Soft X-ray FEL beamline

SACLA Users' Meeting 2017

Shigeki Owada
On behalf of SACLA

Outline

- **Introduction**
- **Design & Performance**
- **User operation**
- **Beamline upgrades**
  - **Arrival timing monitor**
  - **Sub-μm focusing system**
  - **Future plan**

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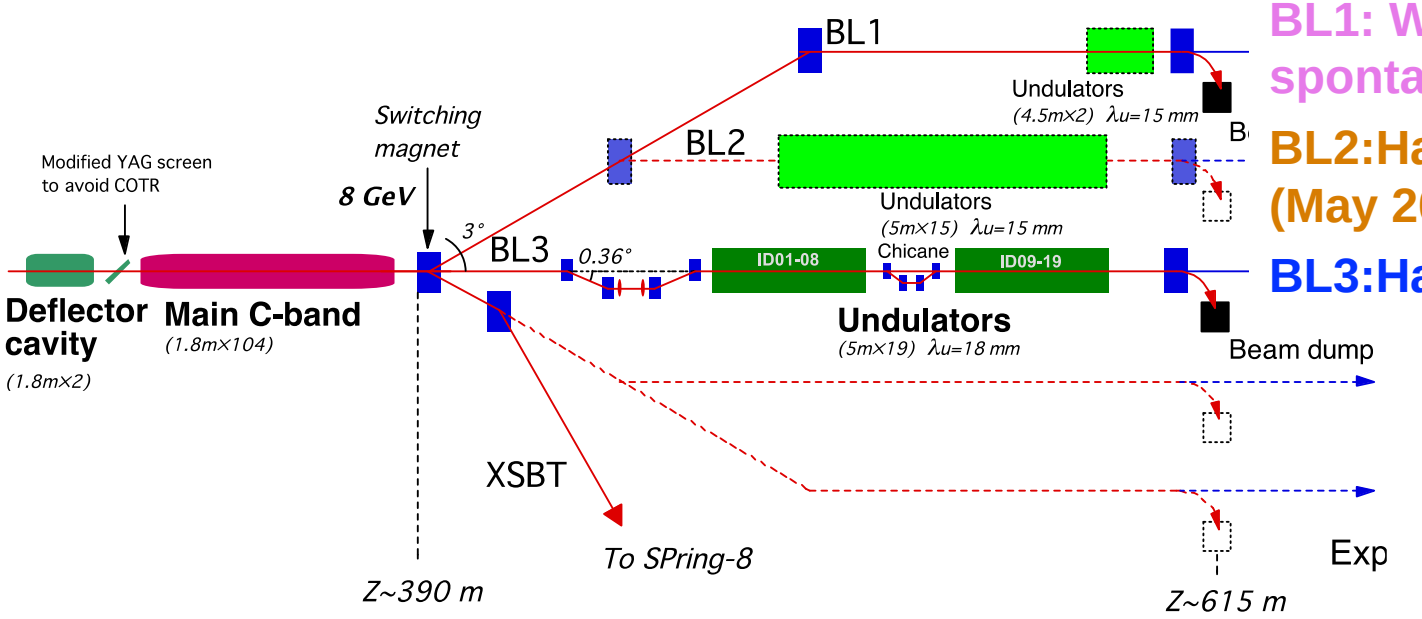
Utilization of soft X-ray at SACLA

SACLA started user operation in Jun. 2012



BL1: Wide-range spontaneous emission

BL2:Hard X-ray FEL (May 2015~)

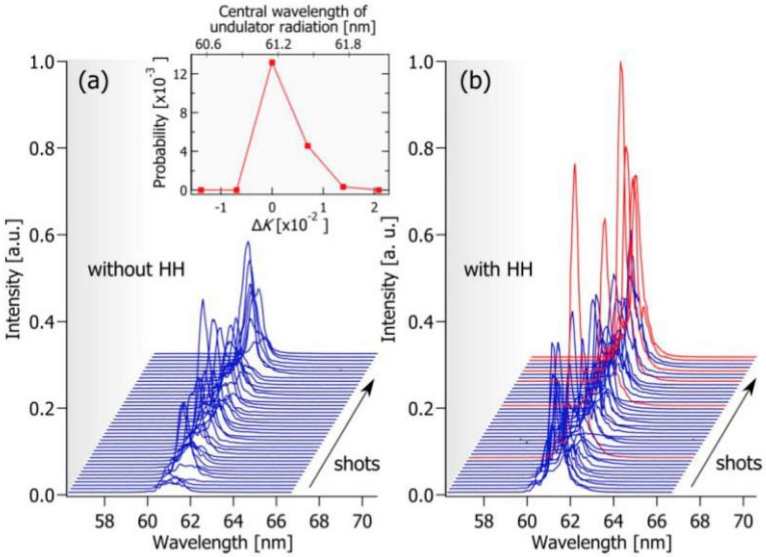
BL3:Hard X-ray FEL

More research opportunities in softer X-ray region

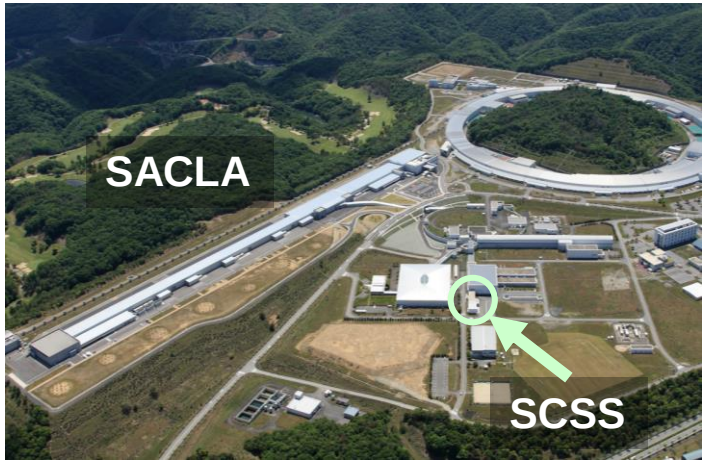
Relocation & re-employment of the SCSS

SCSS (SPring-8 Compact SASE Source)

- SACLA prototype machine
  - R&D for the compact FEL
  - Utilization of FEL
- Milestone
  - 2005 Construction & commissioning
  - 2006 First lasing
  - 2007~ User operation
  - 2012~ User operation at SACLA
  - 2013 Decommissioned



HHG-seeded FEL, T. Togashi, *et al.*, *Opt. Express*, 19, 317, (2011).



	SACLA	SCSS	Ratio
E-beam energy	8 GeV	250 MeV	32:1
Length	700 m	< 60 m	11:1
Accelerator units	64	2	32:1
No. of Undulators	18	2	9:1
Photon energy	4 - 15 keV	20 - 24 eV	< 700:1

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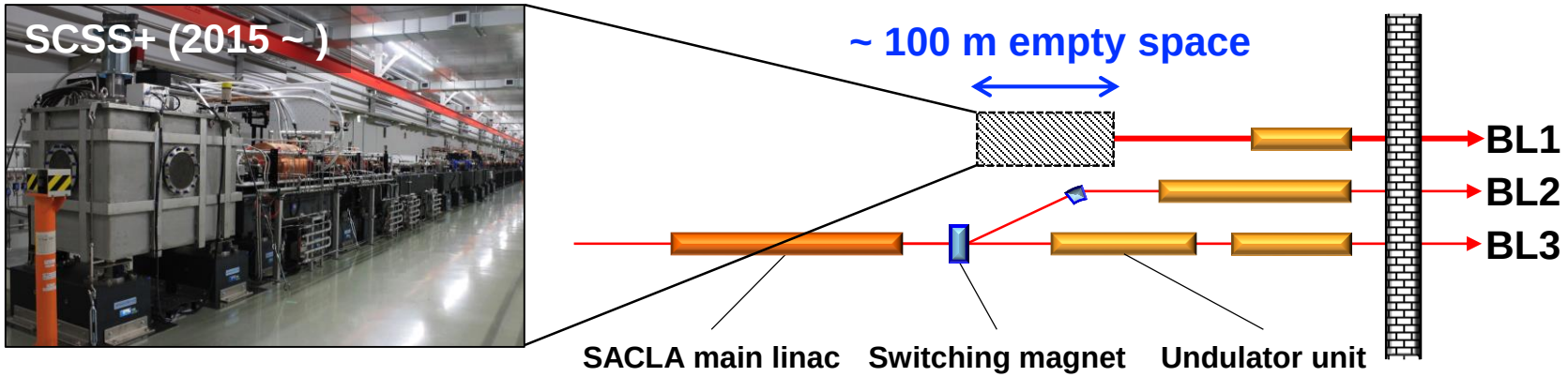
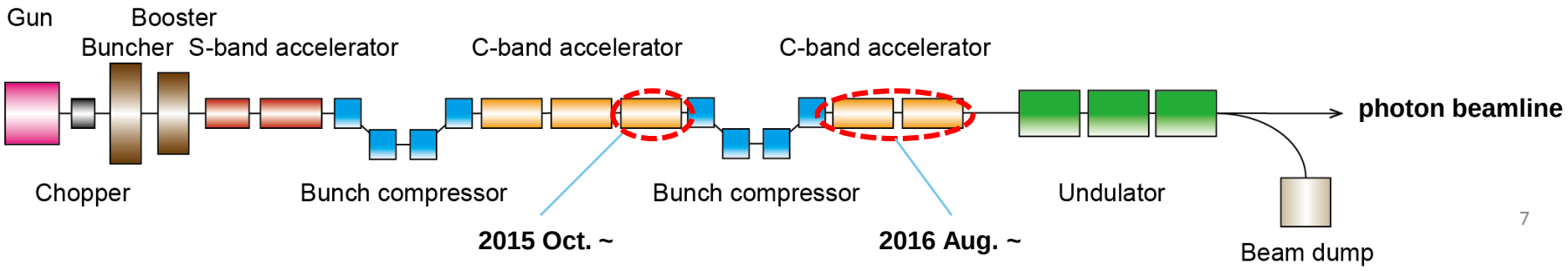
Light source

- Relocation of the SCSS to the SACLA undulator hall

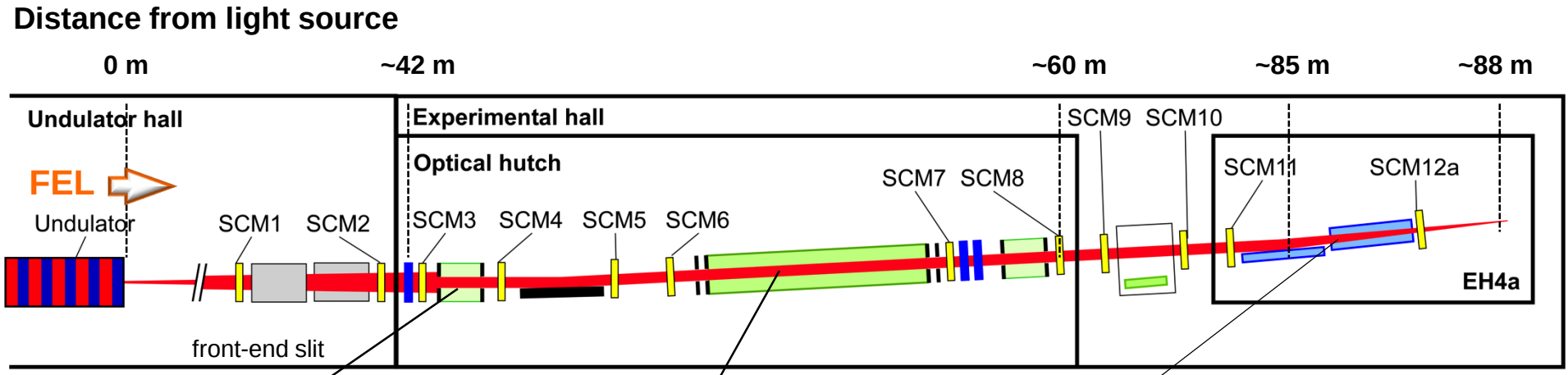


- Upgrade of the SCSS (SCSS+)

	SCSS (~2013)		2015 Oct. ~		2016 Aug. ~
E-beam energy :	~ 250 MeV	→	~ 500 MeV	→	~ 800 MeV
Photon energy :	~ 20 eV		first lasing ~ 37 eV		~ 150 eV (K = 1.5)



Photon beamline



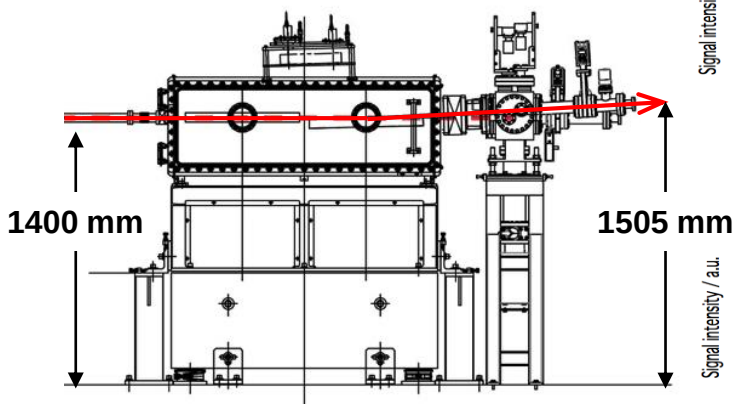
Gas Intensity monitor (GM)
Ion detector
Calibrated by calorimeter

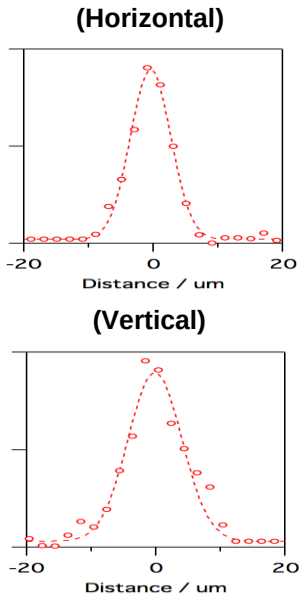
Gas attenuator (GAT)
N_2 or noble gas
L = ~2.6 m
P = 0 ~ 100 Pa

Metal foil (AT)
Al : 0.1 ~ 0.5 μm
Zr : 0.1 ~ 2.0 μm
Sn: 0.1 ~ 0.3 μm

KB mirror system

- Grancing angle = 1.5 deg.
- W.D. = 2 m





Spot size < 10 μm @100 eV

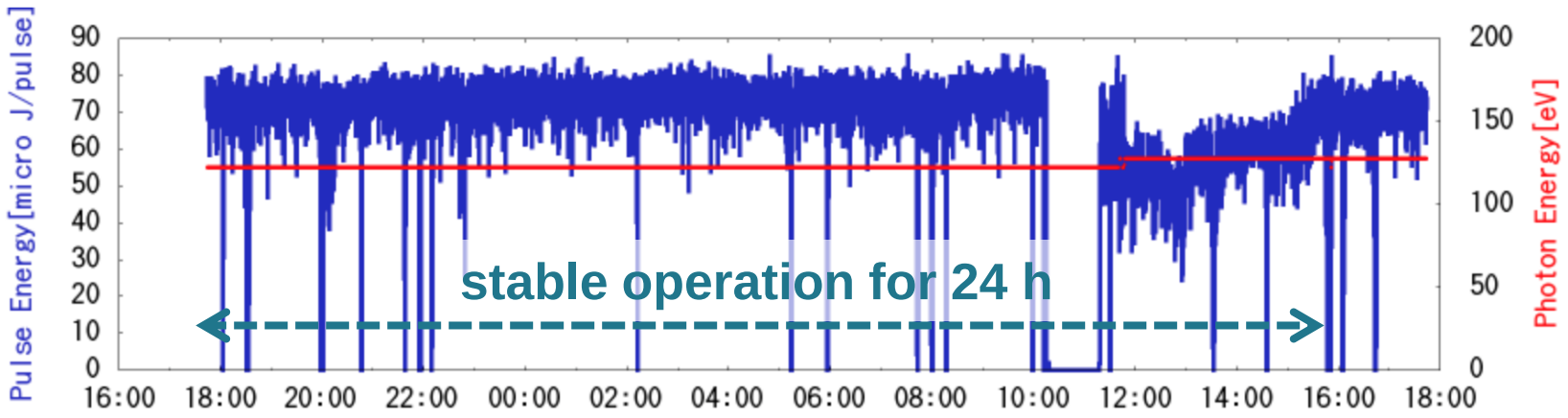
Operation status

2017/12/1	SACLA Operation Status	17:44:00

Operation Mode	
BL1 Study	
Hutch in Use	
BL1 EH4a	
Pulse Energy	Photon Energy / Wavelength
69.3 micro J/pulse	127.6 eV / 9.7 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
60 Hz	23.8 %

~ 80 μJ (100 eV, @end station)
BL transmittance: ~90 %

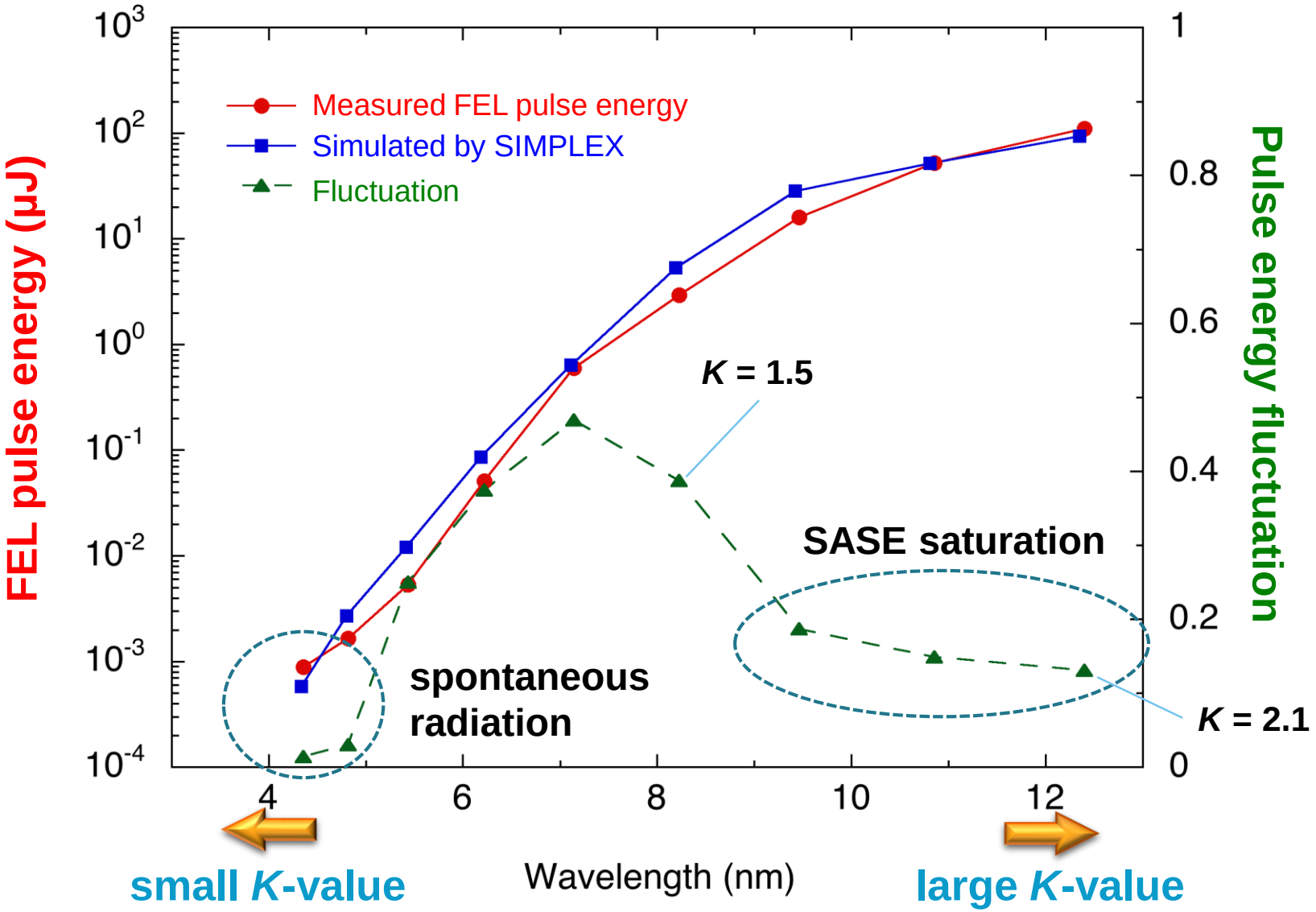
40 ~ 150 eV for routine operation



Operation parameters

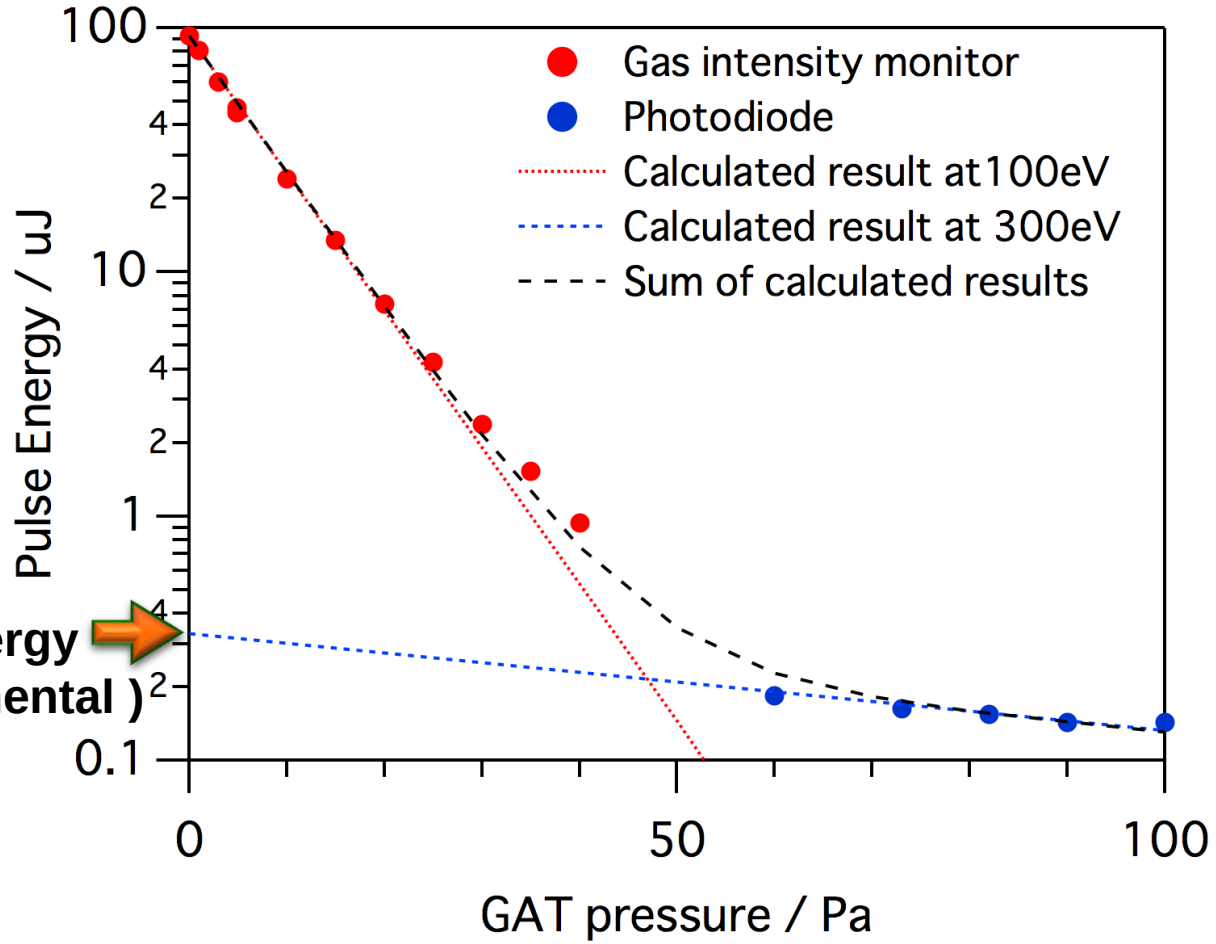
	BL1 (SXFEL)		
E-beam			
Energy	250 MeV	< 800 MeV	5 ~ 8 GeV
Charge	~ 0.3 nC	~ 0.3 nC	~ 0.3 nC
Rep. rate	20 Hz	60 Hz	30 Hz (60 Hz)
Undulators			
Total length	9 m	14 m	106 m
Periodic length	15 mm	18 mm	18 mm
K value	< 1.5	< 2.1	< 2.1
FEL			
Photon energy	20 ~ 25 eV	40 ~ 150 eV	4 ~ 15 keV
Pulse energy	10 ~ 30 μJ/pulse	~ 80 μJ/pulse (@ 100 eV)	~ 600 μJ/pulse (@ 10 keV)
Pulse duration		a few hundred fs	< 8 fs

Gain curve measurement



Estimation of 3rd harmonics at 100 eV

- Pulse energy vs. Gas attenuator (N_2) pressure
- 3rd harmonics contribution is estimated at 100 eV



3rd harmonics energy (~ 0.3 % of fundamental)

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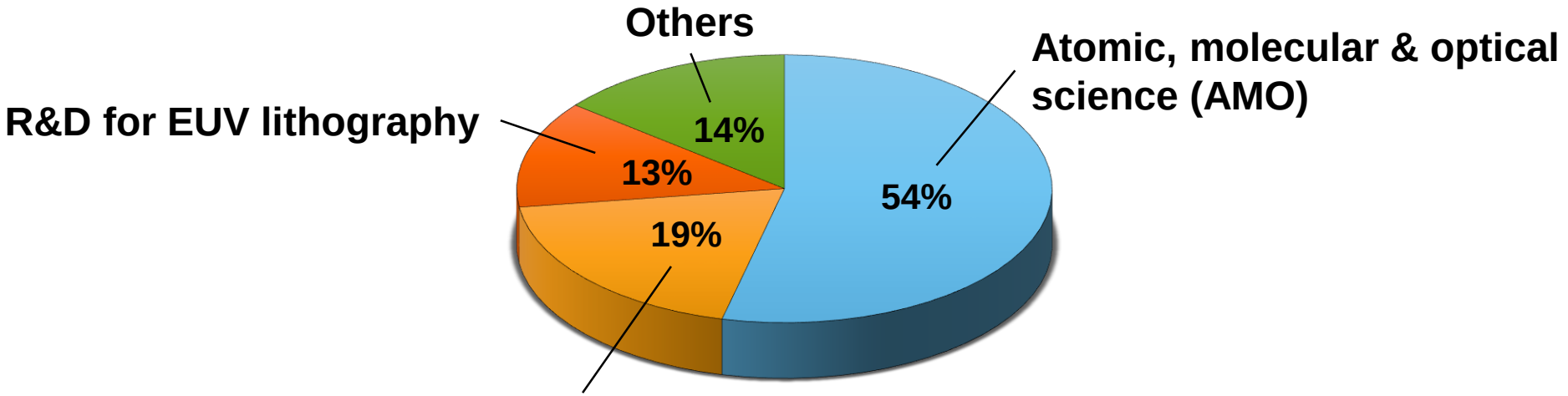
User operation

- User operation: Jul. 2016 ~
- Beamtime : 5 ~ 7 shifts (1 shift = 12h)
- 6 ~ 7 proposals / half year

Research field at BL1 (FY2016 - 2017)



Ultrafast material science

- Resonant second harmonic generation
- Magneto-optic Kerr effect (MOKE)

Prof. Matsuda (12/11 14:30 ~)

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Arrival timing measurement at BL1

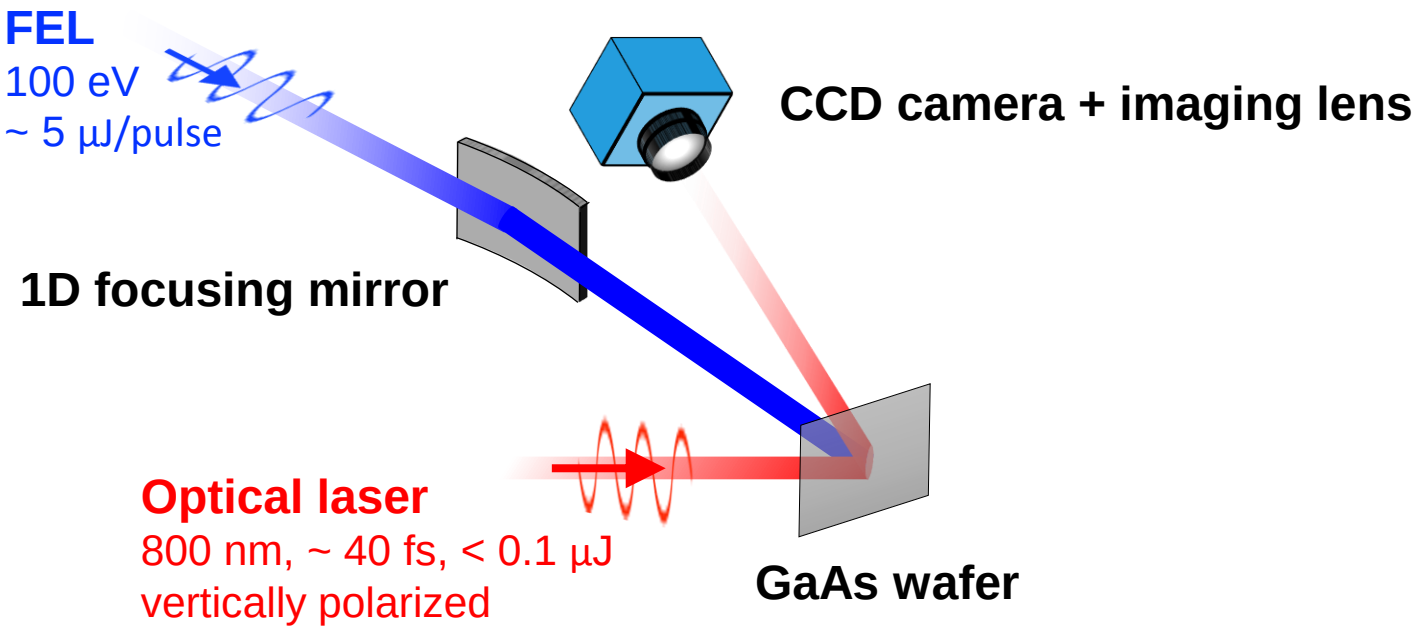
- Reflectivity change combined with spatial encoding

  Small penetration depth of GaAs (< 30 nm @100 eV)

- 1D focusing for enhancing efficiency

  ~ 5 μJ/pulse, 70 μm (H) × 3300 μm (V), FWHM

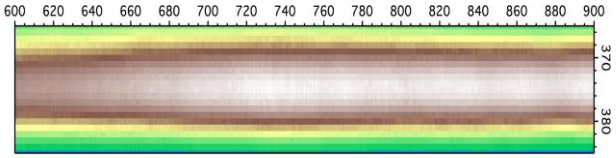
  => fluence = ~ 3 mJ/cm^2 << damage threshold



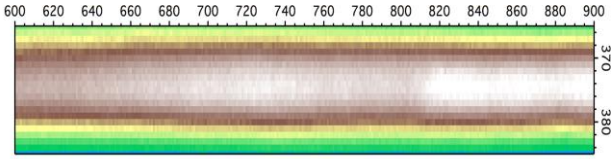
Results

❖ Reflectivity change of GaAs

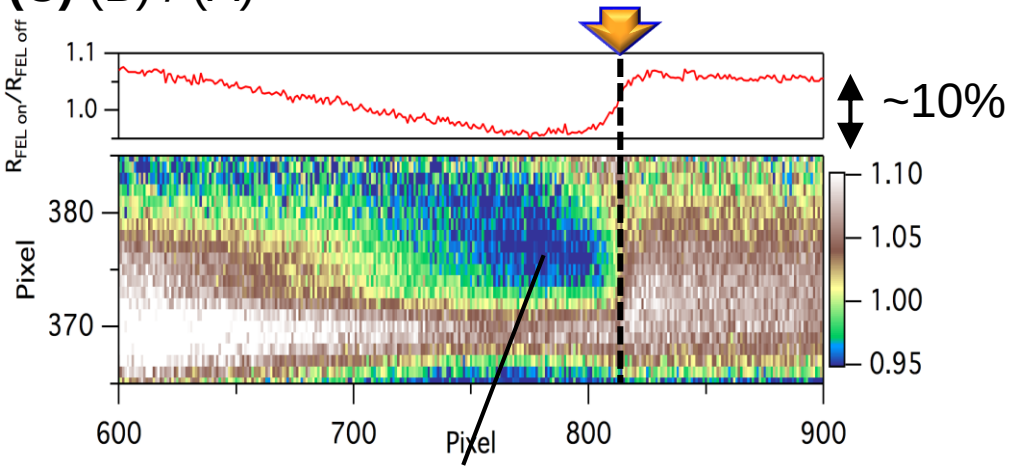
(A) FEL off



(B) FEL on

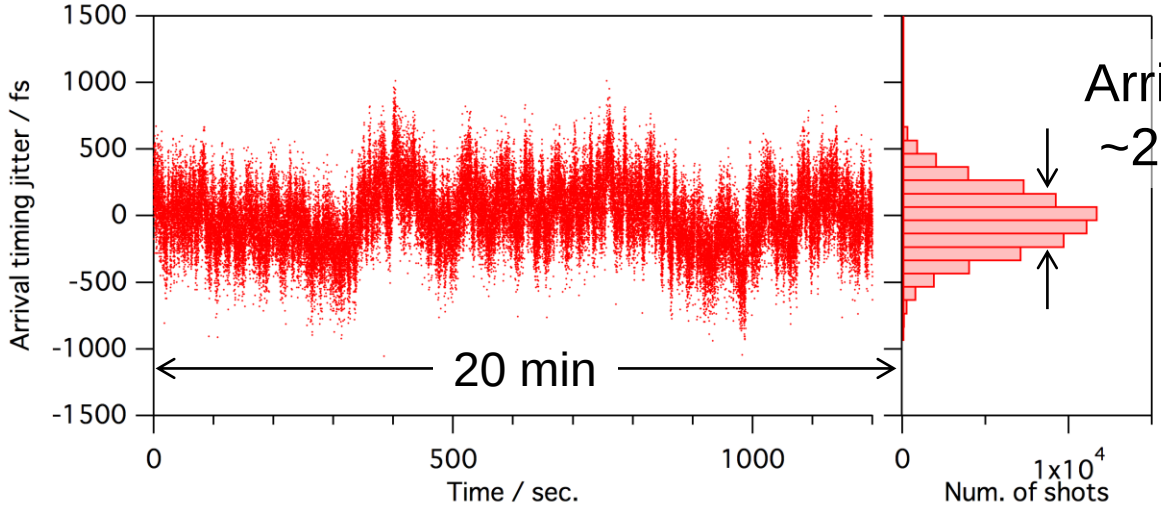


(C) (B) / (A) edge = relative arrival timing



Lower reflectivity = FEL earlier than Opt. Laser

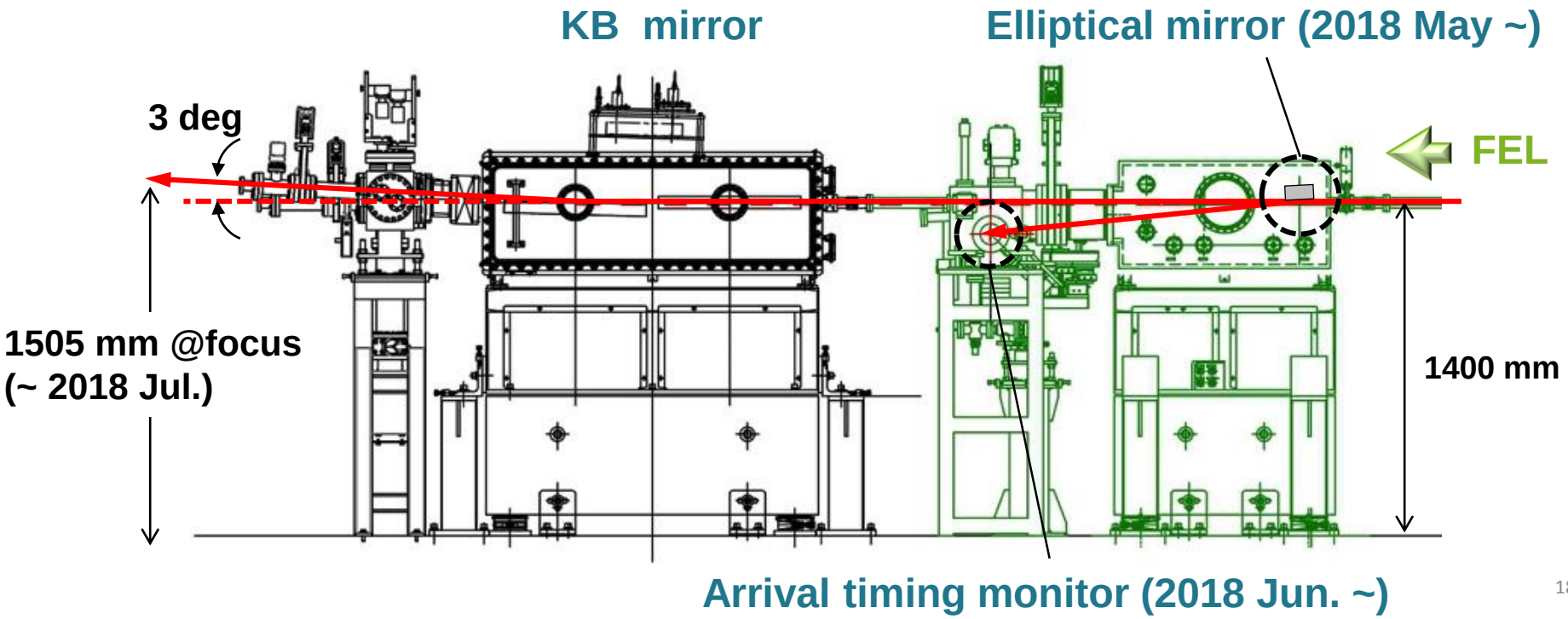
❖ Jitter evaluation



Arrival timing jitter:
~250 fs (RMS)

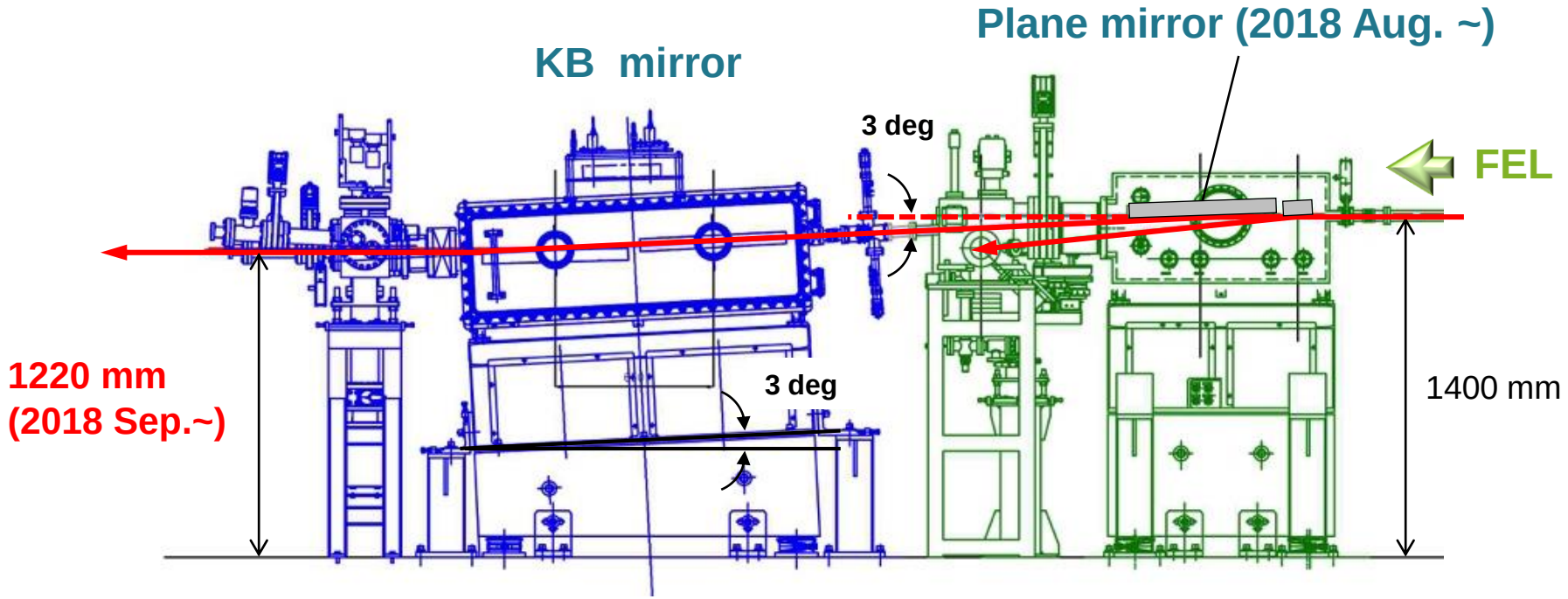
Arrival timing monitor

- Wavefront-splitting for beam branching
  - Elliptical mirror for 1D focusing (f = 1300 mm)
  - Branching ratio : < 10 %
- Installation & Commissioning : 2018 May~



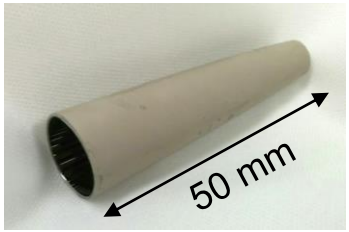
Beamline upgrade

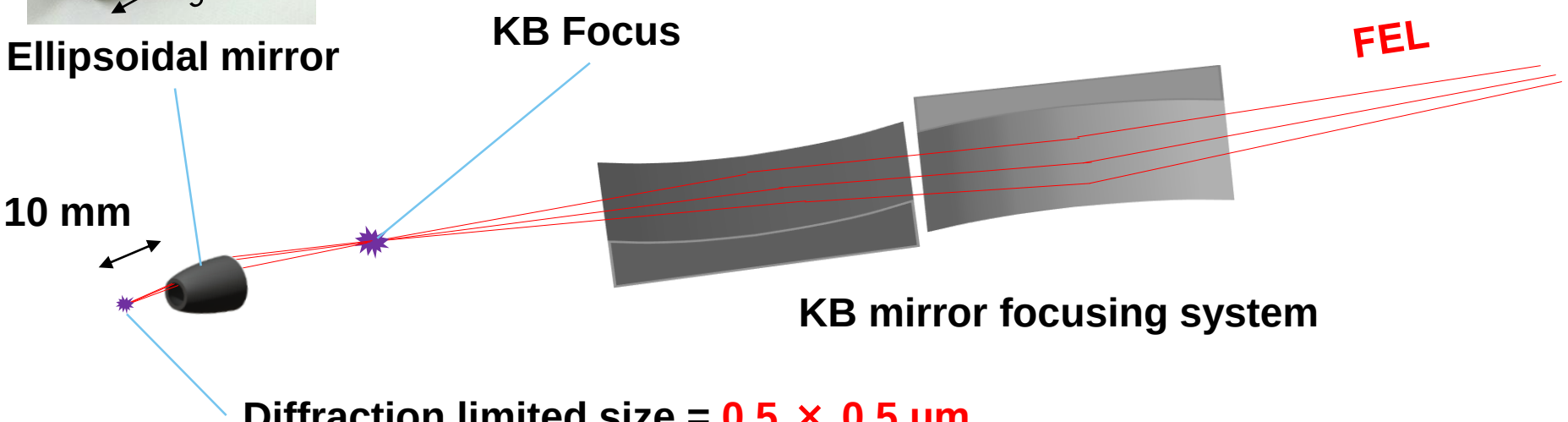
- Plane mirror with 1.5 deg glancing angle
  - Beam axis : Horizontal
  - Beam height : 1505 mm => 1220 mm (@focus position)
- Installation : Aug. 2018 ~



Sub-1μm focusing system

Collaborated with Prof. Mimura & H. Motoyama (U Tokyo)
supported by SACLA Research Support Program for Graduate Students



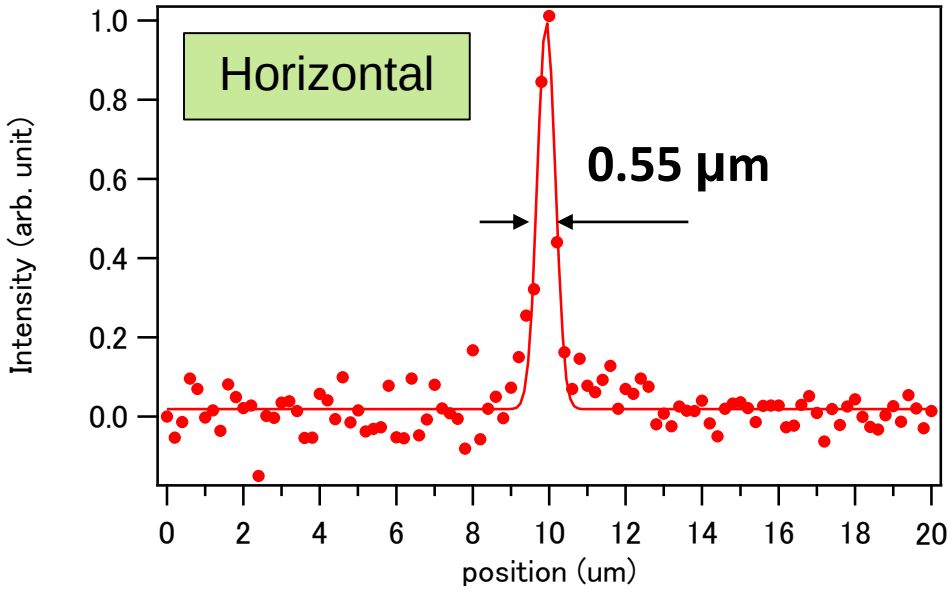


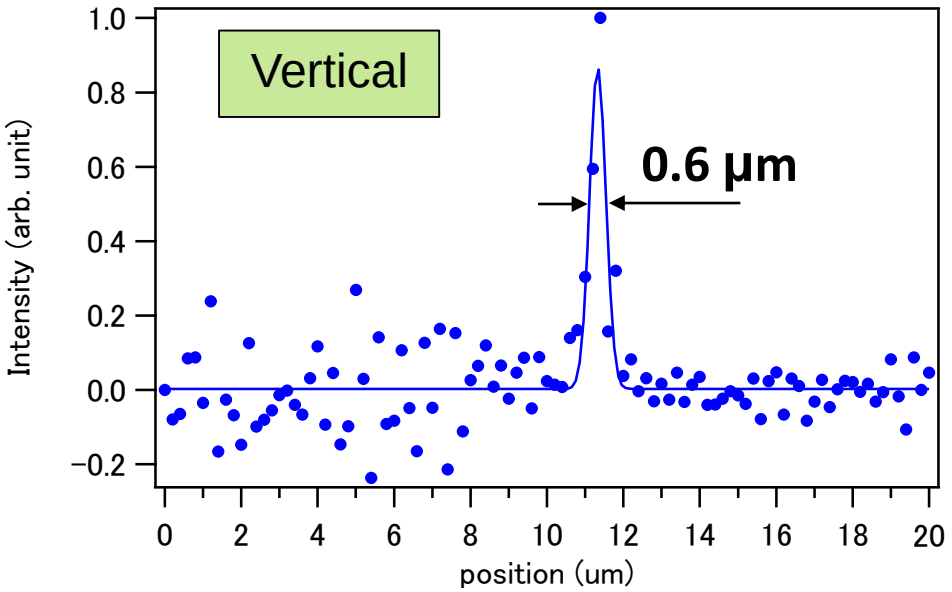
Using KB mirrors…

- Beam size become smaller = Mirror length become shorter
- Light source position = KB focus position

Results

Spot size measured by knife-edge scan





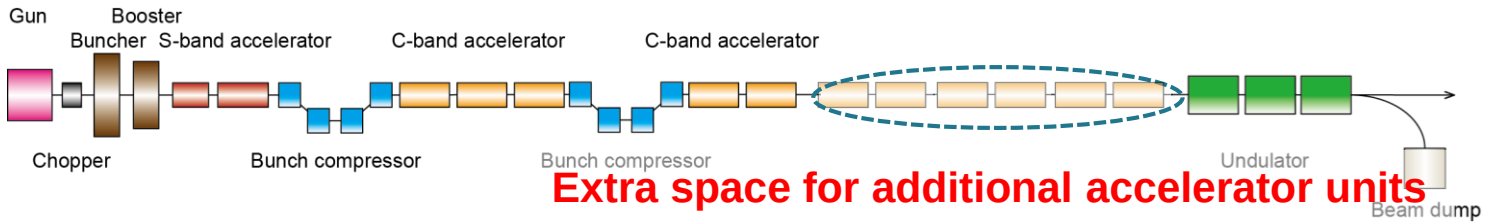
Peak intensity : ~1×10^{17} W/cm^2 (80 μJ, ~100 fs)

Perspectives

- C-band accelerator units for higher energy

  E-beam energy : ~ 0.8 GeV → < ~ 1.7 GeV

  Photon energy : ~ 100 eV @K=2.1 → < ~ 470 eV @K=2.1



- Polarization control (helical undulator, etc.)

- Soft X-ray/Hard X-ray pump-probe experiment

  SCSS+ linac is synchronized to SACLA main linac

Summary

- The SCSS was re-employed and upgraded.
  (~100 μJ @ 100 eV)

- We started user operation from Jun. 2016.

- We will continue facility upgrades and beamline development.

Thank you for your attention