FEL06 highlights
Berlin, August 27-September1

organized by BESSY and Rossendorf

http://www.bessy.de/fel2006/proceedings/

most of the talks is there slides and audio!

Sessions

- The Angstrom Challenge
- Seeded FELs
- Energy Recovery FELs
- The Challenge of fs-Pulses and Synchronization
- FEL Oscillators and Long Wavelength FELs
- FEL Theory
- FEL Technology I
- FEL Technology II
- X-ray Optics and Detectors
- New Science at the FELs

1 day trip to Rossendorf and Dresden

FEL prize

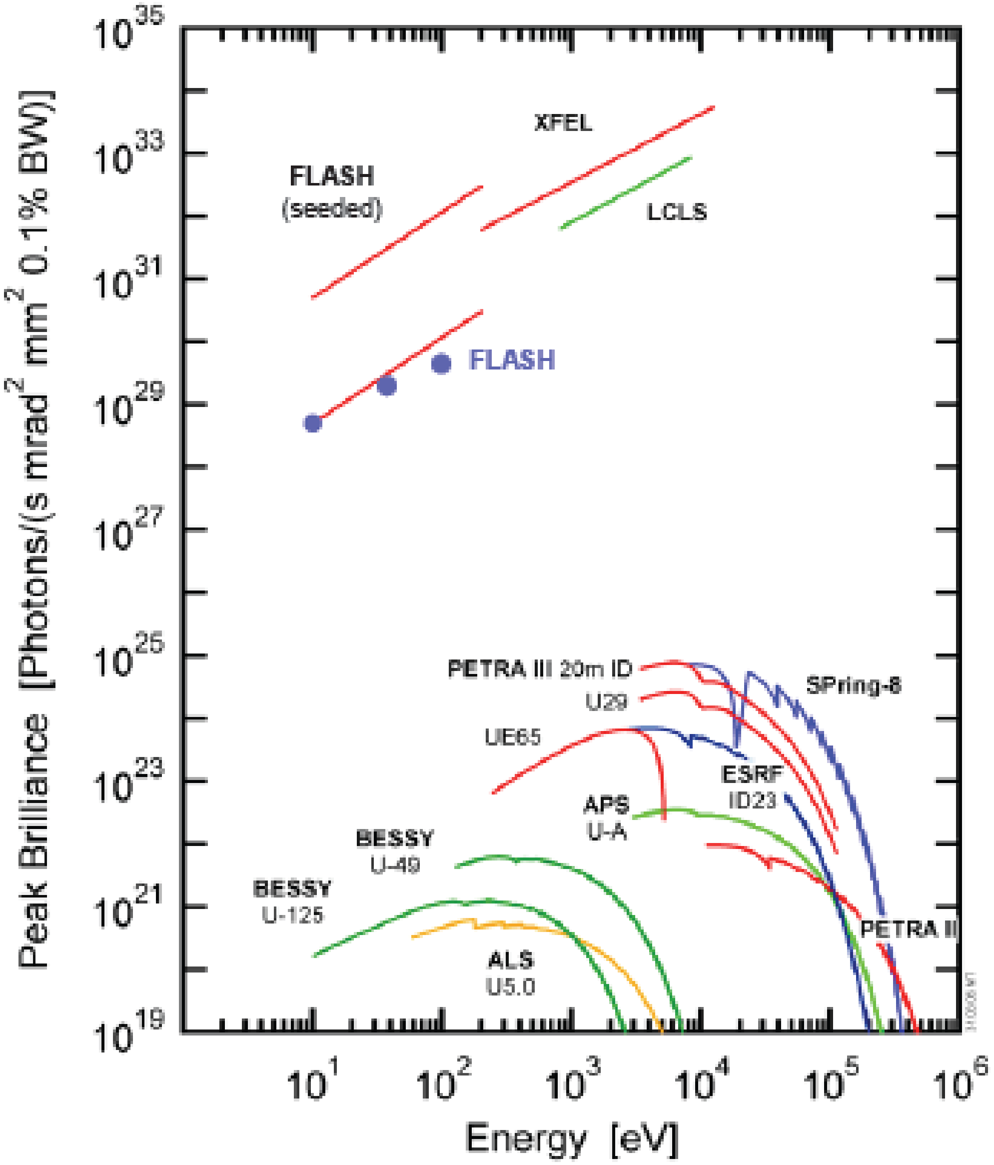
A. Gover get the prize in 2005, gave a talk (lecture) this year

J. Rossbach and E. Saldin get FEL prize this year for contributions to the SASE FEL (Saldin started to work on ~ 25 years ago)

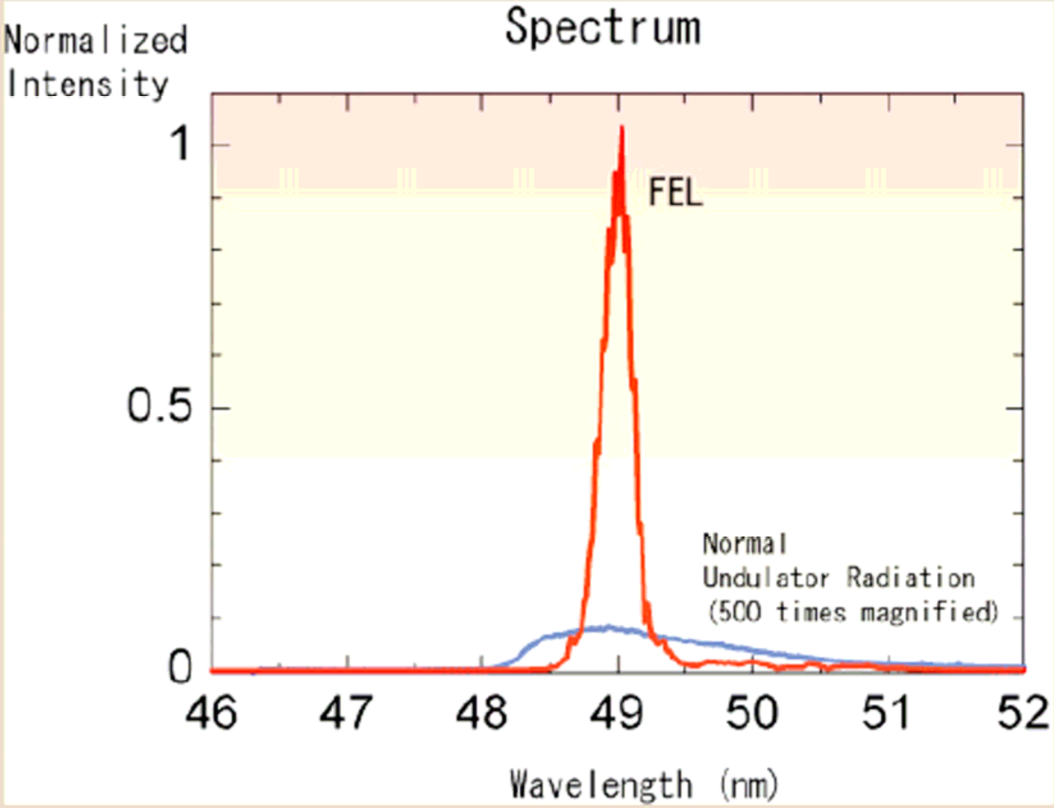
First lasing

- Lasing at 13 nm of the SASE FEL at FLASH (DESY)
- First Lasing at SCSS (RIKEN Spring-8)
- First Lasing at 198 nm Single-pass High Gain FEL at the NSLS SDL (BNL)
- Rossendorf second FEL at ~ 60 um

FLASH lasing at 13 nm



First Lasing at SCSS Prototype Accelerator.



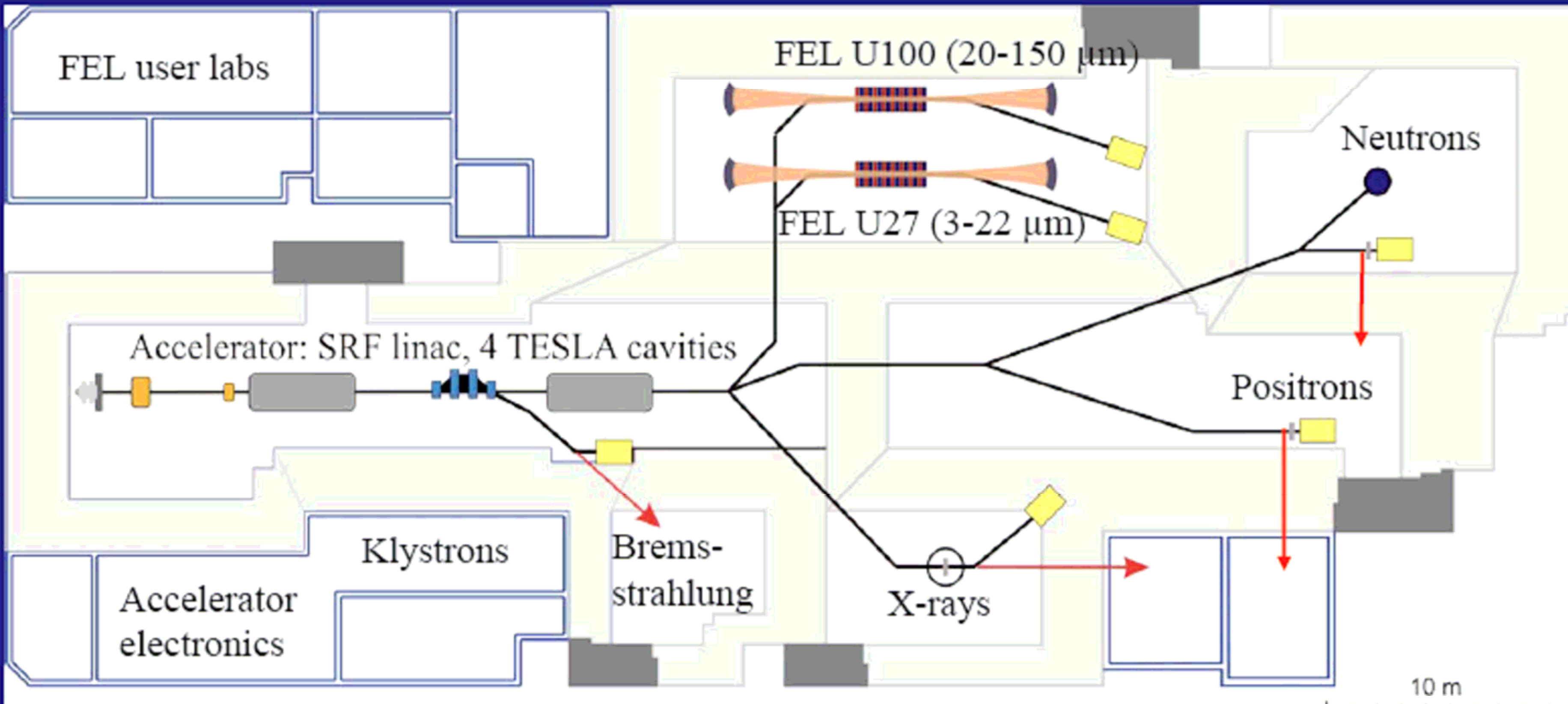
- The first lasing: 49 nm
- E-beam energy : 250 MeV
- Bunch charge: 0.25 nC
- Bunch length: (< 1 pse)
- Peak Current (> 300 A)

- At moment spectrum width 0.5 nm is dominated by e-beam energy fluctuation ~ 0.2%.

SDL lasing(s)

- Intro: Source Development Lab (SDL)
- Our First Lasing of FELs Below 200 nm @ NSLS SDL
  1. SASE @193 nm
  2. 4th harmonic HGHG: 795 nm → 199 nm
  3. First E-SASE lasing

ELBE Layout

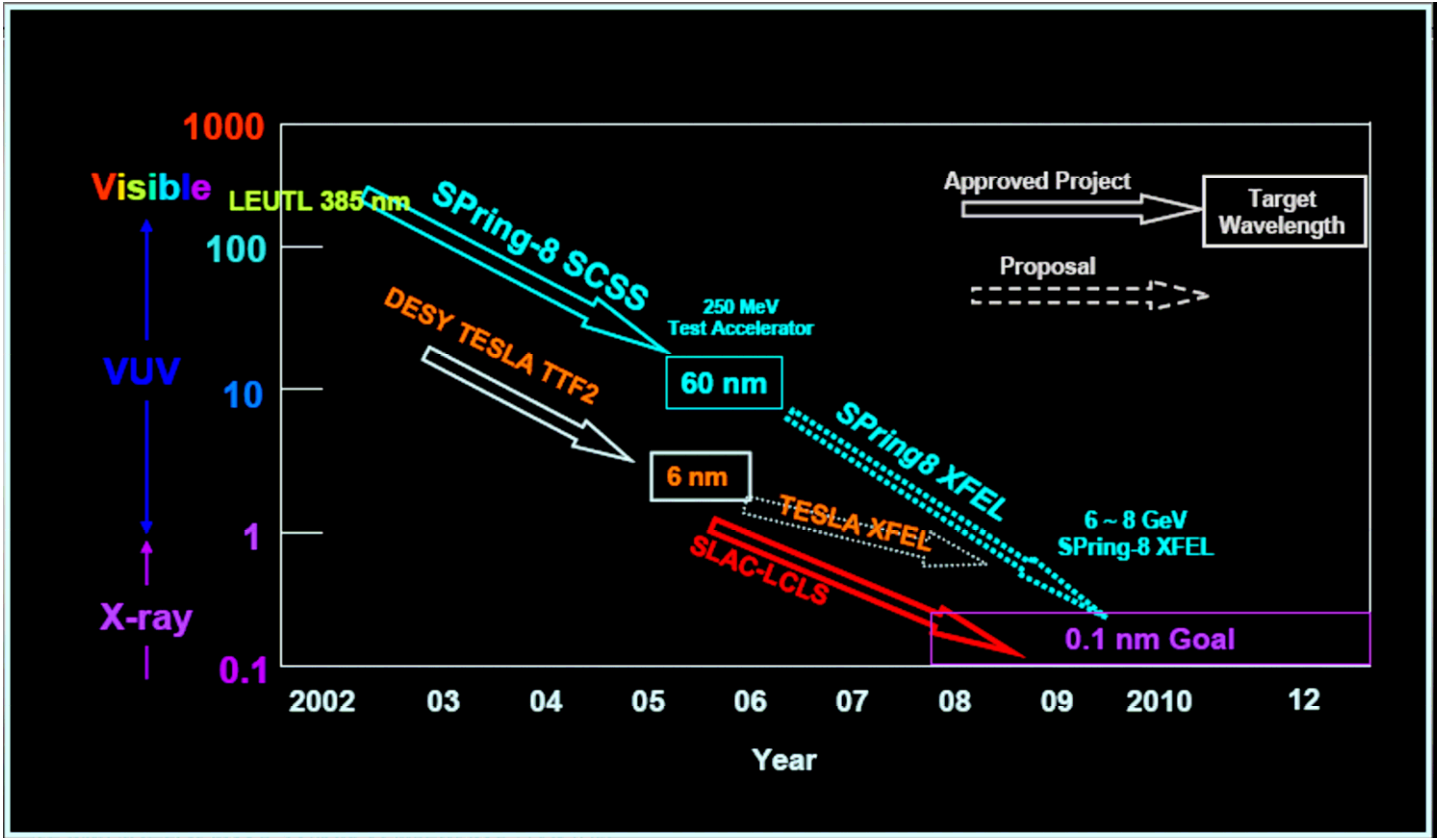


- Start Bremsstrahlung experiments : 2002
- Channeling radiation (X-ray's) : 2003
- IR-Radiation : FEL 1 first lasing 7.05.2004
- FEL 2 first lasing 21.08.2006
- Neutron and Positrons planned for 2007

The Angstrom Challenge

- Status of the Linac Coherent Light Source (D. Dowell)
- Results and Lessons from FLASH (B. Faatz)
- The European XFEL Project (R. Brinkmann)
- Optical Klystron Enhancement to SASE X-Ray FELs (Y. T. Ding for LCLS)
- Status of Japanese XFEL Project and SCSS Test Accelerator (Shintake)

The Angstrom Challenge



from LCLS

LCLS Design Parameters

Fundamental FEL Wavelength	**1.5**	**15**	Å
Electron Beam Energy	13.6	4.3	GeV
Normalized Slice Emittance (rms)	1.2	1.2	mm-mrad
Peak Current	3.4	3.4	kA
Energy Spread (slice rms)	0.01	0.03	%
Bunch/Pulse Length (FWHM)	≤ 200	≤ 200	fs
Saturation Length	87	25	m
FEL Fundamental Power @ Saturation	8	17	GW
FEL Photons per Pulse	1	29	10^{12}
Peak Brightness @ Undulator Exit	0.8	0.06	10^{33} *

* photons/sec/mm^2/mrad^2/ 0.1%-BW

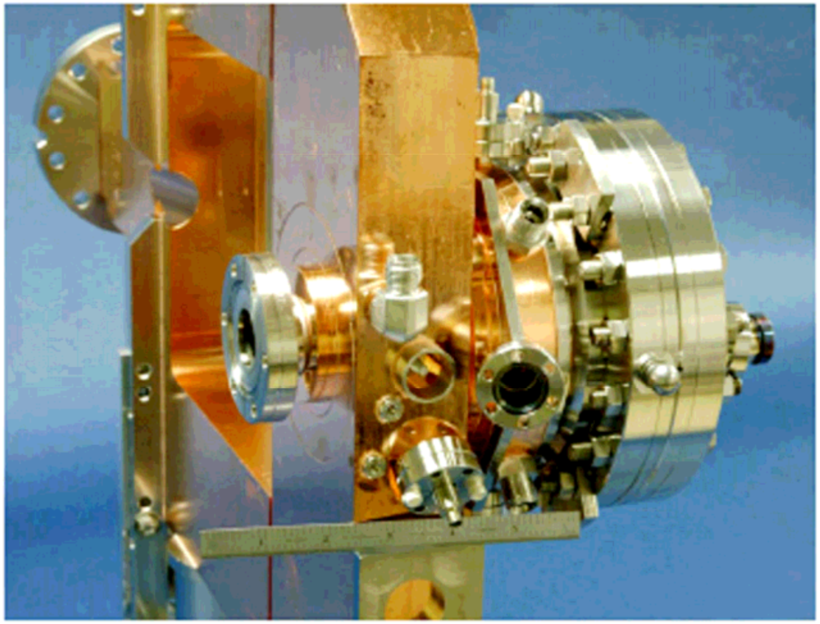
from LCLS

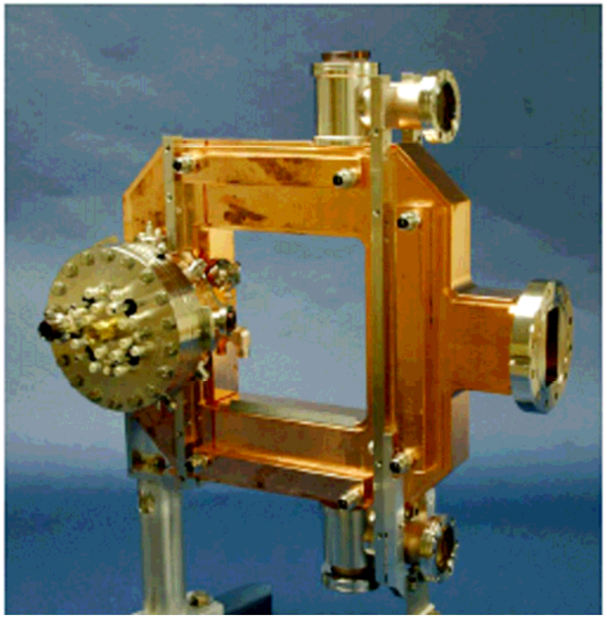
Technical Challenges for Angstrom FEL's

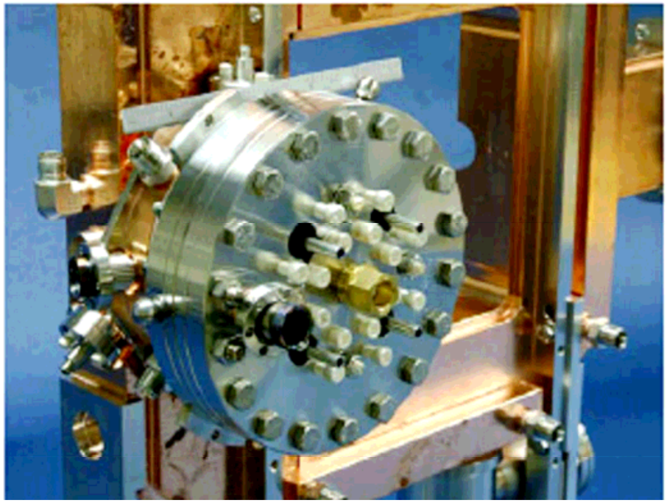
- Gun emittance
  - Cathode emittance, uniformity, and quantum efficiency
  - RF field quality
  - gun solenoid field uniformity and alignment
- Drive laser reliability, stability and 3D shaping (UV diagnostics)
- Emittance preservation
  - Optical aberrations and CSR
  - Wakefields
- Beam Instabilities (CSR, Longitudinal space charge)
  - Laser-Heater
- Bunch length diagnostics and control
- Alignment
  - gun to solenoid etc.
  - undulator
- Magnetic Measurements
  - Beamline components
  - New measurement facility for undulators
- RF power stability
- Vibrations
- Temperature stability and control

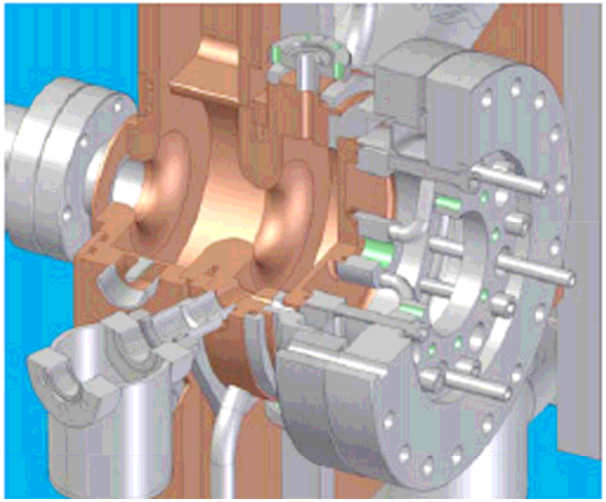
from LCLS

RF Gun Fabrication and Cold RF Testing Finished & Preparing for High-Power Tests









from LCLS

Summary

- LCLS construction has begun:
  - Laser building at Sector 20 finished
  - Drive laser delivered, installed & operating
  - RF gun fabricated and high-power testing in Sept.
  - Beamline through BC1 installation begun
  - Final Focus Test Beam (FFTB) removed for LCLS construction
  - Undulators arriving from ANL and being magnetically shimmed in new Magnetic Measurement Facility (MMF)
- LCLS design addresses many of the varied technical challenges of Angstrom FELs
- Commissioning of Injector through BC1 to begin in early 2007
- On schedule for first light in 2008 and beam for users in 2009.

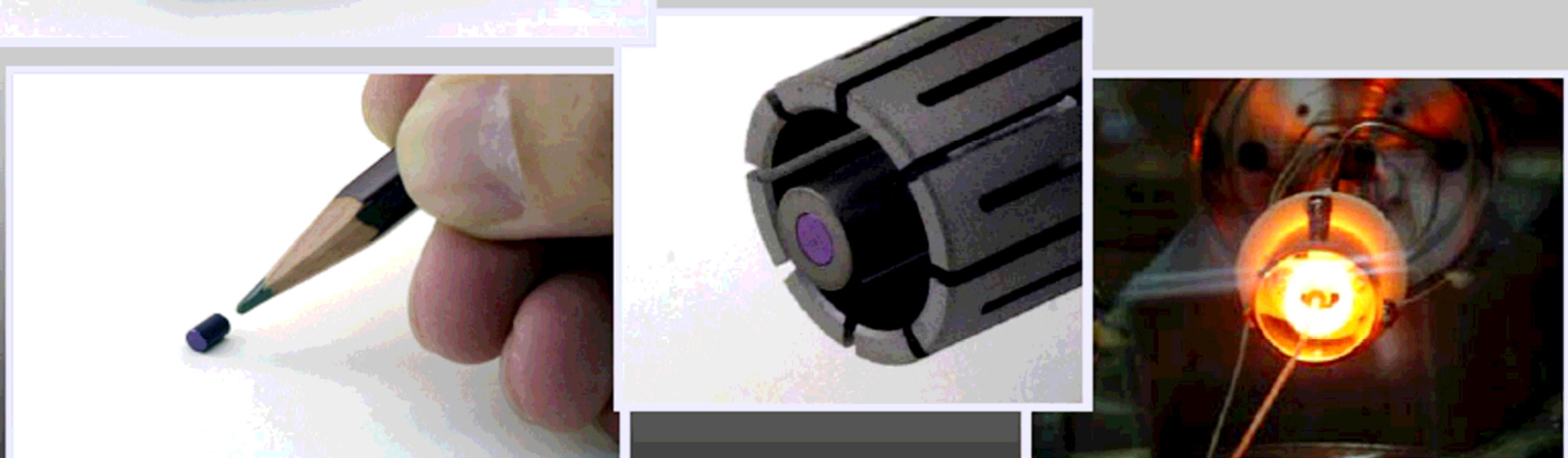
SCSS and Japanese XFEL

		Prototype	X-ray FEL	
Beam Energy	E	0.25	8.0	GeV
X-ray Wavelength	λ	60	0.1	nm
Beam Emittance	ε_n	2	1.0	πmm.mrad
Bunch Length	Δ_z FWMH	150 0.5	75 0.25	μm psec
Transverse Beam Size	$\sigma_{x,y}$	100	25	μm
Peak Current	I_p	1	4	kA
Charge per bunch	q	0.5	1	nC
Undulator Parameter	λ_u K	15 1.3	18 1.3	mm
Length	L	9	80	m
FEL Saturation Length	L_{sat}	10	80	m

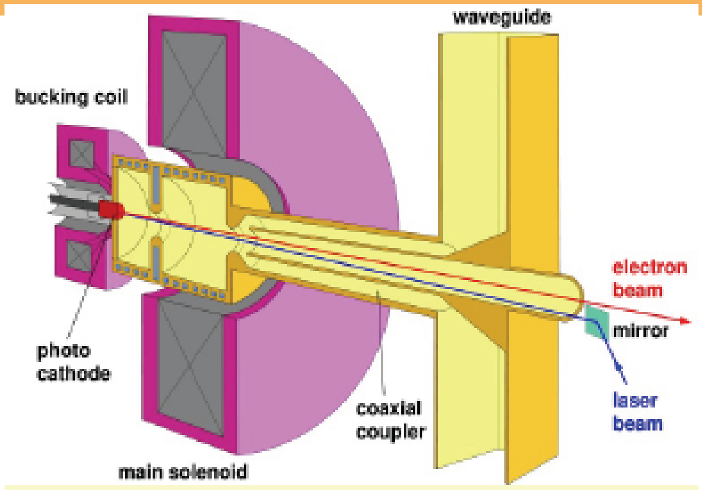
SCSS and Japanese XFEL

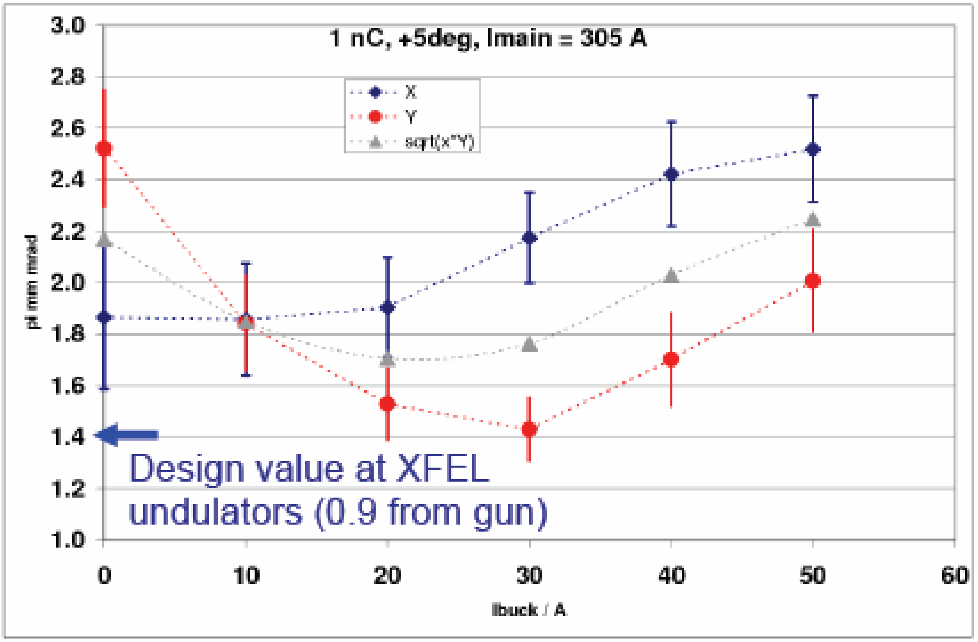
CeB_6 Cathode & Heater Assembly

- CeB_6 Cathode 3 mm Diameter
- Emittance 0.4 π.mm.mrad
  (thermal emittance, theoretical)
- Beam Current 3 Amp. at 1450 deg.C
  (using graphite heater)
- Current Density > 40 A/cm^2



Injector development (DESY Zeuthen & FLASH)

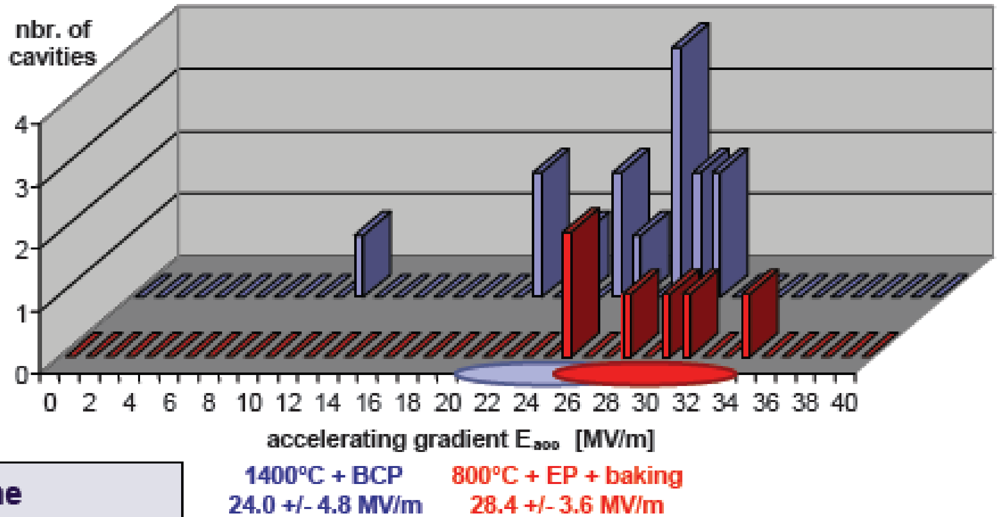




On-going programme:

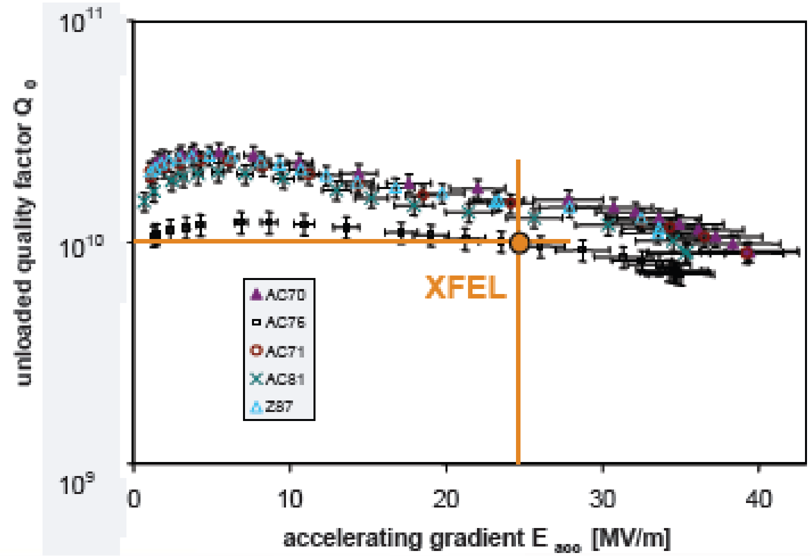
- increase the gradient on the cathode from 40 MV/m to 60 MV/m
- further improve the transverse and longitudinal laser profile (collab. Max-Born Institute, Berlin)
- PITZ gun now part of FLASH injector

Results From Cavity Acceptance Tests



Comparison of the accelerating gradients at $Q=10^{10}$ in the first performance test after the full preparation sequences using etching with post-purification at 1400°C (blue) and electro-polishing with 800°C annealing (red).

'Excitation curves' of the best cavities treated with 800°C furnace treatment and electro-polishing. The XFEL baseline gradient of 23.6 MV/m is exceeded by a significant margin.



EPAC2006 prize: → Lutz Lilje, DESY

Accelerator technology - collaborative effort

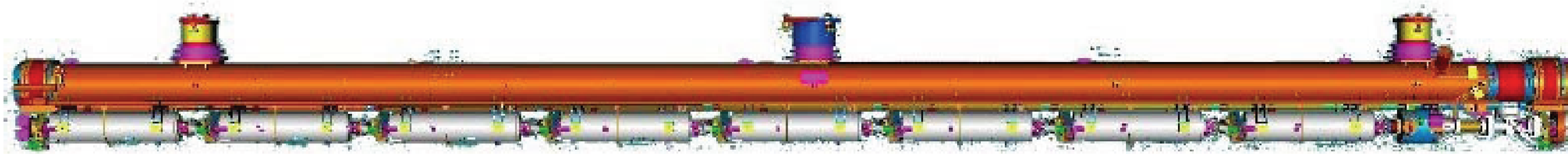
Industrial study module assembly (M6)

2 more cryostats (TTF3/INFN) ordered

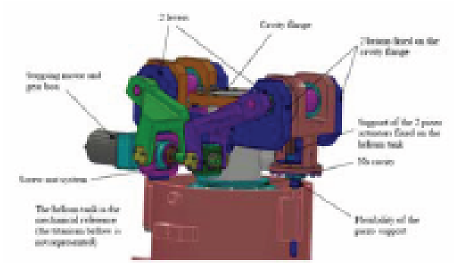
Superferric magnet (CIEMAT)

BPM (Saclay)

Integrated HOM absorber

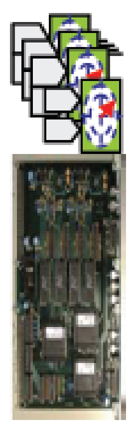


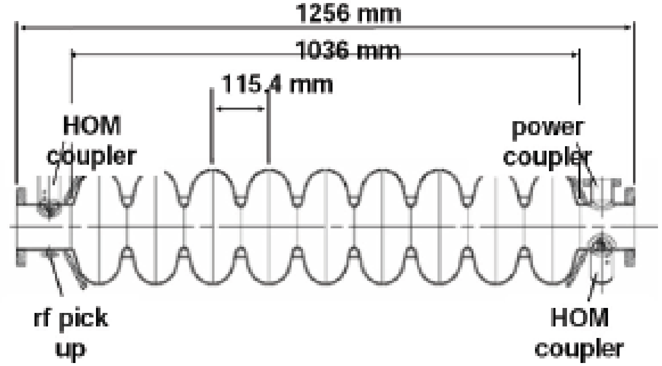
Length quantized n-λ/2 (possibility of ERL)



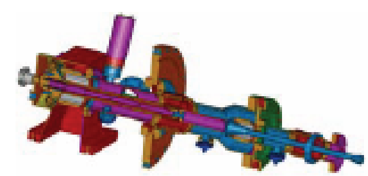
Tuner w/piezo (Saclay)

Industrialization in preparation





LLRF development (collab. Warsaw/Lodz)



TTF3-type coupler

Industrialization launched (Orsay)

Seeded FELs

- Very good talks and a lot of activity in the field (however, a lot of resources as well)

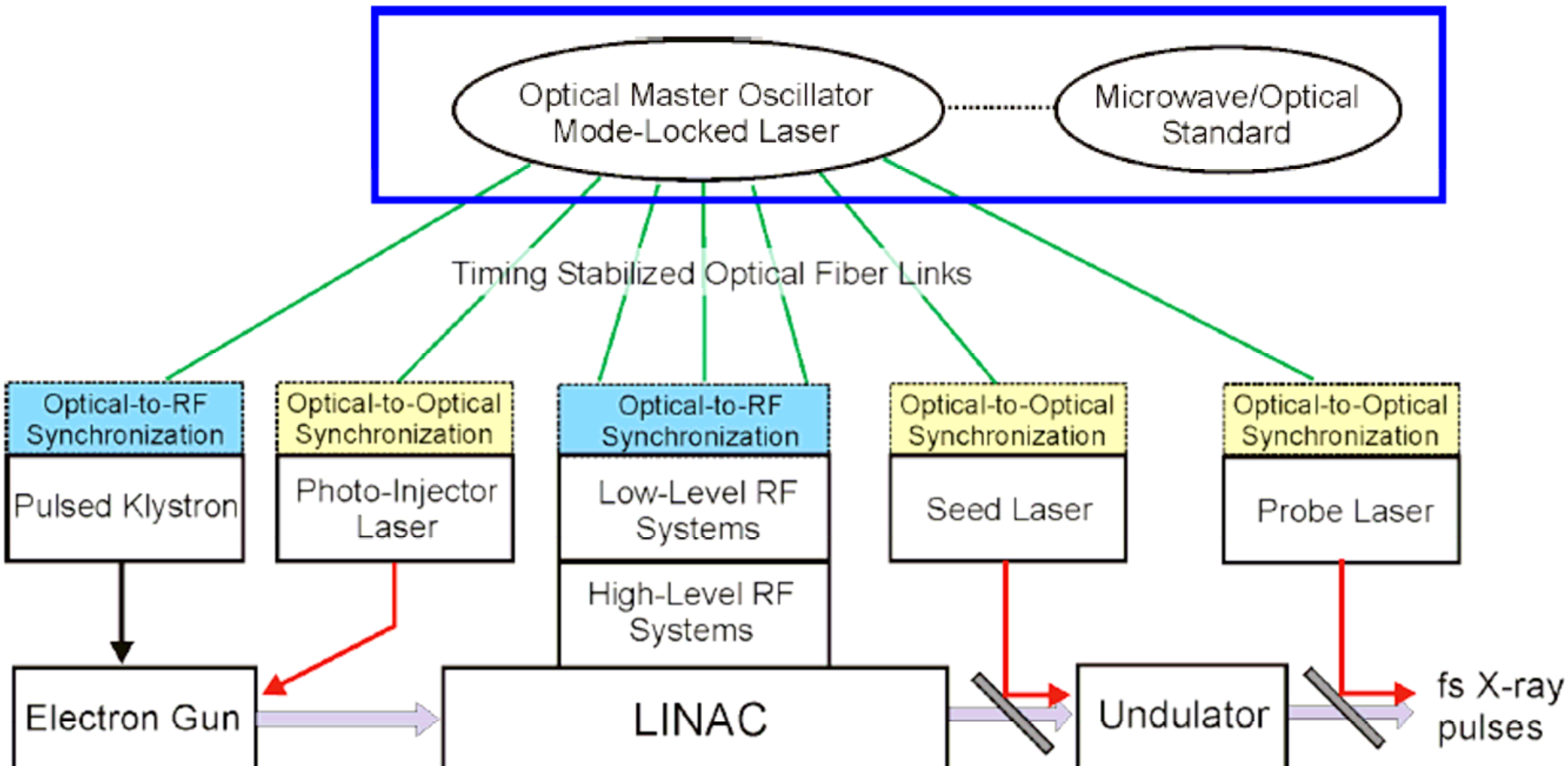
- BESSY, FERMI@ELETTRA, 4GLS, RIKEN-Sping8 and others…

- very sophisticated simulations of beam dynamic as well as FEL interaction

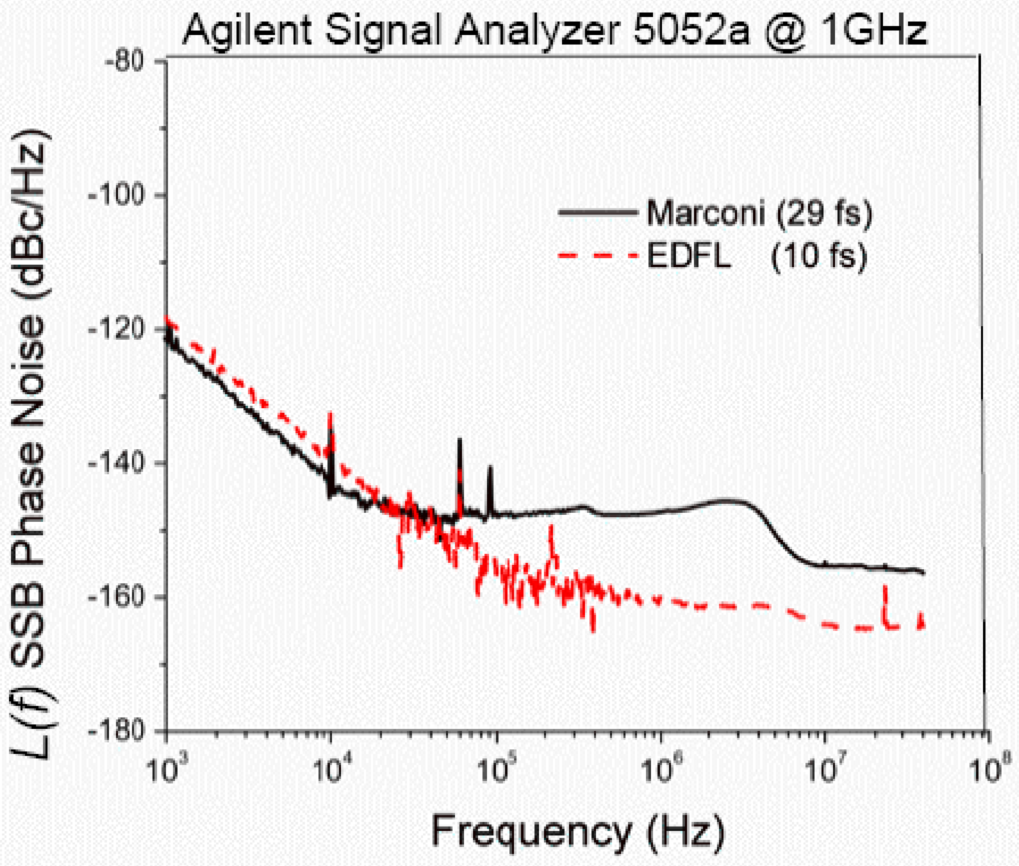
- BNL (SDL) experiments

The Challenge of fs-Pulses and synchronization

- For LLRF (machine operation) and for diagnostics
- Talk from MIT is a very good overview and very impressive results



Phase Noise (Timing Jitter) Measurements



$$\Delta t_{rms} = \frac{\sqrt{2\int_{f_1}^{f_2} L(f)df}}{2\pi f_0}$$

Δt_{rms}[10kHz,22MHz] = 10 fs

Kaertner et al, PAC 2005.
Winter et al, FEL 2005.

- Noise floor limited by photo detection
- Theoretical noise limit <1 fs

Summary and Outlook

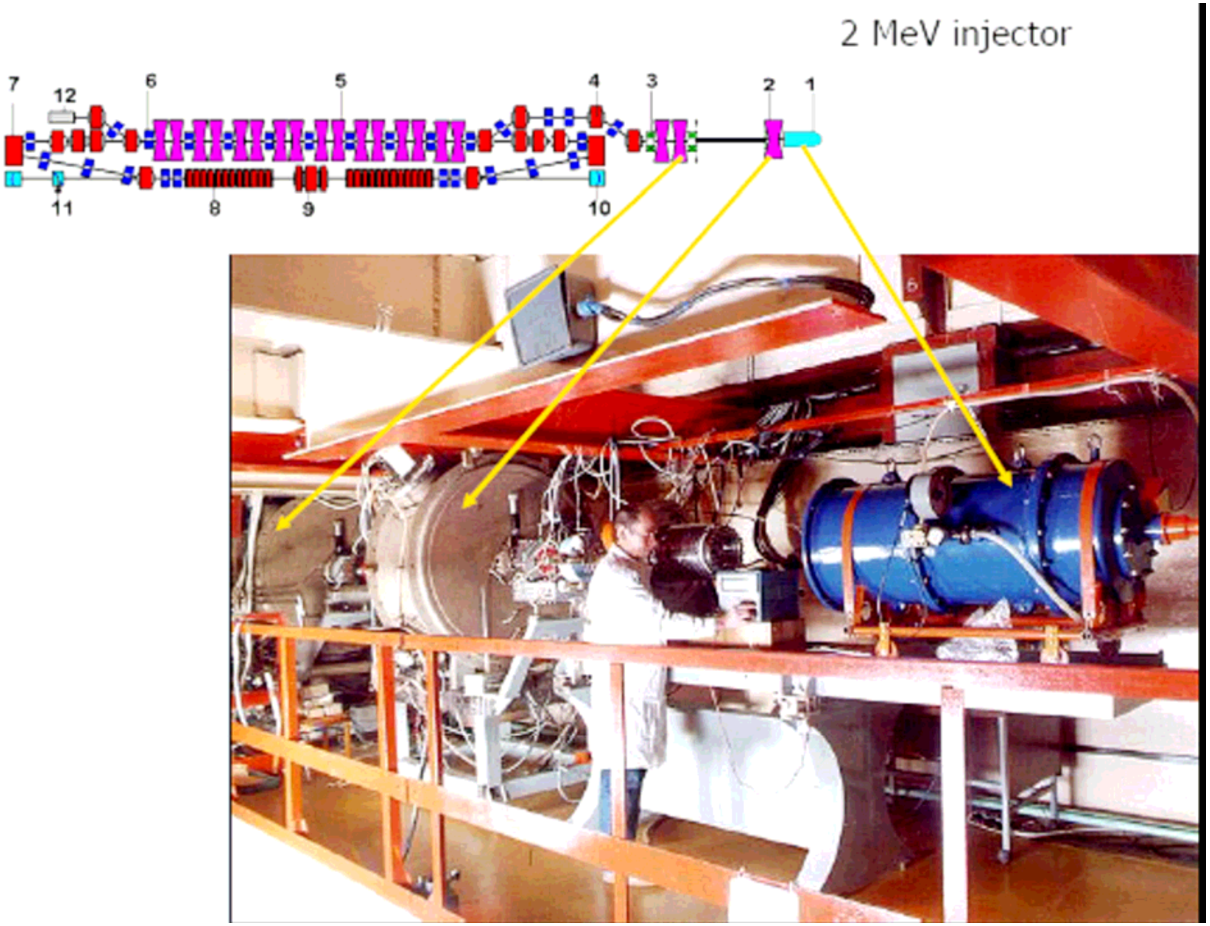
- **Optical master oscillator**: Ultrashort pulse trains from mode-locked lasers have excellent phase/timing noise properties. (~10 fs → <1 fs)
- **Timing-stabilized fiber links**: initial demonstration in the accelerator environment. Optical cross-correlation system in progress for low-jitter, drift-free operation. (short-term ~10 fs → long-term <1 fs)
- **Optical-to-RF synchronization**: Balanced optical-RF phase detectors are proposed for femtosecond and potentially sub-femtosecond optical-to-RF synchronization. (~3 fs → long-term <1 fs)
- **Optical-to-optical synchronization**: Balanced optical cross-correlation. Long term stable sub-femtosecond precision is already achieved. (<1 fs)

(Sub-)femtosecond timing synchronization and stabilization for 4th generation light sources can be accomplished.

Energy recovery FELs

- Performance Achievements and Challenges for FELs Based on ERLs
  (G. A. Krafft, JLab)
- Future Light Sources: Integration of Lasers, FELs and Accelerators at 4GLS
  (J. A. Clarke, Daresbury)
- FEL Oscillation with a High Extraction Efficiency at JAEA ERL FEL
  (N. Nishimori, JAEA/FEL)
- On the Design Implications of Incorporating an FEL in an ERL
  (G. Neil, JLab)
- Optical Design of the Energy Recovery Linac FEL at Peking University
  (Z. C. Liu, PKU/IHIP, Beijing)
- Status of the Novosibirsk High Power Terahertz FEL
  (N. Vinokurov, BINP)

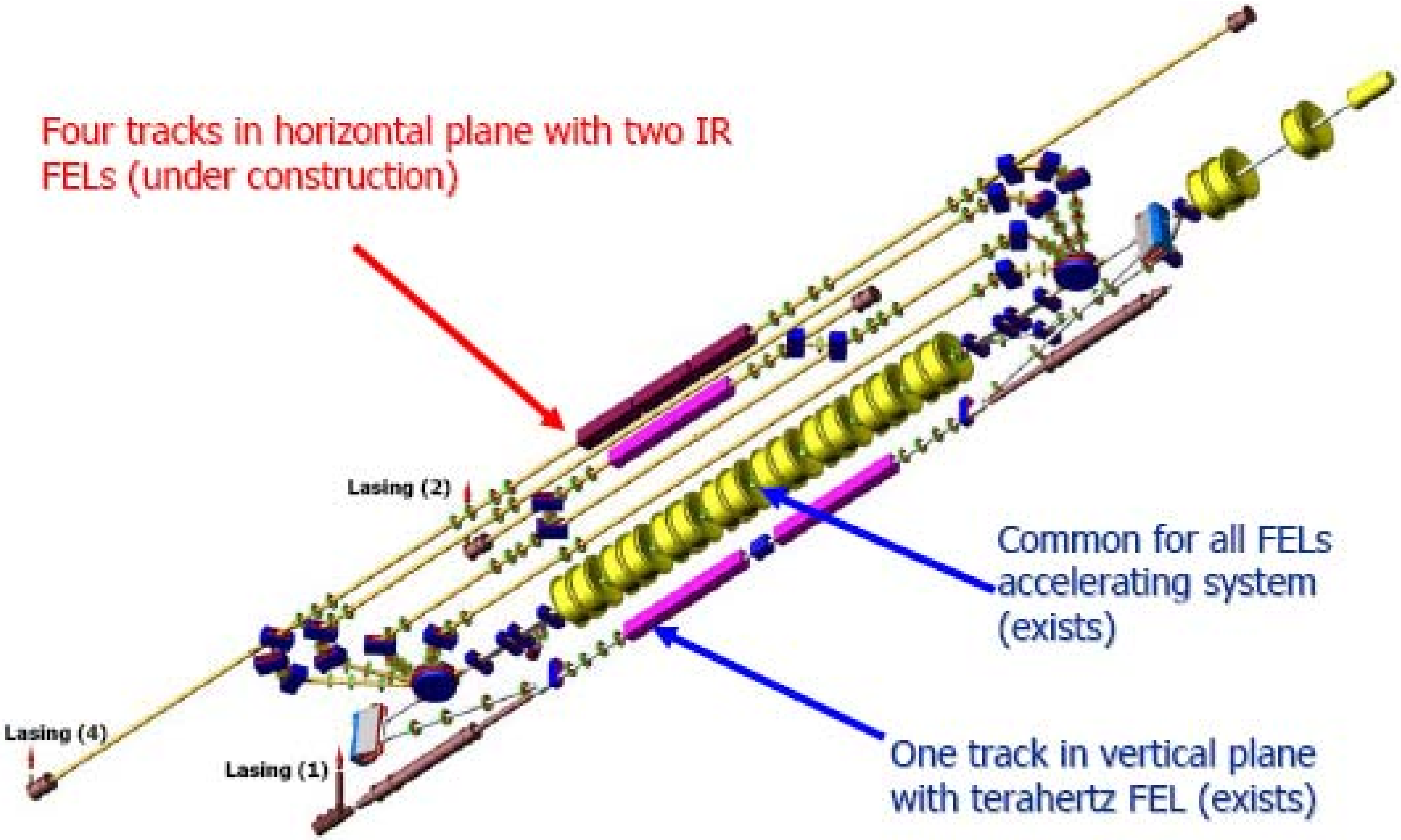
BINP FEL



♦ Bunch repetition rate, MHz	up to 22.5
♦ Charge per bunch, nC	1.5
♦ Start bunch length, ns	1.5
♦ Final bunch length, ns	0.12
♦ Final energy, MeV	2

- run 20 mA routinely
- can run up to 40 mA!

BINP FEL



Four tracks in horizontal plane with two IR FELs (under construction)
Lasing (2)
Lasing (4)
Lasing (1)
Common for all FELs accelerating system (exists)
One track in vertical plane with terahertz FEL (exists)