SACLA users meeting (Spring-8), Sept. 6, 2018

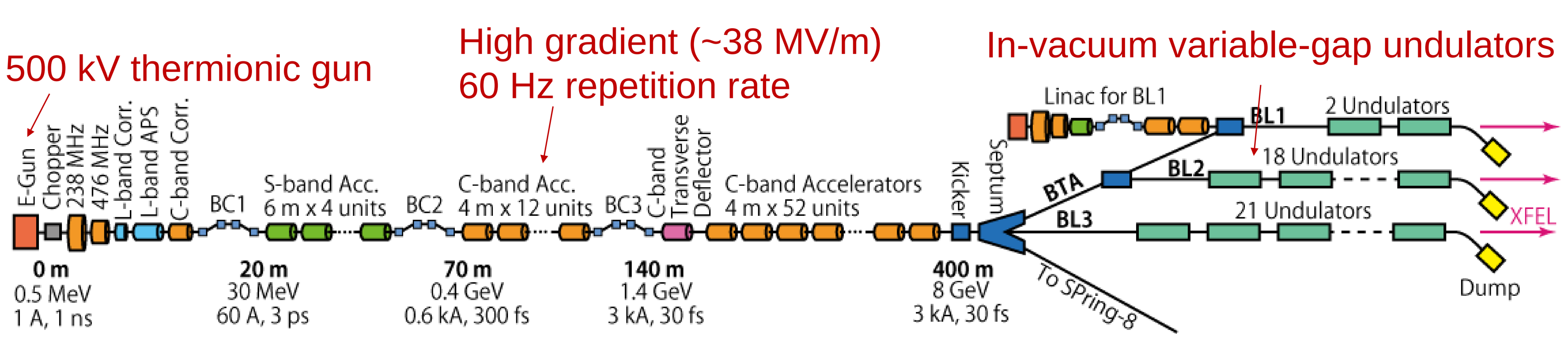
Status of multi beamline operation at SACLA

RIKEN SPring-8 center, JASRI, SPring-8 services

Parallel operation of two XFEL beamline with 10 kA beam was realized.

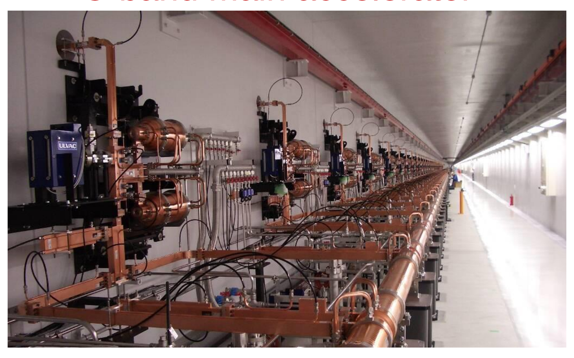
- New optics of BL2 dog-leg suppressed CSR induced instabilities.
- 60 Hz beam switching with 10 ppm accuracy works well.
- Beam energy and bunch length are independently controlled.

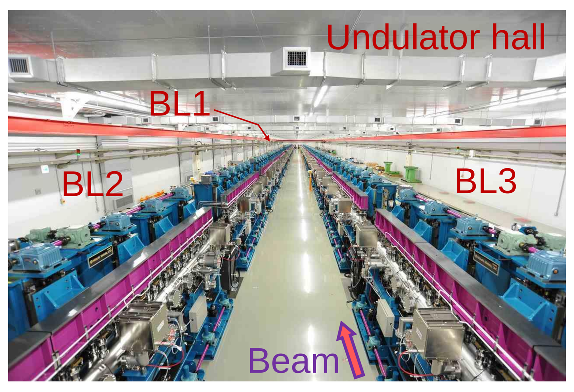
SACLA overview



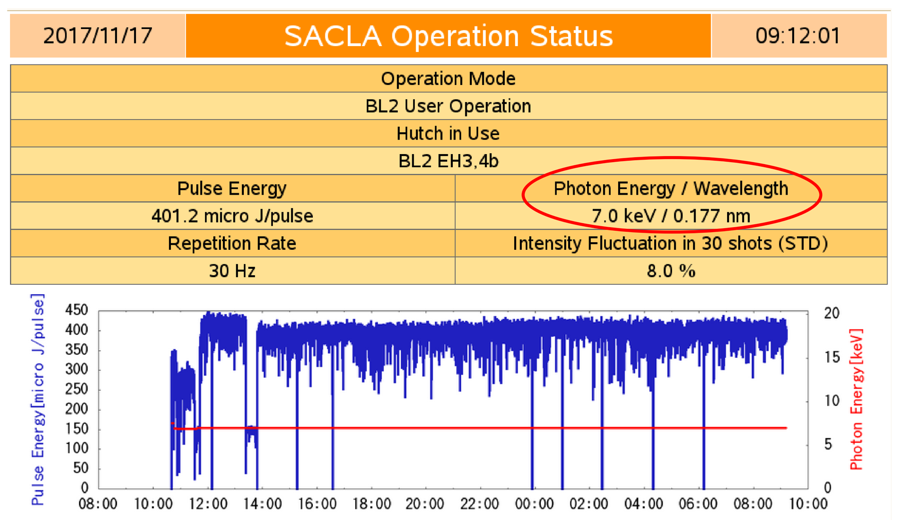
	BL3 / BL2	BL1
Electron beam energy	8.5 GeV (max.)	800 MeV (max.)
Bunch charge	0.2 – 0.3 nC	0.2 – 0.3 nC
Peak current	>10 kA	>300 A
Pulse repetition rate	60 Hz (max.)	60 Hz (max.)
Photon energy	4 – 15 keV (0.08 – 0.3 nm)	20 – 150 eV (8 – 60 nm)
FEL pulse energy	~0.6 mJ @10 keV	~100 μJ @100 eV
Pulse width	<10 fs	<1 ps
Spectrum band width	0.5 %	3%

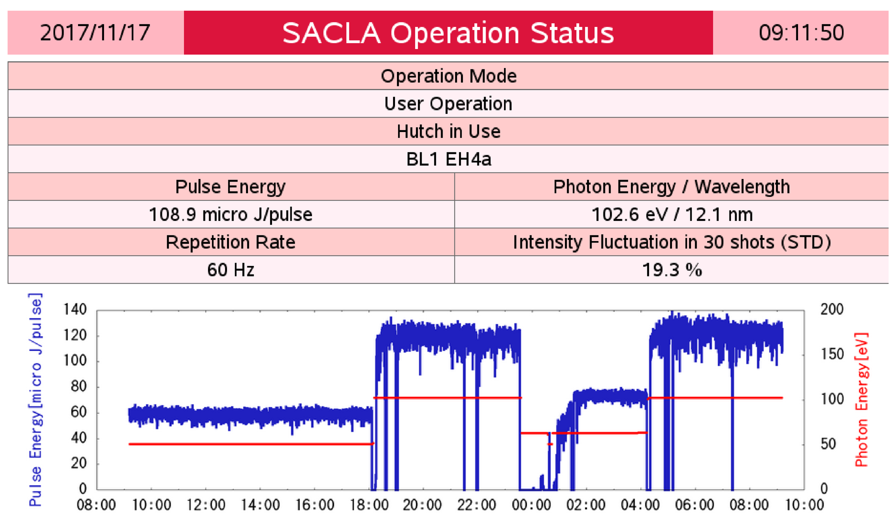
C-band main accelerator

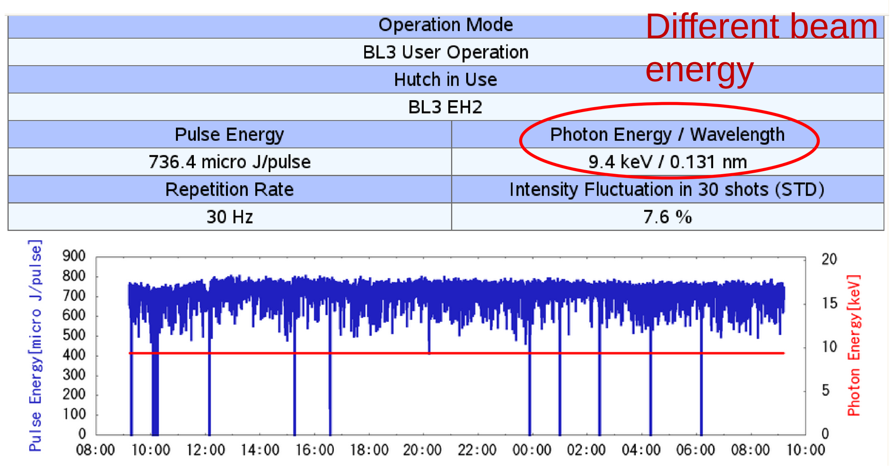




- Total operation: 5,900 hours (FY2016)
  User run: 3,400 hours (BL2+3)
  Setup, tuning: 2,400 hours
- In order to increase user availability, we started the parallel operation of BL2 and BL3 since Sept. 2017.
- Pulse switching of 60 Hz beam with arbitrary beam energy (5~8 GeV).







Pulse-to-pulse control of the electron beam

T. Hara, et. al., Phys. Rev. ST Accel. Beams 16, 080701 (2013)

- Electron beam energy and the pulse length can be independently tuned for BL2 and BL3, to provide different XFEL photon energy and intensity.
- Optimum bunch profile is different for BL2 and BL3.
- New "synchronized" accelerator control system enables us to control the beam with pulse-to-pulse basis, like virtual 2 XFEL machines.

Pulse-to-pulse control

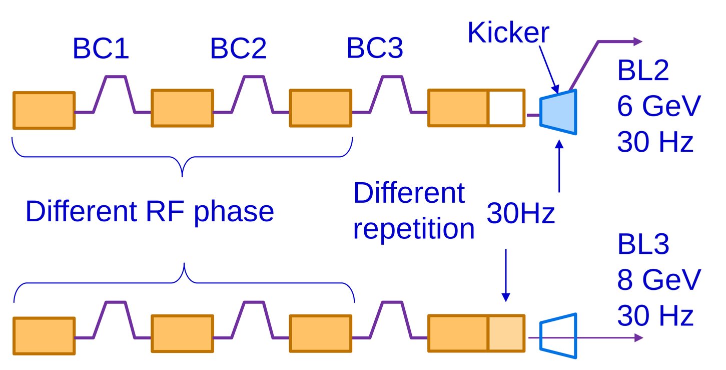
- Beam energy
  controlled with repetition rate of the RF units
- Pulse length
  controlled with RF phase of the RF cavities
- Beam route (BL2 or BL3)
  kicker magnet at switchyard

Pulse-to-pulse monitor

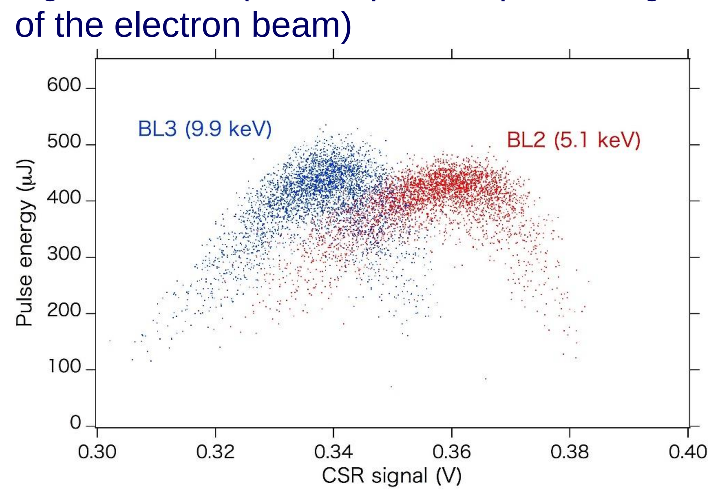
- Beam trajectory
  with cavity-type beam position monitors (BPM)
- Beam charge
  with current transformers (CT)
- Pulse length
  with coherent-synchrotron-radiation (CSR) monitors

- For the synchronization, we installed reflective memory board on each VME crate, and communicate with each other.
- Beam route information is shared and referred for pulse-to-pulse control of each RF unit.

Schematic of "synchronized" accelerator control system

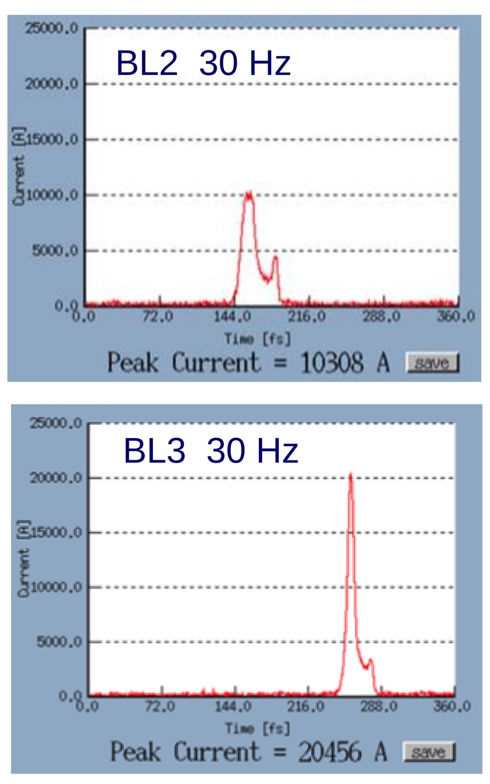


SASE pulse energy as a function of CSR signal at BC3 (=correspond to pulse length of the electron beam)

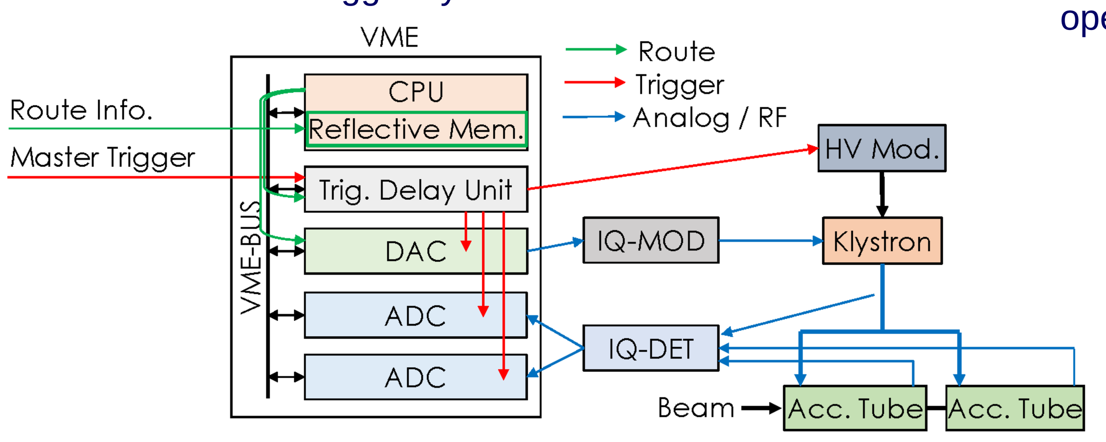


Example of the operation with different pulse length and peak current of the beam.

Alternately operated



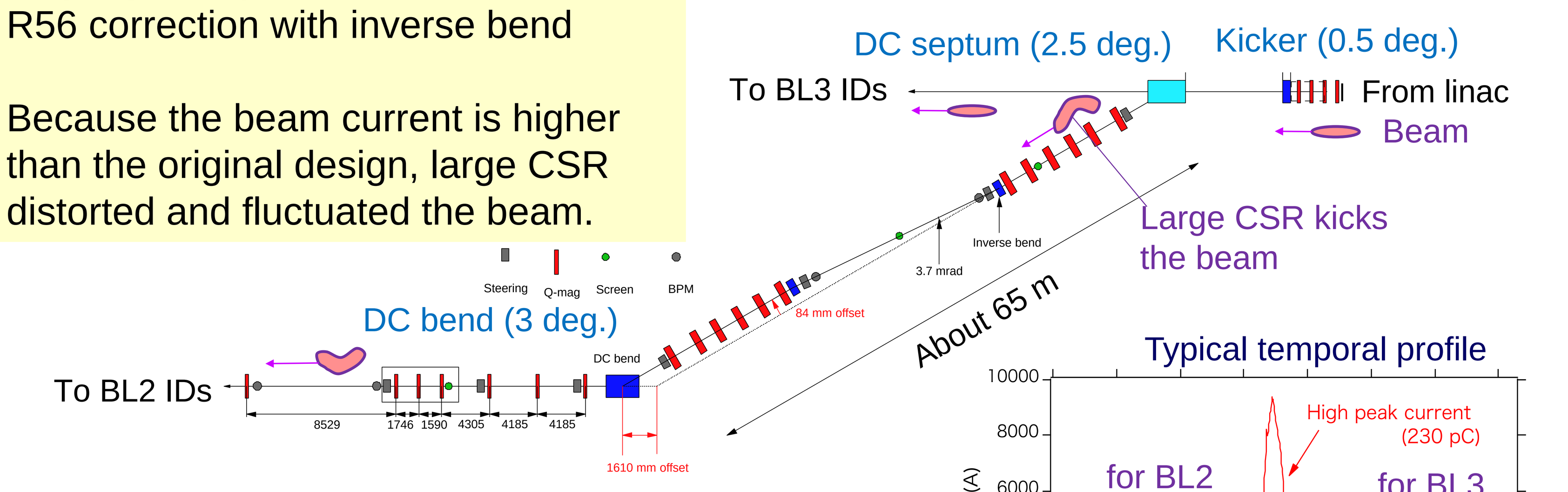
Low level RF and trigger system for each RF unit



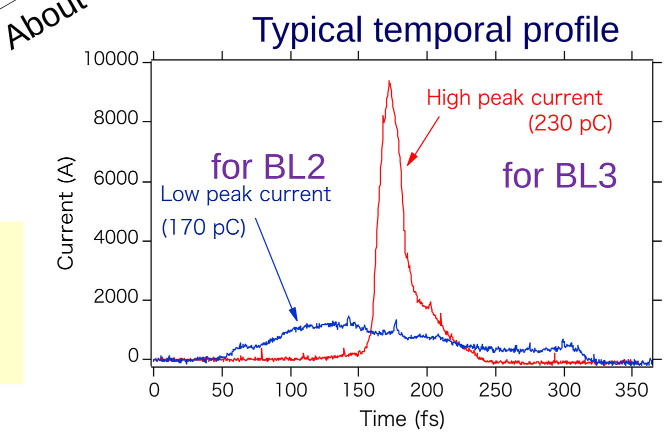
Old beam transport to BL2 (2014~2016)

T. Hara, et. al., Phys. Rev. Accel. Beams 19, 020703 (2016)

- Beam deflection: Kicker + DC septum
- Dog-leg transport
- R56 correction with inverse bend
- Because the beam current is higher than the original design, large CSR distorted and fluctuated the beam.

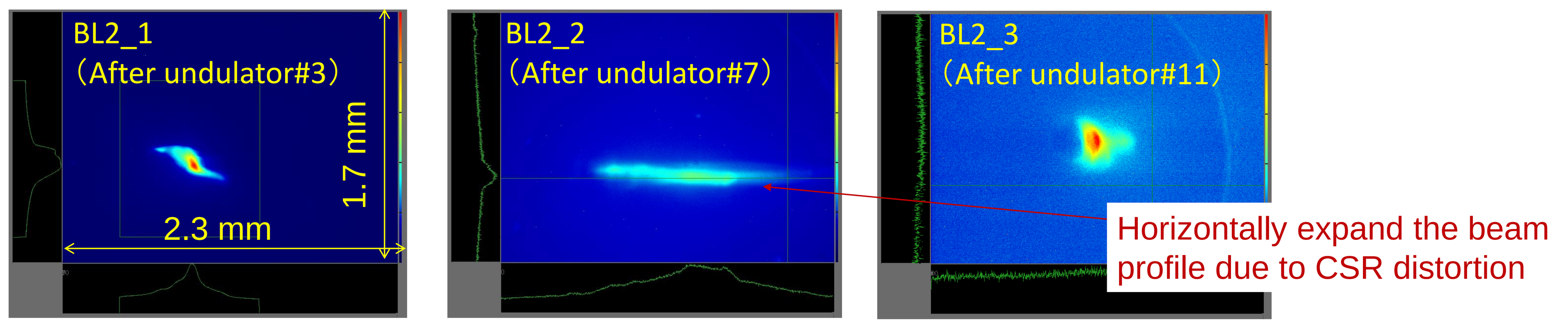


- Finally, we reduced the peak current 10 kA → 2 kA
- SASE intensity became lower than BL3
- Difficult to execute parallel operation



• Beam profile with old beam optics (2015)

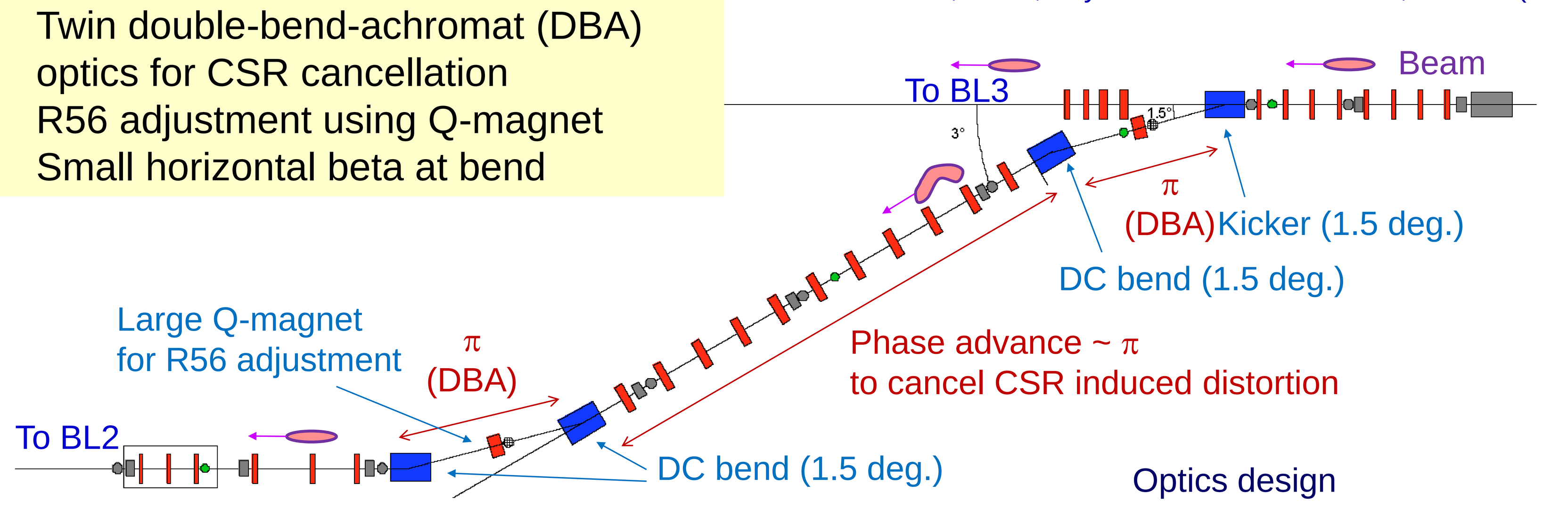
Electron beam 7.8 GeV, 10 kA



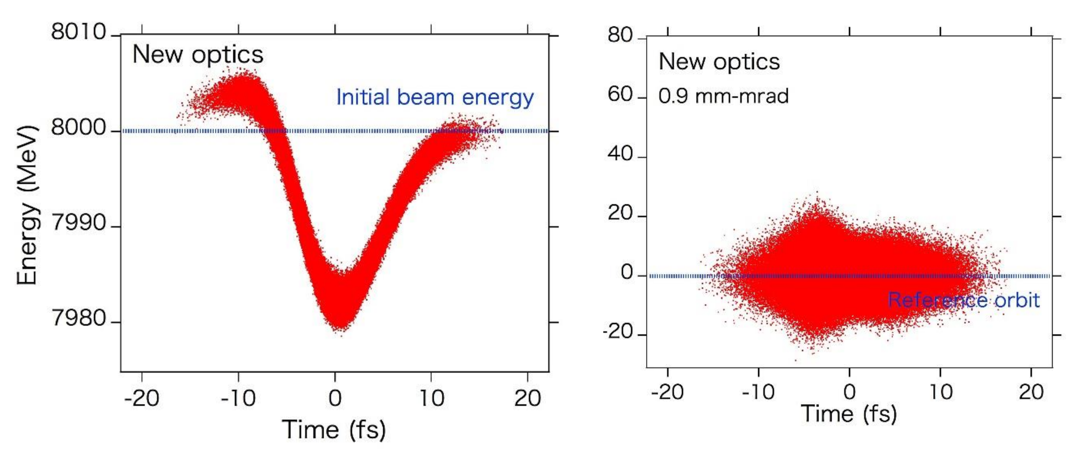
New beam transport to BL2 (2017~)

T. Hara, et. al., Phys. Rev. Accel. Beams 21, 040701 (2018)

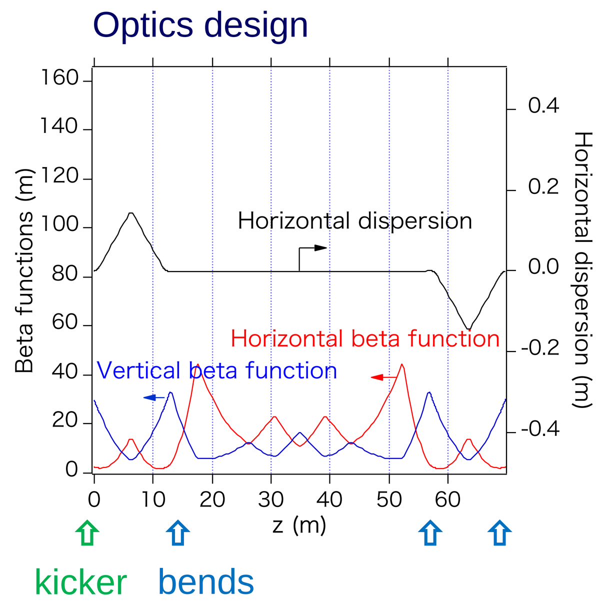
- Twin double-bend-achromat (DBA) optics for CSR cancellation
- R56 adjustment using Q-magnet
- Small horizontal beta at bend



Simulation of energy and horizontal divergence distribution after BL2 dog-leg (10 kA, gaussian beam, initial 0.8 mm-mrad)



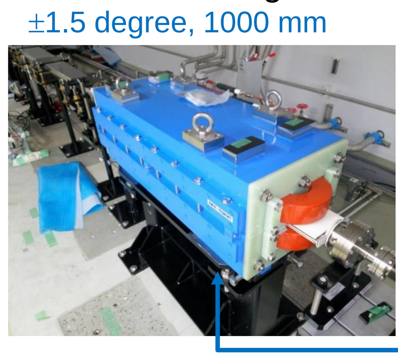
Optics design



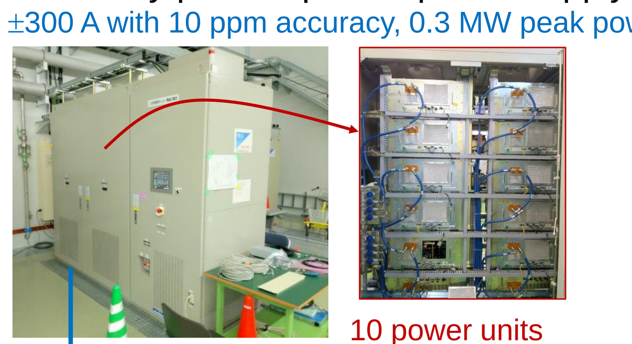
New kicker magnet and power supply

C. Kondo, et. al., Rev. of Sci. Instr. 89, 064704 (2018)

New kicker magnet
±1.5 degree, 1000 mm

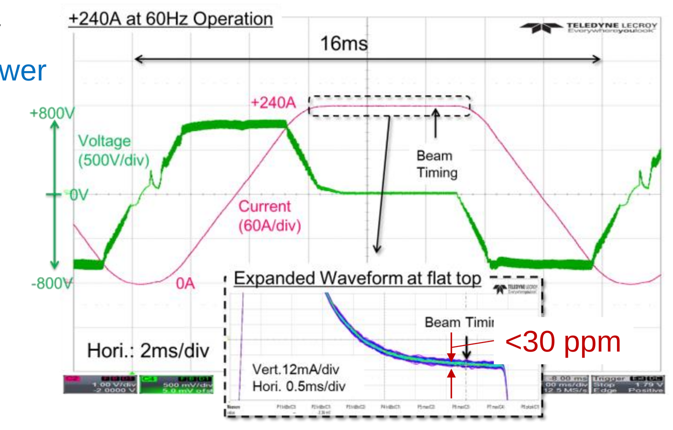


Extremely precise pulsed power supply
±300 A with 10 ppm accuracy, 0.3 MW peak power



Pulse current of ±300 A

10 power units using SiC-MOSFET

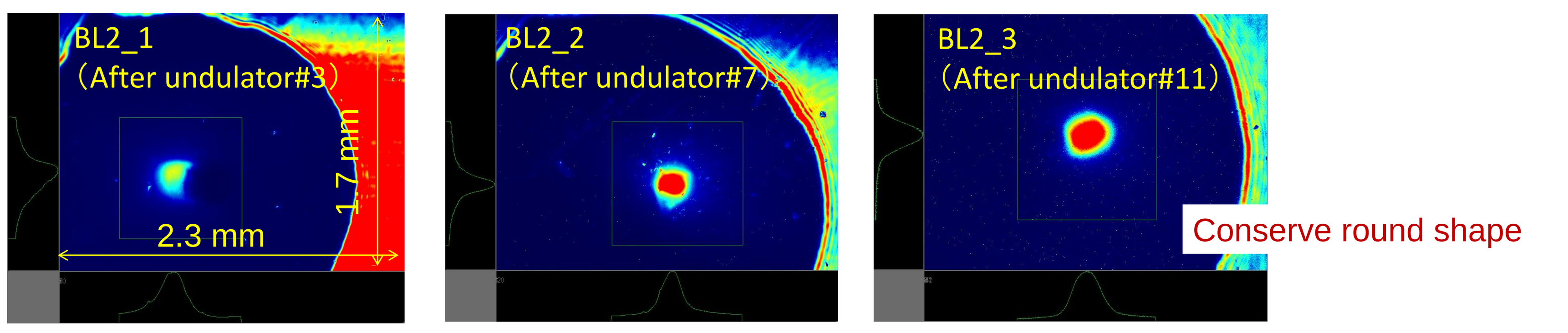


Measured beam performance at BL2

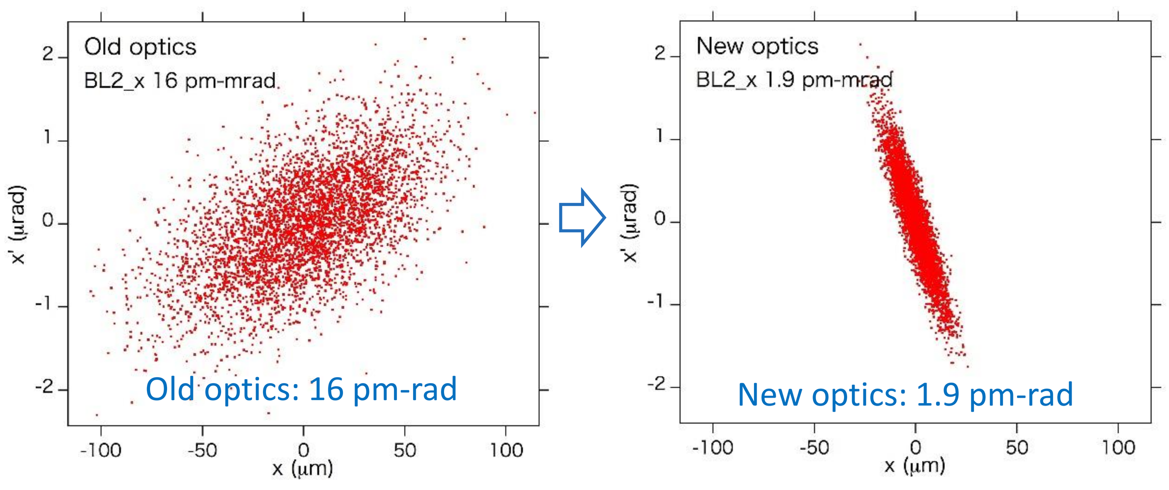
- CSR induced degradation and instability was suppressed.
- Sufficient beam property and stability for SASE lasing at BL2.
- Kicker magnet also stable enough.

• Beam profile with new beam optics (2017)

Electron beam 7.8 GeV, 10 kA



• Horizontal jitter emittance for 7.8 GeV, 10 kA beam



•Jitter emittance as a function of phase advance between two DBAs