology.

Nonlinear Harmonic Generation and Gain Improvement in Free Electron Laser with Planar Wiggler and Ion-channel Guiding — WEPD56

Fateme Bazouband, Behrouz Maraghechi (AUT, Tehran)

Harmonic generation is one of the effective methods to decrease the required electron voltage for strong free electron laser (FEL) interaction. Low voltage compact FELs operating in microwave to infrared frequency spectrum, have valuable applications in industry and medicine because of their small size and low cost. The odd harmonic generation in spontaneous emission spectrum of FEL with planar wiggler and ion-channel guiding is studied analytically. The nonlinear odd harmonics are simulated and the gain of third harmonic is improved using ion-channel guiding and wiggler tapering.

Cavity Desynchronization Dynamics in a Short-pulse Waveguided FEL — WEPD57

Vitali Zhaunerchyk (Uppsala University, Uppsala), Dick Oepts (FOM Rijnhuizen, Nieuwegein), Rienk Jongma, Wim J. van der Zande (Radboud University, Nijmegen)

Due to the lethargy effect in short-pulse FEL oscillators, i.e., those FEL oscillators which operate at slippage parameters larger than unity, the gain for stimulated emission is small and a few tens of microseconds are not enough to achieve optical power saturation. The gain can be enhanced via reduction of the cavity length. However, since in this case the roundtrip time of optical pulses is desynchronized from the repetition rate of the electron bunches, reduction of the cavity length leads to lowering of the saturated optical power and for short-pulse FELs it is not straightforward to achieve high saturation power in combination with high small-signal gain. For instance, it was demonstrated that it could be achieved by ramping the repetition rate of an RF LINAC [*]. Our work based on numerical calculations demonstrates that for a short-pulse FEL in which a waveguide is employed the synchronism can be sustained with a shortened cavity thanks to the group velocity dispersion induced by the waveguide. Our results have been obtained for the new THz FEL FLARE at the Radoud University Nijmegen in the Netherlands.

[*] R. J. Bakker et al. Phys. Rev. E 48, R3256 (1993).

Coherent Undulator Radiation from High Repetition Rate Short Electron Pulses — WEPD58

Wai Keung Lau, Ming-Chang Chou, Jiing-Yi Hwang, An-ping Lee (NSRRC, Hsinchu), Nuan-Ya Huang (NTHU, Hsinchu)

Sub-100 fsec electron pulses are produced from the 30 MeV NSRRC thermionic rf gun injector by beam selection in the alpha magnet as well as velocity bunching in the rf linac. The coherent infrared radiation from a pulsed helical undulator driven by such high rep.-rate electron beam being investigated theoretically. Recent progress of the installation of the injector will also be presented.

FLUTE, a Compact Accelerator-based Source for Coherent THz Radiation — WEPD59

Somprasong Naknaimueang (Karlsruhe Institute of Technology (KIT), Karlsruhe), Pawel Wesolowski (FZK, Karlsruhe), Erhard Huttel, Anke-Susanne Mueller, Michael Johannes Nasse, Robert Rossmanith, Marcel Schuh, Markus Schwarz (KIT, Karlsruhe), Michael Schmelling (MPI-K, Heidelberg), Romain Ganter (PSI, Villigen)

FLUTE is a test facility for a compact accelerator-based THz source in the final design phase at the Karlsruhe Institute of Technology (KIT) in cooperation with Paul Scherrer Institute (PSI), Switzerland. The design is based on a 7 MeV photo injector, an S-band linac with a maximum energy of 50 MeV and a bunch compressor. The machine will be operated in a wide range of bunch charges, from 10 pC up to 3 nC. The final bunch length after the compressor is dominated by space charge effect in the photo injector and the coherent synchrotron radiation (CSR) in the compressor. This paper gives an overview over the status of the project and presents results of simulations for the different operating regimes. In addition, THz spectra generated by different processes (CSR, coherent transition radiation and coherent edge radiation) for different, charge dependent, bunch shapes will be discussed.

Outcoupling Methods for THz FELs — WEPD60

Keith Cohn, Joseph Blau, William B. Colson, Steven Grey (NPS, Monterey, California)

There are several issues that are encountered when designing a Free Electron Laser (FEL) oscillator in the terahertz (THz) regime. One such issue is that there are few inexpensive materials that are suitable for forming a semi-transparent outcoupling mirror. In an attempt to mitigate this particular issue, the focus of this presentation is to explore various outcoupling techniques for a notional FEL oscillator in the THz regime. The advantages and disadvantages of several outcoupling methods will be discussed, including hole outcoupling, single mesh outcoupling, and double mesh outcoupling. Simulation results will be presented, showing the effects of these various methods on FEL extraction and optical beam quality.
This work has been supported by the Office of Naval Research.

Dispersion Relation and Radiation Properties of the Defected 1 Demensional Metalic Photonic Crystal — WEPD61

Kyu Ha Jang, Young Uk Jeong, Kitae Lee, Seong Hee Park, Nikolay Vinokurov (KAERI, Daejon)

We derived the dispersion relation of the one-demensional array of plasmonic metamaterials which are consisted of serveral metallic gratings by applying effective medium theory. In paticular, concerning with the radiation property by electron beam over the structure, surface wave of the fundamental transverse-magnetic mode are examined using 3D PIC code.
This work was supported by the WCI program of the NRF funded by MEST(NRF Granted Number:WCI2011-001)

Microtron using Photocathode for THz FEL — WEPD62

Sunjeong Park, Kyu Ha Jang, Young Uk Jeong, Kitae Lee, Seong Hee Park, Nikolay Vinokurov (KAERI, Daejon), Eun-San Kim (Kyungpook National University, Daegu)

A microtron is the particle accelerator that periodically accelerates electrons in the RF resonator with alternating electric field and has a circular orbit because of the constant and uniform magnetic field. The radius of electron motion and the energy of the electrons are increased when the electrons pass through the RF resonator. Korea Atomic Energy Research Institute has operated the microtron with thermionic cathode for the THz Free Electron Laser(FEL). When using the thermionic cathode which is built in th RF resonator, the length of the electron beam is long because the electrons emint continuously according to the RF period and some of them accelerate if they are in the correnc phase. In this case, the low peak current is gained and efficiency of beam is degraded as several bunches of beam accelerate at the same time with different radius and interact each other. Using photocathode, however, only one bunch is accelerated in the RF resonator and has short pulse and high peak current. We present the dynamics of electron beam in the microtron and the phase of laser injection at the microtron with photocathode.
This work was supported by the WCI program of the NRF funded by MEST(NRF Granted Number:WCI2011-001)

Development of a THz-FEL Beam Delivery System for User Applications — WEPD63

Sangyoon Bae, Kyu Ha Jang, Young Uk Jeong, Ha Na Kim, Kyung Nam Kim, Kitae Lee, Jungho Mun, Seong Hee Park (KAERI, Daejon), Ji Young Lee (InLC Technology, Daejeon)

We constructed a beam transfer system which transmits high-power THz beams made from the KAERI THz free-electron laser to 4 optical tables for users experiments on bio and material researches. By using CODE V, we designed the optics for the beam delivery system. To reduce the THz loss through air, we put the THz delivery optics in vacuum. Total length of the transfer system is 12.8 m, which is constituted by one collimating crystal quartz lens, seven flat mirrors and four windows. To reduce the loss caused by the reflection and diffraction of a 40-mm-diameter THz beam through the vacuum pipes, we used a vacuum tube having an internal diameter of 216 mm. We used polypropylene films having a thickness of 0.5 mm for the windows of the vacuum transfer line to the experimental tables. Its active diameter is 152.4 mm and the transmittance for the wave of 3 THz is around 90%. The delivered THz beams at the experimental tables showed Gaussian-like beam profiles. Also, we could focus it up to 300 μm in FWHM by using a 4-inched off-axis parabolic mirror.

FEL Gain Measurement with a Novel Method — WEPD64

Masaki Fujimoto, Akinori Irizawa, Goro Isoyama, Fumiyoshi Kamitsukasa, Ryukou Kato, Keigo Kawase, Hiroki Ohsumi (ISIR, Osaka), Shigeru Yamamoto (KEK, Tsukuba), Shigeru Kashiwagi (Tohoku University, Sendai)

The FEL gain is an important factor characterizing performance of the FEL. We used to derive the gain of the THz-FEL at Osaka University from the macropulse shape measured using a Ge:Ga detector with the time resolution of ~10 ns. The method was recently found faulty because the response of the detector shows strong non-linearity in amplitude at a high intensity level. We, therefore, have developed a new method for the gain measurement using a silicon bolometer, which has a very high linearity over the wide intensity range. The detector has the time resolution of ~1 ms, which is much longer than the FEL macropulse of a few microseconds, so that it measures energy in the macropluse. In order to derive the temporal revolution of FEL power, the number of amplifications is varied by changing the macropulse length of the electron beam. The sensitivity of the detector is also high, so that we could measure the energy development of the FEL over 6~7 orders of magnitude at a wavelength ~100 micrometers in combination with appropriate absorbers. We will report results of the measurement and analysis of the FEL gain.

Design and Numerical Simulation of THz-FEL Amplifier in Kyoto University — WEPD65

Mahmoud Abdel Aziem Bakr (Assiut University, Assiut; Kyoto University, Kyoto), Toshiteru Kii, Kai Masuda, Hideaki Ohgaki, Mohamed Omer, Kyohei Shimahashi, Kyohei Yoshida, Heishun Zen (Kyoto University, Kyoto)

Design of a compact and economic THz free-electron laser (FEL) amplifier, which consists of a BNL-type 1.6 cells photocathode radio frequency gun, Solenoid, transport line and short undulator, has been studied at Kyoto University. The electron beam energy to obtain FEL with a wavelength of the range 150~400 μm was calculated to be 4.1~7.0 MeV for a bunch charge of 1.0 nC/bunch. The numerical calculations of the electron beam from the RF gun up to the undulator entrance are carried out using Parmela code and the FEL properties from the undulator will be simulated using GENESIS 1.3. The expected FEL spectral was estimated using 4~5 undulator periods with ~30 cm length and 0.3 T magnetic field. Details of the design concept, numerical calculations and results will be presented in the conference.

Phase Space Manipulation with Laser Generated THz Pulses — WEPD66

Steven Jamison, Trina Tsao-Tin Ng (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), David James Holder, David Newton, Andrzej Wolski (The University of Liverpool, Liverpool), Matthew James Cliffe (The University of Manchester, Manchester)

Ultrafast lasers are able to generate THz pulses with >1MV/m field strengths, and with controllable electric field temporal profiles. We report on an experiment to demonstrate the use of laser generated THz pulses to manipulate the γ-z correlation of a ~ 20MeV electron bunch on a sub picosecond time scale. The manipulation is achieved in free space, without external magnetic fields or undulators, by the interaction of the bunch with the longitudinal electric field of a co-propagating THz pulse in a TEM10*-like mode. We discuss the potential for arbitrary phase space control, including the possibility of correcting temporal jitter and driving electron beams into synchronization with the laser.

UCLA Seeded THz FEL Undulator-Buncher Design

WEPD68

Stephen C. Gottschalk, Robert Norman Kelly (STI, Washington), Sven Reiche (Paul Scherrer Institut, Villigen), Chan Joshi, Sergei Tochitsky (UCLA, Los Angeles, California)

UCLA is planning to build a THz user facility. One is a seeded THz FEL tunable in the range of 0.5 - 3 THz or even 3-9 THz in an optical klystron configuration. Another* relies on microbunching at 340 micron using a 3.3 cm undulator or even driving the FEL with an electron beam from a laser-plasma accelerator. These FEL's make use of a 2.1m long pre-buncher, chicane and shorter, 110cm long radiator. Chicane requirements are modest. A round copper waveguide with 4.8mm ID will be used. We will describe the magnetic design and measured performance of the gap tunable undulators, mechanical design of the entire system, vacuum boxes, waveguides and expected operational approaches. Both undulators have 33mm periods and curved poles for two-plane focusing. Discussions will be included on issues associated with fabricating, sorting and shimming curved pole undulators. A new optimization method will be described that was used to meet magnetic requirements with a minimum volume of magnetic material.

**S. Tochitsky et al, "Seeded FEL Microbunching Experiments at the UCLA Neptune Laboratory", Advanced Accelerator Conference 2010*

Special Lecture -2-

Chair: Hiroyuki Hama

High-Power Terahertz Generation and Terahertz Nonlinear Spectroscopy — WEOEI01

Koichiro Tanaka (Kyoto University, Kyoto)

Recent development of ultra-short pulse technologies allows us to drive large amplitude motion of electron and ion coherently. The intense terahertz (THz) pulse resonant with the vibration frequency is promising to drive vibrations more directly and in coherent manner. In the case of semiconductors, one may coherently control the electronic system in the sub-level structures of quantum structures with intense THz waves. We recently succeeded to generate intense terahertz pulses by Cherenkov scheme with tilted wave-front technique in the LiNbO3 crystal [1, 2]. The maximum electric field is now larger than 1 MV/cm, which ponderomotive energy is as large as 10 eV. The ponderomotive energy is strong enough to ionize bound electronic states in solids such as donors and accepters and easy to induce nonlinear optical effects in solids [3]. In this talk, we would like to review first the state of the art of the high-power THz-wave generation with femtosecond lasers including Cherenkov-scheme in non-linear crystals and air-plasma generation. Then we will focus recent results on THz nonlinear optical phenomena induced by THz electric field larger than 100 kV/cm in molecular crystals [4], semiconductors [5] and ferroelectric materials [6].

[1] J. Hebling, G. Almási, I. Z. Kozma, and J. Kuhl, “Velocity matching by pulse front tilting for large-area THz-pulse generation,” Opt. Express, vol.10, pp. 1161-1166, 2002.

[2] H. Hirori, A. Doi, F. Blanchard, and K. Tanaka, “Single-cycle THz pulses with amplitudes exceeding 1 MV/cm generated by optical rectification in LiNbO3,” Appl. Phys. Lett., vol. 98, pp. 091106-1-091106-3, 2011.

[3] K, Tanaka, H. Hirori, and M. Nagai, "THz Nonlinear Spectroscopy of Solids", IEEE Transactions on Terahertz Science and Technology, 1, 301-312 (2011).

[4] Mukesh Jewariya, Masaya Nagai, and Koichiro Tanaka, "Ladder Climbing on the Anharmonic Intermolecular Potential in an Amino Acid Microcrystal via an Intense Monocycle Terahertz Pulse", Phys. Rev. Lett., 105, 203003 (2010).

[5] H. Hirori, K. Shinokita, M. Shirai, S. Tani, Y. Kadoya, and K. Tanaka, " Extraordinary Carrier Multiplication Gated by a Picosecond Electric Field Pulse," Nature Commun. 2, 594 (2011).

[6] I. Katayama, H. Aoki, J. Takeda, H. Shimosato, M. Ashida, R. Kinjo, I. Kawayama, M. Tonouchi, M. Nagai, and K. Tanaka "Ferroelectric soft mode in a SrTiO3 thin film impulsively driven t,o the anharmonic regime using intense picosecond terahertz pulses", Phys. Rev. Lett. 108, 097401 (2012).

FEL Technology -2- : Stability, Optics, Beamline

Chair: Hirokazu Maesaka

Strategies for achieving sub-10fs timing in large-scale FELs — THOAI01

Russell Wilcox, John Byrd, Lawrence Doolittle, Gang Huang (LBNL, Berkeley, California), Josef Frisch, Alan Fry (SLAC, Menlo Park, California)

Current and planned X-ray FELs produce pulses with sub-10fs duration, requiring comparable timing stability to enable pump/probe experiments. We describe methods of achieving stability on this time scale, for FEL facilities hundreds of meters long. Our approach is based on CW and amplitude modulated optical signals delivered over fiber to pulsed lasers. A comprehensive design approach includes control of modelocked laser oscillators, amplifiers, propagation paths, arrival time diagnostics and finally cross-correlation between pump and probe signals at the experiment. Design options depend on global FEL parameters such as repetition rate. We show that current laser technology is capable of supporting performance at the few-femtosecond level using these techniques. High precision is achieved by leveraging recently developed, frequency stable spectroscopic lasers and optical clocks, as well as the mature field of fiber interferometry. Current experimental results using pulsed and CW lasers are described.

This work was supported by the U.S. Department of Energy under contract DE-AC02-05CH11231.

Photon Beam Transport Systems at FERMI@Elettra: Microfocusing FEL Beam with a K-B Active Optics System — THOA02

Lorenzo Raimondi, Alessandro Abrami, Flavio Capotondi, Marco De Marco, Claudio Fava, Simone Gerusina, Riccardo Riky Gobessi, Maya Kiskinova, Nicola Mahne, Eric Mazzucco, Emanuele Pedersoli, Luca Rumiz, Giovanni Sostero, Cristian Svetina (ELETTRA, Basovizza), Marco Zangrando (ELETTRA, Basovizza; IOM-CNR, Trieste), Fulvio Parmigiani (ELETTRA, Basovizza; Università degli Studi di Trieste, Trieste), Daniele Cocco (SLAC, Menlo Park, California)

FERMI@Elettra, the first seeded EUV-SXR FEL facility, located at Sincrotrone Trieste S.C.p.A., is under advanced commissioning. It will provide ultrashort (10-100 fs) pulses with high peak brightness in the range 100-4 nm. The photon diagnostics section (PADReS) has been installed and commissioned during the last years. Three of the four installed beam lines (EIS-TIMER, EIS-TIMEX, DiProI and LDM) will employ active X-ray optics for focusing and beam-shaping. For DiProI and LDM the beam focusing is accomplished by K-B active X-ray optic mirrors to reach the fundamental diffraction limit. This system allows work with the two different undulator chains FEL1 and FEL2, which have different source locations, and perform an accurate mirror shaping and wave front optimization. In this work we present preliminary results of measurements with the DiProI beamline end-station. A focal spot size <20 μm at 32 nm has been obtained. We also compare these measurements with the predictions computed with a numerical method based on physical optics (Raimondi-Spiga Code [1]) starting from the mirror surface profile characterization. Measurements and simulations are in agreement.

[1] Raimondi L., Spiga D., 2011, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 8147 of Society

Use of Fringe-Resolved Autocorrelation for the diagnosis of the wavelength stability of a FEL

THOA03

Yu Qin, Toshiteru Kii, Takashi Nakajima, Hideaki Ohgaki, Xiaolong Wang, Heishun Zen (Kyoto University, Kyoto)

For the spectroscopic applications of a FEL it is very important to monitor its wavelength stability. The most straightforward way is to take a laser spectrum at once with an array-type photodetector. This, however, is not an easy task at the wavelength regions (<190 nm or >1100 nm) where a Si-based array-type photodetector does not work. An alternative method has to be developed. In this paper we propose to use the autocorrelation setup, which is usually used to measure the pulse duration, to monitor the wavelength stability of a FEL. During the numerical simulation to demonstrate the above idea, we have included various kinds of instabilities such as the central wavelength, intensity, and pulse duration as well as the chirps. Our results show that we can estimate the stability of the wavelength from the width of the upper envelope of fringe-resolved autocorrelation (FRAC) signals: Given the same pulse duration the FEL pulse with larger wavelength instability results narrower envelope width of FRAC signals. Based on this fact, the FRAC can be used as a tool to diagnose the wavelength stability in the wavelength region where a direct spectrum measurement is not possible.

LUNEX 5 FEL Line Magnetic Elements

THOA04

Chamseddine Benabderrahmane, Marie-Emmanuelle Couprie, Clement Evain, Marie Labat, Alexandre Loulergue, Fabrice Marteau, Mathieu Valléau (SOLEIL, Gif-sur-Yvette),
Gael Lebec (ESRF, Grenoble)

LUNEX 5 (free electron Laser Using a New accelerator for the Exploitation of X-ray radiation of 5th generation) aims at investigation the production of short intense and coherent pulses in the soft X-ray region with innovative schemes (such as echo and seeding with harmonics generated in gas) and compact design. The undulators of the FEL line are designed to provide high field short period devices: modulators are in-vacuum undulators with a period of 30 mm and 0.27 m long radiators are in cryo-ready vacuum undulators with period of 15 mm and 3 m long with a cryogenic option, relying on SOLEIL development experience of NdFeB U20 hybrid in-vacuum undulators and 2 m long PrFeB U18 cryogenic undulator operated at 77 K installed on a long straight section of SOLEIL. In addition, the line comports electromagnetic quadrupoles for the beam focusing; chicane dipoles for the beam compression and an electromagnetic bending magnet for the beam dump. A prototype of cryo-ready radiator is under design. Variable permanent magnet quadrupoles are under study for the transport of the Laser WakeField Accelerator towards the undulators.

New Concepts

Chair: Sandra Biedron

Improving Laser-plasma Accelerator Beam Quality for FELs — THOBI01

Eric Esarey, Carlo Benedetti, Min Chen, Cameron Guy Robinson Geddes, Wim Leemans, Carl Bernhardt Schroeder, Jeroen van Tilborg (LBNL, Berkeley, California)

Present laser-plasma accelerator (LPA) experiments at LBNL produce up to 1 GeV electron beams in cm-scale plasmas using tens of TW laser pulses. Such beams have been successfully coupled to a conventional undulator, producing synchrotron radiation. Presently, beam quality limits FEL applications. In this paper we discuss methods of triggered electron beam injection into a laser-plasma accelerator to improve the beam quality. Laser-triggered injection, ionization injection, and the use of plasma density tailoring will be discussed. Short pulse, PW laser systems are presently under constructed, and future experiments using PW lasers aim at the production of 10 GeV electron beams accelerated over less than 1 m of plasma. We report on progress toward achieving compact 10 GeV electron beams using BELLA (Berkeley Lab Laser Accelerator).

This work was supported by the Director, Office of Science, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Transverse Gradient Undulator to Enhance the FEL Performance for a Laser-plasma Accelerator — THOB02

Zhirong Huang, Yuantao Ding (SLAC, Menlo Park, California),
Carl Bernhardt Schroeder (LBNL, Berkeley, California)

Compact laser-plasma accelerators can produce high energy electron beams with low emittance, high peak current but a rather large energy spread. The large energy spread hinders the potential applications for coherent FEL radiation generation. In this paper, we discuss a method to compensate the effects of beam energy spread by introducing a transverse field variation into the FEL undulator. Such a transverse gradient undulator together with a properly dispersed beam can greatly reduce the effects of electron energy spread and jitters on FEL performance. We present theoretical analysis and numerical simulations for SASE and seeded XUV and soft x-ray FELs based on laser plasma accelerators.

The Generator of High-power Short Terahertz Pulses — THOB03

Nikolay Vinokurov (BINP SB RAS, Novosibirsk), Young Uk Jeong (KAERI, Daejon)

The multi-foil cone radiator to generate high field short terahertz pulses with the short electron bunches is described. A round flat foil plates with successively decreasing radius are stacked, comprising a truncated cone with axis z. The gaps between foils are equal and filled by some dielectric (it may be vacuum). A short relativistic electron bunch propagates along the z axis from left to right. At high enough particle energy the energy losses and multiple scattering does not change the bunch shape significantly. Then, passing through each gap between foils, the bunch radiates some energy into the gap. After that the radiation pulses propagates radially. For the TEM-like waves with longitudinal (along the z axis) electric and azimuthal magnetic field there is no dispersion in these radial lines, therefore the radiation pulses conserve their shapes (time dependence). At the cone outer surface we have synchronous circular radiators. Their radiation fields forms the conical wave. The cone angle may be optimized, moreover, the nonlinear dependence of the foil plates radii on their longitudinal coordinate z may be used for the wave front shape control.

Use of Monocapillary X-Ray Optics as a Means to Reduce Linewidth and Fluctuations in SASE FELs — THOB04

Alexander Liway Lin, Gil Travish (UCLA, Los Angeles)

The Self Amplified Spontaneous Emission (SASE) operation of high-gain Free Electron Lasers (FELs) allows for amplification from "noise" when no suitable seed sources are available. While SASE FELs can achieve high powers and short radiation pulses within the X-ray region, they are hindered by large linewidths and fluctuations in amplitude and temporal profiles. Various approaches have been proposed to "clean up" the spontaneous emission and produce better effective seed signals. This paper presents the use of monocapillary X-ray optics as an alternative to current methods to improve SASE operation. A monocapillary tube placed at the beginning stages of the undulator can reduce the bandwidth and enhance a narrow band of the spontaneous emission amplified by the FEL. Monocapillary tubes guide radiation due to total external reflection, and the critical angle of the guiding is dependent on the frequency of the radiation (and indirectly on the surface profile and materials).

Funding Agency : UCLA

FEL Technology -3- :

Undulators, Monitors, Beam diagnostics

Chair: Dong-Eon Kim

X-ray Based Undulator Commissioning in SACLA | THOCI01

Takashi Tanaka (RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo)

SACLA, the SPring-8 Angstrom Compact free electron LAser, achieved first lasing in June 2011 at the wavelength of 0.12 nm, which soon got down to 0.08 nm. After further beam tuning aiming at higher laser power and more stable operation, the user operation started in March 2012. In SACLA, 18 segments of in-vacuum undulator have been installed to achieve FEL saturation in an x-ray region. Each segment is 5-m long and placed with a 1.15-m long interval for installation of diagnostics and magnetic components. Because of such a segmented structure, we have many error sources that can lead to gain reduction. For example, the undulator K value can fluctuate from segment to segment, the electron beam can be kicked by the misalignment of quadrupole magnets, and so on. In order to eliminate all these errors, we have to optimize many parameters related to undulator operation. Such an optimization process is referred to as undulator commissioning. In SACLA, the undulator commissioning has been carried out based on the characterization of x rays both in spontaneous radiation and FEL radiation. In this paper, the details of the commissioning procedure and the achieved results are reported.

Determination of Temporal FEL Pulse Properties: Challenging Concepts and Experiments | THOC02

Nikola Stojanovic, Stefan Düsterer, Bernhard Schmidt, Evgeny Schneidmiller, Siegfried Schreiber, Mikhail Yurkov (DESY, Hamburg), Rolf Mitzner (HZB, Berlin), Markus Drescher, Wilfried Wurth (Uni HH, Hamburg)

One of the most challenging tasks for the FEL photon diagnostics is the determination of the pulse duration - even more so information on the temporal substructure. The knowledge of the temporal pulse characteristics is important for wide range of experiments, from interaction of materials with high intensity radiation to ultrafast pump-probe studies. Here, the temporal resolution depends on the pulse duration as well as on the precise arrival time between the pump and probe pulse. Due to the wide range of available parameters at the existing and planned FELs, the photon energies are ranging from VUV to X-rays and pulse durations from sub fs up to 1ps range. Thus, a variety of methods has to be considered in order to characterize its temporal structure. Moreover due to the statistical nature of the SASE process, the pulse shape (consisting of multitude of sub-pulses) varies from shot to shot. Ultimately, single-shot pulse characterization is needed, which by far increases the level of complexity comparing to averaging techniques utilized so far. Here we present an overview of the different pulse diagnostics techniques that were utilized at FLASH in Hamburg.
Funding Agency : BMBF, 05K10CHC

Two-dimensional Coherence Measurements of FEL Radiation: The Heterodyne Speckle Approach

THOC03

Matteo David Alaimo, Michele Manfredda, Marco Alberto Carlo Potenza (Universita' degli Studi di Milano & INFN, Milano), Marie Labat (CEA/DSM/DRECAM/SPAM, Gif-sur-Yvette; ENEA C.R. Frascati, Frascati (Roma)), Marcello Artioli, Luca Giannessi, Alberto Petralia, Marcello Quattromini, Vincenzo Surrenti, Amalia Torre (ENEA C.R. Frascati, Frascati (Roma)), Marco Bellaveglia, Enrica Chiadroni, Giampiero Di Pirro, Massimo Ferrario, Giancarlo Gatti, Andrea Renato Rossi (INFN/LNF, Frascati (Roma)), Alberto Bacci (INFN/LNF, Frascati (Roma); Istituto Nazionale di Fisica Nucleare, Milano), Julietta V. Rau (ISM-CNR, Rome), Luca Serafini (Istituto Nazionale di Fisica Nucleare, Milano), Vittoria Petrillo (Istituto Nazionale di Fisica Nucleare, Milano; Universita' degli Studi di Milano, Milano), Alessandro Cianchi (Università di Roma II Tor Vergata, Roma)

A heterodyne speckle approach has been applied for measuring the transverse coherence of FEL radiation in SASE regime in the optical region (400nm) at SPARC (LNF, Frascati - Italy). It turned out that the coherence length is comparable with the beam size and only slight variations of the coherence properties have been observed after the 5th undulator section. The technique needs a very essential setup composed only by a water suspension of commercial colloidal particles and a CCD camera. The Complex Coherence Factor is retrieved from the Fourier analysis of the interference pattern generated by the stochastic superposition of the almost spherical waves scattered by the particles and the unperturbed transmitted beam (heterodyne speckles). This approach does not require the engineering of ad-hoc devices and provides a two-dimensional map of the transverse coherence without any a-priori assumption about its functional form. The method is suitable for one-shot characterization and it works in the X-ray wavelength as well. It has been previously developed and tested to be effective with synchrotron radiation [*,**] (ID02 and ID06 at ESRF, Grenoble).

** M.D. Alaimo, M.A.C. Potenza, M. Manfredda, G. Geloni, M. Sztucki, T. Narayanan & M. Giglio, Phys. Rev. Lett. 103 (2009).*
*** M. Manfredda et al., in preparation*

Femtosecond X-ray Pulse Duration and Separation Measurement using a Cross-Correlation Technique

THOC04

Yuantao Ding, Franz-Josef Decker, Zhirong Huang, Henrik Loos, James Welch, Juhao Wu, Feng Zhou (SLAC, Menlo Park, California), Paul J. Emma (LBNL, Berkeley, California), Chao Feng (SINAP, Shanghai)

At the Linac Coherent Light Source (LCLS), the emittance-spoiling foil is a very simple and effective method to control the output x-ray pulse duration [*]. In addition, double slotted foil can be used to generate two femotsecond x-ray pulses with variable time delays. In this paper, we report the first measurement of x-ray pulse duration and double x-ray pulse separation by using a cross-correlation technique between x-rays and electrons [**]. The measured pulse separation can be used to calibrate the foil setup, and pulse duration of less than 3 fs rms has been achieved. This technique can be used to provide critical temporal diagnostics for x-ray experiments that employ the emittance-spoiling foil.

[*] P. Emma et al., PRL 92, 074801 (2004).
[**] G. Geloni et al., DESY 10-008.

Thursday Poster Session

- **FEL Technology -3- : Undulators, Monitors, Beam diagnostics**
- **New Concepts**
- **FEL Applications**

The MID Station at the European X-ray Free-Electron Laser (XFEL.EU) facility — THPD01

Anders Madsen (European XFEL GmbH, Hamburg)

The Materials Imaging and Dynamics (MID) station at the forthcoming European XFEL facility will allow investigations of materials using wide- and small-angle X-ray scattering techniques. The special features of the radiation from XFEL.EU allow novel experiments to be conducted, for instance exploiting the temporal structure and coherence properties of the X-rays. Of particular interest are the investigations of fast and ultra-fast dynamics using X-ray speckle correlation techniques and coherent X-ray diffractive imaging. The MID station will also provide new possibilities for time-resolved scattering in general and the use of high energies (> 20keV) is also foreseen for certain experiments. The MID station features appropriate X-ray optics to tailor the beam for the aforementioned experiments and will also be equipped with an optical laser pump system. The instrumentation foreseen comprises an in-vacuum sample handling/positioning system as well as a very long vacuum pipe hosting a detector at the end. Highly specialized and optimized 2D pixel detectors are currently being developed to be able to fulfill the scientific goals of the MID station.

A Study of the Effects of Imperfect X-ray Coherence on Coherent X-ray Diffraction Experiments Using an X-ray Free-Electron Laser — THPD02

Quinn Robert Marksteiner, John Barber, Richard Sandberg (LANL, Los Alamos, New Mexico)

The pulses generated by an x-ray free electron laser (XFEL) have high power and brilliance, but are not perfectly coherent. Several successful X-ray diffraction imaging experiments have recently been performed at LCLS, including the imaging of whole viruses and protein nanocrystals in three dimensions. At the proposed MaRIE hard X-ray facility at LANL, the x-ray FEL will be used to image objects that are larger than the FEL beam, so that the demands on transverse coherence of the FEL become more stringent. Theory for incoherent light predicts that CXDI can only be done when the transverse coherence length of the X-ray beam is at least 2x the sample size*. With electron emittances comparable to the emittances in LCLS, the transverse coherence of the MaRIE baseline design is 80%, which means that the FWHM spot size of our X-ray beam is approximately the same size as the coherence length of our beam. We investigate this issue by using ray beams generated from Genesis** simulations to simulate an x-ray diffraction experiment, and then attempting to do image reconstruction. Results of these simulations will be shown, and methods of mitigating this problem will be discussed.

[*] Miao, J., et al., Physical Review B, 2003. 67(17): p. 174104. [**] S. Rieche, Nucl. Instrum. Methods Phys. Res. Sect. A, vol. 429, p. 243, 1999.

We acknowledge the support of the LDRD program at Los Alamos National Laboratory.

Towards ESR Spectroscopy with FLARE: New Semiconductor Plasma Switches — THPD03

Szymon Smolarek, Hans Engelkamp, Rienk Jongma, Wim J. van der Zande, Frans Wijnen (Radboud University, Nijmegen), Giel Berden, Britta Redlich (FOM Rijnhuizen, Nieuwegein)

The peculiar (macro-/micro-) pulse structure of normal conducting LINAC driven FELs is not optimal for all experiments. The problem is especially pronounced in case of Electron Spin Resonance (ESR) spectroscopy where new possibilities opened by the FIR wavelength range of FLARE (100µm ~ 1500 micron) will be accessible only if generation of sub-microsecond pulse sequences with controlled pulse separation and duration are achieved. Laser-activated semiconductor switches have been already developed for FIR beam slicing*. Nevertheless, the long wavelength operation of FLARE and resulting FIR beam parameters bring new difficulties like large active surface areas and slow electron-hole recombination rates at low carrier concentrations. Additional difficulties arise from specific requirements for the ESR-capable pulse slicing system that differ from existing systems providing single, ultrashort FIR pulses**. In this work we present our first steps to improve existing solutions using Silicon On Oxide and gold doped silicon wafers. We present theoretical simulations together with preliminary experimental results that confirm the feasibility of the proposed solution.

** F. A. Hegmann and M. S. Sherwin, Proc. SPIE 2842, 90 (1996) **A. Y. Elezzabi, J. Meyer and M. K. Y. Hughes, Appl. Phys. Lett., 1995, 66, 402.*

The Nijmegen THz-FEL is funded via the ‘Big Facilities’ programme of the Netherlands Organisation for Scientific Research (NWO).

Applications of Infrared FELs — THPD04

Giel Berden, Jos Oomens, Britta Redlich (FOM Rijnhuizen, Nieuwegein), Alexander van der Meer (FOM Rijnhuizen, Nieuwegein; Radboud University, Nijmegen)

Perhaps triggered by successful user applications at several IR FEL facilities, more IR FELs are currently being developed, as stand alone or as part of an x-ray/VUV FEL facility for two color experiments. This contribution gives an overview of applications at the FELIX infrared user facility, where experimental campaigns have provided new insights in various fields such as astronomy, proteomics, chemistry, and material science.

Observation of High Harmonic Generation from 6H-SiC Irradiated by MIR-FEL — THPD05

Kyohei Yoshida, Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Ryota Kinjo, Takuya Komai, Kai Masuda, Hani Hussein Negm, Hideaki Ohgaki, Kensuke Okumura, Mohamed Omer, Marie Shibata, Kyohei Shimahashi, Konstantin Torgasin, Heishun Zen (Kyoto University, Kyoto)

Silicon Carbide (SiC) is attractive as the next generation power devices, heat resistance material and so on. In addition, 6H-SiC is investigated as the material for high harmonic generation [1]. For verifying the possibility of high harmonic generation by 6H-SiC irradiated by MIR-FEL, we measured the emission spectrum from 6H-SiC irradiated by MIR-FEL whose center wavelength was 7.8 μm. As the result, we clearly observed the emissions at 963 nm, 861 nm and 775 nm, which correspond to harmonics of 8th, 9th and 10th wavelength respectively. In this meeting, we will present and discuss about the high harmonic generation introduced by MIR-FEL.

[1] Hiroaki Sato, Makoto Abe, Ichiro Shoji, Jun Suda, and Takashi Kondo, J. Opt. Soc. Am. B, Vol. 26, No. 10(2009), 1892-1896

Bioluminescence and its Dynamics in Enchytraeus Japonensis by Irradiation of Free Electron Laser — THPD06

Satoshi Kurumi, Kaoru Suzuki, Tomohito Taima (Nihon University, Tokyo), Ken Hayakawa, Yasushi Hayakawa, Toshinari Tanaka (LEBRA, Funabashi), Fumio Shishikura (Nihon University School of Medicine, Tokyo)

We report on the experiment results of bioluminescence from Enchytraeus Japonensis by free electron laser (FEL) irradiation, and discuss about migration of bioluminescence on Enchytraeus Japonensis body. In this experiment, we observed behaviors or dynamics of FEL irradiated Enchytraeus japonensis for a few seconds by change coupled device (CCD) camera. One shot of FEL (wavelength: 2940 nm, pulse width: 200 fsec) which resonated with hydroxyl stretching vibration was irradiated to center of the Enchytraeus Japonensis head. After FEL irradiation, head was amputated, and orange bioluminescence was generated from around the laser irradiation area. Immediately after laser amputation of the head (0.1 seconds later), yellow bioluminescence was observed, and intensity of this luminescence was increasing after 0.3 seconds. This bioluminescence migrated into living cells from the head toward the trunk of the body. 10.0 seconds later, newly blue bioluminescence was generated from Enchytraeus Japonensis head. Wavelengths of these bioluminescence were as below, orange was from 600 nm to 650 nm, yellow was from 500 nm to 600 nm, blue was from 400 nm to 450 nm.

"John. E. Wampler and B. G. M. Jamieson, Comp. Biochem. Physiol., Vol. 66B, p. 43 (1980)","R. Tadokoro, M. Sugio, J. Kutsuna, S. Tochinai and Y. Takahashi, Current Biology, Vol. 16, p. 1012 (2006)"

FEL for Apply Physics — THPD07

Vladimir Vasilevich Gorev (NRC, Moscow)

In this report I give an overview of the theoretical investigations in FEL for apply nuclear physics.

Pit Formation on Dental Hard Tissues Using Two Different Free Electron Laser Sources, LEBRA-FEL and KU-FEL

THPD08

Toshiro Sakae (Nihon University School of Dentistry at Matsudo, Matsudo-shi), Toshiteru Kii, Hideaki Ohgaki, Heishun Zen (Kyoto University, Kyoto), Ken Hayakawa, Yasushi Hayakawa, Manabu Inagaki, Takao Kuwada, Keisuke Nakao, Kyoko Nogami, Isamu Sato, Toshinari Tanaka (LEBRA, Funabashi)

According to the increased usage and demands of lasers in dentistry, research and development of the more reliable and functional lasers are needed. In the case of caries treatment, the lasers generated by commercial apparatus are not enough to dig the dental enamel and/or dentin tissues. Our previous studies showed that FEL generated at LEBRA has a potential to form pits on these dental hard tissues easily, and that the effective wavelength depends on the tissue types sensitively at about 3000 nm. To progress the FEL study on dental tissues, it is needed to spread the range of wavelengths more than that at LEBRA, between 2000 and 6000 nm. The newly established KU-FEL is able to generate the FEL of wavelength between 5000 and 13000 nm. Combining the two FEL sources, we found a new result that the dental hard tissues were easily dug by 7800 nm KU-FEL, which wavelength has not been presumed before. In the combination of LEBRA-FEL and KU-FEL, the wider knowledge on the FEL action on dental tissues will be achieved.

This study was supported by a Grant for Supporting Project for Strategic Research by MEXT, Japan (S0801032) and by the ZE Research Program, IIAE, Kyoto University (A-17).

On the Focusing Properties of Linear Undulators

THPD09

Marcello Quattromini, Emanuele Di Palma, Luca Giannessi, Alberto Petralia (ENEA C.R. Frascati, Frascati (Roma)), Marcello Artioli (ENEA-Bologna, Bologna)

This contribution investigates the focusing properties of PPM linear undulators. The problem of identifying the conditions that ensure the existence of the electron beam eigenstates in the undulator lattice for a given working point of electron beam energy and resonant wavelength has been studied. For any given undulator lattice, a bandlike structure can be identified defining regions in the energy-wavelength plane where no matching can be found, i.e. it turns to be impossible to transport the electron beam so that optical functions be periodic at lattice boundaries. Some specific cases are discussed for the SPARC FEL undulator.

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Construction and Testing of a Short-period Non-conventional PPM Undulator in the Context of the Sparx Initiative

THPD10

Marcello Quattromini, Giuseppe Dattoli, Mario Del Franco, Elio Sabia (ENEA C.R. Frascati, Frascati (Roma)), Luca Giannessi (ELETTRA, Basovizza; ENEA C.R. Frascati, Frascati (Roma)), Raffaella Geometrante, Mauro Zambelli (ELETTRA, Basovizza; KYMA, Trieste), Marcello Artioli (ENEA-Bologna, Bologna), Giorgio Soregaroli (Euromisure srl, Pieve S. Giacomo (Cremona)), Julietta V. Rau (ISM-CNR, Rome), Tadej Milharcic (KYMA, Trieste), Mirko Kokole (KYMA, Trieste; KYTE, Sezana)

The Sparx initiative includes an R & D on the definition, design and construction of non-conventional magnetic undulator. In this paper we describe the features and technical solutions adopted for the construction of a 1.4 m long, variable gap,short period, non conventional magnetic undulator. Particular emphasis is dedicated to the technical solutions adopted for the assembly and regulation of the magnetic blocks, and the system adopted for the measurement and characterization of the device. Finally, some scenarios for possible use of the undulator on Sparc (ENEA / INFN / CNR) beam line is discussed. Presently, the delivery/testing of the device is scheduled for Summer/Fall 2012.

Funding Agency: Italian Ministry for University and Research (MUR)

The JLAB UV Undulator

THPD11

Stephen C. Gottschalk (STI, Washington), Stephen Vincent Benson, Steven Wesley Moore (JLAB, Newport News, Virginia)

Recently the JLAB FEL has demonstrated 150 W at 400 nm and 200 W at 700 nm* using a 33mm period undulator designed and built by STI Optronics. This paper describes the undulator design and performance. Two key requirements were low phase error, zero steering and offset end fields and small rms trajectory errors. We will describe a new genetic algorithm that allowed phase error minimization to 1.8 degrees while exceeding specifications. The mechanical design, control system and EPICS interface will also be summarized.

**S. V. Benson et al., "Beam Line Commissioning of a UV/VUV FEL at Jefferson Lab, presented at the 2011 FEL Conference, Shanghai, China, Aug. 2011*

Design and Performance of the NLCTA-Echo 7 Undulators — THPD12

Stephen C. Gottschalk (STI, Washington)

The Echo-enabled harmonic generation (EEHG) FEL at SLAC NLCTA has shown coherent radiation in the seventh harmonic (227 nm) of the second seed laser*. Earlier experiments demonstrated 3rd and 4th EEHG**. We describe design and performance of the 33mm and 55mm period undulators built by STI Optronics and used for these experiments. Magnetic design of the 33mm period undulator was based on an earlier curved pole, two-plane focusing undulator for the UCLA seeded THz FEL***. This design used an evolutionary optimizer and custom pre/post processing FEA codes to maximize field strength with minimum magnetic material while achieving specified two-plane focusing. The 55mm undulator was identical to the JLAB IR FEL and APS UA U55 designs. A challenge for both these devices was achieving tight normal and skew trajectory excursions (<500 G-cm2), zero trajectory offset and < 10 G-cm steering without end correctors over a 5mm diameter horizontal and vertical region with a 4 month delivery requirement. We will also describe a new tuning method based on operations research linear programming that was used to help meet these goals over a 2X larger region while maintaining 1 deg phase errors.

**D. Xiang et al, Phys. Rev. Let. 108 024802 (2012)*
***D. Xiang et al, Phys. Rev. Let. 105 114801 (2010)*
**** S. Gottschalk et al, "UCLA Seeded THz FEL Undulator-Buncher Design", this conference*

Design and Performance of the Wedged Pole Hybrid Undulator for the Fritz-Haber-Institut IR FEL — THPD13

Stephen C. Gottschalk, Terence Ellis DeHart, Robert Norman Kelly, Michael Offenbacker, Art Steven Valla (STI, Washington), John Rathke, Alan Murray Melville Todd (AES, Medford, NY), Hans Bluem, David Dowell (AES, Princeton, New Jersey), Sandy Gewinner, Heinz Junkes, Gerard Meijer, Wieland Schöllkopf, Weiqing Zhang (FHI, Berlin), Ulf Lehnert (HZDR, Dresden)

An IR and THz FEL with a design wavelength range from 4 to 500 microns has been commissioned at the Fritz-Haber-Institut (FHI) in Berlin, Germany. Lasing at 28 MeV and a wavelength of 18 micron was achieved in Feb 2012*. We describe the performance of the undulator built and installed at FHI by STI Optronics for use in the mid-IR range (< 50 micron) and 15-50 MeV beam energy. The undulator was a high field strength wedged pole hybrid (WPH) with 40mm period, 2.0m long, minimum gap 16.5mm. A new improvement was including radiation resistance in the magnetic design. We will discuss the measured magnetic and mechanical performance; central and zero steering/offset end field magnetic designs; key features of the mechanical design and gap adjustment system; new genetic shimming algorithms and local/EPICS control systems.

**W.Schöllkopf et al., "First Lasing of the IR FEL at the Fritz-Haber-Institut Berlin", this conference*

Composite Poles for Cryogenic In-Vacuum Permanent Magnet Undulators — THPD14

Carsten Kuhn, Johannes Bahrdt, Michael Scheer (HZB, Berlin), Werner Theisen (Ruhr-Universität Bochum, 44801 Bochum), Martin Schmidt (Technische Universität Berlin, 10587 Berlin)

Cryogenic in-vacuum permanent magnet undulators with periods less than 10 mm and correspondingly narrow gaps require complex pole designs made of different materials to achieve highest field strengths. An assembly by clamping the individual parts is rather complicated and adhesive methods may be difficult to employ in cryogenic devices. Alternatively, we develop new methods to join the pole pieces with various thermal processes like welding or brazing. Mechanical and magnetic properties after assembly are discussed.

Novel Magnet Production Technique used for an Elliptically Polarizing Undulator — THPD15

Erik Jan Wallén, Karl Ingvar Blomqvist, Franz Hennies (MAX-lab, Lund), Johannes Bahrdt (HZB, Berlin), Franz-Josef Boergermann (Vacuumschmelze GmbH & Co. KG, Hanau)

A common problem for elliptically polarizing undulators (EPUs) is that the magnetic forces give a mechanical deflection in the magnet holder construction when changing the undulator phase. Gluing horizontally and vertically magnetized blocks together can increase the mechanical stability of the magnet holders, which has been done for 10 EPUs built at the BESSY II light source. The gluing process of pairs of magnetized magnet blocks is time-consuming, expensive and difficult to carry out with high positional precision. A novel magnet production technique has been developed where un-magnetized pairs of blocks are glued together before magnetization. The large number of parts, the time for assembly, and the cost of the EPU can be reduced with the novel magnet production technique. The novel magnet production method has been used for a 2.6 m long EPU of APPLE-II type, which is under construction at MAX-lab. The frame for the EPU is made of cast iron in order to get a small mechanical deformation when changing phase in the inclined mode. The paper includes detailed descriptions of the novel magnet production technique, including measurements of the magnetization, and the new EPU.

Tuning and Testing of the Prototype Undulator for the European XFEL — THPD18

Yuhui Li, Uwe Englisch, Joachim Pflueger (European XFEL GmbH, Hamburg)

The European X-ray Free Electron Laser (EXFEL) uses large undulator systems with a total length of approximately 500 meters. The main part of the system is 91 5m long undulator segments. All segments are gap variable planar undulators. In the next 2 to 3 years all these 91 undulators will be manufactured and subsequently measured and tuned in order to meet the EXFEL field specifications. In order to match the tight schedule and to reach the high qualification, fast and reliable measurement methods and fine tuning algorithms must be established and be tested before the mass production starts. In this paper we report the tuning results of the undulator prototype for the EXFEL. It is shown that good quality is achieved which satisfies all specification asked by the European XFEL. It is also shown that the measurement and tuning procedures work well, fast and are straightforward to apply.

Technical Overview of SwissFEL Undulator Section — THPD19

Romain Ganter, Masamitsu Aiba, Hans-Heinrich Braun, Marco Calvi, Albert Fuchs, Eike Hohmann, Rasmus Ischebeck, Haimo Joehri, Boris Keil, Natalia Milas, Marco Negrazus, Sven Reiche, Stephane Sanfilippo, Thomas Schmidt, Peter Wiegand (Paul Scherrer Institut, Villigen)

Starting after Linac 3 at z ~ 430 m (z = 0 being the gun photocathode position), the so-called Aramis Hard-X ray undulator section extends over 170 m, from the energy collimator to the electron beam dump. Electrons enter the undulator section with a maximum energy of 5.8 GeV, a slice emittance below 0.43 μm and a peak current of 3 kA with 200 pC of charge. A prototype of the in-vacuum undulator (U15) is currently under assembly. Most of the other beamline components have been designed and for some of them prototypes are already ordered (quadrupoles, beam position monitors, phase shifters, alignment quadrupoles; mechanical supports; safety components). The paper will describe how constraints like temperature drifts, stray magnetic field, wakefields, beam losses, costs are taken into account for the design of components and building (undulators are however described in details in a companion paper).

Linear Polarization Control with Cross-polarized Helical Undulators at FERMI — THPD21

Enrico Allaria, Bruno Diviacco (ELETTRA, Basovizza)

FERMI@Elettra is a free electron lasers user facility based in Trieste Italy. The first FEL line (FEL-1) is based on the high gain harmonic generation schemes and covers the spectral range from about 80nm down to 20nm with high quality FEL pulses. FERMI radiators have been designed to allow control of the FEL polarization. APPLE-II undulators have been adopted for FERMI that can change the polarization from horizontal to vertical, to circular right and left. It is however known that depending on the required magnetic strength the change of polarization can imply a strong change in the focusing properties of the undulator into the electron beam. This makes the polarization change, especially from horizontal to vertical, not straightforward since an accurate control of the electron beam matching is needed. In this work we report a study where horizontal-vertical polarization switching is done using the cross-polarized undulators scheme.

Demonstration of Bulk High-Temperature Superconductor Staggered Array Undulator — THPD23

Ryota Kinjo, Yong-Woon Choi, Hidekazu Imon, Toshiteru Kii, Kai Masuda, Kazunobu Nagasaki, Hani Hussein Negm, Hideaki Ohgaki, Mohamed Omer, Marie Shibata, Kyohei Shimahashi, Konstantin Torgasin, Kyohei Yoshida, Heishun Zen
(Kyoto University, Kyoto)

B0 = 1.3 T was achieved with a 10-mm period and 4-mm gap small prototype of bulk high-temperature superconductor staggered array undulator. High-field short-period undulator is a key technology for FEL, especially for short-wavelength FEL. We have developed an undulator using bulk high-temperature superconductors in a staggered array configuration. We made experiments of normal- and hybrid-type of the undulator with the 10-mm period and 4-mm gap prototype in a 2-T superconducting solenoid at around 10 K. In the conference, we will reports a behavior of the undulator at high-field and low-temperature region, a cause to limit B0 in the prototype, and achievable B0 if the cause is solved.

Origin of Shift Dependent Multipoles in Apple-II Undulators — THPD24

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

APPLE-II insertion devices are very flexible devices for production of variably polarized photons. This devices inherently suffer from shift dependent integrated field multipoles that can reach values which can seriously deteriorate quality of the electron beam. Since there is no really effective shimming method for correction of this errors, it is important to understand where they originate. Paper presents a study of integrated field multipoles shift dependency based on deformation of magnetic array due to magnetic forces. We have modeled separately deformations of each magnet keeper in the magnetic array. Model calculations have shown that most of integrated field multipole dependency on the shift is due to mechanical deformation in combination with magnetic effects.

Feasibility of Diagnostics Undulator Studies at ASTA — THPD25

Alex Lumpkin, Manfred Wendt (Fermilab, Batavia), John Byrd (LBNL, Berkeley, California)

The high-power electron beams for the Advanced Superconducting Test Accelerator (ASTA) facility involve up to 3000 micropulses with up to 3.2 nC per micropulse in a 1-ms macropulse. With beam energies projected from 45 to 800 MeV the need for non-intercepting diagnostics for beam size, position, energy, and bunch length is clear. Besides the rf BPMs, optical synchrotron radiation (OSR), and optical diffraction radiation (ODR) techniques already planned, we propose the use of undulator radiation from a dedicated device for diagnostics with a nominal period of 4-5 cm, a tunable field parameter K, and a length of several meters. We propose time resolving the e-beam properties within the macropulse by viewing the undulator radiation with standard gated ICCD's (size and position) and a streak camera coupled to an optical spectrometer (energy, bunch length, and phase). The feasibility of extending such techniques in the visible regime at a beam energy of 125 MeV into the UV and VUV regimes with beam energies of 250 and 500 MeV will be presented.

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Design and Fabrication of a Variable-period Helical Undulator for a Table-top Free-electron Laser — THPD26

Jungho Mun, Kyu Ha Jang, Young Uk Jeong, Kitae Lee, Seong Hee Park, Nikolay Vinokurov (KAERI, Daejon), Min Yong Jeon (Chungnam National University, Daejoen)

This study is about a design of a helical undulator for a compact terahertz (THz) free-electron laser (FEL). We propose a variable-period (V-P) helical undulator using the permanent magnets (PMs) for a compact source. The concept of the design is based on a structure of a hybrid PM planar undulator. The hybrid planar undulator uses the pole pieces interposed between the PMs. The two sets of the planar structure are intercrossed in the horizontal plane with the phase difference of quarter per one period. It can generate a strong circular magnetic field along the undulator axis. In addition, it can change the wavelength of the radiation from FEL by changing the undulator period length. The period lengths of the undulator can change from 23 mm to 26 mm by using mechanical motorizing systems. The mechanical variation of undulator period is realized by the longitudinal repulsion force between the PMs. The designed undulator has same maximum field strength of ~1 Tesla on axis in the whole range of period length. Numerical analysis of the V-P helical undulator using a 3-D simulation tool and the demonstration of a prototype will be presented.

This work was supported by the World Class Institute Program of the National Research Foundation of Korea funded by the Ministry of Education, Science-Technology of Korea(NRF Grant Number:WCI2011-001)

Status of PAL-XFEL Undulator System — THPD27

Dong Eon Kim, Moo-Hyun Cho, Hong Sik Han, Jung Yun Huang, Young-Gyu Jung, Hong-Gi Lee, Ki-Hyeon Park, Hyung Suck Suh (PAL, Pohang, Kyungbuk), In Soo Ko (POSTECH, Pohang, Kyungbuk)

Pohang Accelerator Laboratory (PAL) is developing 10 GeV, 0.1 nm SASE based FEL for high power, short pulse X-ray coherent photon sources named PAL-XFEL. At the first stage PAL-XFEL needs two undulator lines for photon source. PAL is developing undulator magnetic structure based on EU-XFEL design. The hard X-ray undulator features 7.2 mm min magnetic gap, and 5.0 m magnetic length with maximum effective magnetic field larger than 0.908 T to achieve 0.1nm radiation at 10 GeV electron energy. Soft X-ray undulator system has 8.3 mm undulator gap with 33.4 mm magnetic period. In this report, the status of the undulator project including mechanical design, magnetic design, phase shifter, quadrupole design are summarized.

Beam Diagnostic Systems for PAL-XFEL — THPD28

Changbum Kim, Hyojin Choi, Jae-Young Choi, Jung Yun Huang, Heung-Sik Kang, Do Tae Kim, Byung-Joon Lee, Chang-Ki Min (PAL, Pohang, Kyungbuk)

The XFEL project in Pohang Accelerator Laboratory (PAL) requires low beam-emittance (< 1 μm·rad), ultra-short bunch length (25 μm ~80 fs), high peak current(~3.5 kA), high stability of beam energy (< 0.01%), and measurement and steering of beam trajectory within micrometers (< 2 μm). Therefore, beam diagnostics for SASE XFEL should be, focused on attaining femto-second precision in the measurement of temporal beam parameters, and sub-micrometer precision in beam position measurement. Charge measurement and energy measurement are important as well. In this work, technical concepts regarding the diagnostic monitors will be summarized and present status of them will be described.
Funding Agency : Korean Ministry of Education, Science and Technology

R&D towards a Delta-Type Undulator for the LCLS* — THPD29

Heinz-Dieter Nuhn, Yuantao Ding, Georg L. Gassner, Zhirong Huang, Eugene Michael Kraft, Yurii Levashov, Timothy M. Montagne, James Welch, Zachary Wolf, Juhao Wu (SLAC, Menlo Park, California), Alexander Temnykh (CLASSE, Ithaca, New York)

The LCLS generates linearly polarized, intense, high brightness x-ray pulses from planar fixed-gap undulators. While the fixed-gap design supports a very successful and tightly controlled alignment concept, it provides only limited taper capability (up to 1% through canted pole and horizontal position adjustability) and lacks polarization control. The latter is of great importance for soft x-ray experiments. A new compact undulator design (Delta) has been developed and tested with a 30-cm-long in-vacuum prototype at Cornell University, which adds those missing properties to the LCLS undulator design and is readily adapted to the LCLS alignment concept. Tuning Delta undulators within tight, FEL type tolerances is a challenge due to the fact that the magnetic axis and the magnet blocks are not easily accessible for measurements and tuning in the fully assembled state. An R&D project is underway to install a 3.2-m long out-of-vacuum device in place of the last LCLS undulator, to provide controllable levels of polarized radiation and to develop measurement and tuning techniques to achieve x-ray FEL type tolerances. Presently, the installation of the device is scheduled for August 2013.
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Fast, Absolute Bunch Length Measurements in a Linac using an Improved RF-phasing Method — THPD30

Paul J. Emma (LBNL, Berkeley, California), Christopher Behrens (DESY, Hamburg), Henrik Loos (SLAC, Menlo Park, California)

There is great demand for a fast, accurate method to measure the absolute bunch length of an electron beam in a linac. Many ideas are available, with one of the most attractive based on the transverse RF deflector*. Since this specialized technology can be costly and unavailable, we introduce an alternate method using accelerating RF with the same robust characteristics (fast, accurate, and absolute). This method is based on the 'RF zero-phasing' scheme**, but includes several significant improvements based on experience with the RF deflector method.
** R. Akre et al., Proc. of PAC-01, p. 2353. ** D. X. Wang et al., Proc. of PAC-97, p. 2020.*
We are grateful to the US Department of Energy under contract number DE-AC02-76SF00515.

Sub-femtosecond Hard X-Ray Pulse from Very Low Charge Beam at LCLS — THPD31

Violetta Wacker (DESY, Hamburg), Yuantao Ding, Josef Frisch, Zhirong Huang, Claudio Pellegrini, Feng Zhou (SLAC, Menlo Park, California)

The Linac Coherent Light Source (LCLS) is an x-ray free-electron laser (FEL) at SLAC National Accelerator Laboratory, supporting a wide range of scientific research with an x-ray pulse length varying from a few to several hundred femtoseconds. There is also a large interest in even shorter, single-spike x-ray pulses, which will allow the investigation of matter at the atomic length (Å) and time scale (fs). In this paper, we investigate the FEL performance using 1pC and 3pC electron bunches at LCLS, based on the start-to-end simulations. With an optimization of the machine setup, simulations show that single spike, sub-femtosecond, hard x-ray pulses are achievable at this low charge.

Generation and Measurement of Subpicosecond Electron Beam in Photoinjector — THPD32

Zhigang He (USTC/NSRL, Hefei, Anhui)

The generation of a subpicosencond electron beam in photoinjector was studied by improving the acceleration gradient of the gun, suitably tunning the charge of the bunch and the acceleration phase. To measure the bunch length, an nondestructive bunch length measurement technology by using the coherent Cherenkov radiation method was considered.

Generation of Ultra-short Electron Bunches at FLASH — THPD33

Juliane Roensch-Schulenburg, Eugen Hass, Tim Plath, Marie Rehders, Jörg Rossbach (Uni HH, Hamburg), Nicoleta Baboi, Marie Kristin Bock, Michael Bousonville, Christopher Gerth, Karsten Klose, Torsten Limberg, Uros Mavric, Holger Schlarb, Bernhard Schmidt, Siegfried Schreiber, Bernd Steffen, Silke Vilcins (DESY, Hamburg), Sascha Schnepp, Thomas Weiland (TEMF, TU Darmstadt, Darmstadt), Aleksandar Angelovski, Rolf Jakoby, Andreas Penirschke (TU Darmstadt, Darmstadt), Alexander Kuhl (TU Darmstadt, Darmstadt; Uni HH, Hamburg)

In order to produce radiation pulses of a few femtoseconds at FELs like FLASH, different concepts have been proposed. Probably the most robust method is to create an electron bunch, which is in the most extreme case as short as one longitudinal optical mode. For FLASH this translates into a bunch length of a few micrometers only. In order to mitigate space charge effects, the bunch charge needs to be about 20 pC. The technical requirements to achieve this goal are discussed. This includes beam dynamics studies to optimize the injection and compression of small charge electron bunches. A reduced photo injector laser pulse duration helps to relax the RF tolerance which scales linear with the compression factor. A new photo injector laser with sub-picosecond pulse duration in combination with a stretcher is used to optimize the initial bunch length. The commissioning of the new laser system and first experiments are described. Limitations of the presently available electron beam diagnostics at FLASH for short, low charge bunches are analyzed. Improvements of the longitudinal phase space diagnostics and the commissioning of a more sensitive beam arrival time monitor are described.
The work is supported by German Federal Ministry of Education and Research (BMBF) within Joint Project - FSP 301 under the contract number 05K10GU2.

Statistical Analysis of FLASH Radiation in Spectral Domain to Characterize Pulse Duration — THPD34

Svitozar Serkez, Natalia Gerasimova, Vladimir Rybnikov (DESY, Hamburg)

Machine set-up for short pulses at FLASH requires fast photon pulse duration diagnostics. In case of SASE FEL a statistical analysis of spectral distributions can be applied to retrieve an estimate on pulse length (*). We report on development of a diagnostics tool based on spectral analysis at FLASH. A prerequisite for such an analysis, a capability to resolve spiky structures of single FEL pulses, is ensured by resolving power of high resolution spectrometer at the PG2 beamline of FLASH greater than 10.000 (**). Two dependencies, of photon pulse energy fluctuations in spectral window and of second order spectral correlation function, are calculated and fit with unknown pulse length in assumption of certain pulse shape. If investigation on fluctuations is a delicate method, the second order spectral correlation function is robust to measurement and lasing conditions. Other strength of analysis on second order correlation function is its applicability in saturation (***). The influence of FLASH particularities, e.g. energy chirp and degree of transverse coherence below 1, on second order correlation function and pulse length estimate are discussed.

(*) E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov, Opt. Com. 148 (1998) 383
(**) N. Gerasimova et al., J. Mod. Opt. 58 (2011) 1480
(***) A. Lutman et al., Phys. Rev. ST Accel. Beams 15, 030705 (2012)

Photon Beam Diagnostics at FLASH — THPD35

Günter Brenner, Susanne Bonfigt, Markus Braune, Ulf Jastrow, Barbara Keitel, Svea Kreis, Henning Kühn, Michael Markert, Elke Plönjes, Andrei Sorokin, Kai I. Tiedtke
(DESY, Hamburg)

FEL photon beam diagnostics provides information on important laser beam parameters for tuning and optimization of the FEL during commissioning and user experiments. Due to the laser's unique properties such as extremely high peak powers and short pulse lengths a shot-to-shot diagnostics of the FEL radiation is particularly challenging. Yet, this pulse-resolved characterization of the photon beam is essential for most user experiments. In order to monitor important parameters such as radiation pulse intensity, beam position and spectral as well as temporal distribution, sophisticated concepts have been developed and used at FLASH - always coping with the highly demanding requirements of user experiments as well as machine operation. Here an overview on the latest developments and achievements regarding photon diagnostic devices at FLASH will be presented, with emphasizes on pulse resolving intensity and energy detectors based on photoionization of rare gases (GMD, OPIS), beamline transmission measurements and wavelength determination employing the online VLS grating spectrometer.

A Photoionization Instrument for Online Wavelength Monitoring for FLASH — THPD36

Markus Braune, Susanne Bonfigt, Barbara Keitel, Henning Kühn, Andrei Sorokin, Kai I. Tiedtke (DESY, Hamburg), Pavle Juranic (DESY, Hamburg; PSI, Villigen PSI)

Due to the statistically fluctuating output of SASE FELs it is important to monitor the properties of the radiation pulses permanently in order to tune and optimize the machine performance and meet the user requirements. The photon diagnostics section at Free electron LASer in Hamburg (FLASH) developed a device for FEL wavelength monitoring based on photoionization of gaseous targets like rare gases for which photo ionization cross sections and binding energies are well-known. This instrument comprises one ion and three electron time-of-flight spectrometers. The intensity ratio of singly and doubly charged target ions shows a monotonic change over a certain photon energy range and hence represents a sensitive measure of the FEL wavelength. With the electron spectrometers the time of flight of the photo electrons of the target gas is recorded which corresponds to its kinetic energy and therefore - considering the binding energy - almost directly to the photon energy. Wavelength variation of the FEL during operation can be monitored by observing the change in the ion intensity ratio and photo electron time-of-flight, respectively, with an accuracy of better than 1eV in the VUV range.

Beam Dynamic Studies for the Generation of Short SASE Pulses at FLASH — THPD37

Marie Rehders, Jörg Rossbach (Uni HH, Hamburg), Juliane Roensch-Schulenburg (CFEL, Hamburg; Uni HH, Hamburg), Holger Schlarb, Siegfried Schreiber (DESY, Hamburg)

Many users at FLASH work on pump-probe experiments, where time resolution is determined by the duration of the SASE pulses. Therefore users have expressed the strong wish for shorter XUV pulses. The shortest possible pulse is a single longitudinal optical mode of the SASE radiation. The most direct way to realize this at FLASH would be to reduce the electron bunch length to only a few µm at the entrance of the undulator section. In the ideal case a bunch charge of 20pC is sufficient for the generation of such short bunches. A shorter bunch duration directly at the photo-cathode helps to overcome technical limitations of the bunch compression due to RF induced non-linearities and collective effects. Beam dynamic studies are being performed to optimize the parameters of the photo injector laser, of the accelerating modules, and of the bunch compression. This includes particle tracking starting from the cathode though the accelerating modules with the ASTRA code and through the dipole chicanes using CSRtrack. A comparison of the beam dynamics simulations with measurements is presented in this contribution. The expected SASE pulses are being simulated with the Genesis code.
The project is supported by the Federal Ministry of Education and Research of Germany (BMBF) under contract No. 05K10GU2 and FSP301.

Laser Wavelength Tuning by Variable-gap Undulators in SACLA — THPD38

Kazuaki Togawa, Toru Hara, Hitoshi Tanaka, Takashi Tanaka
(RIKEN SPring-8 Center, Sayo-cho, Sayo-gun, Hyogo)

Wavelength tunability by variable-gap in-vacuum undulators is one of the features of SACLA. To fully utilize this advantage, it is important to suppress gap-dependent field errors down to the tolerance level, sub-microradian per undulator segment, which assures high SASE amplification gain enabling XFEL power saturation. For this purpose, we introduced a 'feed-forward correction' scheme, which is well-known technique in third-generation light sources. However, in linac-based XFELs, it was not easy to make a sufficiently accurate correction table to cancel out error fields due to shot-by-shot beam orbit and energy fluctuation propagating from the accelerator. By using cross-correlation technique based on the accelerator model, we so far succeeded in suppressing the gap-dependent orbit distortion down to a 10-micron level over the undulator section. Owing to this effort, experimental users at SACLA can quickly change the laser wavelength in a few seconds according to their demands by setting only the undulator K-value. In this conference, we will report the present status of wavelength tuning by the undulator gap in SACLA and problems to be solved towards the perfect control.

The Analysis of Electron Orbits in a Free Electron Laser with a Coaxial Wiggler Field — THPD39

Roghayeh Ghahremaninezhad, Amirhossein Ahmadkhan Kordbacheh
(IUST, Narmac, Tehran)

An analysis of single-electron orbits in a free-electron laser based upon a coaxial hybrid wiggler (CHI) is presented. The particle trajectories in the combined CHI wiggler and an axial guide magnetic field are developed making use of the numerical computations of a set of nonlinear differential equations of motion when the fundamental, third and fifth spatial harmonics of the coaxial wiggler field are taken into account. It is found that each of the third and the fifth spatial harmonics of CHI wiggler give rise to a new group III and IV orbits which produce their own higher order of magnetic resonance in larger cyclotron frequencies. The analysis proved that the wiggler-induced velocity of group III and IV orbits may increase noticeably if the cyclotron frequency is adjusted at their own magnetoresonances. The evolution of the beam cross section is presented and it displays a helix along the z-axis. The electron, injected into the wiggler region onto the equilibrium trajectories, may remain away from the waveguide walls if the initial orbit radius is taken around r_0, where the radial component of the wiggler magnetic field is minimum.

Femtosecond Electron Bunch Measurement using THz Cherenkov Radiation in Dielectric Materials — THPD40

Jinfeng Yang, Koichi Kan, Takafumi Kondoh, Atsushi Ogata, Yoichi Yoshida (ISIR, Osaka)

A novel method of femtosecond electron bunch measurement has been proposed using THz Cherenkov radiation in dielectric materials. When the ultrashort electron beam moves to the dielectric materials, such as a hollow quartz tube covered by a metal, the electron induced coherent Cherenkov radiation is occurred as a frequency spectrum in THz range with discrete components (higher mode radiations). The intensities of the THz components and the width of the frequency spectrum are determined strictly by the bunch length. In the preliminary experiments, we succeeded to observe the THz Cherenkov radiation from a 200 fs electron bunch using mm-sized dielectric tubes. It was found that the radiation spectra are dependent on the bunch length. The higher mode radiations are appeared by decreasing the electron bunch length.

A Simple Model for the Generation of Ultra-Short Radiation Pulses — THPD41

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

A method for generating a single broadband radiation pulse from a strongly chirped electron pulse is described. The evolution of the chirped electron pulse in an undulator may generate a pulse of coherent spontaneous radiation of shorter duration than the FEL cooperation length. An analytic expression for the emitted radiation pulse is derived and compared with numerical simulation.

R&D Towards Ultra Compact X ray FEL with a Laser based Wiggler — THPD42

Vitaly Yakimenko (BNL, Upton, Long Island, New York)

Scheme to use laser based wiggler to generate coherent x rays with extremely bright electron beam was presented at FEL 2010. The challenges to realize FEL gain in the Compton back scattering interaction can be split in three categories: development of the suitable laser (1ps, 30J capable CO2 laser); high brightness electron (70MeV, 30nm normalized emittance,1.5 kA peak current); focusing system with beam diagnostic that will allow to setup this tiny beam. Quick overview of the scheme and relevant R&D towards the goals will be discussed in the presentation.

Progress on a Laser-driven Dielectric Structure for Use as a Short-period Undulator — THPD43

Gil Travish, James Matthew Allen (UCLA, Los Angeles, California), Rodney Yoder (Manhattanville College, Purchase, New York), Huarong Gong (UESTC, Chengdu, Sichuan)

A laser-powered dielectric structure, based on the Micro Accelerator Platform, has been design and offers undulator periods in the micron to millimeter range. This design was shown previously to potentially support a deflection field strength of several GV/m, equivalent to a magnetic undulator with field strength of about 40 T. In this paper, we address a previous problem in the design involving the junction between half periods of the undulator. Because the structure is resonant, flipping from one deflection direction to the opposite one required controlling the phase of the incident laser and reestablishing a new resonance. One solution to this 'phase flipping' problem involves the use of two lasers at different wavelengths to excite adjacent half-periods. This new approach is explored further here along with simulations of the beam trajectory and resulting undulator radiation. We also consider parameter sets that may be possible for these extremely short period undulators.

Towards a Free Electron Laser Virtual Laboratory — THPD44

Giuseppe Dattoli (ENEA C.R. Frascati, Frascati (Roma)), Marcello Artioli, Pier Luigi Ottaviani, Simonetta Pagnutti (ENEA-Bologna, Bologna)

FELs are complex devices and their description reflects such a complexity (*). The possibility of simulating a FEL device using a virtual environment could be interesting both for FEL scientists and users. By 'simulating' we mean the possibility of assembling the different FEL components as in an actual device and check (in real time) how any change in the device assembly may affect the laser operation. The philosophy of simulation is gaining a wider perspective. It is now being implemented with a new concept: it is not only aimed at predicting the performance of the device by means of an appropriate numerical code, but also at providing a kind of Computer Aided Design (CAD) environment, allowing the composition of the device as long with its output characteristics (**). Once a device is designed, its functional block can be connected to other devices, resembling the actual experiment (or application) setup: in this way the design environment becomes a virtual lab. If also mechanical and geometrical design features will be embedded, then the next step will be a 3D virtual reality lab for a whole FEL facility simulation, enabling users to plan and check hypothetical real testcases.

**G.Dattoli, P.L.Ottaviani, S.Pagnutti, Booklet for FEL design, A Collection of Practical Formulae, ENEA Frascati,(2008)*

***X. Chen, et al, Proc. of Earth and Space 2010, Honolulu, pp.3843-3852,(2010)*

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Beam Dynamics and Performance of ERL-driven X-ray FEL — THPD45

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

In this talk we present a self-consistent concept of ERL generated e-beam to drive an array of X-ray FELs. We use eRHIC multi-pass ERL design to explore all relevant beam dynamics. First, we study effects of incoherent and coherent synchrotron radiation on the e-beam parameters and present the set of parameters providing for the emittance preservation. Second, we present a sing bunch compressing scheme (similar to scheme described in [1]) with large compression ratio, which suppresses emittance growth caused by CSR. Finally, we present simulation result for soft- and hard-X-ray FELs driven by such electron beam. We compare projected performance of such facility with world's existing and proposed FEL facilities.

[1] Merger Designs for ERLs, V.N. Litvinenko, R.Hajima, D. Kayran, Nuclear Instruments and Methods in Physics Research A 557 (2006) 165

Optical Afterburner for a SASE FEL — THPD46

Nikola Stojanovic, Alaa Al-Shemmary, Robert Riedel, Evgeny Schneidmiller, Franz Tavella, Mikhail Yurkov (DESY, Hamburg), Michael Foerst (CFEL, Hamburg), Michael Gensch (HZDR, Dresden)

Radiation Pulse from a SASE FEL consists out of spikes and induces energy modulations on the electron beam*. We exploit these modulations and induce intense optical radiation using THz undulator at FLASH (optical afterburner). Envelope of the optical afterburner pulse closely resembles the envelope of the x-ray pulse* and marks arrival time of XUV pulses with accuracy of few fs**. We characterize properties of the optical pulse using standard laser diagnostics techniques (i.e. FROG). Main result comes from the pulse duration measurement that we use to derive envelope of the x-ray radiation pulse duration which is in sub-100 fs range. We also demonstrate amplification concept and amplification by factor of 100 which, once improved will provide FLASH with naturally synchronized visible/near-infrared source for pump-probe experiments.

** E.L. Saldin, et. al., Phys. Rev. ST Accel. Beams 13, 030701 (2010)*
*** U. Fruehling et. al., Nature Photonics 3, 523 - 528 (2009)*
**** Proceedings of IPAC2011, San Sebastián, Spain.THPC084*

Funding Agency: BMBF, 05K10CHC

Progress on the Generation of Undulator Radiation in the UV from a Plasma-based Electron Beam — THPD47

Guillaume Lambert, Sebastien Cordes, Victor Malka, Kim Ta Phuoc (LOA, Palaiseau), Jean-Michel Ortega (CLIO/ELISE/LCP, Orsay), Ahmed Ben Ismail, Elsa Benveniste, Arnd Specka (LLR, Palaiseau), Romain Bachelard, Fabien Briquez, Marie-Emmanuelle Couprie, Marie Labat, Alexandre Loulergue (SOLEIL, Gif-sur-Yvette)

Recently, at the Laboratoire d'Optique Appliquée, progresses have been made for the development of 5th generation light sources based on plasma-accelerator. Electron beams of tens of picocoulomb at about 200 MeV has been generated at the interaction of a 1 Joule, 30 fs laser focussed on a 3 mm long gas target at an electron density of 5 1018 cm-3. Then, the electron beam was refocused with a quadrupoles triplet inside a 60 cm long undulator composed of 34 periods of 18 mm with a deflection parameter equal to 1. In these conditions synchrotron radiation UV light has been measured. This constitutes a promising first step in the view of realizing FEL based on plasma acceleration in future.

Numerical Study of an FEL based on LWFA Electrons and a Laser-plasma Wiggler — THPD48

Remi Lehe, Guillaume Lambert, Agustin Lifschitz, Victor Malka, Jean-Marcel Rax (LOA, Palaiseau), Xavier Davoine (CEA/DAM/DIF, Arpajon)

Recent works* have suggested that laser-wakefield acceleration (LWFA) may be used to produce the electron beam of an FEL. However, when using conventional magnetic wigglers, the requirements on the beam quality are very stringent, and are still challenging with current LWFA beams. An interesting alternative may be to use a laser-plasma wiggler (e.g. a plasma wave or a laser beam). Compared to a conventional one, a laser-plasma wiggler has a field amplitude several orders of magnitude higher - which can place lower constraints on the beam quality. Furthermore, since laser-plasma wigglers also have a typically much shorter period, their total wiggler length is correspondingly shorter, and it may therefore not be necessary to periodically refocus the beam along the wiggler. Taking into account these effects, we evaluate the range of wiggler properties (field, period) that would make the FEL process possible. From this analysis, the counterpropagating laser wiggler** seems to be one of the most promising solutions. We therefore extend the Ming Xie formula*** to a counterpropagating laser wiggler. We use this formula to evaluate the potential use of current state-of-the-art lasers.

** Nakajima, K., Nature phys. 4, 92 (2008)*
*** Bacci, A. et al., Nucl. Instrum. Methods Phys. Res. A 587, 388 (2008)*
**** Xie, M., Nucl. Instrum. Methods Phys. Res. A 445, 59 (2000)*

Steady State Microbunching for High Brightness, High Repetition Rate Storage Ring Light Sources

THPD50

Daniel Ratner, Alex Chao (SLAC, Menlo Park, California), Yi Jiao (IHEP, Beijing)

Modern accelerator light sources are based on either linac-FELs or storage rings. The linac-FEL type has high brilliance (microbunched beam) but low repetition rate. The storage ring type has high repetition rate (rapid beam circulation) but low brilliance. We propose to explore the feasibility of a microbunched beam in a storage ring that promises high repetition rate and high brilliance. The steady-state microbunched (SSMB) beam in a storage ring could provide CW sources for THz, EUV, or soft X-rays. We review several recently proposed SSMB concepts as promising directions for high brightness, high repetition rate light sources of the future.

W-Band Cherenkov Maser Based on a Periodic Surface Field Structure

THPD51

Alan Richard Phipps, Adrian William Cross, Alan Phelps, Craig Robertson, Kevin Ronald, Colin Whyte, Alan Robert Young (USTRAT/SUPA, Glasgow),
Ivan Vasilyevich Konoplev (JAI, Oxford)

Two-dimensional Bragg structures have been useful in producing distributed feedback in an FEM driven by an oversized annular electron beam [1]. The Bragg structures in this case act as frequency selective mirrors allowing the production of narrow band microwaves [2]. This structure can be observed using a hollow, copper, cylindrical waveguide with a sinusoidal grating machined into the walls where the diameter of the waveguide is much larger than λ. Localised surface fields are excited around the perturbations if the structure is radiated by an external electron beam [3]. The resultant eigenfield can be described as a superposition of a near cut-off volume field which synchronises the localised surface partial fields. A relativistic electron beam travelling close to the structure interacts with the spatial harmonics of the surface field propagating with $\upsilon_p < c$. In this paper we demonstrate a novel high Q cavity operating at W band (75-110GHz), where there is coupling between a near cut-off TM0,6 volume field and an evanescent HE1,20 surface field, produced within the structure. Results of the numerical modelling of this device using the PIC code MAGIC will be presented.

[1]. N.S. Ginzburg, N. Peskov, et al, J Appl Phys, 92, pp. 1619-1629, 2002
[2]. I.V. Konoplev, et al, Appl Phys Lett, 92, 211501 2008
[3]. I.V. Konoplev, A. Maclachlan. et al, Phys Rev A, 84, 013826 2011

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Gamma-ray Free-Electron Lasers

THPD52

Henry P Freund, Dinh C. Nguyen (LANL, Los Alamos, New Mexico)

The free-electron laser has demonstrated lasing at Ångstrom wavelength [1] and a sub-Ångstrom FEL has been proposed [2]. The next challenge for the FEL is to produce a coherent beam of gamma rays. This paper outlines a plausible approach to generating coherent beams of 300 keV and 500 keV gamma rays at the 3rd and 5th harmonics of a SASE FEL operating at 0.124 Ångstrom (100 keV). The electron beam and undulator parameters as well as MEDUSA simulation results showing femtosecond pulses with 1E8 coherent gamma photons at 300 keV (0.041 Ångstrom) will be presented.

[1] P. Emma et al., Nature Photonics, 4 (2010) 641-647.
[2] B.E. Carlsten et al., Journal of Modern Optics, 58 (2011) 1374-1390.

Linear Gain and Gain Saturation in a Photonic Free-electron Laser

THPD53

Thomas Denis, Klaus Boller, Joan Lee, Peter van der Slot, Marc Wiecher van Dijk (Mesa+, Enschede)

Photonic crystals are used to manipulate the generation of light, for example, stimulated emission can be enhanced. A photonic free-electron laser (pFEL) applies this enhancement to generate widely tunable coherent Cerenkov radiation from low energy electrons (keV) streaming through the photonic crystal. The lattice constant of the photonic crystal sets an output frequency range that can be covered by varying the beam energy. The output power is scalable by increasing the number of electron beams. To develop such lasers, we calculate the small signal gain of a pFEL by using the Pierce theory, originally developed for slow-wave microwave tubes. We investigate the accuracy of the Pierce theory for pFELs by comparing the results of the theory to the small-signal growth rate observed in particle-in-cell simulations. Results will be presented for a low-energy (12.5 keV), low current (1A) electron beam propagating through a photonic crystal designed to operate at around 15 GHz.

Dynamics of a Multibeam Photonic Free Electron Laser THPD54

Joan Lee, Klaus Boller, Thomas Denis, Peter van der Slot, Marc Wiecher van Dijk (Mesa+, Enschede)

A photonic free-electron laser (pFEL) uses free electrons streaming through a photonic crystal (PhC) to generate tunable coherent radiation. Operation in different spectral regions can be obtained by scaling the lattice period while keeping the electron velocity the same. Increasing both the transverse dimension and the number of distributed electron beams increases the output power and results in a higher quality factor Pf2. Here, we consider a pFEL driven by a set of low energy (~ 10 keV), low perveance (< 0.1 μP) electron beams. A simple and robust PhC structure is used to slow down the phase velocity (match to electron velocity) of a co-propagating electromagnetic wave. The large transverse dimensions of the PhC result in an overmoded system, allowing many transverse eigenmodes of the PhC to interact with the electron beams. Using a particle-in-cell code, we numerically study the dynamics and calculate the small-signal growth rate and output power of the various modes. We show that for an appropriate design of the PhC and selective placement of the electron beams, single-mode operation is possible. We will also present results on the scaling with the number of electron beams.

The Small-angle Bends in High Gain FELs THPD55

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

The possibility to deflect the radiation of a high gain FEL from the undulator line axis may be interesting for some applications. For example, it may be used for separation of helical and linear polarized radiation in an FEL with planar main undulator and helical radiator. Another option is to direct radiation to different experimental stations. The influence of the small-angle bend in the last part of the undulator line on the radiation power is considered. Different ways of the power reduction compensation (e. g., achromatic bends and additional undulator sections) are discussed.

Two-color FEL Generation based on Emittance-spoiler Technique THPD56

Chao Feng, Yuantao Ding, Zhirong Huang (SLAC, Menlo Park, California)

Generation of two-pulse two-color x-ray radiation is attracting much attention within the free-electron laser (FEL) user community. Femtosecond x-ray pulses with variable durations and separation can be simply generated by the emittance-spoiler foil method* at the Linac Coherent Light Source (LCLS). In this paper, we describe three FEL schemes rely on the emittance-spoiler technique for the generation of two intense x-ray pulses with different colors. With a representative realistic set of parameters of LCLS, numerical simulations confirm that two femtosecond x-ray pulses at ten gigawatt level with different wavelengths around 1.8 nm can be generated by these schemes. The central wavelengths of the output pulses can be easily altered by changing strengths of the undulators.

**P. Emma et al., PRL 92, 074801 (2004).*

Application of laser-plasma accelerator beams to FELs THPD57

Carl Bernhardt Schroeder, Carlo Benedetti, Eric Esarey, Wim Leemans, Jeroen van Tilborg (LBNL, Berkeley, California), Yuantao Ding, Zhirong Huang (SLAC, Menlo Park, California), Florian Josef Gruener, Andreas Richard Maier (Uni HH, Hamburg)

Plasma waves excited by high-intensity, short-pulse lasers are able to generate hundreds of GV/m accelerating fields, enabling extremely compact accelerators for applications such as radiation generation. Laser-plasma accelerators (LPAs) produce ultrashort (femtosecond), 0.1-1 GeV electron bunches with high-peak (kA) currents and low (sub-micron) normalized transverse emittance, with 6D beam brightness comparable to state-of-the-art RF linac-based sources. FEL applications are presently limited by the longitudinal phase space distribution of the LPA beam. Beam phase space manipulation is considered to enable the application of LPA beams to FELs. LPA beam decompression (such that the energy spread over a coherence length is less than the FEL parameter) is examined as a path toward realizing an LPA-driven VUV FEL. The possibility of using a flat beam, with an energy correlation with transverse position, in a transverse gradient undulator is also explored. Laser-based FEL seeding options for improved coherence are considered.

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Preliminary Design of Compact Cyclic Accelerator using Laser-Plasma Electron Acceleration — THPD58

Seong Hee Park, Yong-Ho Cha, Kyu Ha Jang, Young Uk Jeong, Kitae Lee (KAERI, Daejon), Nikolay Vinokurov (BINP SB RAS, Novosibirsk), Jaehoon Kim (KERI, Changwon)

Laser accelerators are good for a compact radiation source due to high accelerating gradient and localized shielding, but at the expense of low average flux compared to high average flux from linear RF accelerators. KAERI has been demonstrated the generation of 30 ~ 50 MeV electron beam using 30 TW, 30 fs Ti:sapphire laser system by changing focal length of incident laser. This system is able to generate a few hundred MeV of electron beams with 2~ 3 mm long plasma target which is now under developing. We present the design issues for a compact cyclic accelerator injected by laser accelerated electron beam.

Wake Formation by Fast Multi-Charged Ions in the Beam Driven Plasma Wake-Field Accelerators — THPD59

Alexander Godunov, Ana Samolov (ODU, Norfolk, Virginia), Balsa Terzic (JLAB, Newport News, Virginia)

The wakes in plasma can be driven either by intense laser beams or by employing a bunched relativistic beam of charged particles. A bunch of charged particles traveling through plasma can generate wakefields like ones created by an intense laser pulse. However, beam loading imposes limitations on the quality of the accelerated particle bunch as well as efficiency of the plasma based accelerators. Most research has been concentrated on using relativistic electron bunches moving though plasma for generating plasma wakefields. In this work we explore possibilities for using a fast bunch of multi-charged ions for creating wakefields in plasma. The computational model is based on a modified molecular dynamics approach to simulate a beam driven wake formation in a fully ionized hydrogen plasma.

Design Status of Compact T-ray Pump and X-ray Probe System — THPD60

Kitae Lee, Kyu Ha Jang, Young Uk Jeong, Sergey Vladimirovich Miginsky, Jungho Mun, Seong Hee Park, Sunjeong Park, Nikolay Vinokurov (KAERI, Daejon)

Radiations in THz range, or T-ray can stimulate molecular responses which is strongly related with functions of a molecular, while X-ray diffraction is widely used for the analysis of molecular structures in atomic level. Combining radiations in both range is expected to reveal relations between atomic structure and functions of a molecular. In addition, if two radiations with ultra-short pulse width can be controlled precisely in time, ultra-fast dynamical changes of atomic structure could be investigated. A compact FEL is considered for the generation of a high power T-ray pulse and a bremsstrahlung radiation of an short-bunch electron by a solid target for the ultra-short X-ray pulse. Precise temporal control of two radiations could be realized by utilizing RF photo-cathode gun excited by a ultra-short laser pulse. A design status of the compact T-ray pump and X-ray probe system, and its potential applications will be presented.

Experimental Confirmation of Emittance Models for Metal Photocathodes using Antimony — THPD61

Theodore Vecchione, Howard A. Padmore (LBNL, Berkeley, California)

The emittance of photocathodes has been identified as a key parameter that limits the achievable brightness of free-electron lasers. In recent years theoretical derivations of the sources of emittance have been published intending to provide insight towards minimization. Here we present experimental confirmation of two of these models, one pertaining to intrinsic emittance and the other to a contribution to overall emittance from photocathode surface roughness. In both cases the data matches closely to the theoretical prediction.

Work supported by the Director, Office of Science, Office of Basic Energy Sciences of the U. S. Department of Energy, under Contract No. DE-AC02-05CH11231, KC0407-ALSJNT-I0013, and DE-SC0005713

Mode-locked Coherent Spontaneous Emission Pulse Trains from Current-density Modulated Electron Beams — THPD62

David Dunning, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Lawrence Thomas Campbell, Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

The generation of current-density modulated electron beams is used in FELs both for harmonic up-conversion, and to enhance the gain of the FEL interaction. It has also been proposed as a method to generate trains of ultra-short radiation pulses via coherent spontaneous emission (CSE) in short undulators [1, 2]. Here we assess the output and optimum configuration of such schemes. Non-averaged FEL codes are used, allowing the rotation in phase space of long-scale energy modulation and CSE effects to be modelled correctly.

[1] D. Dunning, et al., Workshop on high-harmonic seeding for present and future short wavelength FELs, Frascati, Italy, (2008). [2] H. Deng and Z. Dai. Chinese Physics C, 34(8), pp. 1140-1147, (2010).

SwissFEL U15 Magnet Assembly: First Experimental Results — THPD63

Marco Calvi (Paul Scherrer Institut, Villigen), Thomas Schmidt (PSI, Villigen)

In the framework of the SwissFEL project, an R&D activity concerning in-vacuum undulator technology is ongoing at the Paul Scherrer Institut. The magnetic field configuration of the hard X-ray SwissFEL undulators has been designed on purpose for a single pass machine. Moreover the permanent magnet material (NdFeB) is manufactured following a novel procedure (Dy diffused in the grain boundaries) to improve the coercivity versus remanence. The assembly and tests of a 44 periods hybrid magnetic structure are presented. Procedures for the magnetic field, trajectory and phase optimization are reported versus experimental results.

SwissFEL U15 Prototype Design and First Results — THPD64

Thomas Schmidt (PSI, Villigen), Marco Calvi (Paul Scherrer Institut, Villigen)

The SwissFEL will have in the base line two undulator lines for the hard- and soft x-ray: U15 in-vacuum and U40 / UE40 APPLE II type undulators with 12 and 15 modules of 4m length each. All undulators are equipped with the same frame and gap drive system to profit best from the series production. The frame is built up from two identical bases and two sides made of cast mineral. In this design, the frame transfers its stiffness to the I-beam through a backlash-free wedge based gap drive system. The interfaces to the inner I-beam for the in-vacuum undulator have been rearranged and reduced significantly. Magnets and poles are carried by an extruded Aluminum block-keeper, which allows an automated tuning of the magnet structure. The prototype of the support structure has been built up during spring 2012 and measuring results will be presented. The full prototype shall be ready for the end of 2012.

High Dynamic Range Beam Imaging with Two Simultaneously Sampling CCDs — THPD65

Pavel Evtushenko (JLAB, Newport News, Virginia)

Transverse beam profile measurement with sufficiently high dynamic range (HDR) is a key diagnostic to measure the beam halo, understand its sources and evolution. In this contribution we describe our initial experience with the HDR imaging of the electron beam at the JLab FEL. On contrary to HDR measurements made with wire scanners in counting mode, which provide only two or three 1D projections of transverse beam distribution, imaging allows to measure the distribution itself. That is especially important for non-equilibrium beams in the LINACs. The measurements were made by means of simultaneous imaging with two CCD sensors with different exposure time. Two images are combined then numerically in to one HDR image. The system works as an online tool providing HDR images at 4 Hz. An optically polished YAG:Ce crystal with the thickness of 100 um was used for the measurements. When tested with a laser beam images with the DR of about 1E+5 were obtained. With the electron beam the DR was somewhat smaller due to the limitations in the time structure of the tune-up beam macro pulse.

Measurements of Martin-Puplett Interferometer Limitations using Blackbody Source — THPD66

Pavel Evtushenko, J. Michael Klopf (JLAB, Newport News, Virginia)

Frequency domain measurements with Martin-Puplett interferometer is one of a few techniques capable of bunch length measurements at the level of ~ 100 fs. As the bunch length becomes shorter, it is important to know and be able to measure the limitations of the instrument in terms of shortest measurable bunch length. In this paper we describe experiment of using blackbody source with the modified Matrin-Puplett interferometer that is routinely used for bunch length measurements at the JLab FEL, as a way to estimate the shortest, measurable with the device, bunch. The limitation comes from high frequency cut-off of the presently used wire-grid polarizer and is estimated to be 50 fs RMS. The measurements are made with the same Golay cell detector that is used for beam measurements. We demonstrate that, even though the blackbody source is many orders of magnitude less bright than the coherent transition or synchrotron radiation, it can be used for the measurements and gives a very good signal to noise ratio in a combination with lock-in detection. We also compare the measurements made in air and in vacuum to show the very strong effect of the atmospheric absorption.

FEL Applications

Chair: Jerome Hastings

Time Resolved Spectroscopy in Condensed Matter Physics	THOEI01

Alexander Föehlisch (Helmholtz-Berlin)

THz Pump-X-Ray Probe Studies of Materials	THOEI02

Aaron Lindenberg (SLAC, Menlo Park, California)

Four Wave Mixing at a Seeded FEL	THOEI03

Claudio Masciovecchio (ELETTRA, Basovizza)

Progress and Projects

Chair: Dinh C. Nguyen

European XFEL Working Point Optimization and Status — FROAI01

Winfried Decking, Torsten Limberg (DESY, Hamburg)

New results of beam parameter measurements at the injector test facility PITZ at DESY, Zeuthen, and the experience of low emittance beam transport in the LCLS called for less conservative assumptions for the beam quality delivered to the SASE undulators. The change in beam parameters and the interests expressed by the users in the first round of workshops concerning the scientific instruments initiated changes in the undulator systems and SASE wavelength ranges. We summarize the present status and highlight recent developments in the European XFEL design.

A Next Generation Light Source at LBNL — FROA02

John Corlett (LBNL, Berkeley, California)

We describe design and R&D progress toward a Next Generation Light Source at LBNL. This future facility, an array of FELs driven by a high repetition-rate and high brightness beam from a CW superconducting linac, will be a transformative new facility for X-ray science. Uniform spacing of bunches, at MHz repetition rate, distributed to independently operating FELs, provides high-power soft X-ray beams of up to ~100 W each. Seeding and self-seeding provide high temporal coherence, with tunability and photon energies to 1.2 keV (1 nm) in the fundamental.
Work supported by the Director, Office of Science, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231

The LUNEX5 Project — FROA03

Marie-Emmanuelle Couprie (CEA/DSM, Gif-sur-Yvette), Alain Dubois, Jan Luning (CCPMR, Paris), Bertrand Carré (CEA, Gif-sur-Yvette), Xavier Davoine (CEA/DAM/DIF, Arpajon), Guillaume Devanz, Michel Luong (CEA/DSM/IRFU,), Laurent Farvacque, Gael Lebec (ESRF, Grenoble), Raphaël Roux (LAL, Orsay), Guillaume Lambert, Remi Lehe, Agustin Lifschitz, Victor Malka, Antoine Rousse, Kim Ta Phuoc, Cedric Thaury (LOA, Palaiseau), Serge Bielawski, Christophe Szwaj (PhLAM/CERCLA, Villeneuve d'Ascq Cedex), Chamseddine Benabderrahmane, Michel Bessière, Pascale Betinelli-Deck, Francois Bouvet, Alain Buteau, Lodovico Cassinari, Jean Daillant, Jean-Claude Denard, Clement Evain, Philippe Eymard, Brigitte Gagey, Christian Herbeaux, Marie Labat, Alain Lestrade, Alexandre Loulergue, Patrick Marchand, Jean-Louis Marlats, Catalin Miron, Paul Morin, Amor Nadji, François Polack, Jean-Baptiste Pruvost, Fernand Ribeiro, Jean-Paul Ricaud, Pascale Roy, Takanori Tanikawa (SOLEIL, Gif-sur-Yvette)

LUNEX5 (free electron Laser Using a New accelerator for the Exploitation of X-ray radiation of 5th generation) aims at investigating the production of short, intense, and coherent pulses in the soft X-ray region (with two particular targeted wavelengths of 20 and 13 nm on the fundamental wavelength). The project consists of a Free Electron Laser (FEL) line enabling the most advanced seeding configurations (High order Harmonic in Gas seeding and Echo Enable Harmonic Generation) and in-vacuum (potentially cryogenic) undulators of 15 and 30 mm period. Two accelerator types feed this FEL line : a Conventional Linear Accelerator (CLA) with superconducting cavities of 400 MeV for the investigations of the advanced FEL schemes, compatible with a future up-grade for high repetition rate; and a 0.4 - 1 GeV Laser Wake Field Accelerator (LWFA), to be qualified in view of FEL application, in the single spike or seeded regime. Two pilot user experiments for time-resolved studies of isolated species and solid state matter dynamics will take benefit of LUNEX5 FEL radiation and provide feedback of the performance of the different schemes under real user conditions.

New Laser Developments for Pump-probe Experiments at SwissFEL — FROA04

Christoph P. Hauri, Fernando Ardana-Lamas, Marta Divall Csatari, Alexandre Trisorio, Carlo Vicario (Paul Scherrer Institut, Villigen), Clemens Ruchert (PSI, Villigen PSI)

We report on recent pump-probe laser source developments for SwissFEL. The demand of ultrashort laser sources in combination with few-femtosecond x-ray Free Electron Lasers is growing since such sources are a prerequisite for cutting-edge time-resolved investigations. Equally important is the precise arrival time measurement of short X-ray pulses in respect to the optical pump. To meet those requests adequate lasers need to be developed. Of particular interest is a compact, laser-based THz source (lambda=60 to 300 um) delivering single-cycle pulses with amplitude of up to 1.5 MV/cm and 0.5 Tesla, respectively. Such strong THz pump lasers allow parasitic use for high-precision arrival time measurement between the x-ray pulse and the optical laser at the experimental station. We show that such intense THz pulses can be efficiently generated in the so-called THz gap (1-10 THz) by means of nonlinear frequency conversion in organic crystals. We furthermore present an overview on high-power single cycle pulses in the infrared wavelength rage (lambda=1-20 um) and latest progress on high-power HHG-based seeding lasers at shortest wavelengths.

FEL Prize Lecture -2-

Chair: Hiroyuki Hama

Towards Compact Short FEL Sources : Seeding and LWFA based FEL — FROBI01

Marie Labat, Marie-Emmanuelle Couprie, Alexandre Loulergue (SOLEIL, Gif-sur-Yvette), Giovanni De Ninno (ELETTRA, Basovizza), Luca Giannessi (ENEA C.R. Frascati, Frascati (Roma)), Philip Russell (Max Planck Institute for the Science of Light, Erlangen), Nicolas Yann Joly (Max Planck Institute for the Science of Light, Erlangen; University of Erlangen-Nuremberg, Erlangen-Nuremberg), Serge Bielawski (PhLAM/CERCLA, Villeneuve d'Ascq Cedex)

The seeding technique, proposed to improve the FEL temporal coherence and to enable more compact schemes, progressed significantly during this last decade. After conventionnal laser sources, eventually doubled or tripled in crystal, high order harmonics generated in gas were successfully used, bringing FELs in the XUV range. We are now involved in the demonstration of a new scheme, using fiber based tunable ultraviolet source. Its output power and tunability are of high interest. Last results obtained with the MaxPlanck Institute and the SPARC teams are presented. Seeding can lead to complex dynamics between the electron and the light pulse. Numerical studies revealed possible pulse splitting effects. We will report on their possible observation in collaboration with the FERMI team. Future FELs may also rely on emerging accelerators generated by laser wakefiled acceleration. Recently, the LUNEX5 project was proposed in France. It consists in one undulator line, fed by either a conventionnal LINAC or a laser wakefield accelerator (LWFA), to deliver XUV fs pulses to pilot user experiments. Preliminary work on radiation optimization of an FEL based on a LWFA will be also presented.

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