The SPring-8 Angstrom Compact Free Electron Laser (SACLA)

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RIKEN Harima Institute

RIKEN SPring-8 Center, XFEL R&D Division

Outline

1. Brief System Overview
2. Beam Commissioning Progress
3. Process to Increase Laser Intensity
4. Achieved FEL Performance
5. Future Upgrade Plan

SASE wavelength λ

$$\lambda = \frac{\lambda u}{2n\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\theta^2\right)$$

Generation of X-ray with lower beam energy requires a shorter undulator period and smaller K-value

Design Concept of SPring-8 Compact SASE Source (SCSS) 

Lower Beam Energy

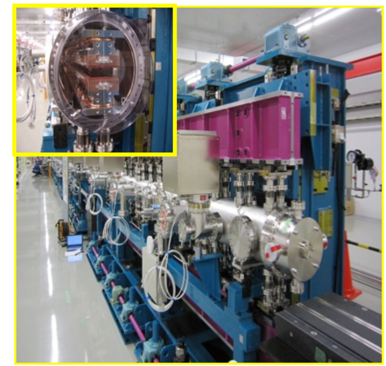
Size Reduction

+

Efficient Acceleration

Further Size Reduction

Smaller Normalized Beam Emittance

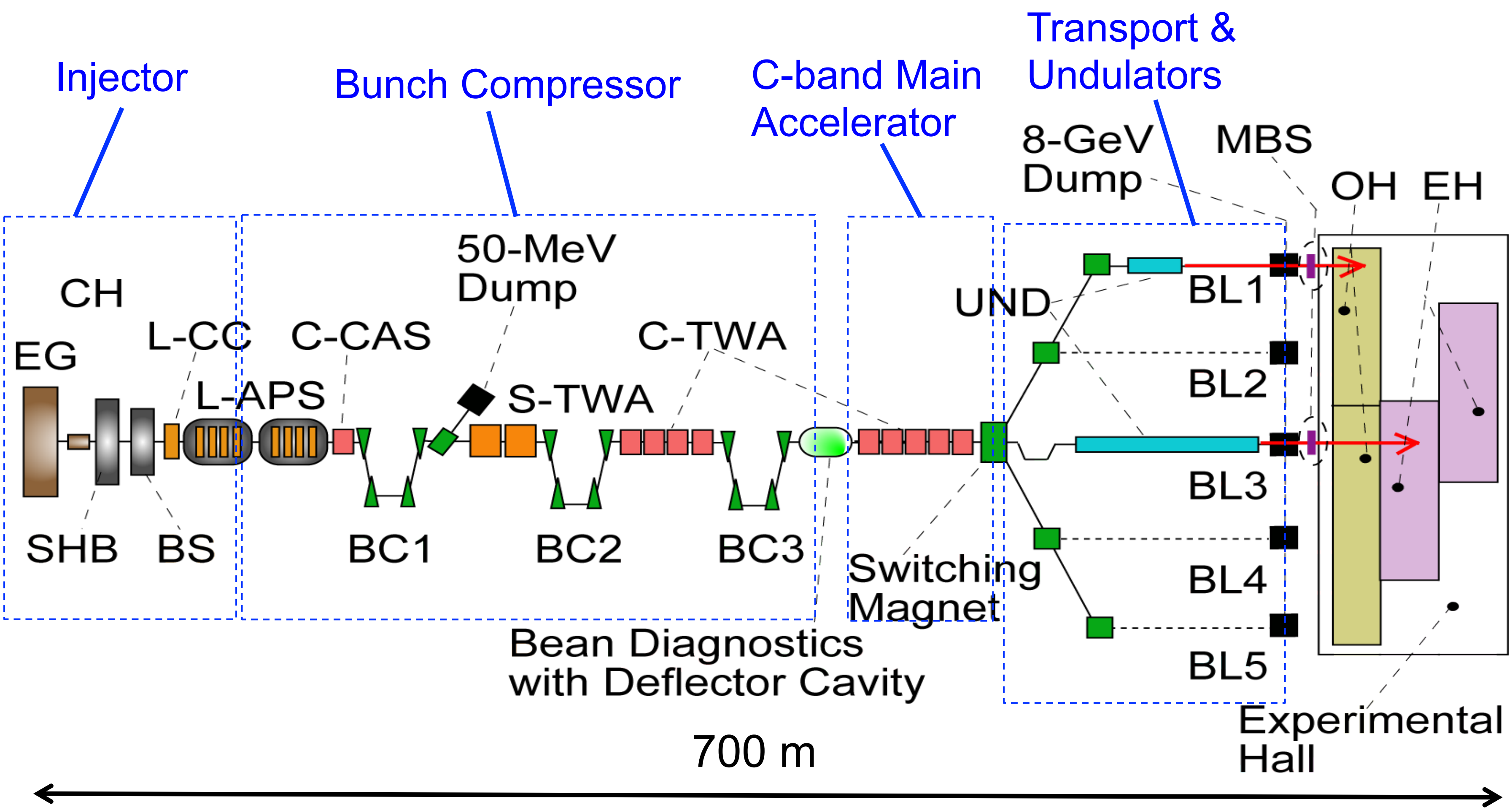


Short period in-vacuum undulator

C-band high gradient acceleration system

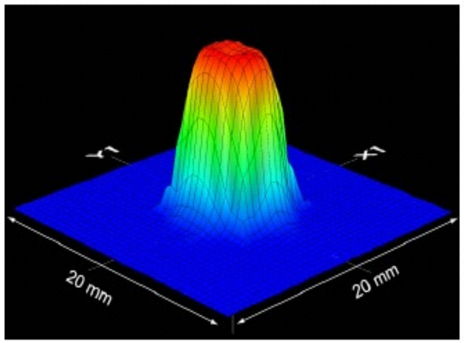
Themionic gun based low emittance injector

Schematic Drawing of SACLA System

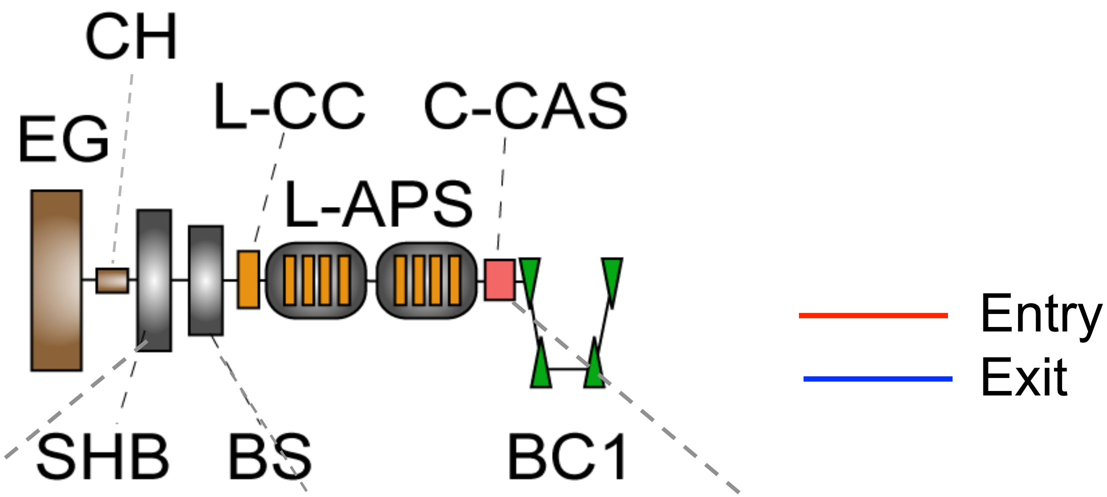


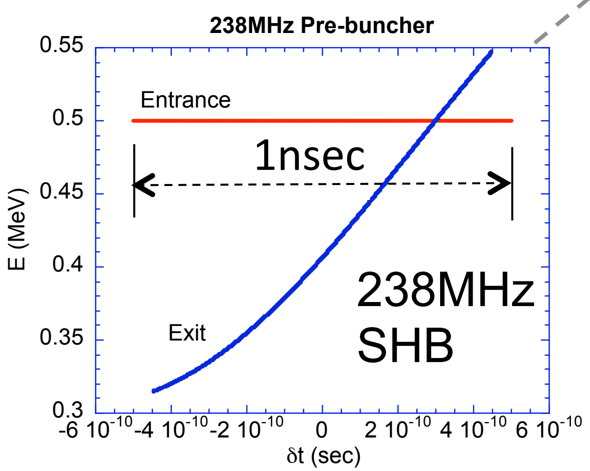
Brilliant Electron Beam Generation

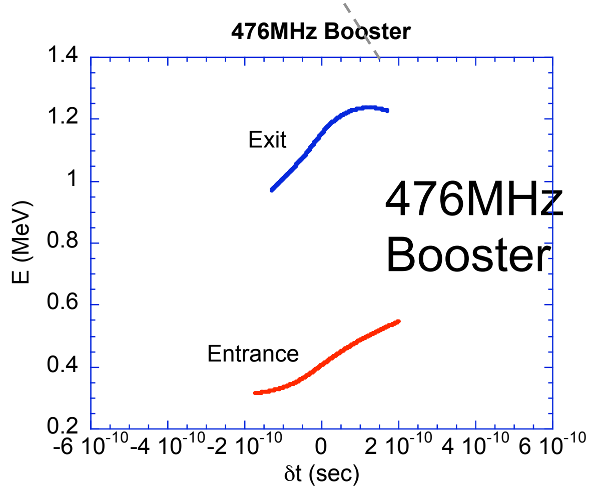
- Pulsed thermionic gun with a single crystal cathode
- Velocity bunching by twin RF potentials

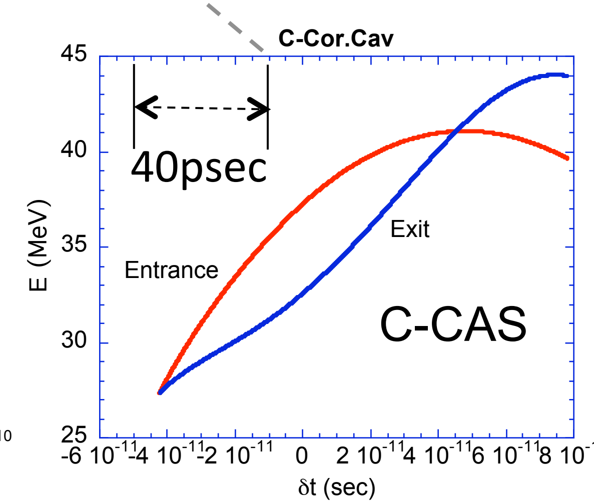


$\varepsilon_n = 0.6\pi\ \mu\text{mrad}$



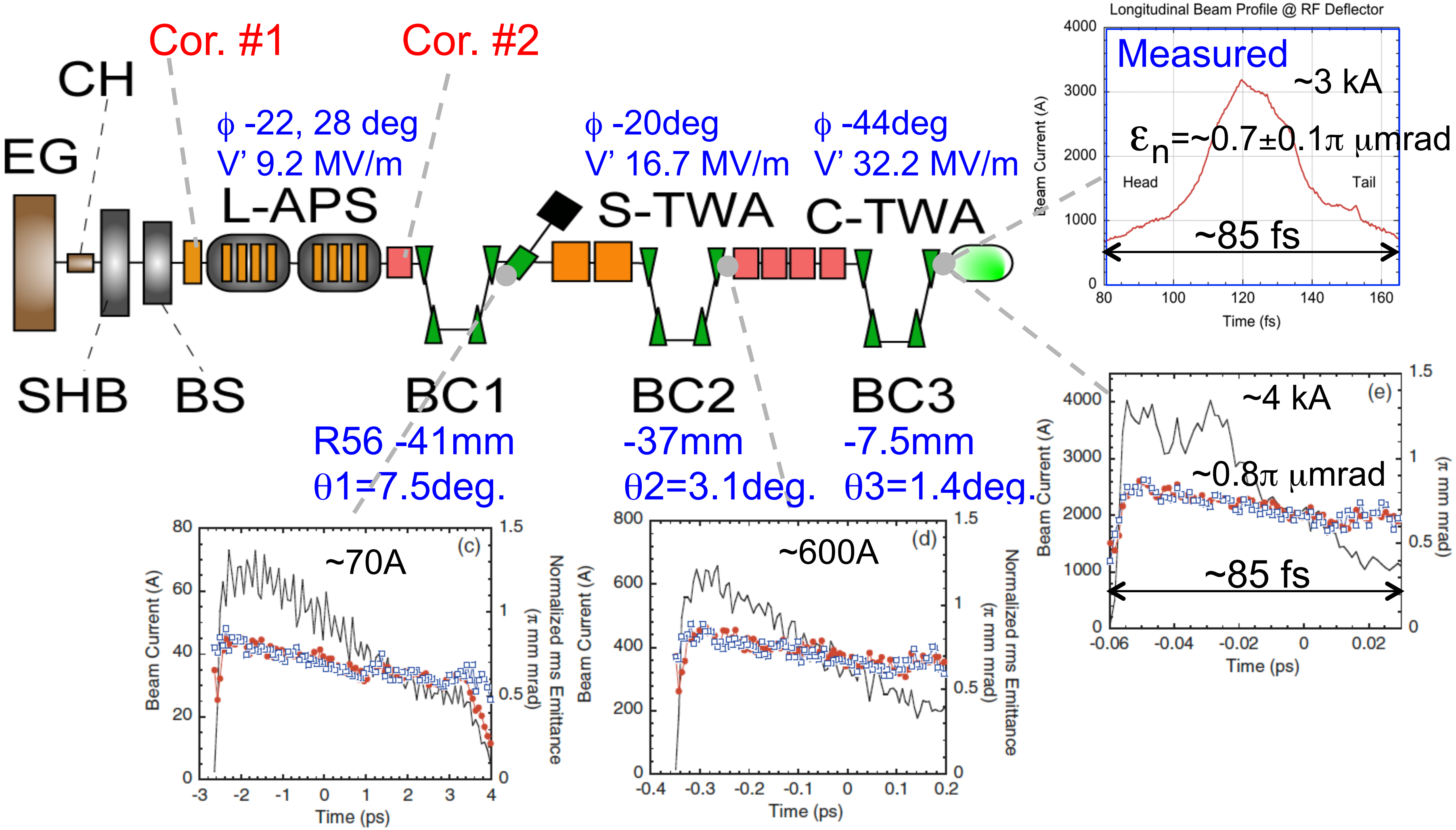






Brilliant Electron Beam Generation

•Three-stage BC system with two nonlinear correctors



Main Parameter & Target Performance

Max. energy	8.5 GeV
Operation mode	Single bunch
Max. repetition	60 Hz
Norm. emitt / Peak curr.	$<1\pi$ μmrad / >3 kA
Wavelength	0.1 nm(0.06)
Pulse duration	30~100 fs
Transverse coherence	Full
Peak power	10 GW level
Peak brilliance	$\sim 10^{33}$

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Progress of XFEL Project

2006~2010 XFEL construction

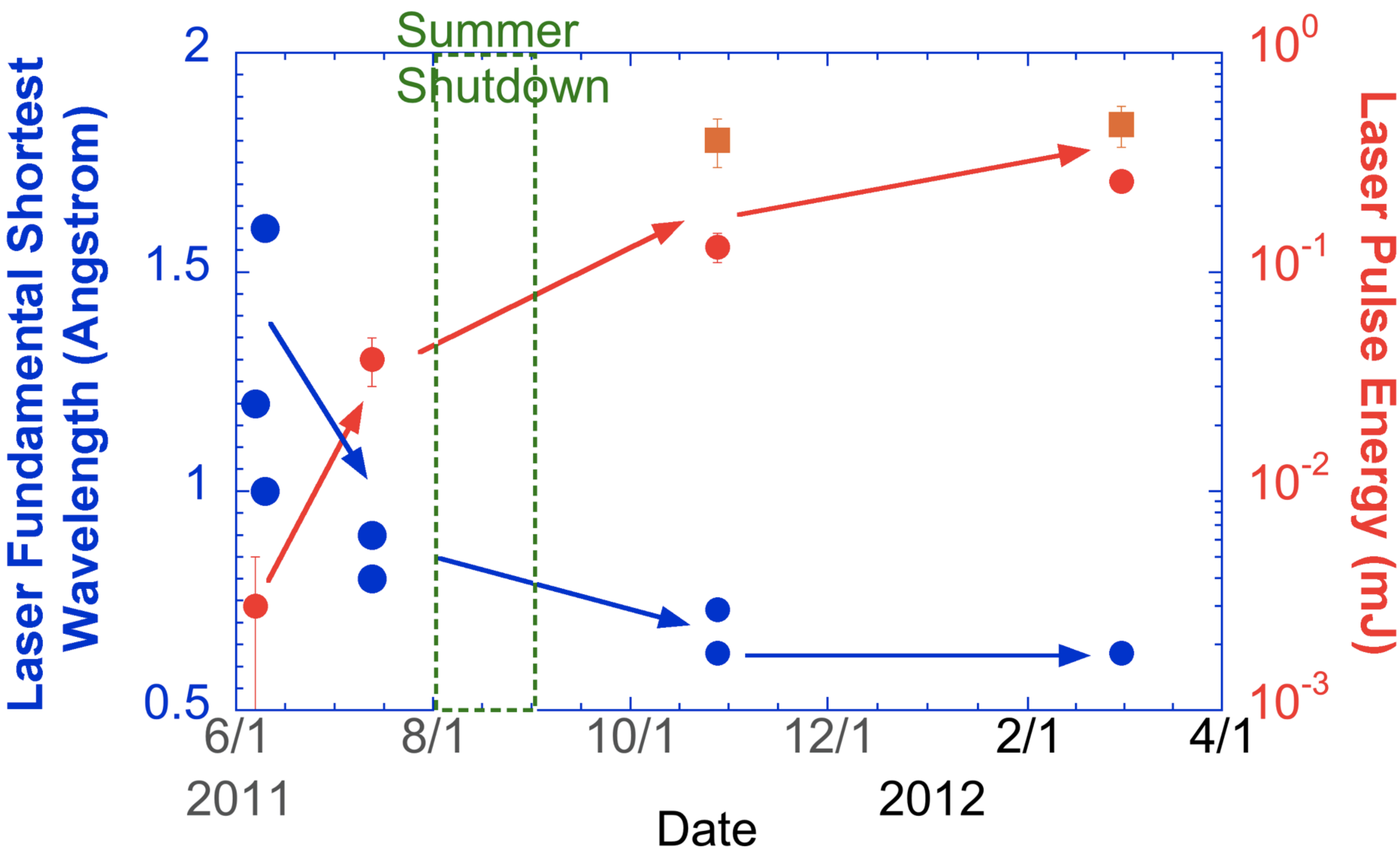
2011

- Feb. 21 Beam commissioning started
- Jun. 7 First lasing at 0.12 nm achieved
- Mid. Oct. SASE power saturation achieved at 0.12 nm

2012

- Mar. 1 User experiments officially started

Evolution of SASE Intensity & Shortest Wavelength



Summary of User Run in March

12-1 2012/3/1 :00:00 – 2012/3/14 10:00
12-2 2012/3/14 10:00 – 2012/3/28 10:00

Operation Time Statistics Unit: hr **Mean fault interval ~30 mn.**

Campaign	Total OP Time	Tuning After Shutdown	BL + Acc. Tuning, R&D, Study and Test	Experiment	Downtime	Availability	User Group
12-1	322:00	96:00	113:23	67:44	5:41	92.3%	Gr1
				44:53	3:11	93.4%	Gr2
12-2	333:20	0:00	218:25	68:11	3:51	94.6%	Gr3
				46:42	2:17	95.3%	Gr4

Operation Condition

Campaign	Beam Energy (GeV)	Repetition (pps)	Wavelength (KeV)	Ave. Intensity (μJ)	Used Beamline	User Group
12-1	7.8	10	12.4	90	BL3 Hard X-ray Beamline	Gr1
	7.8	10	10	200	BL3 Hard X-ray Beamline	Gr1
	7.8	10	10	180	BL3 Hard X-ray Beamline	Gr2
12-2	6.5	10	7	250	BL3 Hard X-ray Beamline	Gr3
	5.2	10	4.5	140	BL3 Hard X-ray Beamline	Gr4

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Disease Symptoms

Small number of electrons meeting the required emittance and peak current

SASE intensity was limited at around 40 μJ/pulse before summer shutdown in 2011 and never increased by tuning efforts using laser intensity as a probe

- Optimize bunching and envelop conditions
  → Reliable emittance measurement
- Optimize beam orbit through undulator beamline
  → Orbit correction procedure & precise UND. gap corr. table

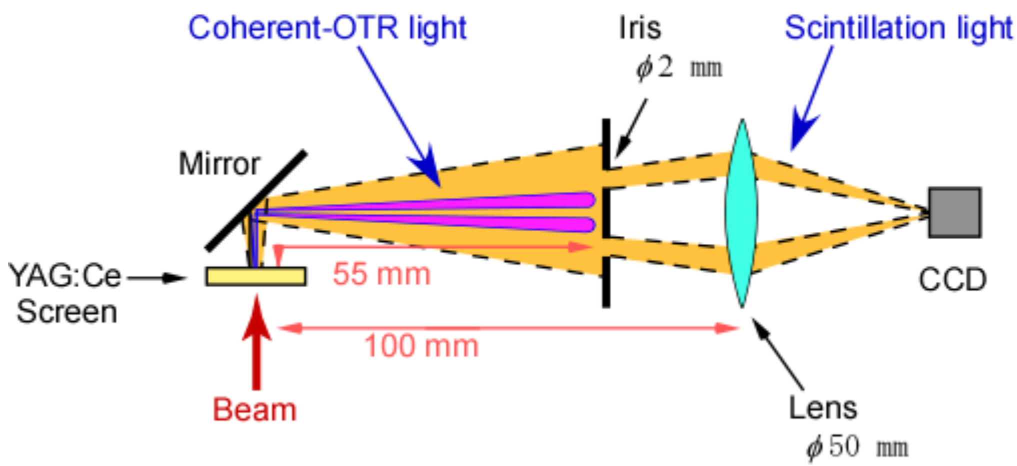
Reliable Projected Emittance Measurement

Widely scattered emittance values showing a clear correlation with the measured condition, minimum spot size

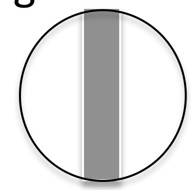
↓

- Insufficient suppression of COTR contamination on CCD
- Un-accurate CCD camera focus

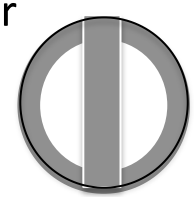
Reliable Projected Emittance Measurement

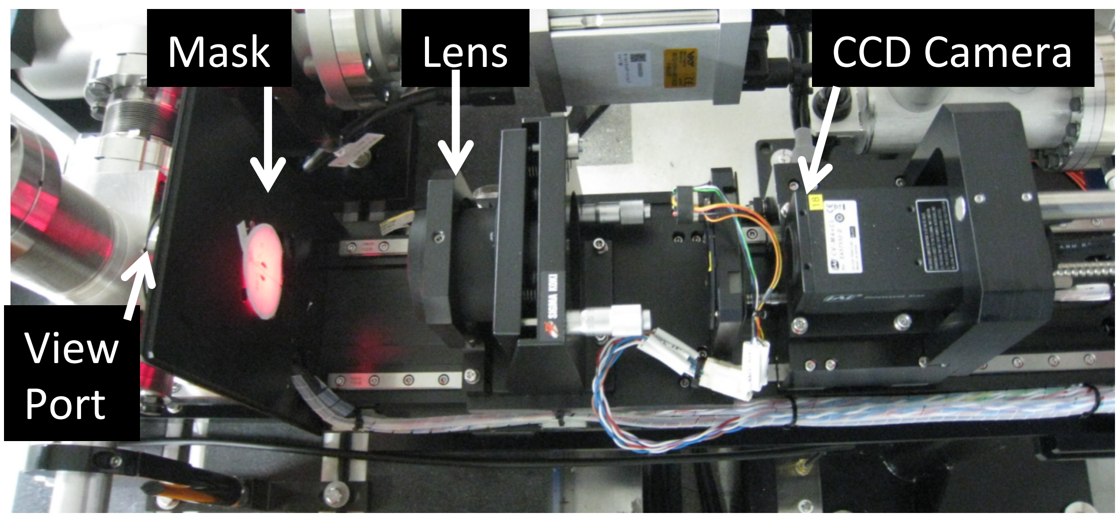


Rectangular Mask

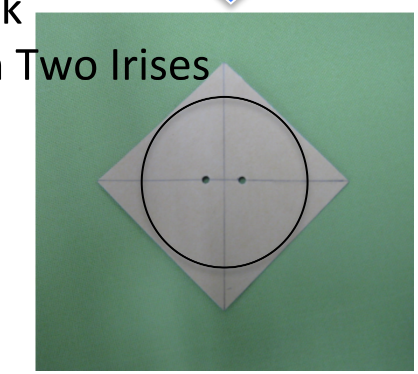


Rectangular Mask + Aperture

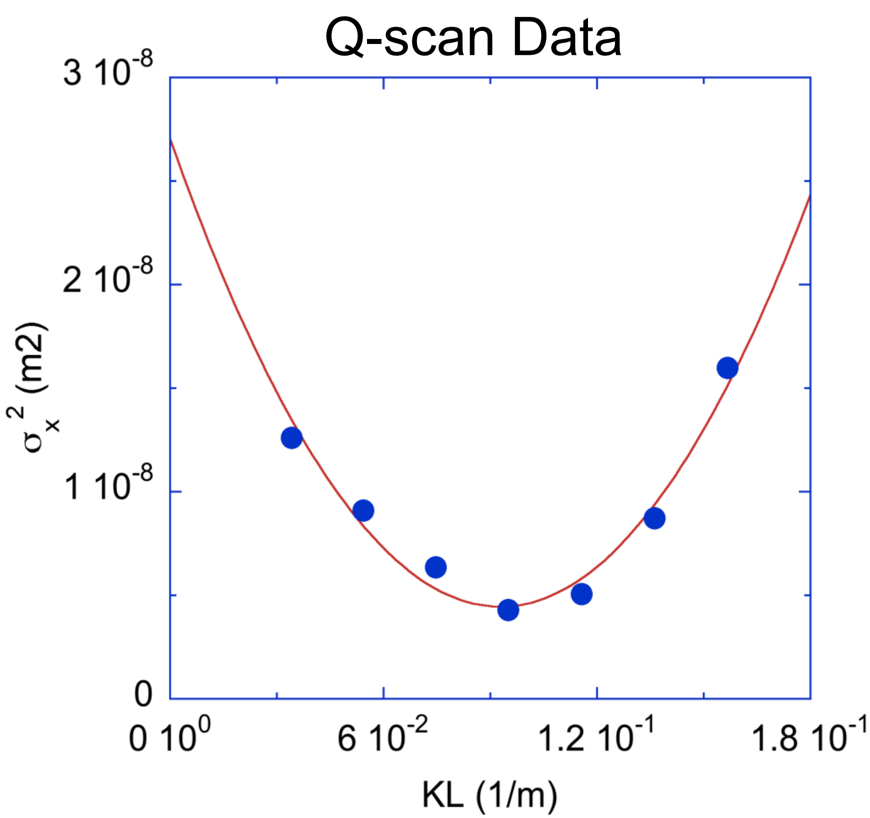


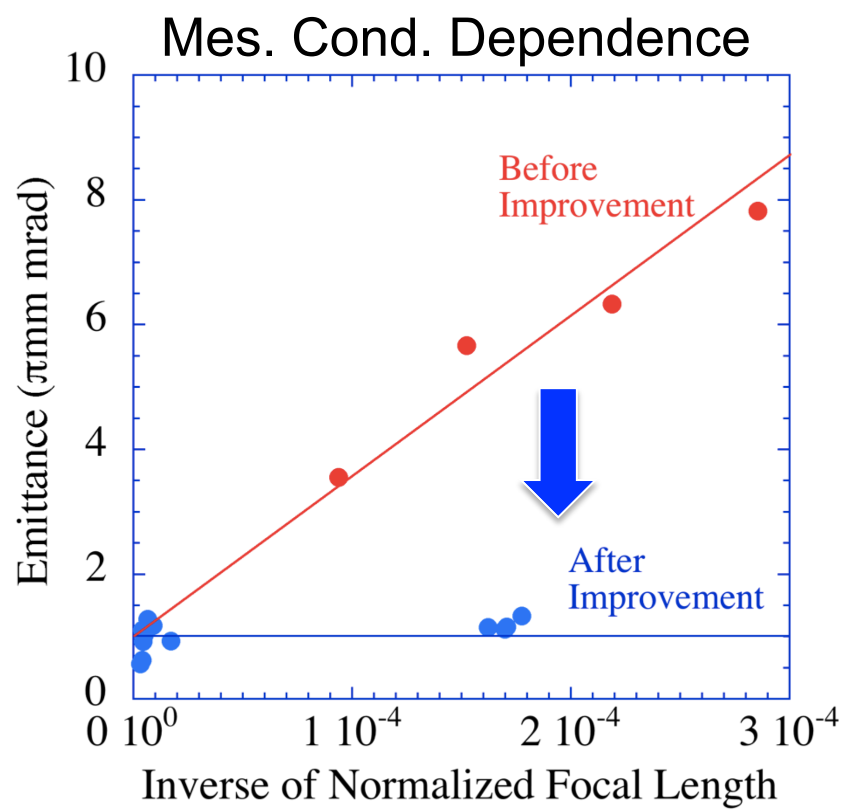


Mask with Two Irises

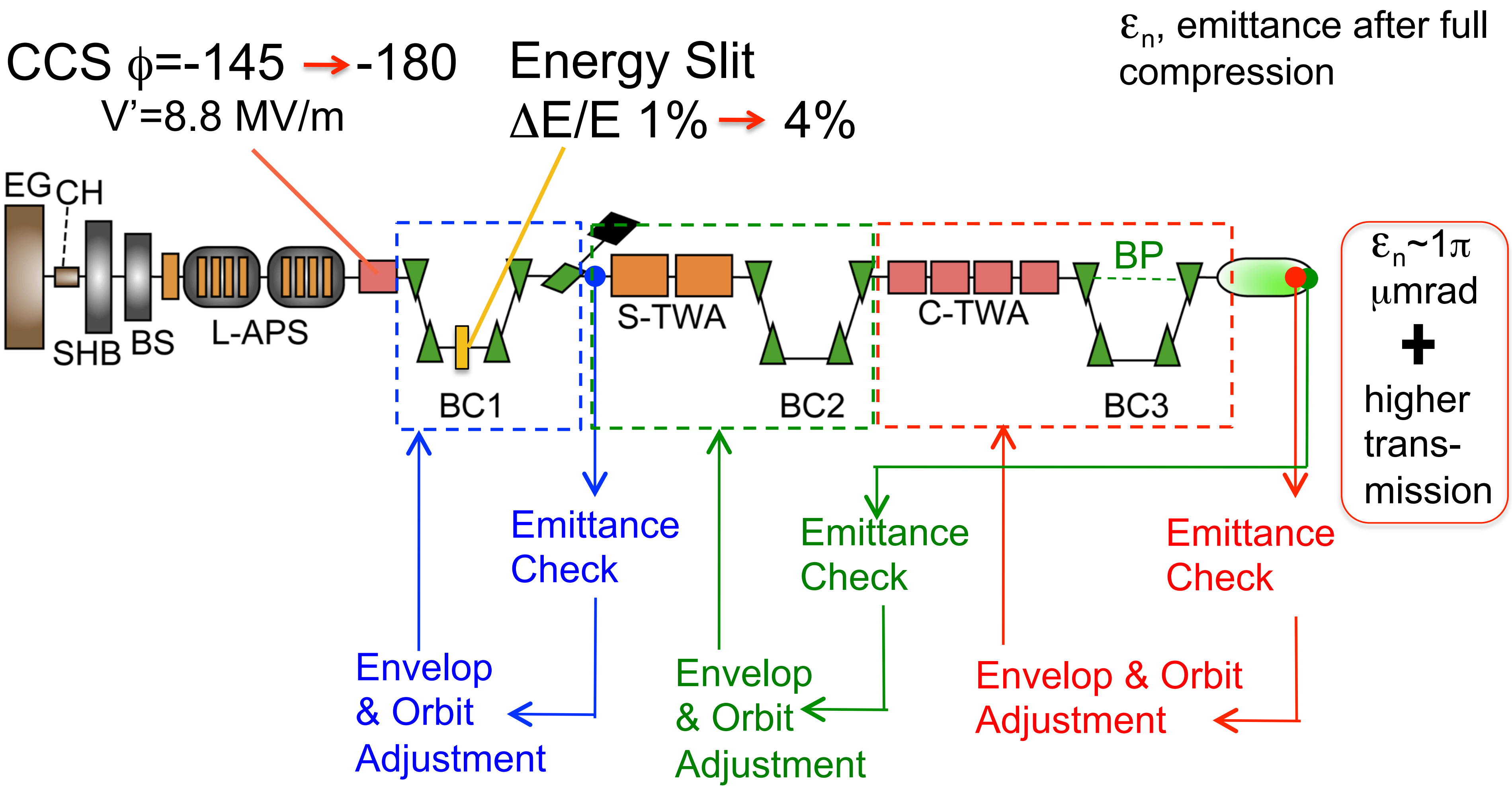


Reliable Projected Emittance Measurement





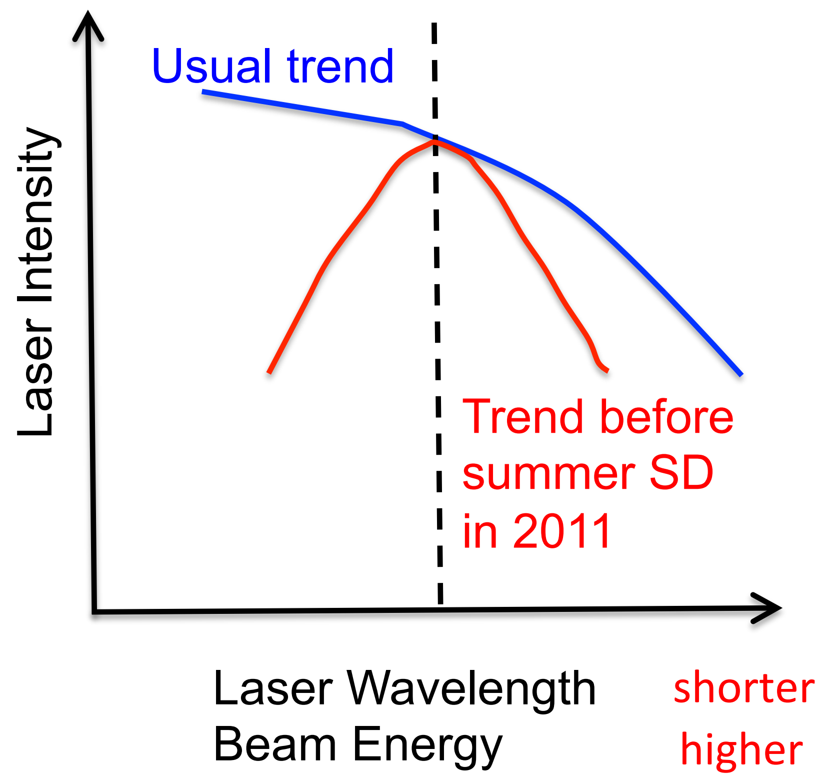
Enlargement of Linearly Compressive Part



Empirical Treatment on Orbit Through Undulator BL

Initially we took conventional correction based on BPM readout in changing K-value and beam energy

Presently we don't correct orbit deviation by BPMs in changing beam energy



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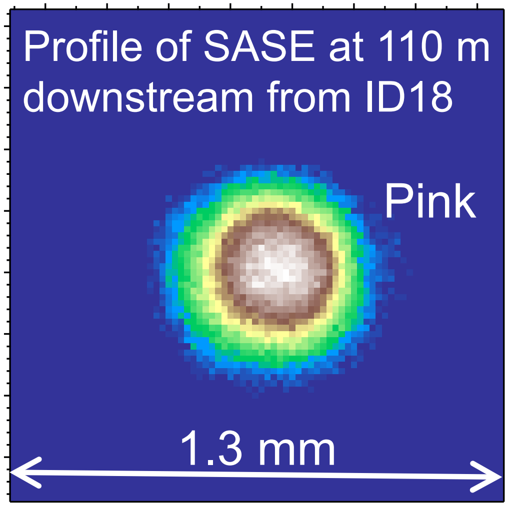
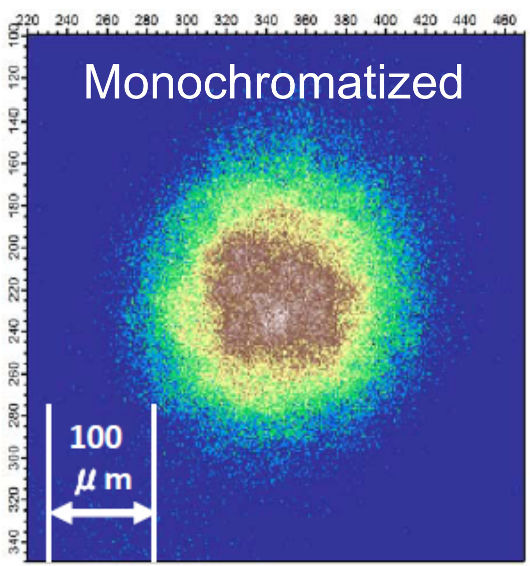
Summary of Present Performance

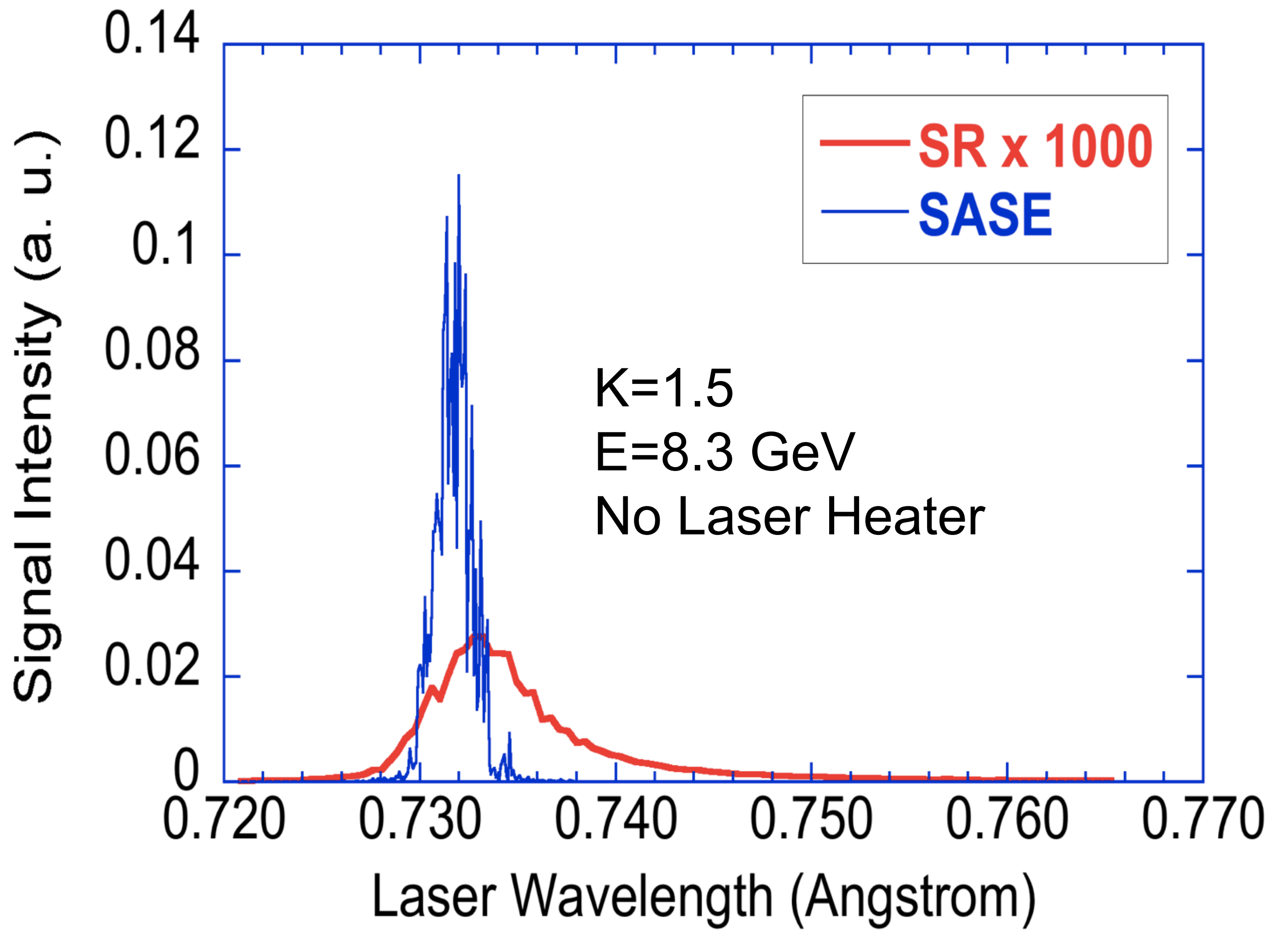
Pulse Energy*	Sub-m J, ~0.25mJ@10keV
Peak Power*	>10 GW (e-beam, 20~30 fs in FWHM)
Intensity Fluctuation*	10~20% (σ)
Lasing Wavelength:	0.63 - 2.8 Å
Spatial Coherence:	nearly full
Repetition:	10 Hz（Max.60 Hz）
Mean Fault Interval:	30~40 min
Recovery time:	1 min.
Operation mode:	24 hr continuous
Reproducibility:	70~80% of the peak

*It depends on the condition

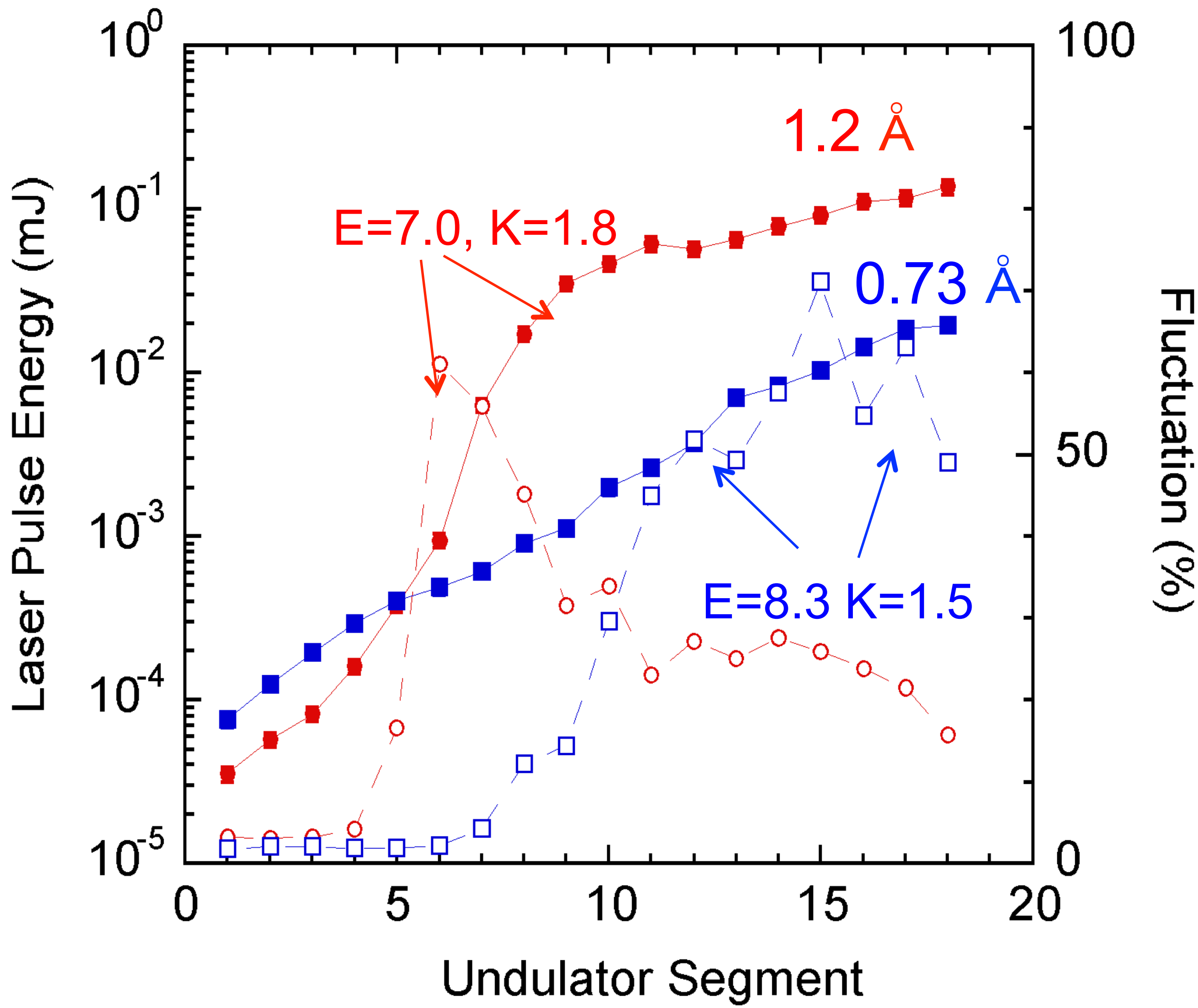
Spectrum & Profiles of SASE FEL



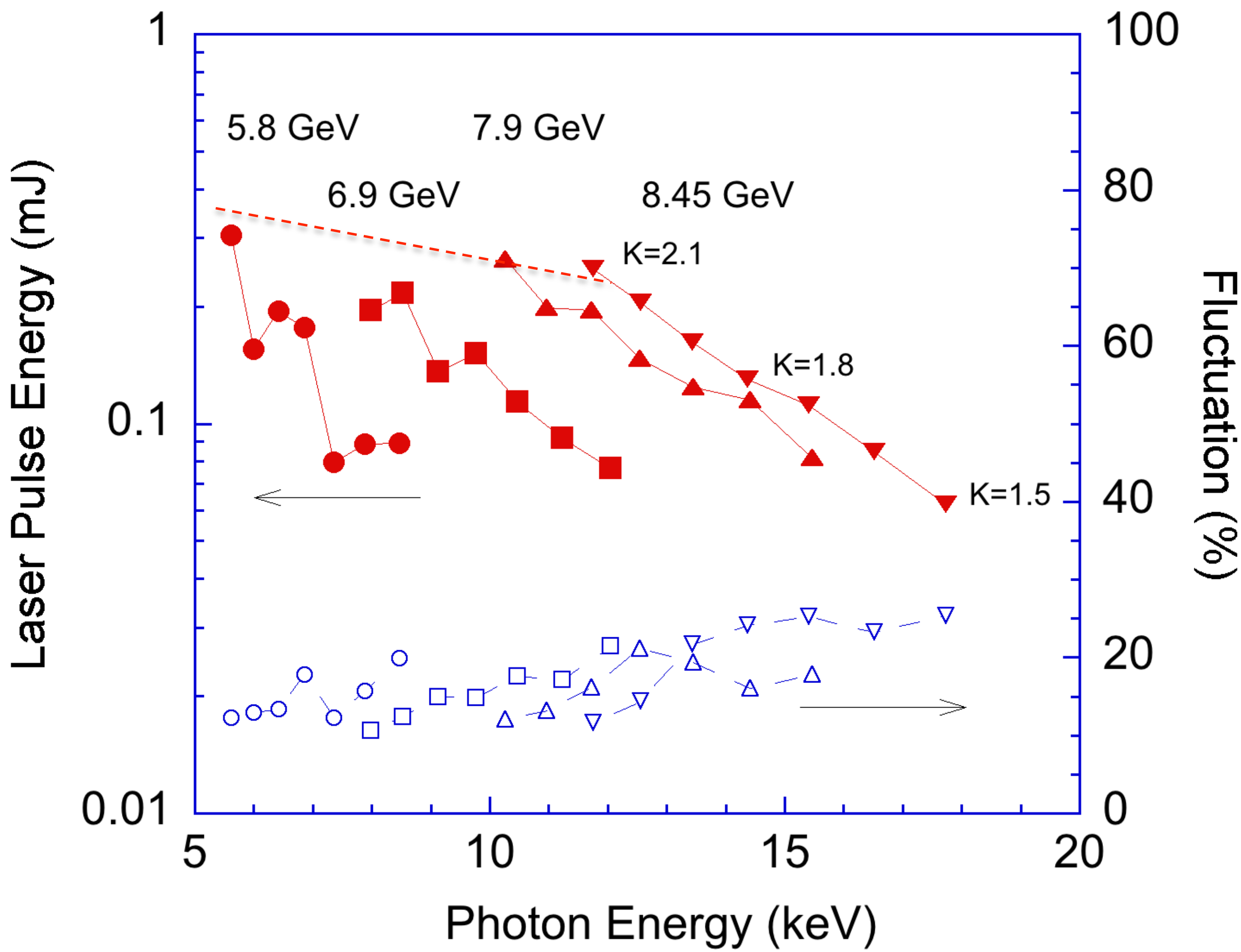




Gain Curve

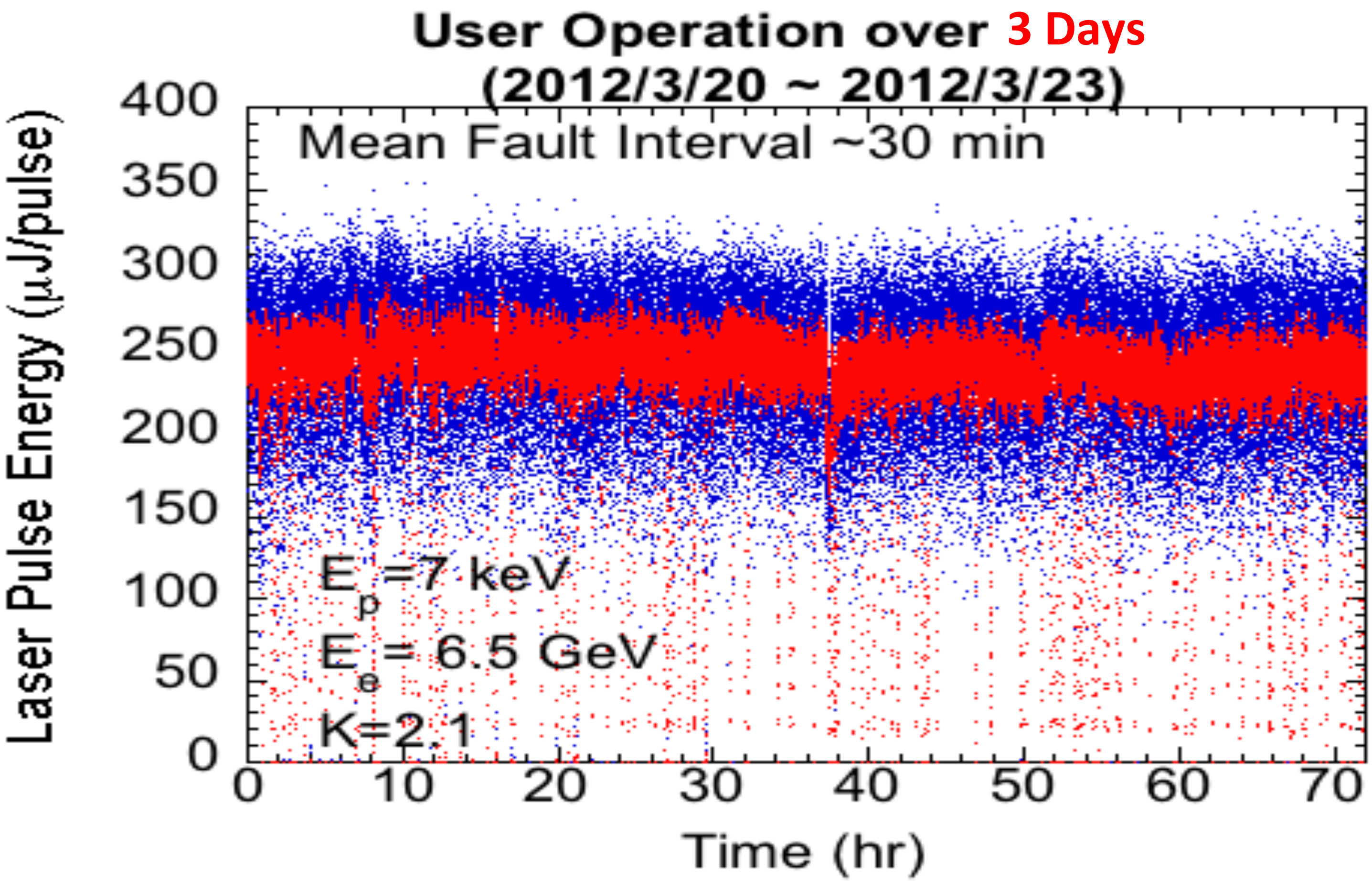

1.2 Å
E=7.0, K=1.8
0.73 Å
E=8.3 K=1.5
Laser Pulse Energy (mJ)
Fluctuation (%)
Undulator Segment
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
100
50
0
0
5
10
15
20

Laser Intensity vs Wavelength



Laser Stability

Laser availability in user experimental run was 92~95% from March to April



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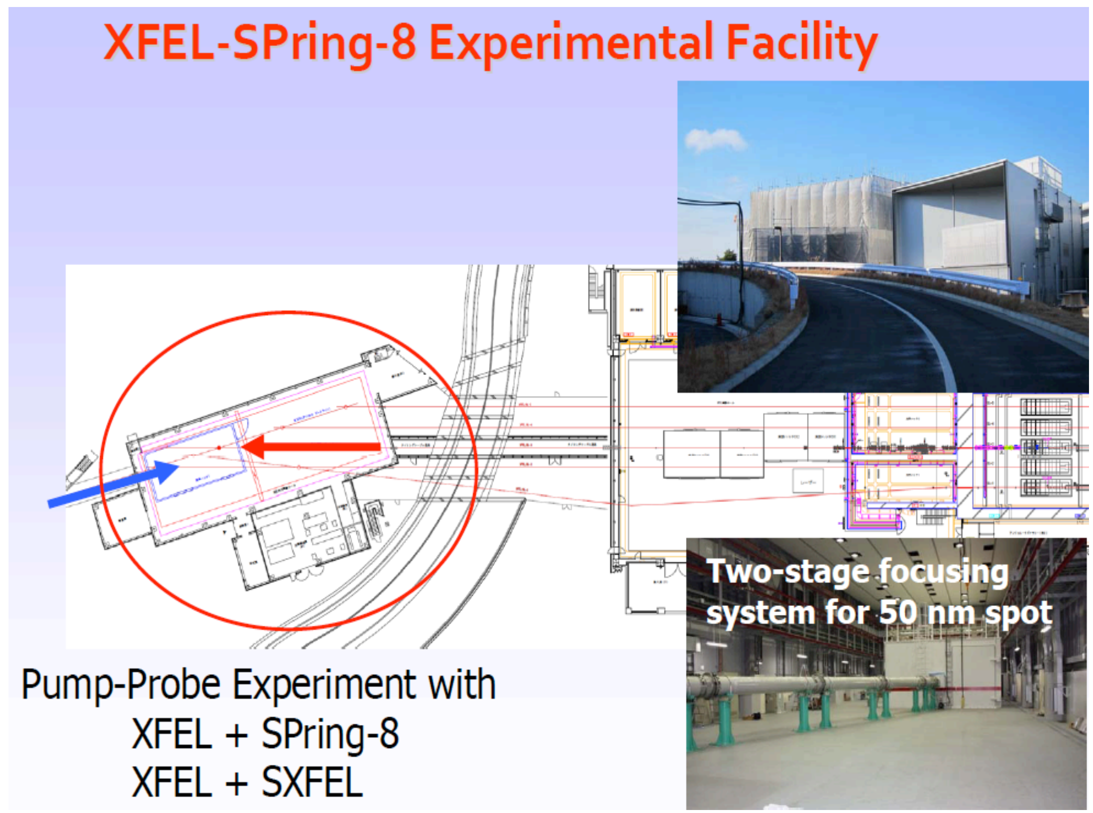
- Synergetic use of both XFEL and SPring-8
- Installing the prototype in SACLA undulator hall and upgrading
- Fast switching of plural BLs
- Seeding of XFEL




Thank you
for your attention!