WG-4 SUMMARIES

- **ERL2011 SUMMARY OF WORKING GROUP 4:**

Brief Review of Beam Instrumentations
at Past ERL/FLS Workshops

Takashi Obina, et al.

- **ERL2011 SUMMARY OF WORKING GROUP 4:**

Instrumentation & Controls

David Gassner, et al.

Brief Review of Beam Instrumentations at Past ERL/FLS Workshops

ERL2011 17.Oct.2011; T. Obina (KEK)

- ERL 2005
  - Working Group 1: Electron Guns and Injector Designs
  - Working Group 2: Optics and Beam Transport
  - Working Group 3: Superconducting RF and RF Control
  - Working Group 4: Synchronization and Diagnostics/Instrumentation
- FLS 2006
  - WG1 - Storage ring based synchrotron radiation sources
  - WG2 - Energy Recovery Linac based synchrotron radiation sources
  - WG3 - Free Electron Lasers
  - WG4 - Low emittance electron guns
  - WG5 - Beam diagnostics and stability
  - WG6 - Insertion devices / New radiation source types
- ERL2007
  - WG1 - Injectors
  - WG2 - Optics
  - WG3 - Superconducting RF
  - WG4 - Synchronization/Diagnostics/Instrumentation
- 2008 ICFA Deflecting/Crabbing Cavity Applications - Not related.

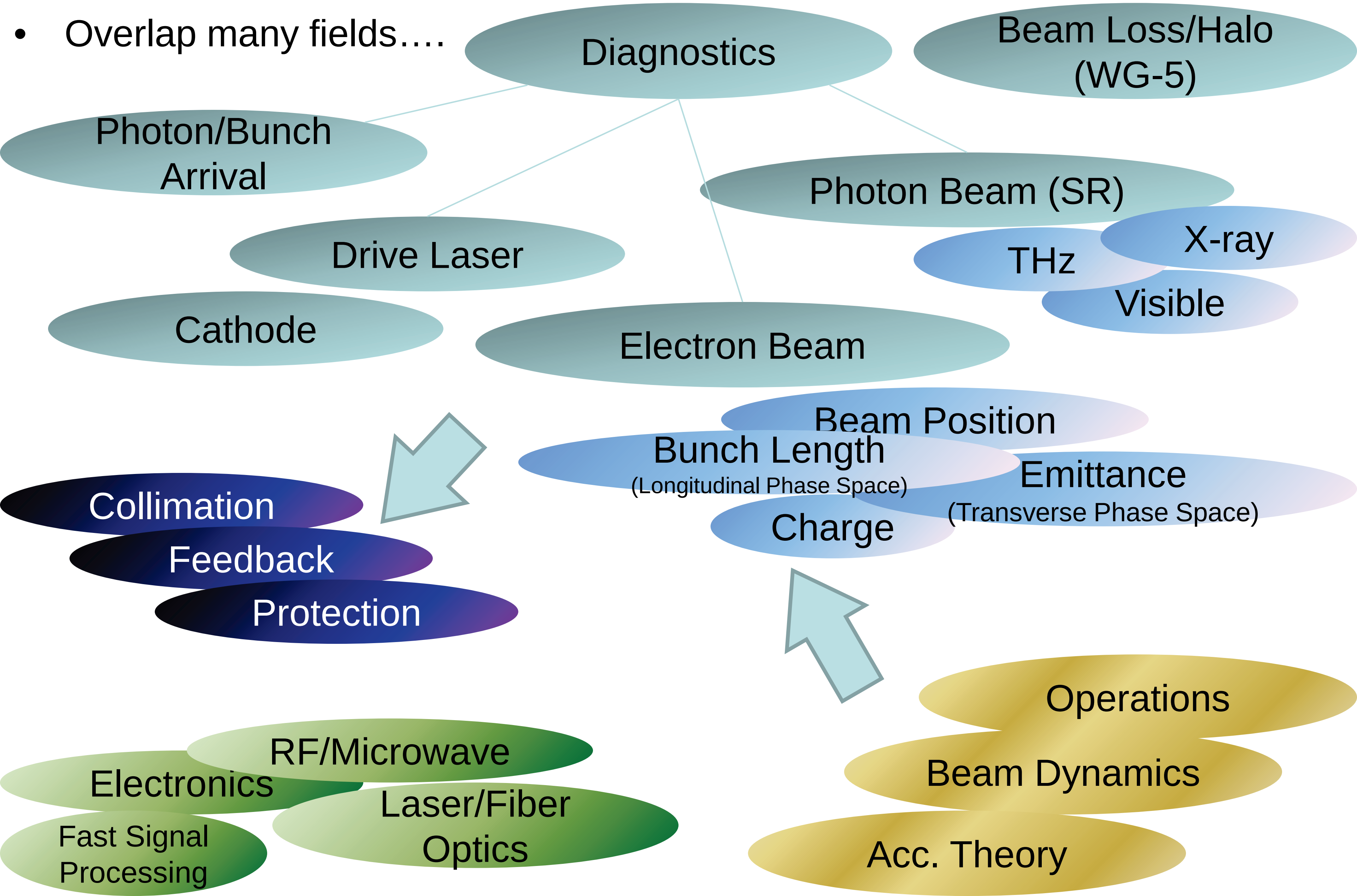
- ERL2009
  - WG1 - Guns &Cathodes
  - WG2 - Optics & Beam Dynamics
  - WG3 - RF & Cryomodules

- FLS 2010
  - WG1 - Scientific Needs for Future X-Ray Sources
  - WG2 - Storage Ring-based Sources
  - WG3 - ERL Based Sources
  - WG4 - FEL based Sources
  - WG5 - High Brightness E-guns
  - WG6 - High Resolution Diagnostics, Timing, and stabilization
  - WG7 - Undulators, Beamlines, X-ray Optics, & Detectors
  - WG8 - Novel Source Concepts

- ERL2011
  - WG-1 Electron Sources
  - WG-2 Beam Dynamics
  - WG-3 Superconducting RF
  - WG-4 Instrumentation and Controls
  - WG-5 Unwanted Beam Loss

Diagnostics/Instrumentations for ERL

- Overlap many fields….



from ERL09/FLS10

- "Instrumentation needs for ERLs"
  - P. Evtushenko (JLAB)

- Diagnostics of
  - Injector Part : Low energy e- beam, drive laser, cathode
  - Main Linac Part : 2-beam problem
- Difficulty due to large dynamic range of beam intensity
- Linac beam is different from "Gaussian" beam in storage ring

Injector Part

- Drive Laser
  - profile (transverse, longitudinal), stability (amplitude, phase)

- Transverse Phase Space
  - multi slit or scanning single slit with screen (YAG, phosphor)
  - pulsed beam only

used/established in many lab.

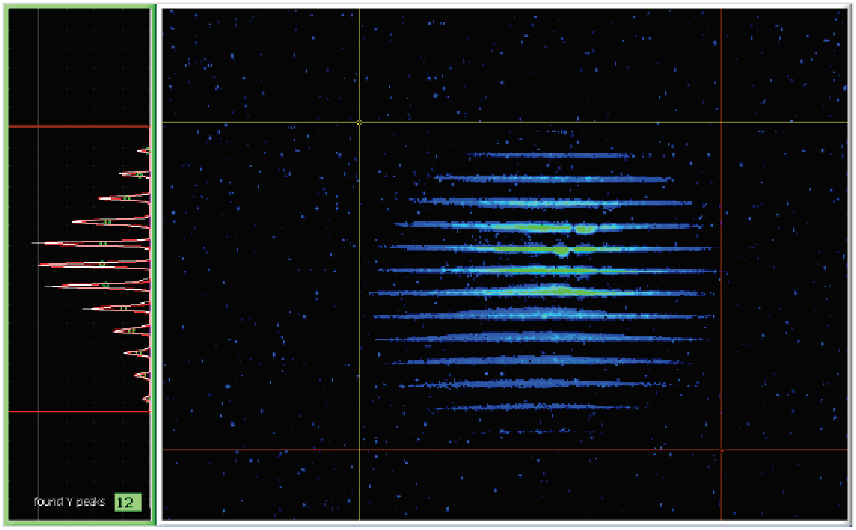
- Longitudinal Phase Space
  - Deflecting cavity structure with screen
  - pulsed beam only

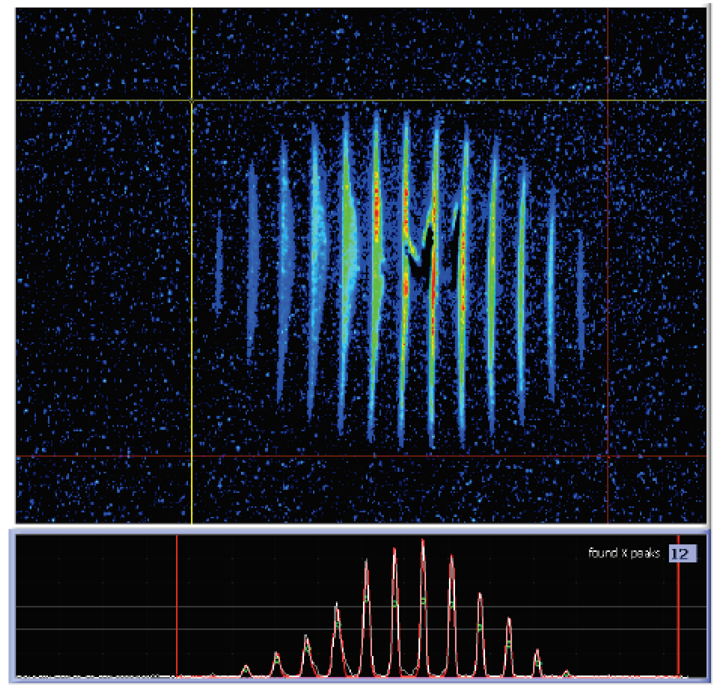
used/established in many lab.

- Cathode Q.E.

Injector / Transverse Phase Space

The multislit or a single slit scanning through the beam (or a beam scanning across the slit) does the job very well (pulsed beam only).





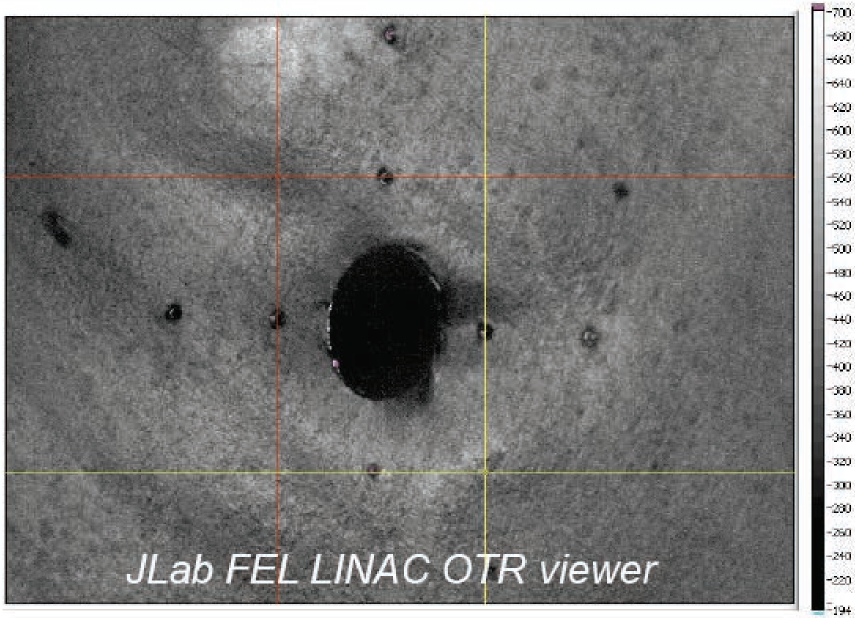
- ✧ well established technique
- ✧ works for space charge dominated beam
- ✧ beam profile is measured with YAG, phosphor or ceramic viewer
- ✧ measures not only the emittance but the Twiss parameters as well
- ✧ enough information to reconstruct the phase space
- ✧ has been implemented as on-line diagnostics
- ✧ works with diagnostics mode only (low duty cycle, average current)

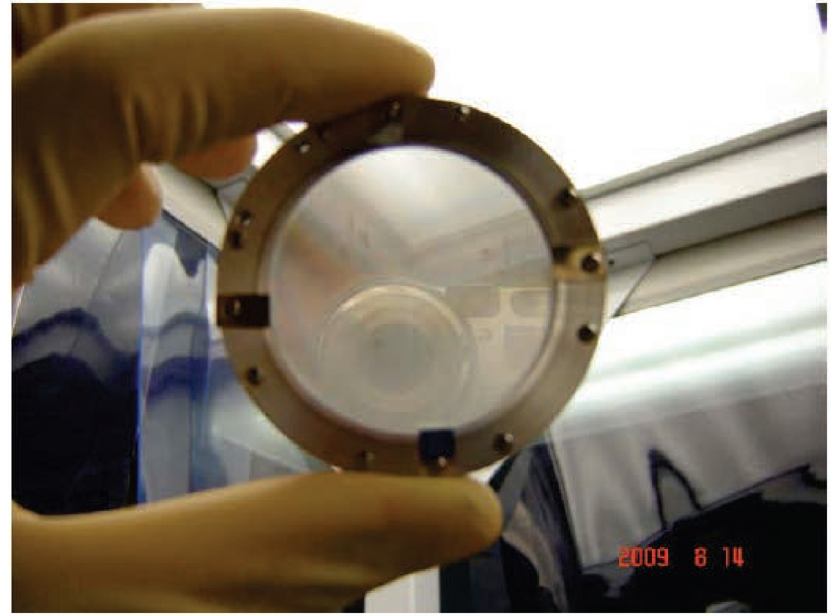
P. Evtushenko, FLS2010

Main Accelerating Part

- 2 beam (accelerating/decelerating)
  - electrode + gating : non-destructive
  - viewscreen with hole (JLAB)

2-pass viewers





- With the ultra bright beam OTR might be useless (OTR → COTR like @ LCLS)
- The best solution might be to use wire scanners *(intercepts small part of the beam)*.
- If the scanner measures radiation created by the wire, must take care of the background.
- Laser wire scanner:

  Will the measurements time and cost be acceptable?

  What is the lowest energy when the technique is practical?
- JLab FEL will test with beam:

  1. Electroformed mesh: 44% transparent ~5 micron thin
  2. Diamond-like carbon foils ~ 1 micron thin

P. Evtushenko, FLS2010

from ERL09/FLS10

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- Diagnostics of
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Other Topics in WG-4

- Coherent OTR
- Timing/Synchronization
- Misc. Topics

Coherent OTR

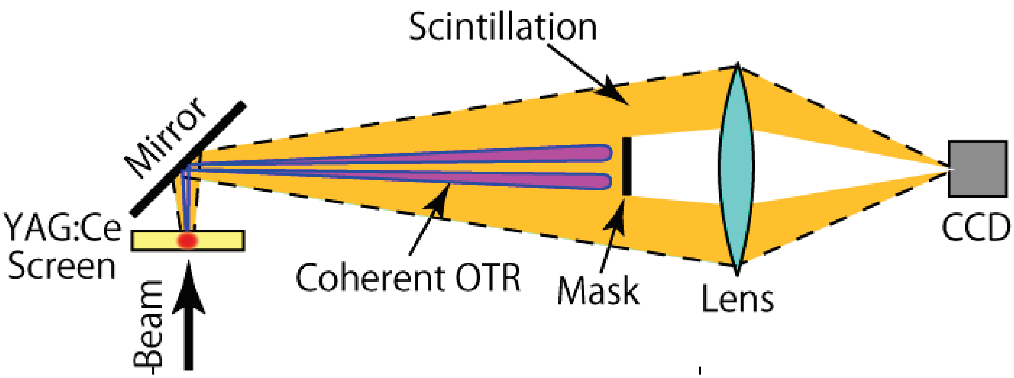
- Strong COTR lead to saturation in the beam images
- Observed in FLASH, LCLS, SAKURA, etc
- "Mask" COTR from normal OTR
  - Maesaka, et. al.; Proc. 8th Annual Meeting of Particle Accelerator Society of Japan (2011)
  - Detail will be shown in WG-4 session

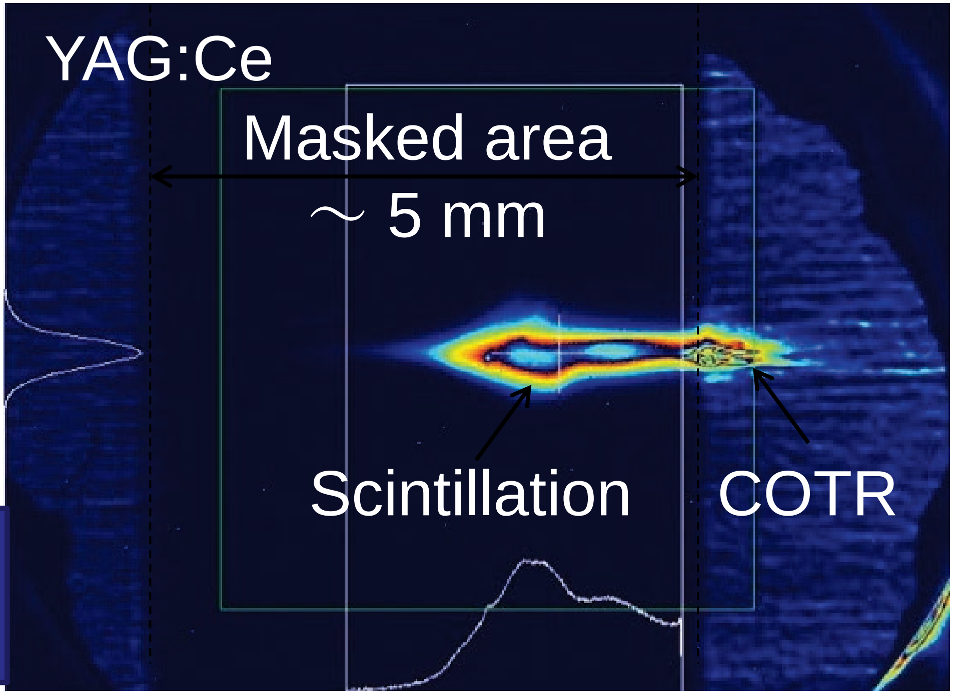
→ Result : Next Slide

Observation and Mitigation of Coherent OTR

- Short-bunch (<100fs) beam produced intense coherent OTR.

- Target was changed to YAG:Ce
- C-OTR was still observed from YAG screen.
- Put an OTR mask
  - 5mm width
  - OTR can be masked because OTR is emitted forward within ~1/γ radian.
- Scintillation of the YAG:Ce has no directional dependence.
  - Scintillation can form the beam image.





C-OTR problem was mitigated by YAG:Ce and OTR mask.

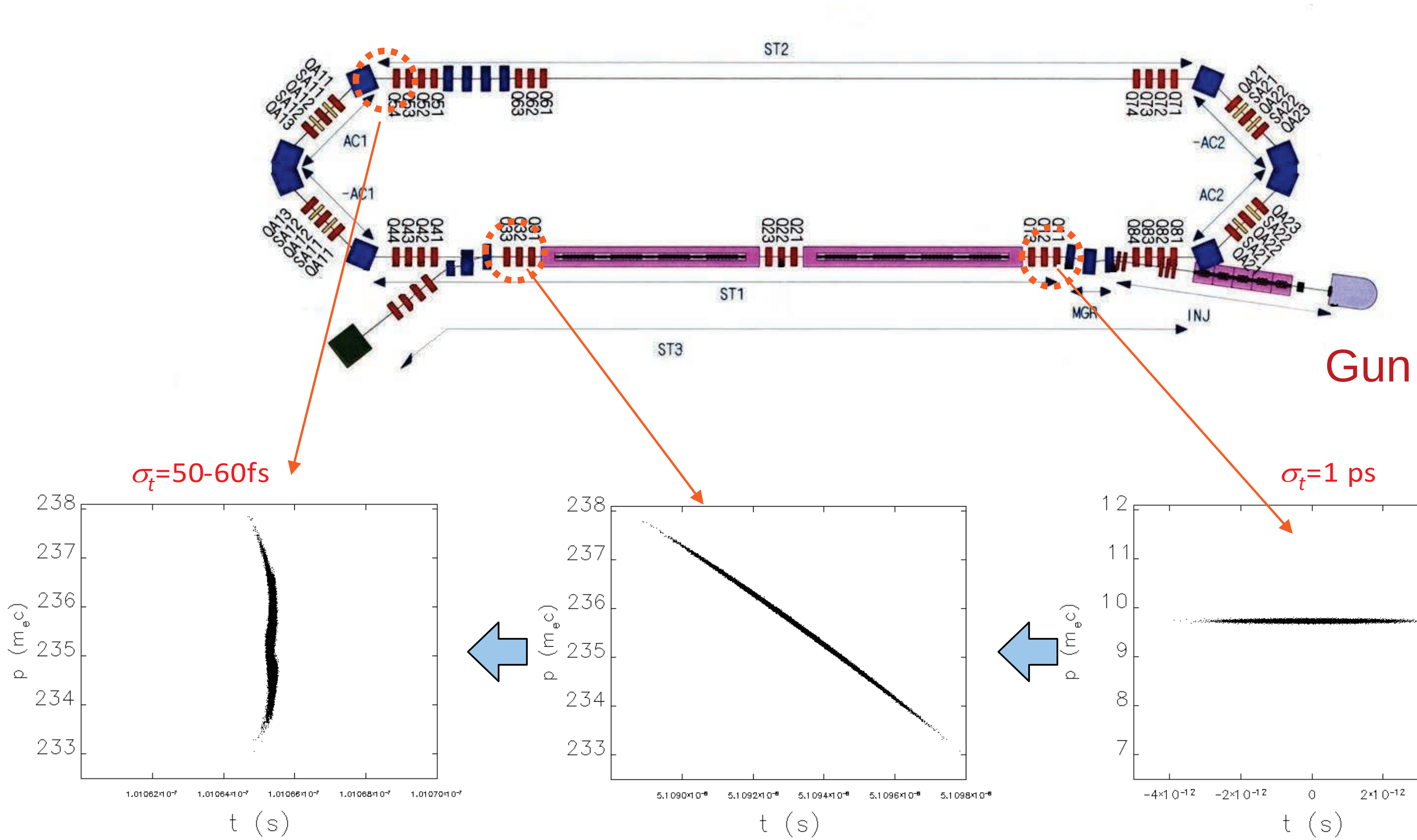
Measured at RIKEN/Spring8 XFEL "SAKURA"; Courtesy H. Maesaka

Timing/Synchronization

- Common topics with FEL facilities
  - LBL/SLAC
  - MIT
  - DESY
  - SPring-8

- Do we need fs timing for ERL? --> Yes.
  - Bunch compression mode for cERL or Multi-GeV class ERL needs precise timing (Nakamura, ERL09)
  - Distribution of master oscillator
  - Timing for user's experiment (Laser-Compton)
  - Bunch arrival monitor

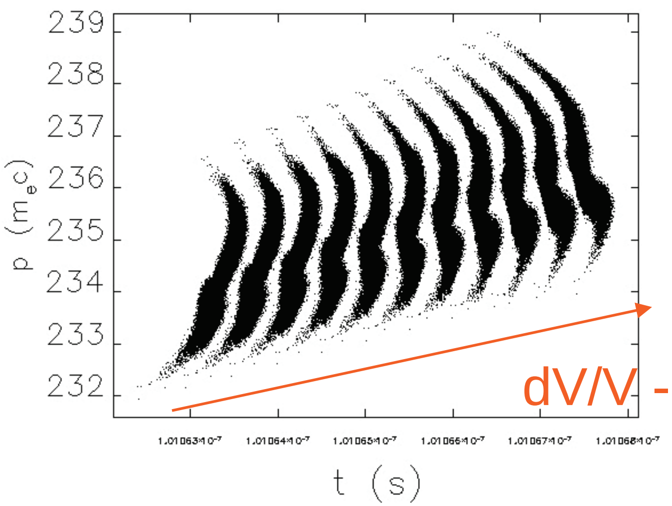
Bunch Compression in cERL



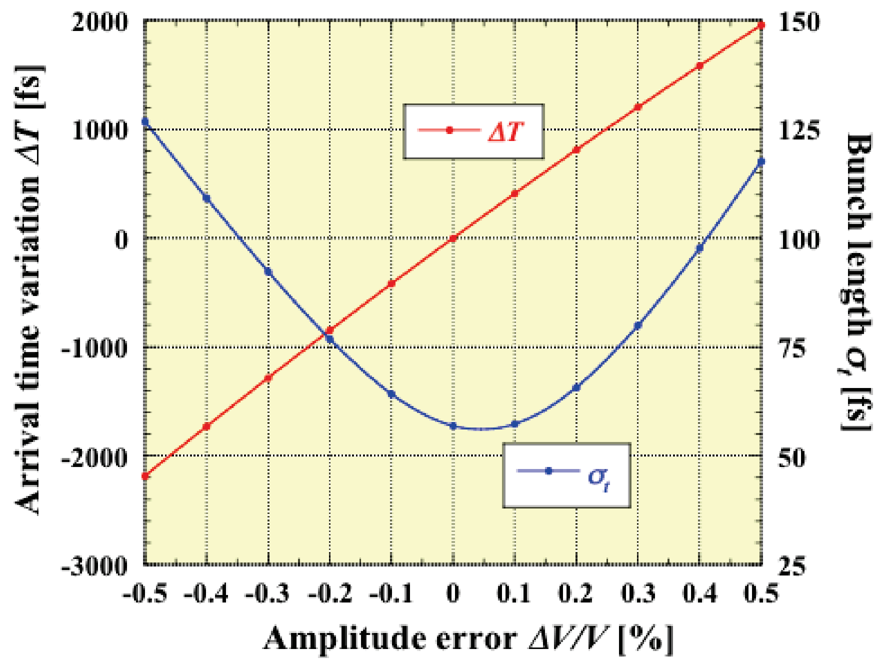
Courtesy N. Nakamura, T. Miyajima (ERL09)

RF amplitude error in main SRF cavity

Initial bunch length	1 [ps]
Normalized emittance	1[mm-mrad]
Momentum spread	
Bunch charge	77[pC]
Injection energy	5[MeV]
Accelerating gradient	15[MV/m]
Beam energy	125[MeV]
RF phase	14.46, 15.00[°]
	0.131



dV/V -0.5% -> +0.5 %



Courtesy N. Nakamura, T. Miyajima (ERL09)

RF phase error in main SRF cavity

Initial bunch length	1 [ps]
Normalized emittance	1[mm-mrad]
Momentum spread	
Bunch charge	77[pC]
Injection energy	5[MeV]
Accelerating gradient	15[MV/m]
Beam energy	125[MeV]
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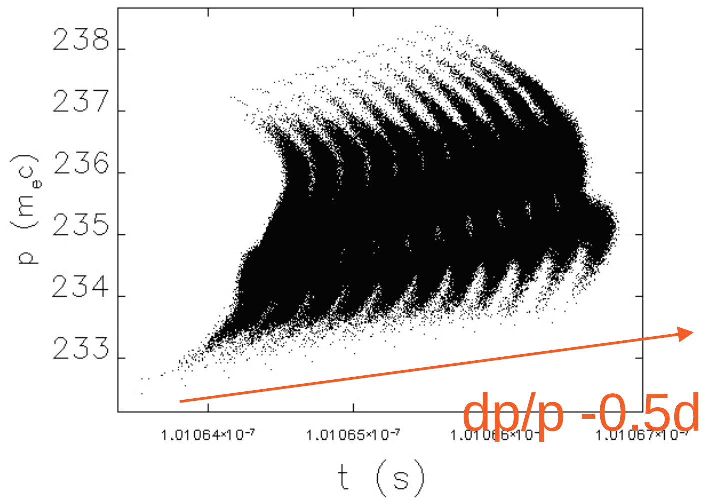
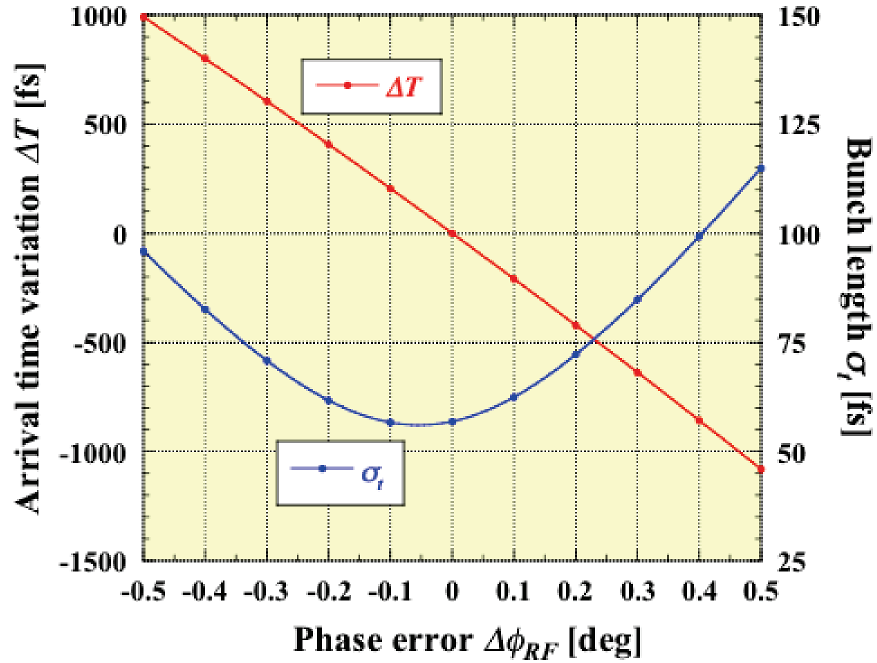


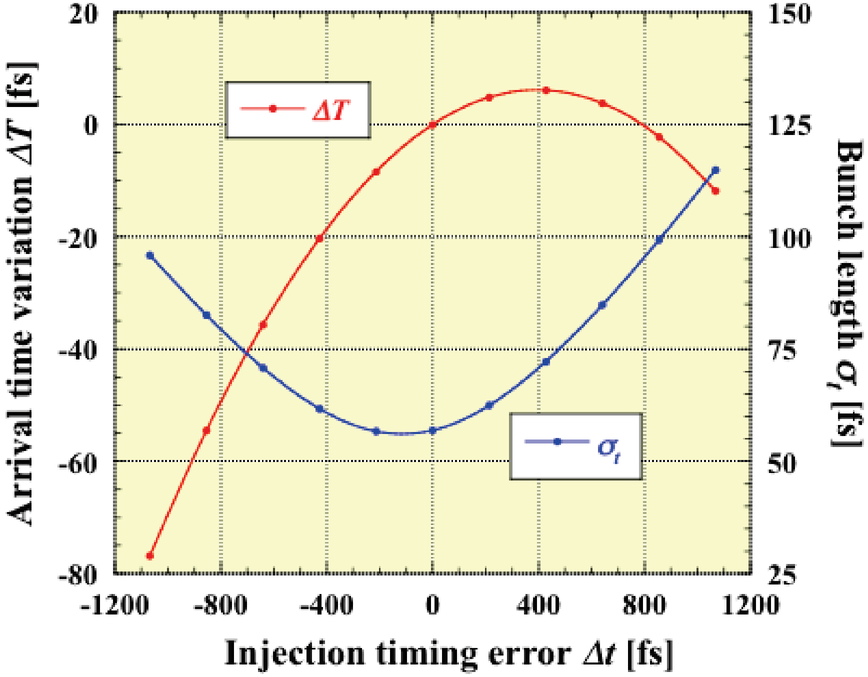
dp/p -0.5deg -> +0.5deg



Courtesy N. Nakamura, T. Miyajima (ERL09)

Injection Timing Error

Initial bunch length	1 [ps]
Normalized emittance	1[mm-mrad]
Momentum spread	
Bunch charge	77[pC]
Injection energy	5[MeV]
Accelerating gradient	15[MV/m]
Beam energy	125[MeV]
RF phase	14.46, 15.00[°]
	0.131



Courtesy N. Nakamura, T. Miyajima (ERL09)

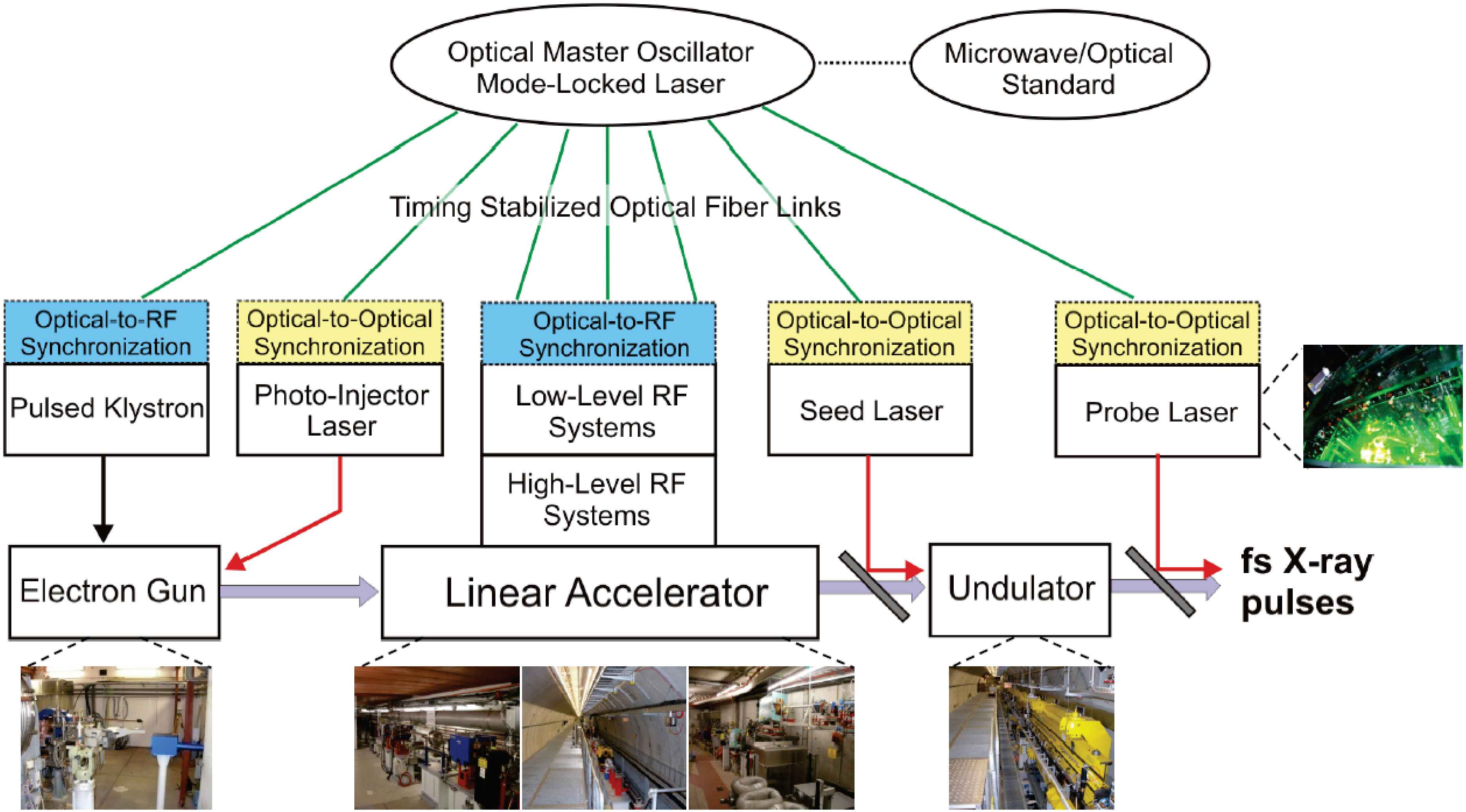
Timing Requirements

- Amplitude and Phase

	cERL (HC, LE)	cERL (BC)	Euro-XFEL	ILC
Amplitude	0.10 %	0.01 %	0.01 %	0.07 %
Phase	0.10 deg	0.01 deg	0.01 deg	0.24 deg

- We supposed Compact-ERL does not require a challenging timing system, however, in the bunch compression mode, we need <u>at least</u> 20 - 40 fs level stable distribution.

Basic Concept

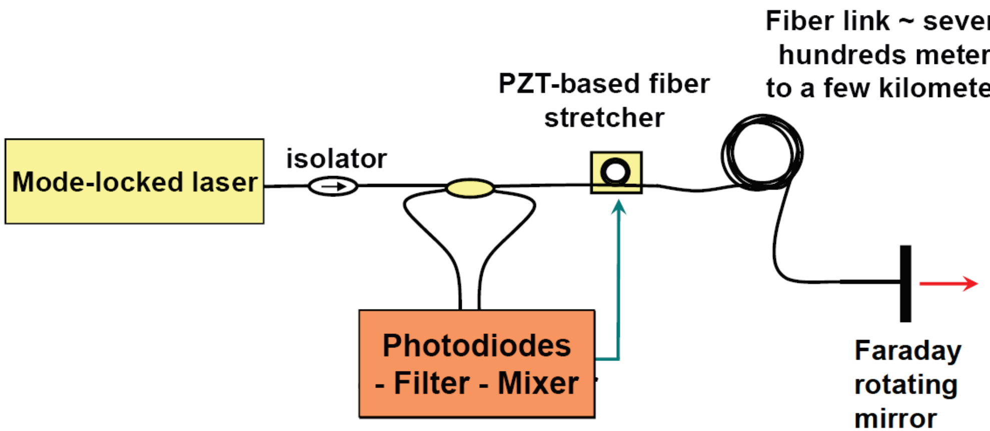


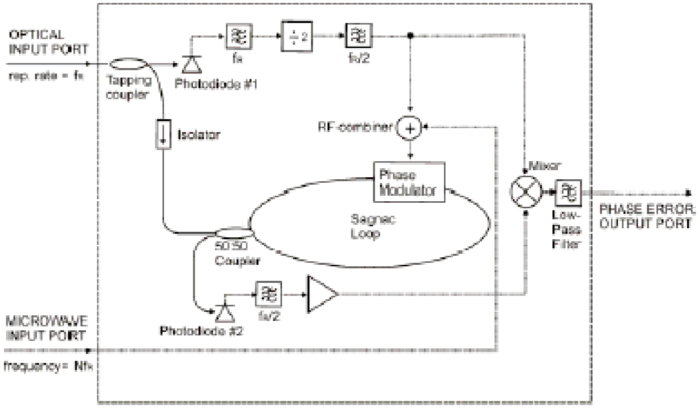
J. Kim, FEL2004

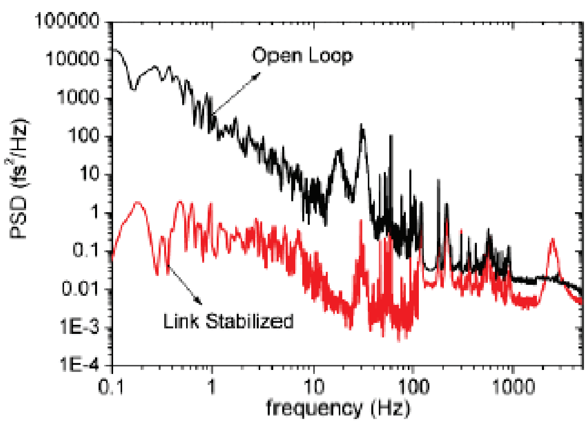
Time domain approach

- femtosec pulse laser
- Utilize optical cross-correlator

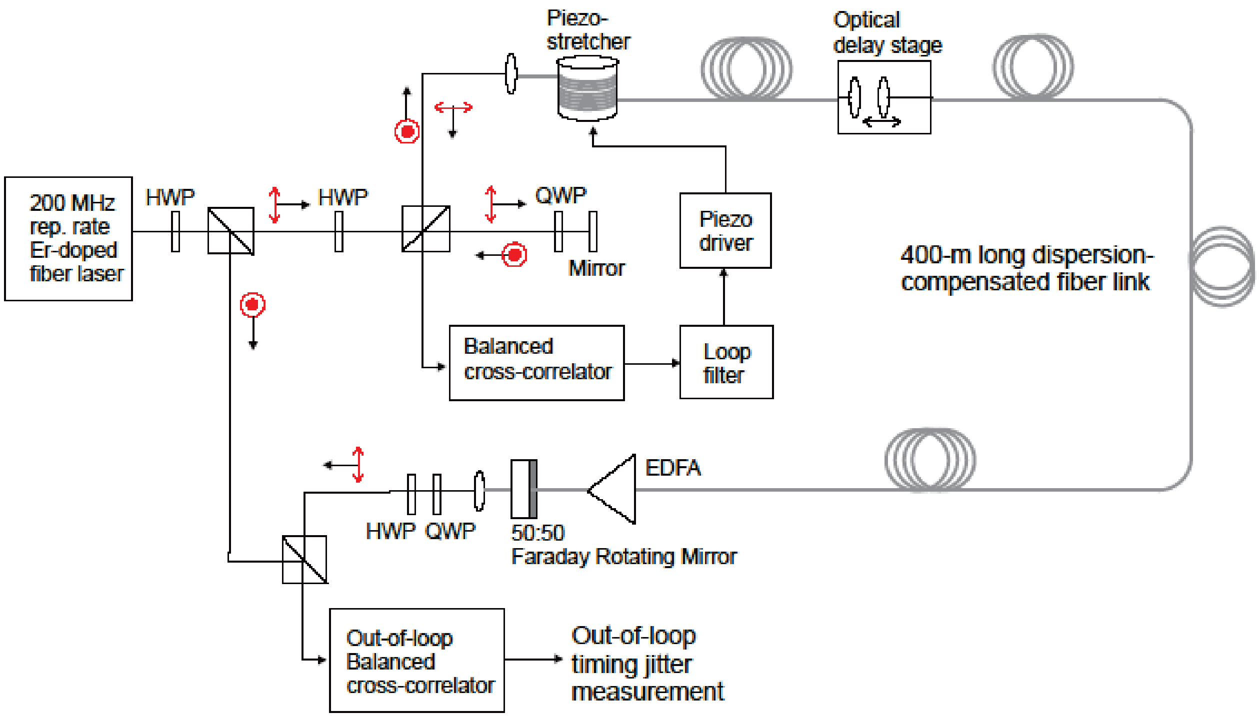
Very sensitive for timing error between short pulses







J. Kim, EPAC2006



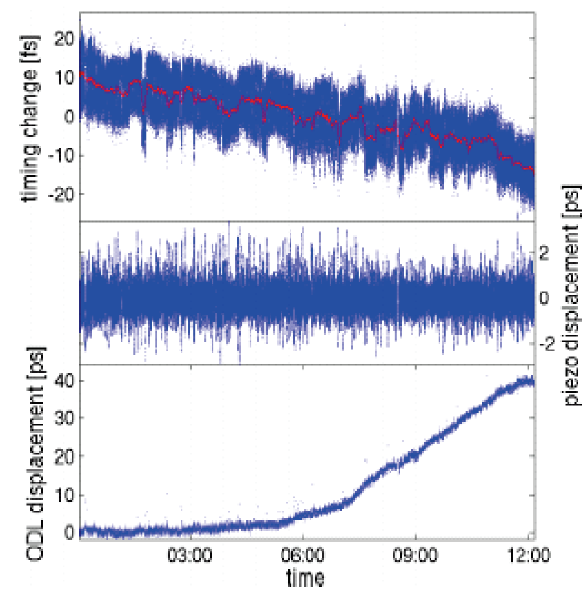
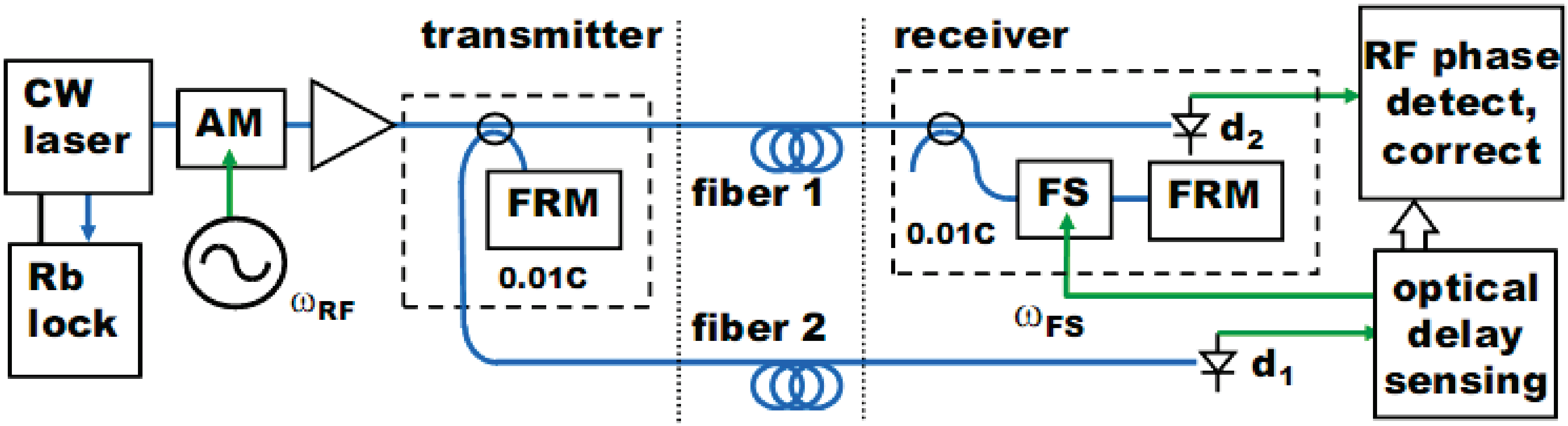


Figure 5: Out of loop drift measurement of a 400 m long fiberlink. Top: end of link timing change (blue). Over 12 hours the rms jitter is (7.5 ± 1.8) fs with a timing drift of 25 fs. The red line indicates changes with a time constant of 100 s. The timing jitter faster than 100 s is (4.4 ± 1.1) fs. Middle: piezo stretcher displacement. Bottom: Displacement of optical delay line (ODL).

J.Kim et al., Opt. Lett. 32(2007)1044
F. Loehl, DIPAC2007

Frequency Domain Approach

Schematic of one link

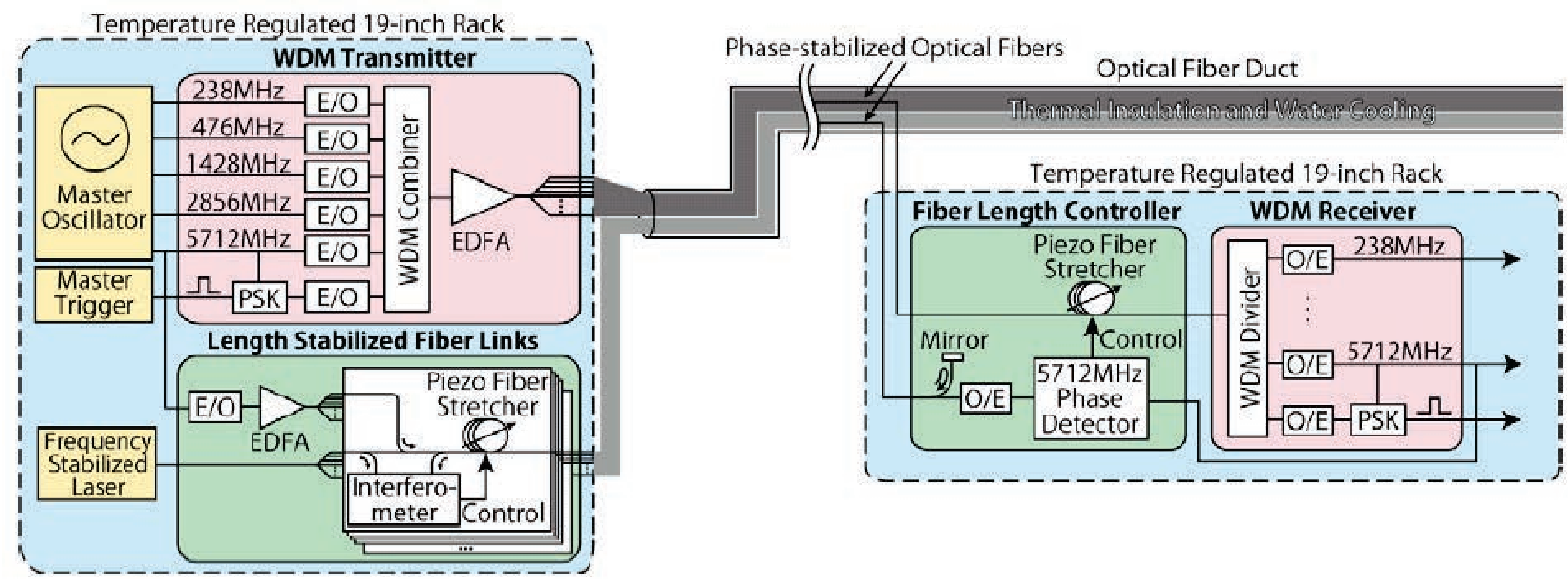


- FRM is Faraday rotator mirror (ends of the Michelson interferometer)
- FS is optical frequency shifter
- CW laser is absolutely stabilized
- Transmitted RF frequency is 2856 MHz
- Detection of fringes is at receiver
- Signal paths not actively stabilized are temperature controlled

Changes in line length are sensed by interferometer, signal sent to receiver

J. Byrd, R. Wilcox (LBNL), FLS2010

SPring-8 (CW + WDM)



Y. Otake, T. Ohshima, H. Maesaka, et.al. FEL2008, FLS2010

Present Status of Timing System

- Timing distribution over stabilized fibers
  - < 10 fs level demonstrated
  - can stabilize daily change
  - < 1fsec is challenging

- Long-term stability
- Cost?

Misc. Topics

- Protection
  - Human / Machine /SRF
- Large Dynamic Range
  - Commissioning (pA, nA) vs Operation (1-10-100mA)
  - Pulse for beam tuning vs CW for operation
- Emittance measurement in large current
  - Laser Wire (cost?)
  - SR is not useful in low energy (-10MeV) part
- Impedance of each component
  - Screen Monitor / View Port (need ‘cover’ when not used?)
  - CT or Cavity BPM (useful in commissioning stage?)

- Commissioning Strategy (menthoned in D. Gassner’s talk)

Working Group 4
Instrumentation & Controls

Takashi Obina (KEK)
David Gassner (BNL)

Presentations will be held in Yogo-Kan Room 127

Working Group 4
Charge - Instrumentation & Controls

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs

Working Group 4 will address technical issues for instrumentation and diagnostics that are designed to measure the electron beam properties required for initial machine set up, safe operation, and to diagnose anomalistic behavior. In addition we will cover synchronization of the electron beam with accelerator RF, external lasers, and experimental equipment.

The main topics to be addressed are:

- **Procedures for commissioning & operations**
- **Transverse orbit measurements and beam profiles**
- **Longitudinal beam instrumentation for energy spread and time profiles**
- **Beam-based machine diagnosis and feedback systems**
- **Synchronization & timing systems for operations & users**
- **Controls topics for system experts, and operations**
- **Passive and active machine protection system**

There are a range of measurements to be performed in each of the major instrumentation topics.

Attendees should present work toward diagnostics that perform one or several of these measurements. Each method proposed should address the measurement ***resolution***, the ***dynamic range*** and ***limitations of the system*** due to physical, technical or noise reasons.

Does the method discriminate between the accelerating and decelerating beams?

BROOKHAVEN NATIONAL LABORATORY

David Gassner
Takashi Obina

Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

These topics can be subdivided into specifics that each proposed diagnostic method should address, including:

Operation phase:

- Early **commissioning** and re-commissioning (start-up from scratch)
- Performance evaluation of the machine (dedicated **machine studies**)
- Full machine performance runs (nominal or user **operations**)

Beam modes (ERL specific):

- Low, medium and high **currents** (I < 0.01mA,<1mA, 1…1000mA)
- Low, medium and high **charge** (Q < 10pC, <100pC, 0.1…10 nC)
- Low, medium or high **bunch rep. rate** (f ~ kHz, ~MHz, ~ GHz)
- Small, medium or large nominal **emittance** (ε < 1um, < 10um, 10 um)
- Short, medium or large **bunch length** (s <100um, <1mm, ~1..10 mm)

Location:

- Drive laser beam line(s), Injector, Acceleration linac, Arcs, up and downstream of bunch compressors, Insertion device, Experiments, Beam dump area.

Working Group 4
Instrumentation & Controls – Talks Agenda

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs

Wednesday:

Invited Plenary Session 7

9:30 **Operations, Controls and Diagnostics for High Power Electron Injectors**
Bruce Dunham (Cornell)

11:00 **BNL Energy Recovery Linac Instrumentation** - David Gassner (*BNL*)

11:30 **Development of Femto-second Timing Distribution System** - Takashi Naito (*KEK*)

Thursday:

11:00 **Turn-by-Turn Monitor Using Fast Gate Switch** - Makoto Tobiyama (*KEK*)

11:30 **Design and Performance of the Synchronization System, and Beam Diagnostic Instruments for SACLA** - Hirokazu Maesaka (*RIKEN/SPring-8*) **(May break into 2 talks)**

16:00 **Beam Instrumentation for the Compact ERL at KEK** - Takashi Obina (*KEK*)

Friday 11:00 **Working Group 4 report.**

Tuesday 16:00-18:30 Kenkyu-honkan

PSP003 Introduction to the PKU-ERL Control System Liwen Feng (PKU/IHIP, Beijing)

Senlin Huang, Lin Lin, Kexin Liu, Fang Wang, He Zhang (PKU/IHIP, Beijing)

For stable operation of the PKU ERL system, a reliable accelerator control system is demanded. The design of Peking University Energy Recovery Linac (PKU-ERL) involves a full-feature EPICS control system. It will control laser system, cryogenic system, vacuum system, magnets, power supplies and beam diagnostic system of the accelerator. FPGA based embedded system is used in the LLRF control system. PLC based process control are used in the control of cryogenic system and power supplies. PC based OPIs are used for monitoring the whole system.

PSP005 R&D of Undulator for PKU-ERL Test Facility Zhiwen Wang (PKU/IHIP, Beijing)

Senlin Huang, Lin Lin, Kexin Liu, Shengwen Quan (PKU/IHIP, Beijing)

An ERL test facility is under construction at Peking University. It will be used as a driver for THz radiation and IR FEL. As the important components for the radiation source, two undulators will be built. The undulator to generate THz radiation will employ the hybrid Halbach structure, with a period of 47.84mm, gap of 10mm, and residual magnetic field of 1.26T. In this paper, both physical design and technical issues of the THz undulator will be presented.

PSP007 INDIVIDUAL HALF-CELLS FREQUENCY MEASUREMENTS IN A DUMBBELL CAVITY

Georg H. Hoffstaetter (Cornell, CLASSE, Ithaca, New York) Valery D. Shemelin, Paul Carriere (CLASSE, Ithaca, New York)

Dumbbell fabrication is a mid-process in fabrication of a multicell cavity. The halfcell frequencies can be deciphered from the frequencies of the TM010 0- and pi-mode. A correction to the earlier derived formulae for the individual cell pi-mode frequencies is presented. The fixture for dumbbell frequencies measurement was created and used in the process of the first Cornell ERL 7-cell cavity fabrication. The measuring system consisted of this fixture, a network analyzer, a load cell, and a computer.

WG 4 & 5 Joint Sessions

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs

- Working Group 4 & 5 will have joint sessions
  - "Beam Loss & Machine Protection" and "Instrumentation & Controls" have many common features.
  - Combined number of talks can fill the allotted time slots for parallel sessions.

Please send in slides from the talks for WG4 report on Friday

Next:

Takashi will give presentation on the history Instrumentation and Diagnostics talks at recent ERL Workshops.

Thank you to all contributors!