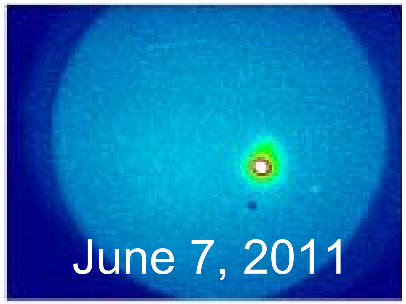
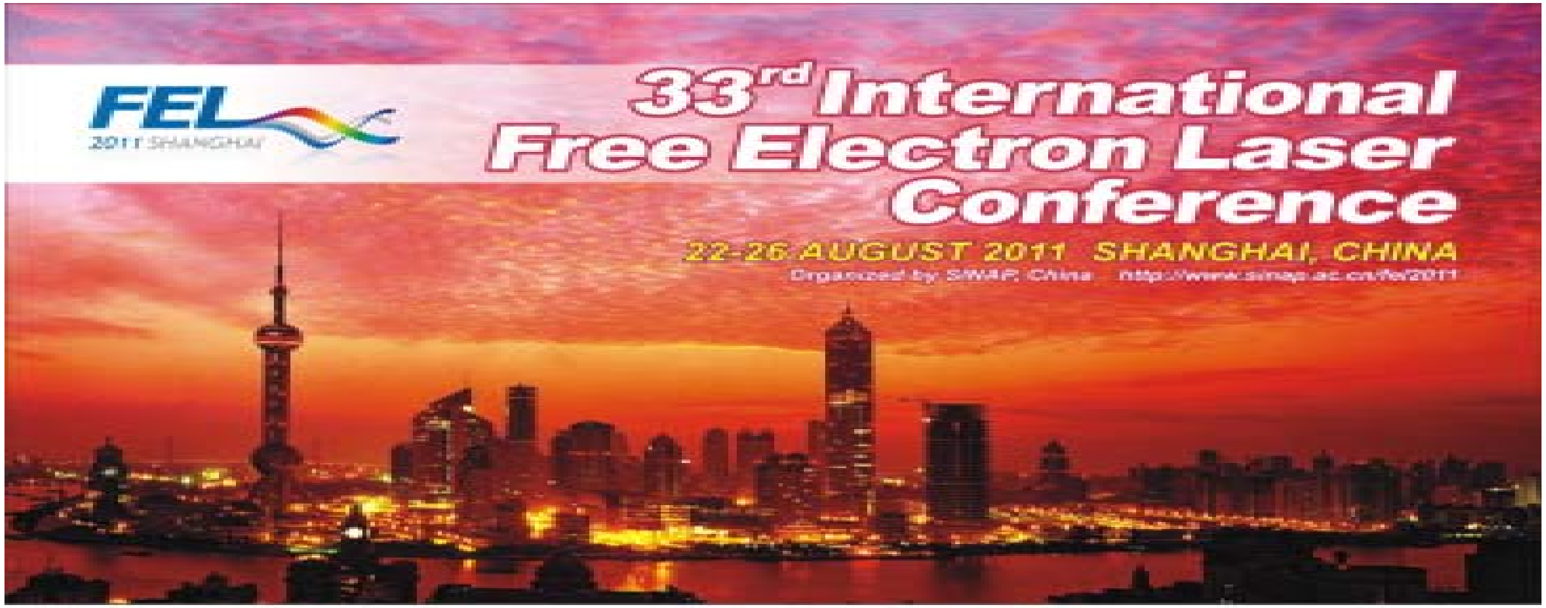
SACLA (XFEL/SPring-8) Project
- Status of Beam Commissioning -



Hitoshi Tanaka, on behalf of all the staffs contributing to the SACLA beam commissioning

XFEL Research & Development Division,
RIKEN SPring-8 Center, RIKEN Harima Institute



SACLA

SPring-8

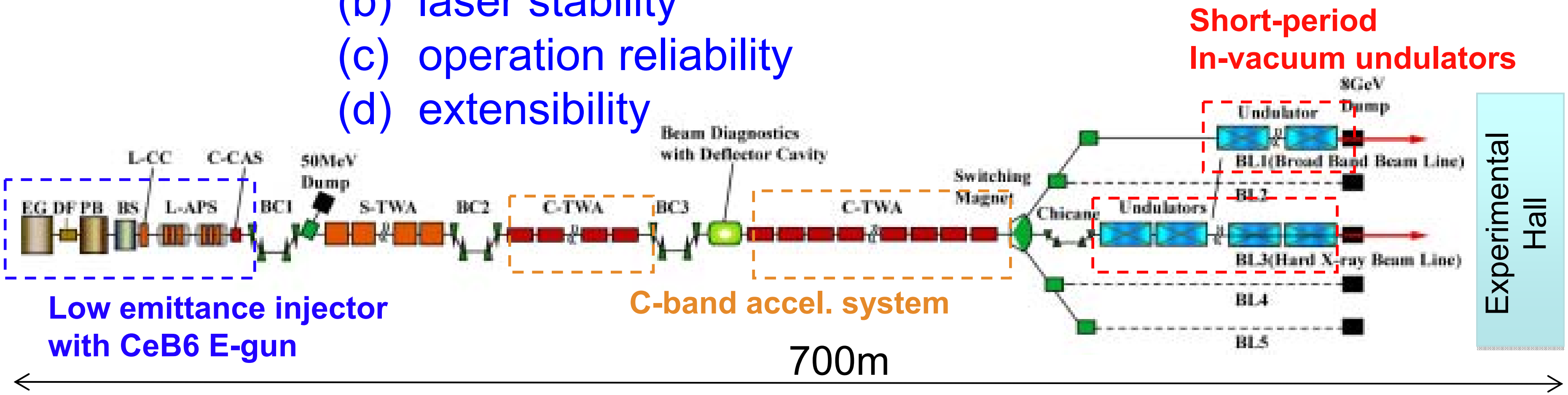
RIKEN

JASRI

1. SACLA System

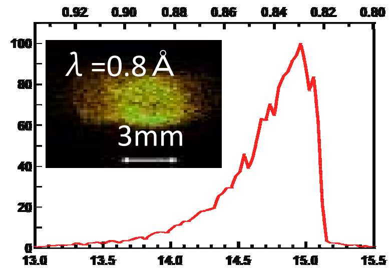
The world's first compact XFEL based on in-vacuum UNDs designed to realize;

(a) small scale
(b) laser stability
(c) operation reliability
(d) extensibility



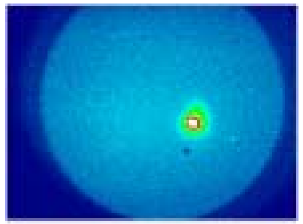
2. Construction & Commissioning Status of SACLA

- 2005 Prototype system constructed
- 2006 Construction of SACLA started
- 2007 EUV SASE power saturation at the proto-type
- 2009 Accelerator & undulator buildings completed
- 2010 RF aging started



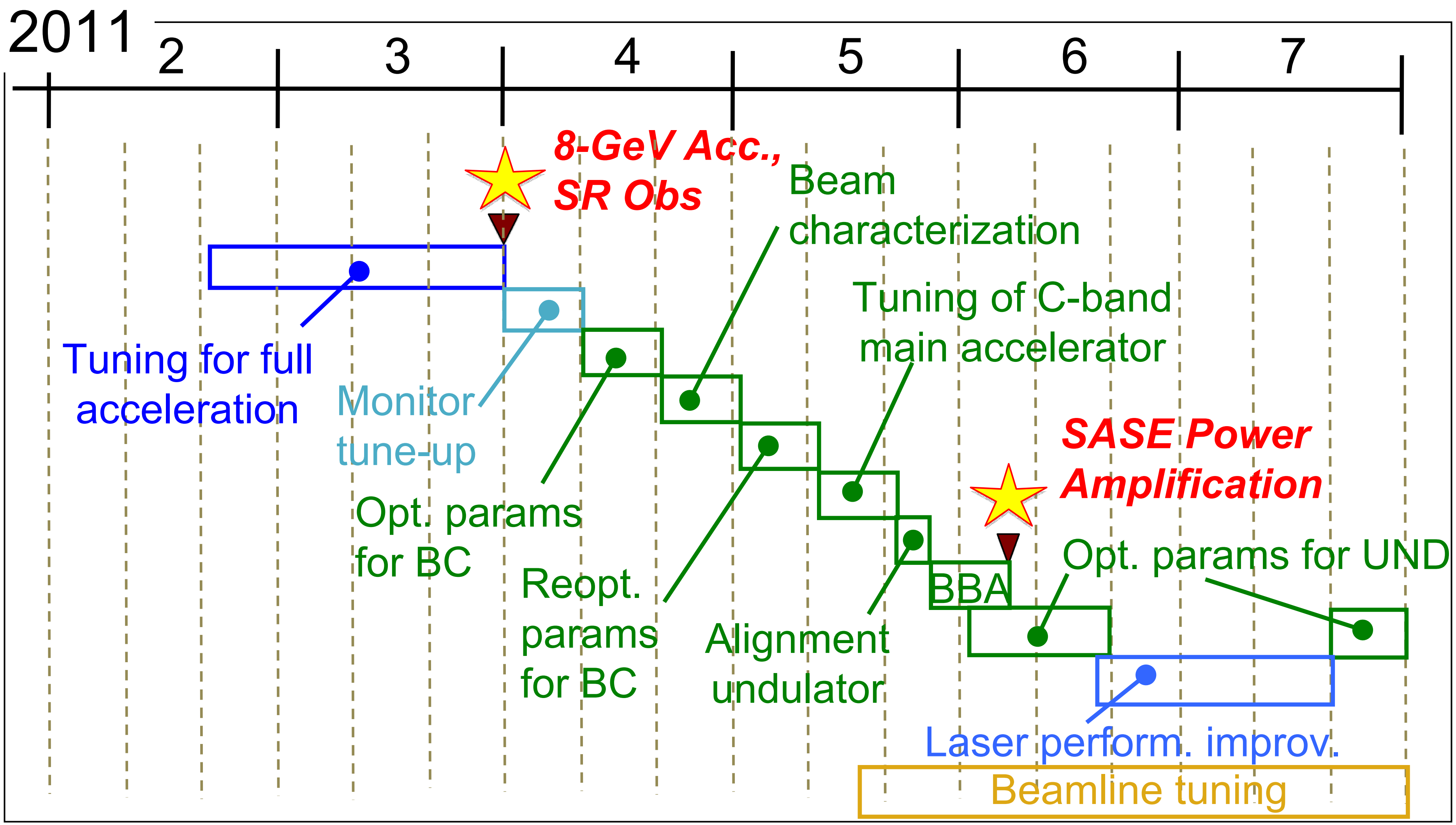
2011

- 21 Feb. Beam commissioning started
- 23 Mar. Full energy accel. achieved & und rad observed
- 7 Jun. First SASE lasing at 0.12 nm
- 17 Jun. Facility inspection completed



- 28 Jul. Beam tuning before summer shutdown terminated

2. Commissioning Schedule until Summer



3. Present Laser Performance (1)

Present Result Summary w/o Laser Heater

Quick beam commissioning (~3 months to the lasing) with a newly constructed machine

Maximum laser power

~4 GW

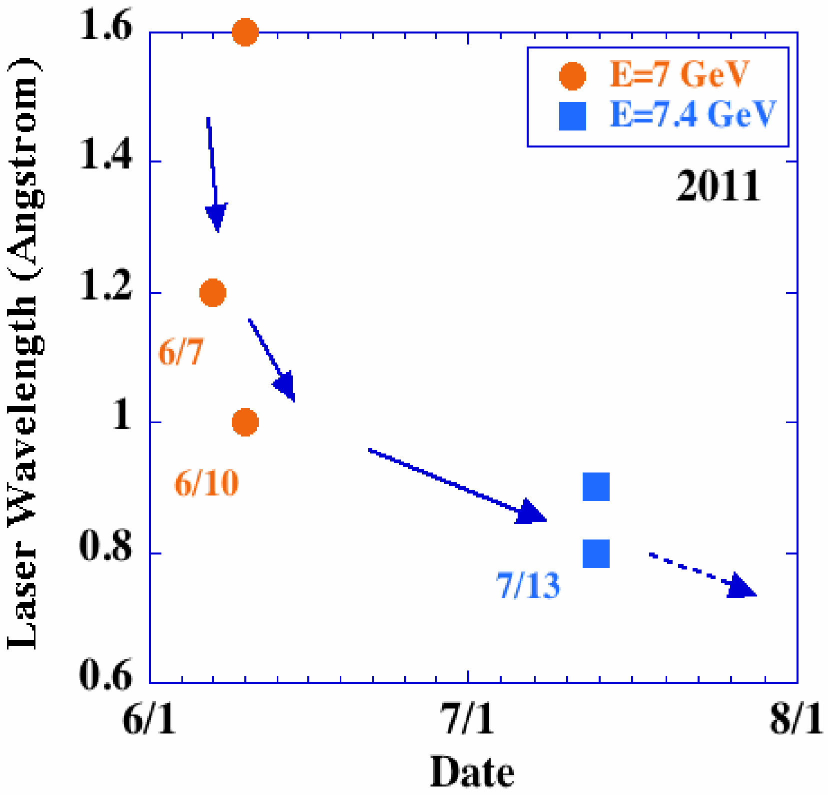
Lasing wavelength range

0.8 ~ 1.6 Å

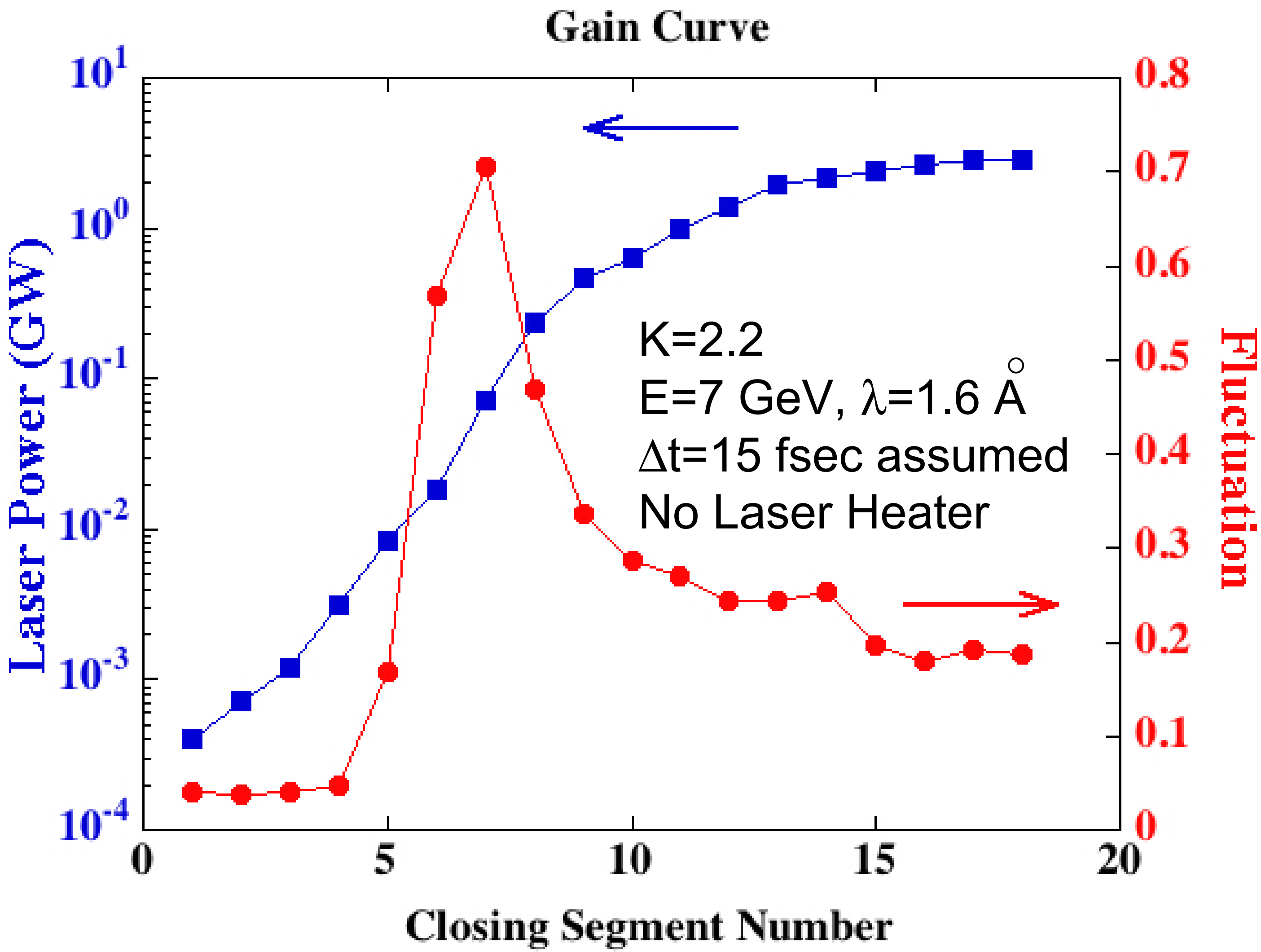
Laser being reproducible

- w/o beam FB keeping the peak current
- at 60~70% of peak intensity

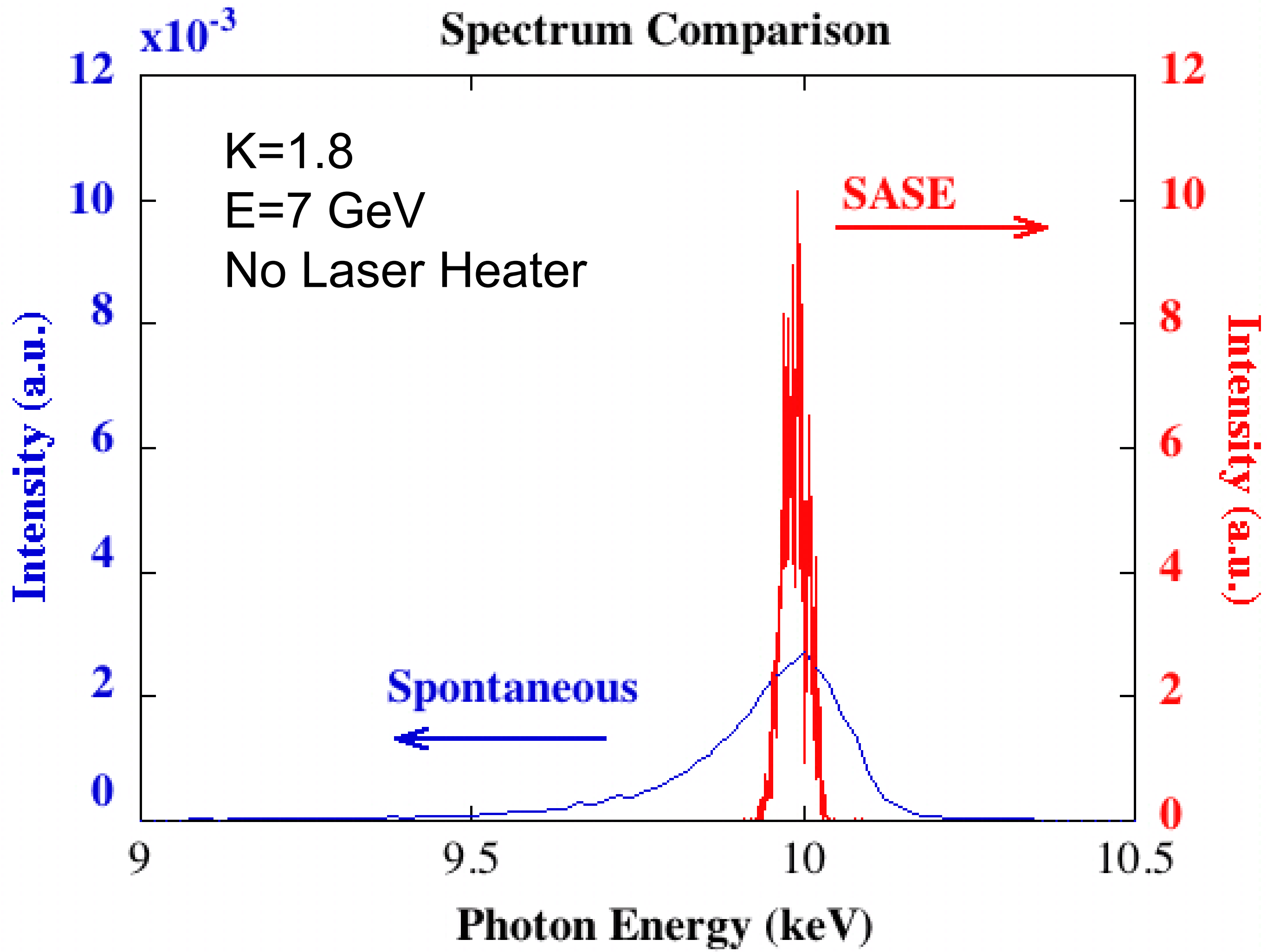
Shortening of Laser Wavelengths



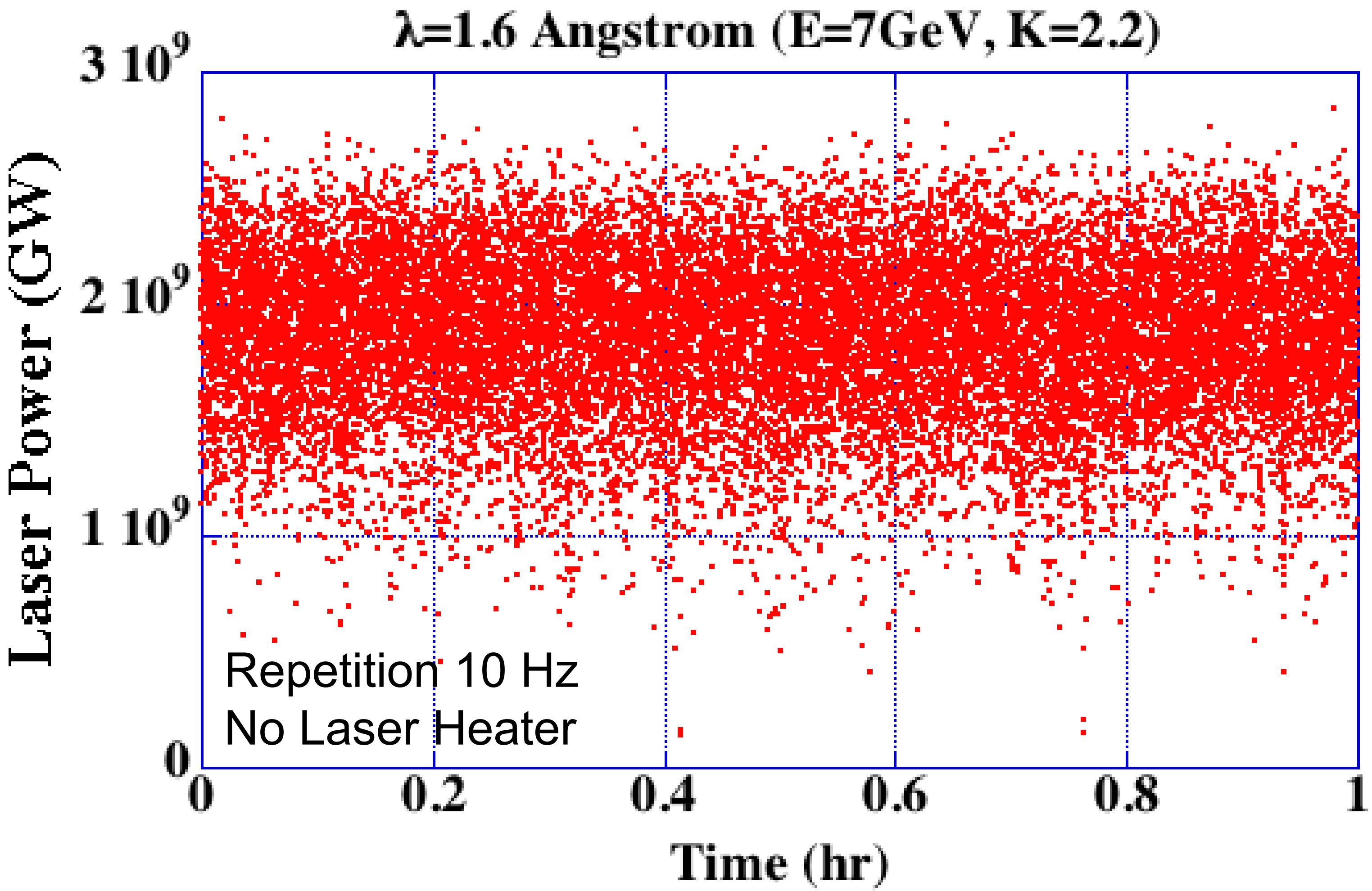
3. Present Laser Performance (2)



3. Present Laser Performance (3)

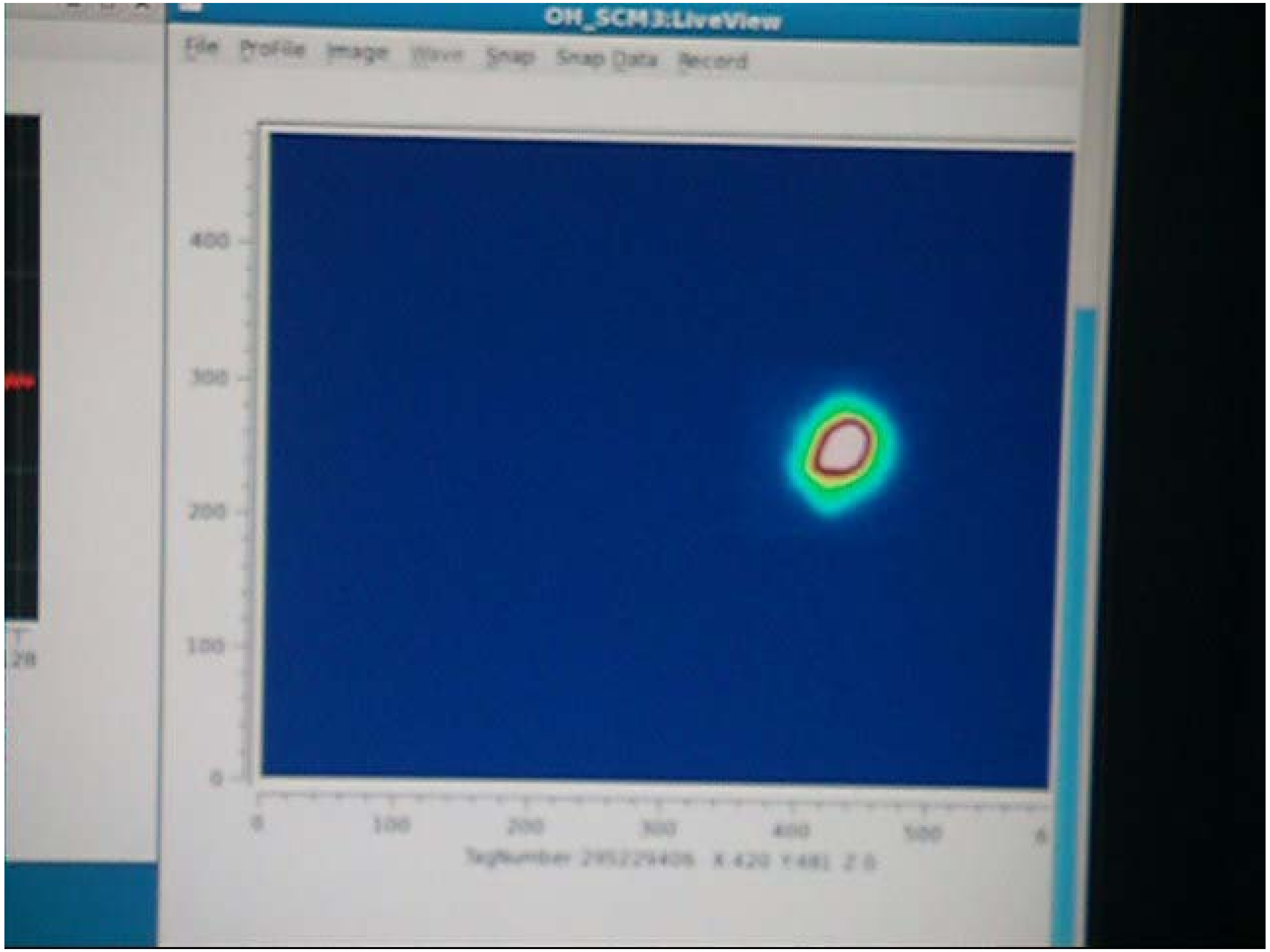


3. Present Laser Performance (4)



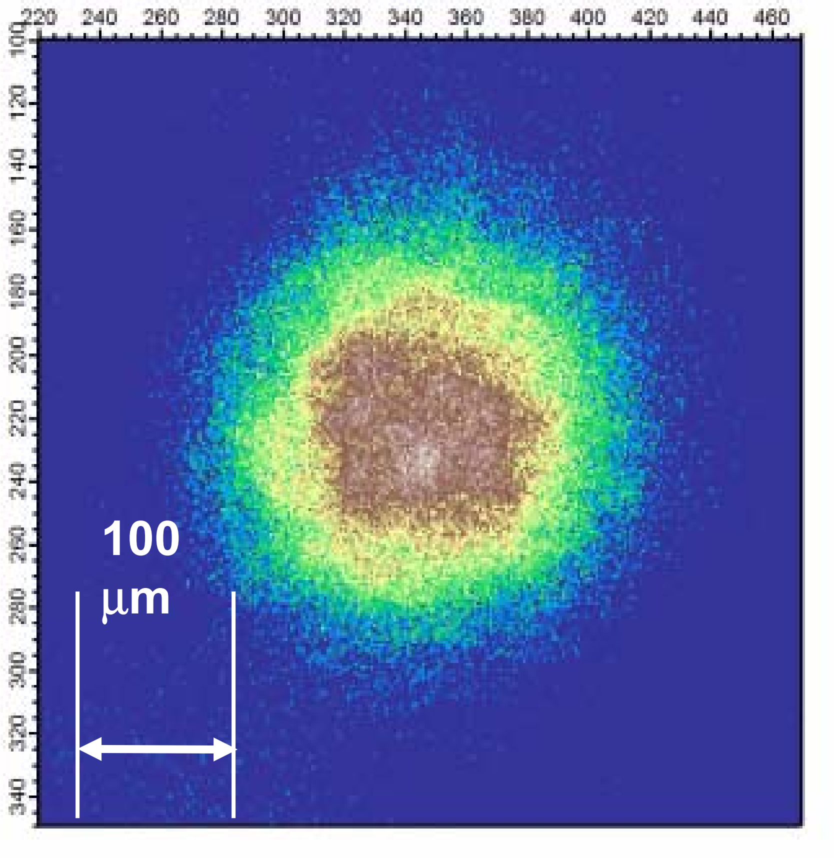
3. Present Laser Performance (5)

Variation of Laser Profile λ=1.2 Å

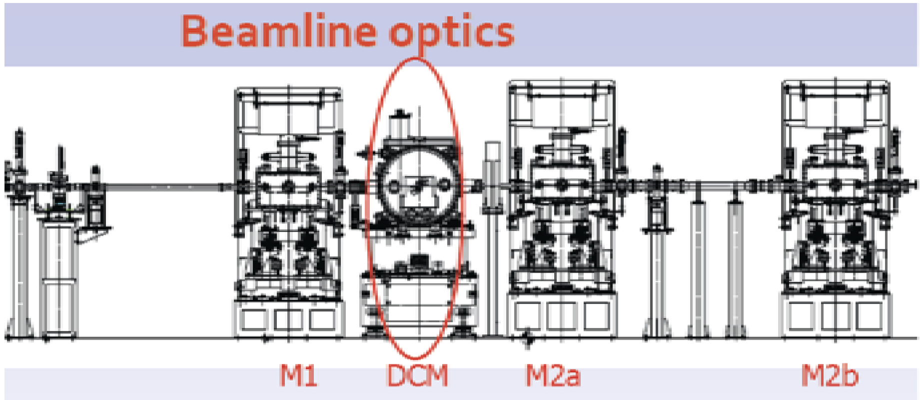


3. Present Laser Performance (6)

Laser Spatial Profile after Monochromatization



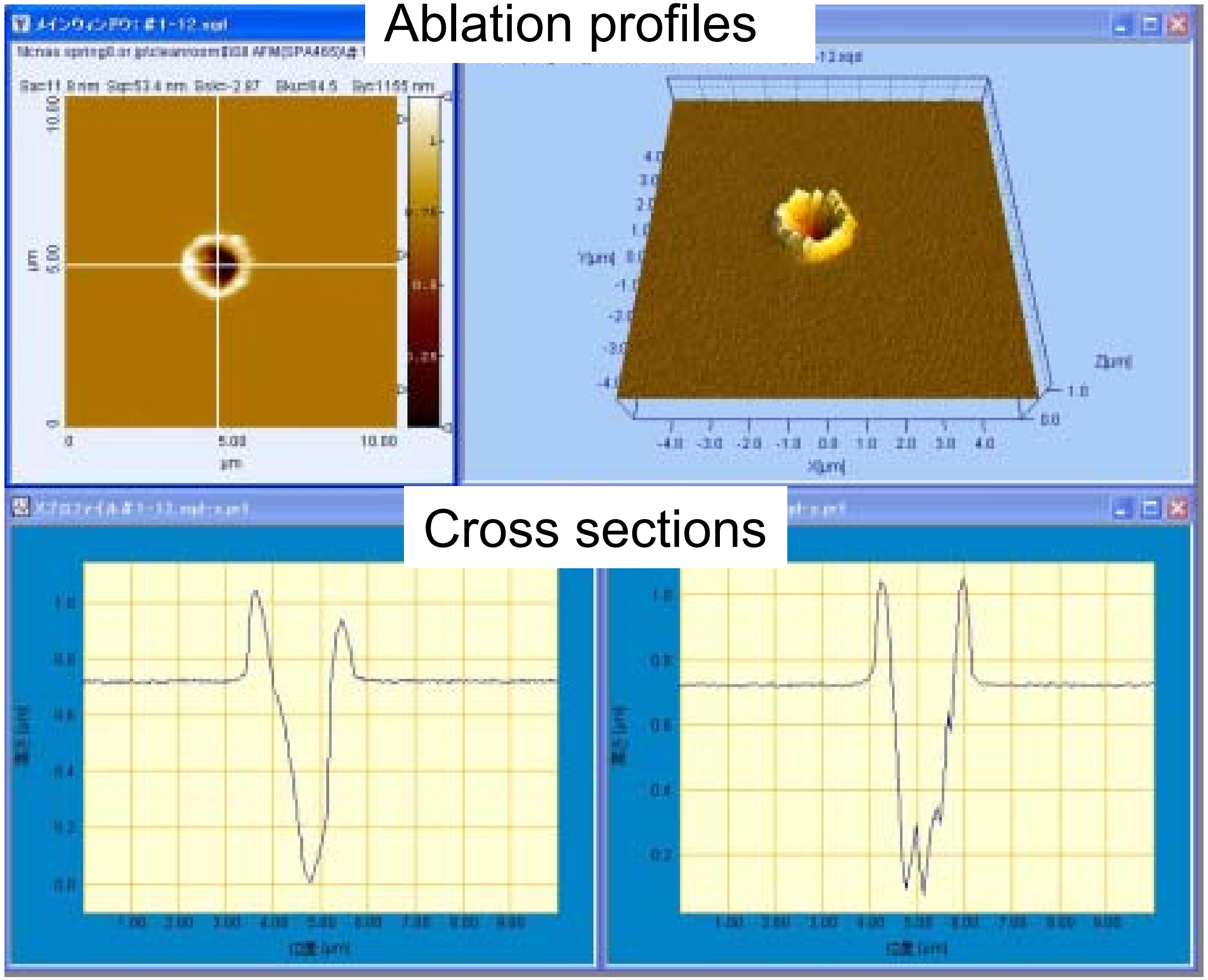
Photon energy: 10 keV
110 m from the exit of ID18



Si(111) DCM covering photon energy range from 4 to 30 keV

3. Present Laser Performance (7)

Focused down to 1.1 μm x 0.9 μm (FWHM)



Ablation pattern by focused XFEL on gold-deposited film

Collaboration with Osaka Univ. (Prof. Yamauchi) and Univ. Tokyo (Prof. Mimura)

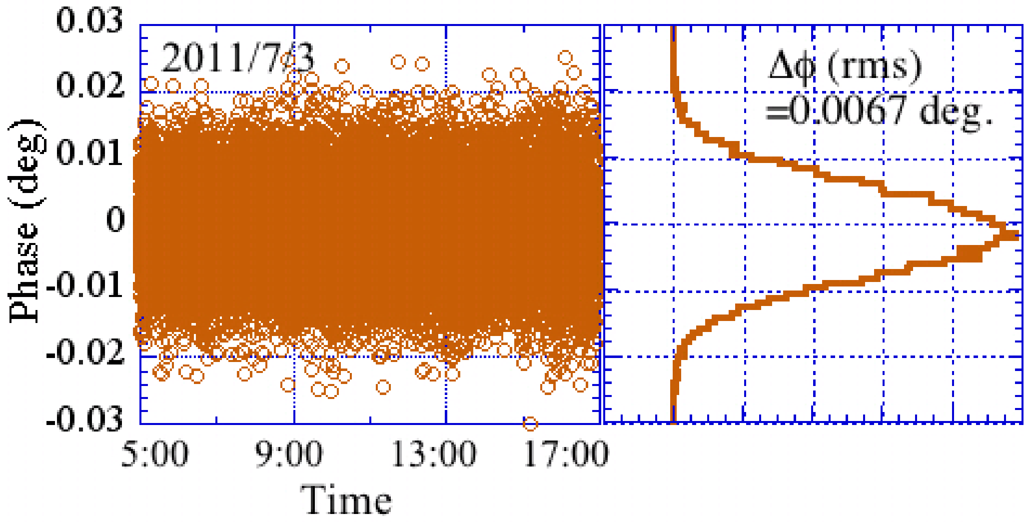
4. Accelerator Performance (1)

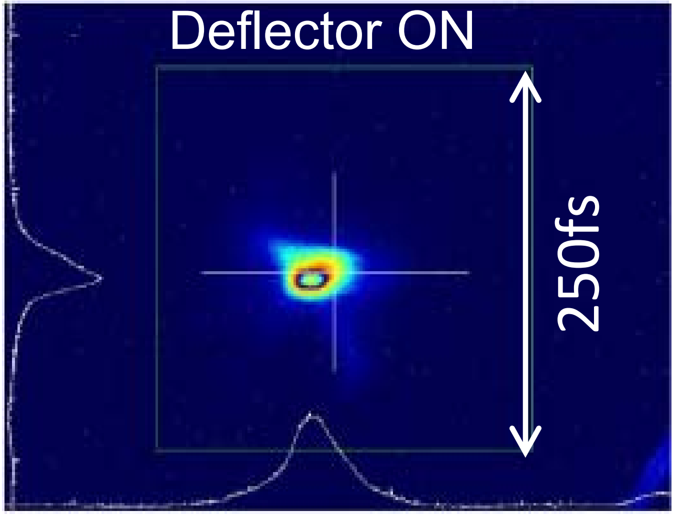
RF Stability High enough for Achieving Stable Bunch Compression

Stability of cavity pickup signals (rms of 10 shots ave. for 12hr)

unit		amplitude		phase (deg.)	
		mes.	target	mes.	target
238MHz	SHB	1.0×10^{-4}	1×10^{-4}	0.0067 78 fs	0.01 120 fs
5712MHz	CB01-1	5.6×10^{-4}	1×10^{-3} *	0.032 16 fs	0.1 * 49 fs

* tolerance for C-band correction accelerator

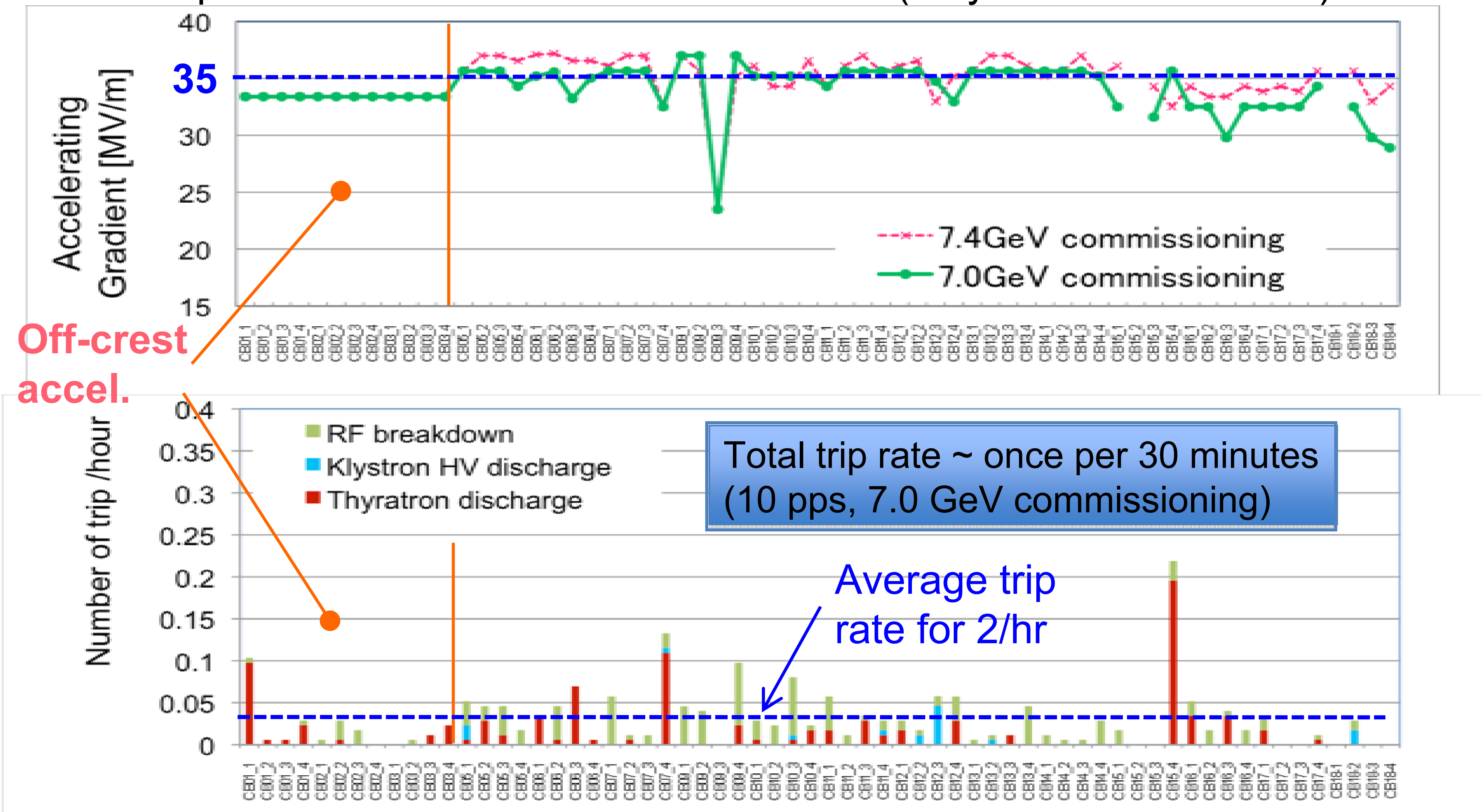




4. Accelerator Performance (2)

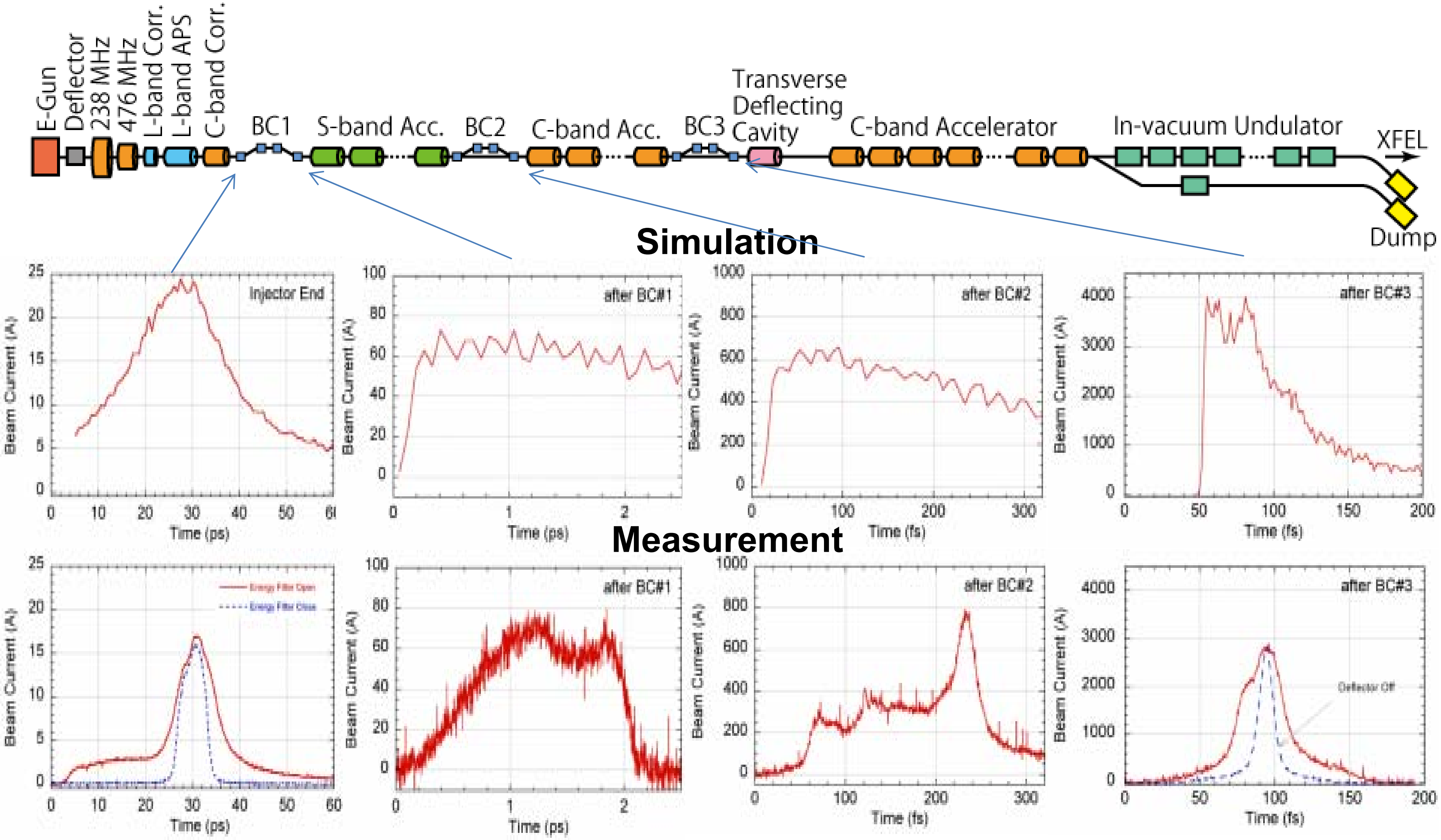
RF System Satisfying a Target Gradient of 35 MV/m

Operation status of C-band accelerator (May 2011 - June 2011)



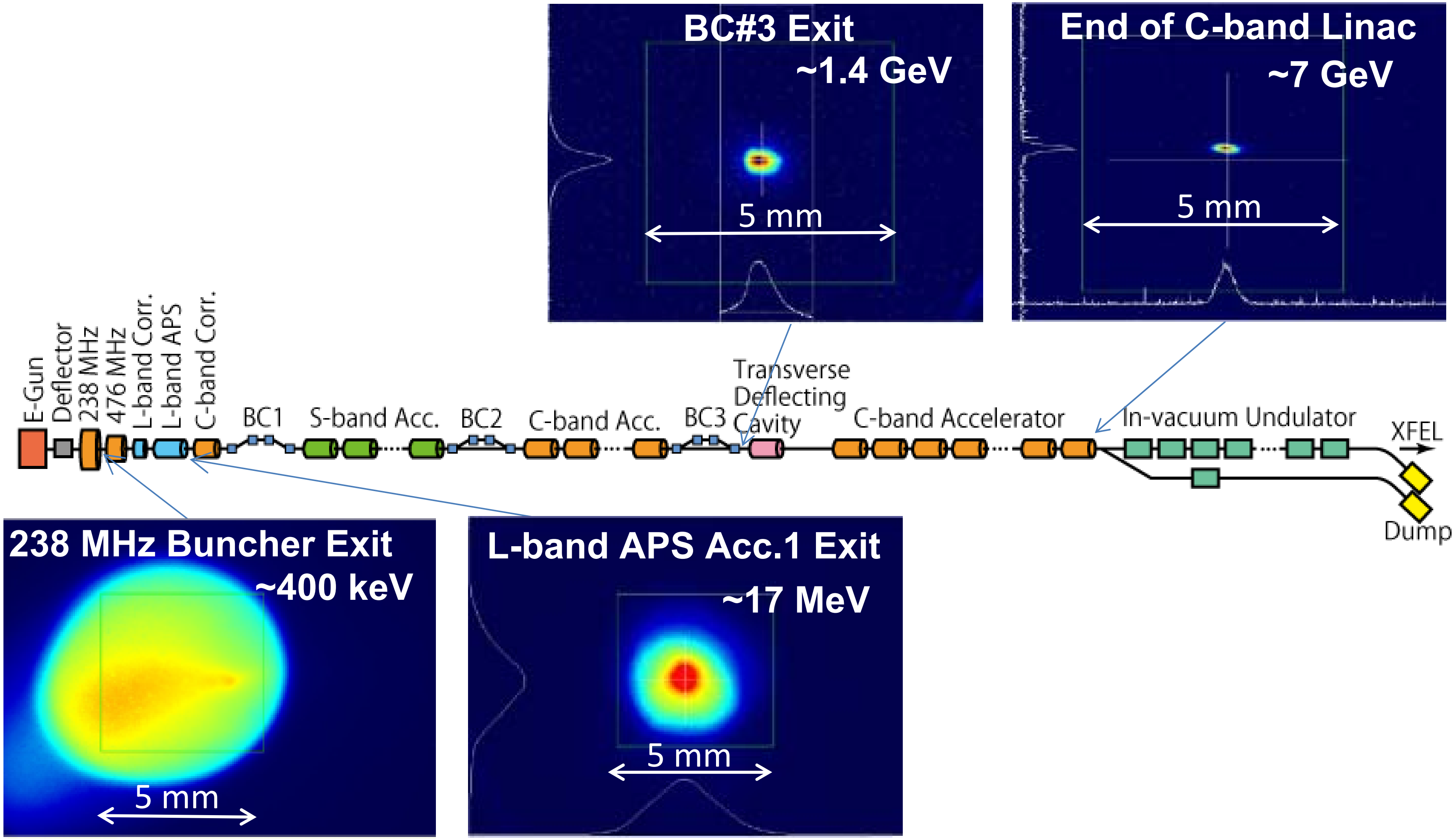
4. Accelerator Performance (3)

Longitudinal Beam Profile over Multi-stage Bunch Compressor



4. Accelerator Performance (4)

Transverse Beam Profile over Linear Accelerator



4. Accelerator Performance (5)

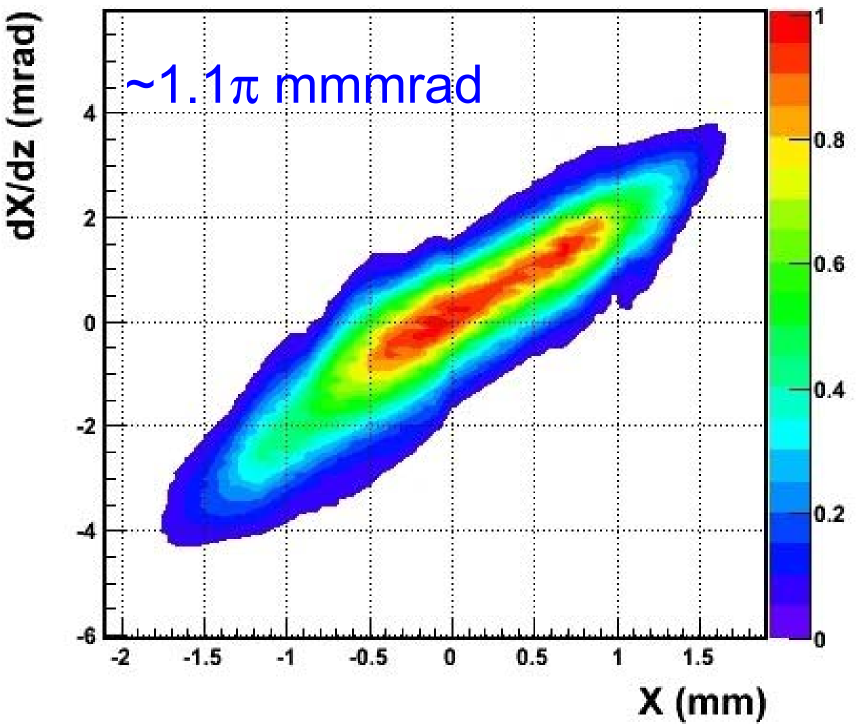
Beam Normalized Projection Emittance

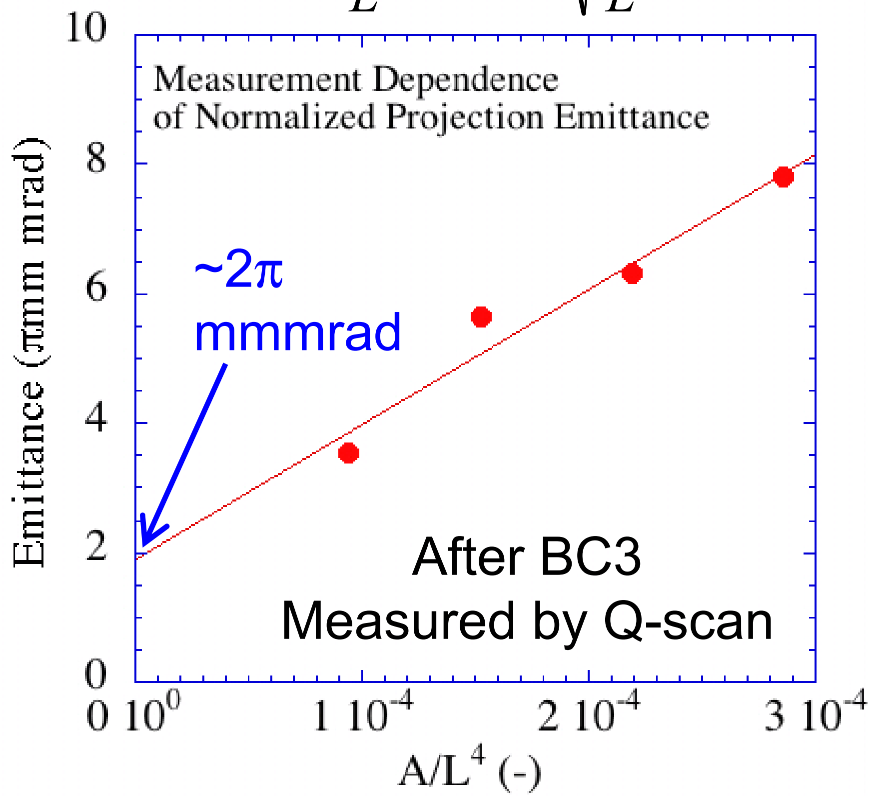
$$\sigma_b^2 = Ax^2 + Bx + C$$

$$= A\left(x + \frac{B}{2A}\right)^2 + D\left(\equiv C - \frac{B^2}{4A^2}\right)$$

$$\varepsilon_b \approx \gamma\beta\frac{\sqrt{AD}}{L^2} = \sqrt{D}\sqrt{\frac{A}{L^4}}$$

Extracted e-beam from e-gun
Energy = 500 keV
Measured by slit-scan





5. Undulator Performance (1)

XFEL Undulator Main Parameters

Magnet Structure	Hybrid Type
Material	NdFeB
Length (m)	5
Period Length (mm)	18
Number of Periods	277
Number of Undulators	18
Minimum Gap (mm)	3.5
Maximum K	2.2
K@λ=0.12 nm, E=7 GeV	~1.8

5. Undulator Performance (2)

XFEL Undulator Tuning Step

Def.
UND=Undulator,
PS=Phase Shifter

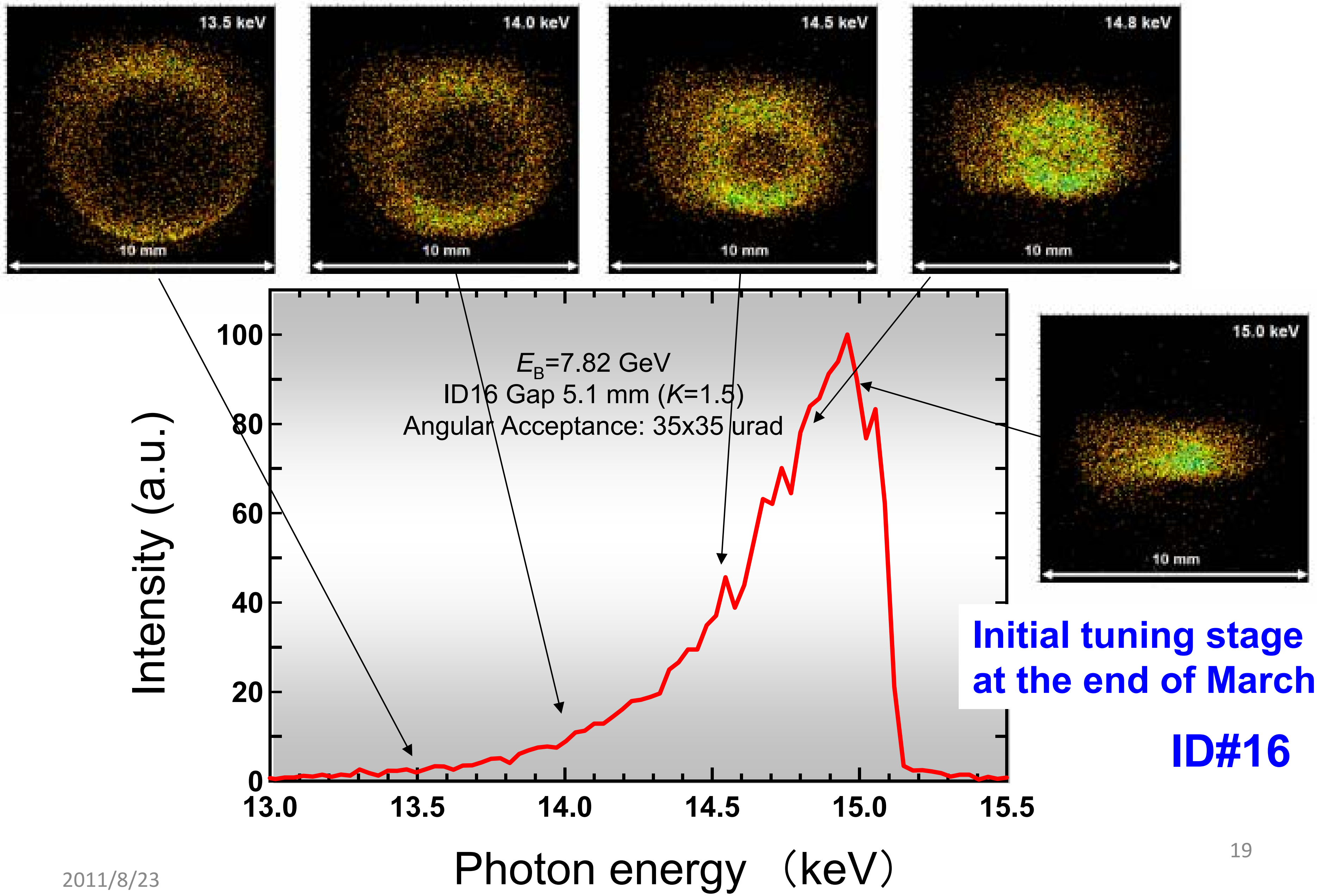
1. Undulator Spectrum Measurement & Check
2. Correction Table for UND & PS Gap Changes < a few μm
3. K-value Fine Tuning $\Delta K/K \sim 5\times10^{-4}$ (3 μm)
4. Electron Beam Orbit Setting & Vertical Alignment of UND
5. PS Gap Preset ~1 μrad $\Delta K/K \sim 1.5\times10^{-4}$ (50 μm)
6. UND K-value Tapering (Peak Current Dependence only Considered)

First lasing trial

After lasing, by using laser intensity as a probe

7. PS Gap Optimization
8. UND K-value Tapering Optimization

5. Undulator Performance (3)

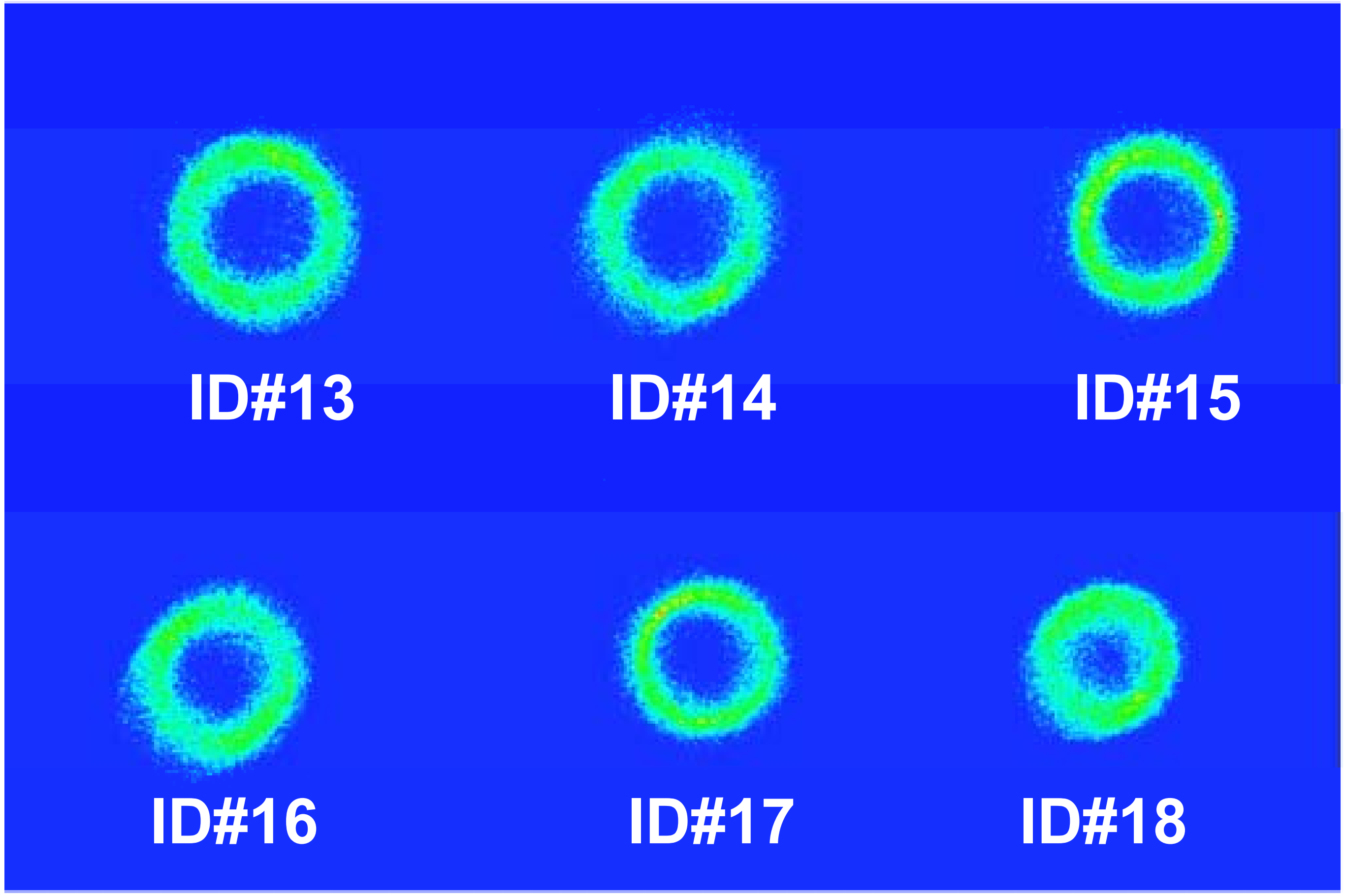


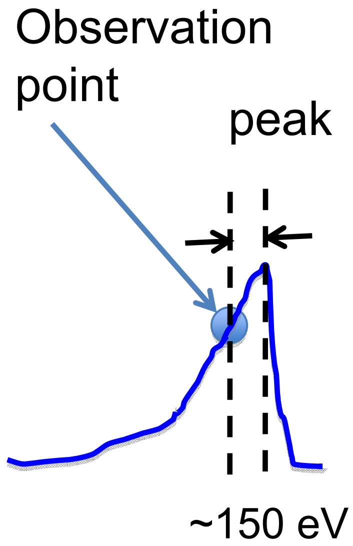
Initial tuning stage at the end of March

ID#16

5. Undulator Performance (4)

After full-beam tuning at the end of July, each spatial distribution at the low energy tail became more clear

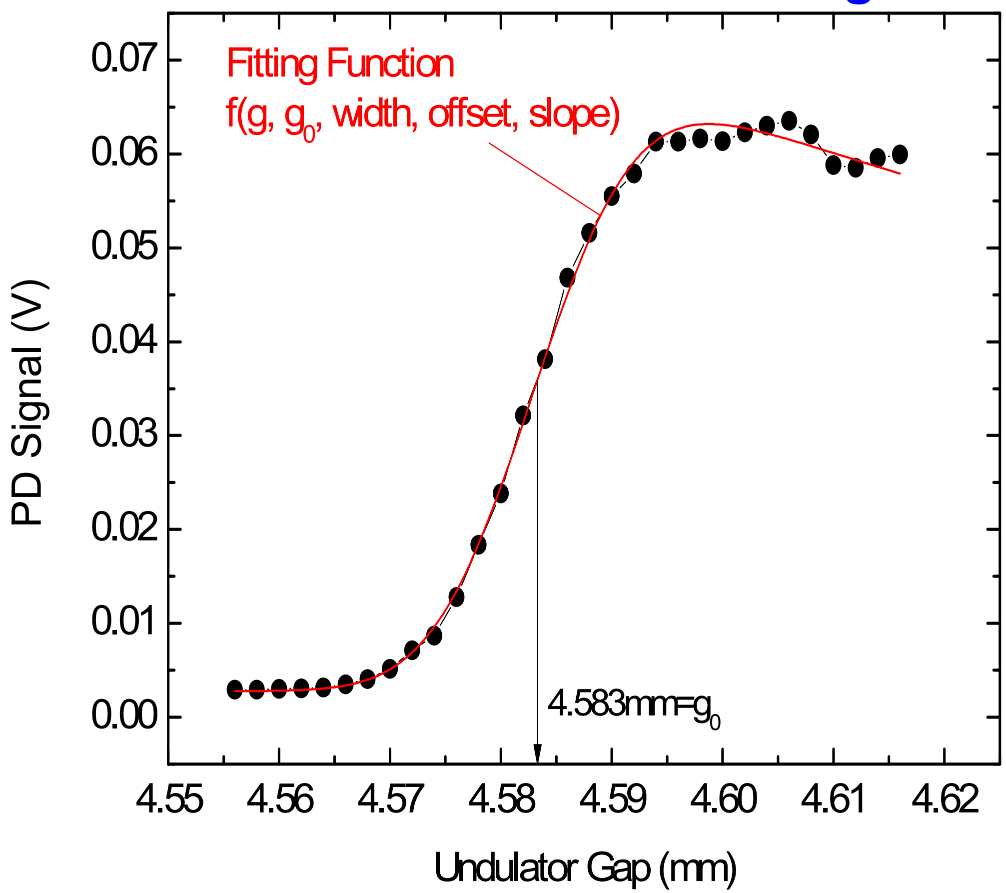




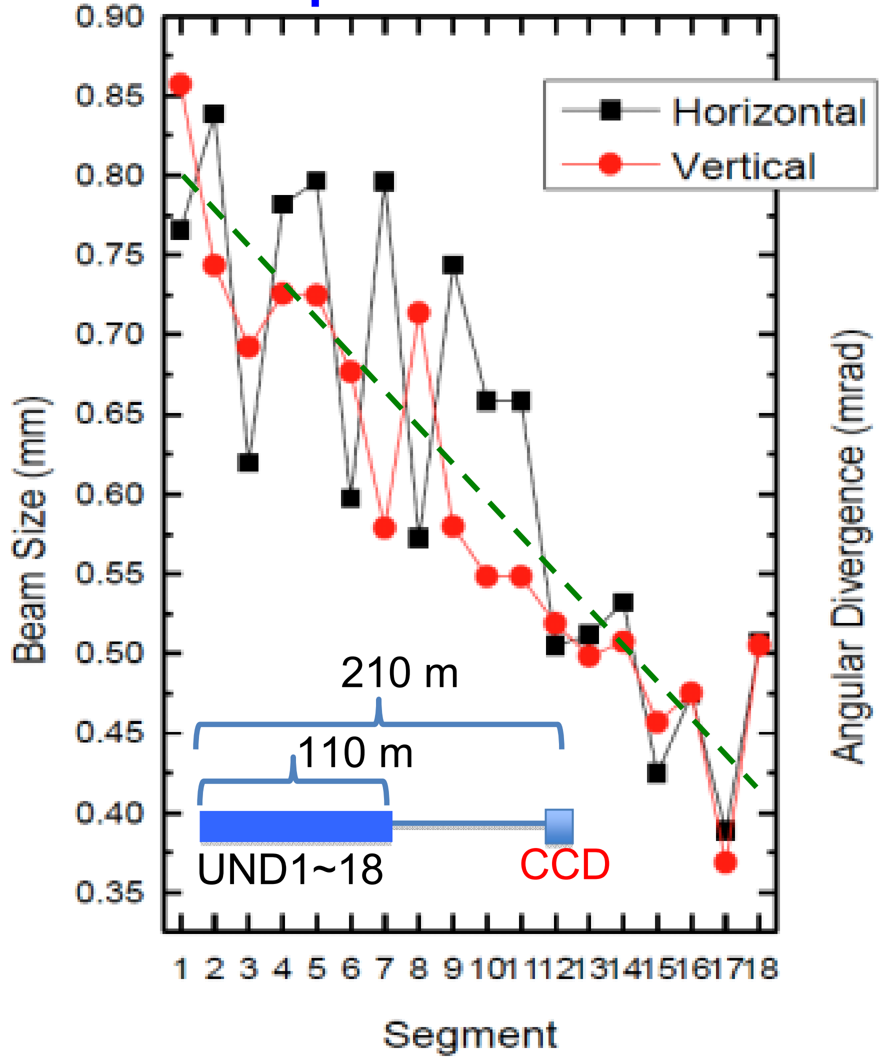
Spectrum of spontaneous radiation

5. Undulator Performance (5)

Precise K-value Tuning



X-ray Beam Size Observed at Optical Hutch



6. Remaining Issues & Future Perspectives

Present schedule is

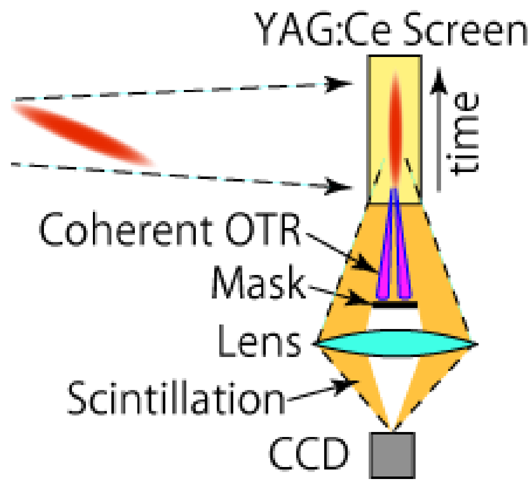
- Tuning restart Sep. 12
- Test use of SASE Middle of Oct.
- User Operation March 2012

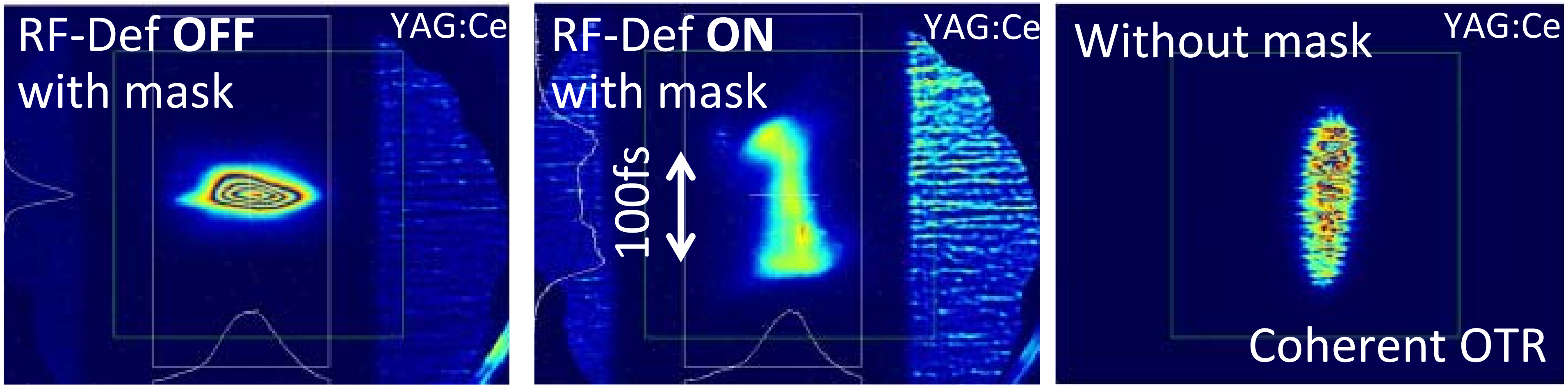
Remaining issues are

- Beam profile measurement downstream of BC3
- Lower pulse energy compared with the expectation
- Unverified alignment precision of beam orbit over UND
- Vertical beam center of mass fluctuation
- Introduction of Long pulse mode (high charge acceleration)
- Feedback control of bunch length drift

COTR Observed in SACLA

Coherent OTR (COTR) was actually a serious problem at the early stage of the beam commissioning. Now, we can tune the bunch compressor owing to a spatial mask in front of the lens.





Temporal profile measurement (screen monitor images at RF deflector)

Interpretation of the Measured Gain Curve