



Status and upgrade of the SACLA accelerator

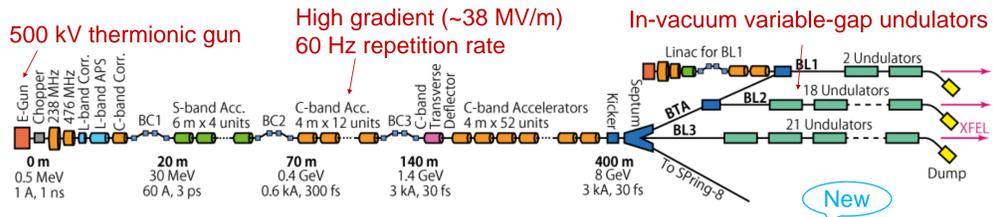
RIKEN SPring-8 center, JASRI, SPring-8 services



Highlights of this year

- 60 Hz beam switching to BL3/BL2 has been routinely operated.
- Electron beam injection from SACLA to SPring-8 has been commissioned.
- We will add two accelerator units to increase beam energy (+250 MeV).

SACLA overview



	BL3 / BL2	BL1	SPring-8 injection
Electron beam energy	8.5 GeV (max.)	800 MeV (max.)	8.0 GeV
Bunch charge	0.2 – 0.3 nC	0.2 – 0.3 nC	0.1 – 0.3 nC
Peak current	>10 kA	>300 A	around 1 kA
Pulse repetition rate	60 Hz (max.)	60 Hz (max.)	10 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%	

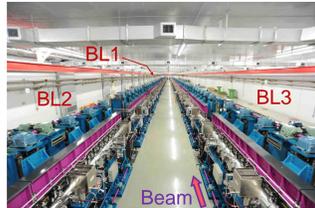
E-Gun and buncher RF cavities



C-band main accelerator



Undulator beamlines

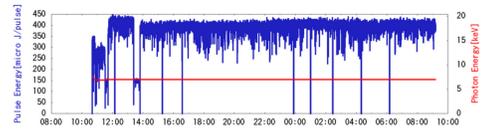
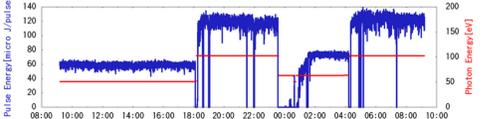


- Total operation: 6,281 hours (FY2018)
- User run: 6,270 hours (BL1+2+3)
- Availability: 97.0%(BL2,3), 94.4%(BL1)
- MTBF: 56 min. (BL2,3), 190 min. (BL1)

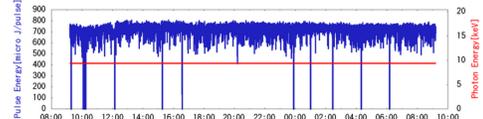
2017/11/17	SACLA Operation Status	09:12:01
Operation Mode		
BL2 User Operation		
Hutch in Use		
BL2 EH3.4b		
Pulse Energy	401.2 micro J/pulse	Photon Energy / Wavelength
Repetition Rate	30 Hz	7.0 keV / 0.177 nm
		Intensity Fluctuation in 30 shots (STD)
		8.0 %

- Pulse switching of 60 Hz beam with arbitrary beam energy (5–8 GeV) has been routinely operated at user run.

2017/11/17	SACLA Operation Status	09:11:50
Operation Mode		
User Operation		
Hutch in Use		
BL1 EH4a		
Pulse Energy	108.9 micro J/pulse	Photon Energy / Wavelength
Repetition Rate	60 Hz	102.6 eV / 12.1 nm
		Intensity Fluctuation in 30 shots (STD)
		19.3 %



2017/11/17	SACLA Operation Status	09:11:50
Operation Mode		
BL3 User Operation		
Hutch in Use		
BL3 EH2		
Pulse Energy	736.4 micro J/pulse	Photon Energy / Wavelength
Repetition Rate	30 Hz	9.4 keV / 0.131 nm
		Intensity Fluctuation in 30 shots (STD)
		7.6 %



Pulse-to-pulse control of the electron beam

T. Hara, et al., Phys. Rev. ST Accel. Beams 16, 080701 (2013)
H. Maesaka, et al., Proceedings of IPAC 2019 conference.

Individual XFEL properties of BL2 and BL3

- Photon energy (Wavelength)
- Intensity and pulse length
- Profile and direction

Common accelerator but pulse-to-pulse control

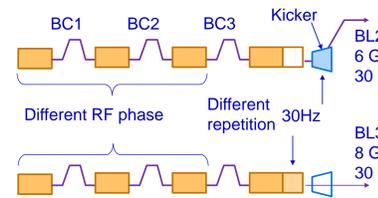
- Beam energy (RF cavity repetition)
- Pulse length (RF cavity phase)
- Beam route (Kicker magnet)
- Beam monitor (Coherent SR monitor, Beam position monitor, Current monitor,...)

New "On-demand switching" system (Sep. 2019 ~)

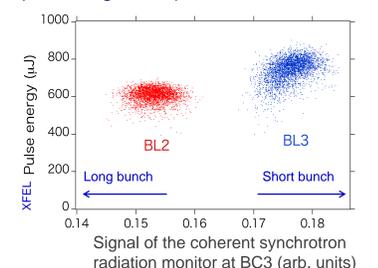
- Accept injection request from SPring-8 ring.
- Switch with arbitrary divide ratio and patterns.
- More flexible operation for user's demand.

Old system	New system allows many patterns
BL2 30 Hz	BL2 10 Hz
BL3 30 Hz	BL3 50 Hz
	BL2 59 Hz
	BL3 49 Hz
	SPring-8 1 Hz
	BL2 1 Hz
	BL3 1 Hz

Schematic of "synchronized" accelerator control system

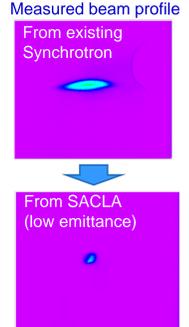
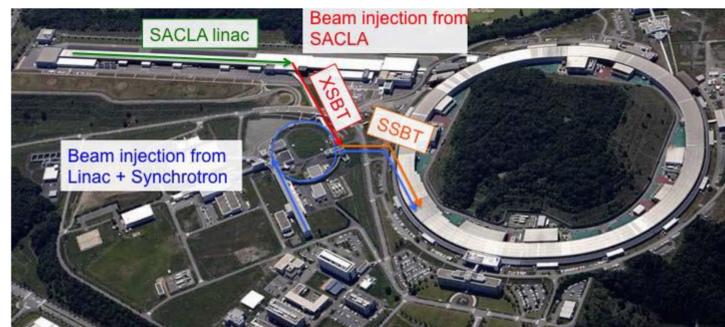


Example of the operation with different pulse length and peak current of the beam.



Electron beam injection to SPring-8

T. Ohshima, et al., Proceedings of IPAC 2019 conference.
H. Maesaka, et al., Proceedings of IPAC 2019 conference.

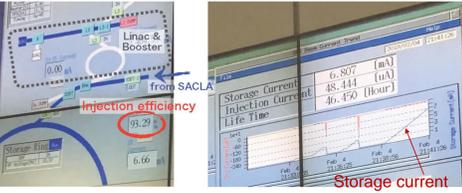
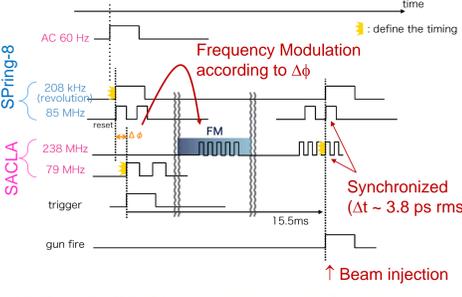


- ### Purpose
- Low emittance electron beam injection, for upgraded storage ring "SPring-8-II".
 - Shut down booster synchrotron and linac for electrical power saving (~several MW).

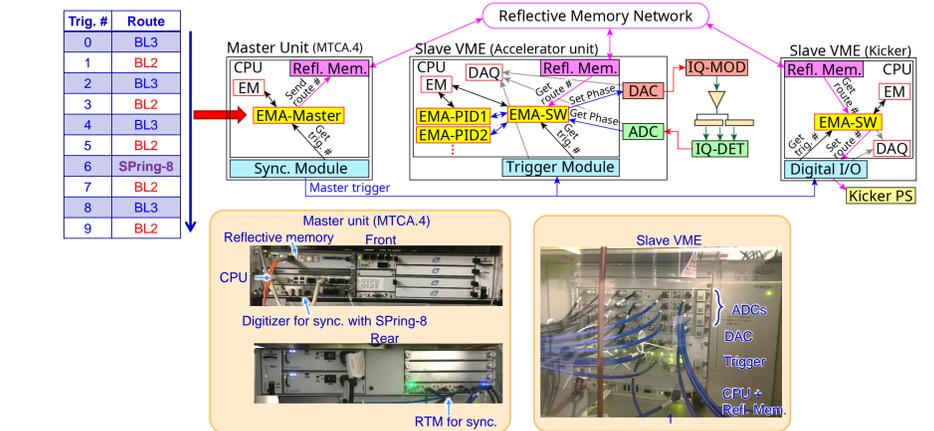
- ### Beam commissioning (Feb. 2019 ~)
- Injection efficiency > 90%
 - Parallel operation of XFEL and injection was tested.
 - Feb. 2020, first user run.

- ### Influence for SACLA beamline
- Missing the beam
 - Initial storage (10 Hz, 5-10 minutes.)
 - Top-up injection (< 1 Hz)
 - FM distorts PLL of laser system
 - Solved problem
 - Trigger timing shift ~200 μs
 - Under consideration

Timing synchronization scheme between SPring-8 and SACLA



Beam route information of each pulse is shared using a reflective memory network.

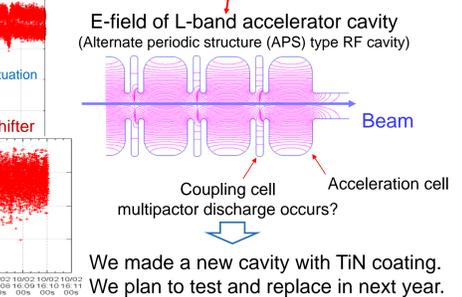
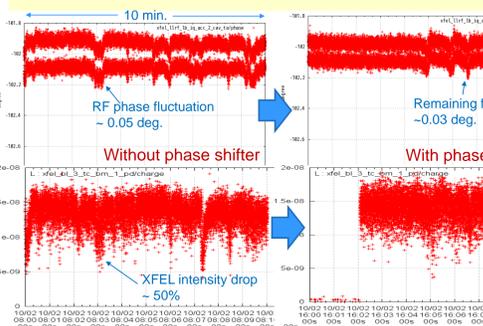


Stabilization of L-band accelerator

L-band RF fluctuates the beam and FEL
RF phase jump ~0.05 degree (=100 fs)
→ electron beam energy & timing change
→ FEL intensity degradation (~50%)

T. Asaka, et al., Phys. Rev. Accel. Beams 20, 080702 (2017)

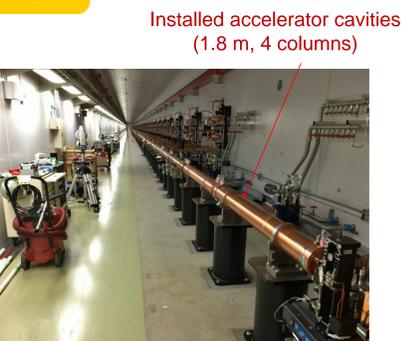
- ### Countermeasure
- Phase shifter (Oct. 2018 ~)
Mitigate the fluctuation.
 - New accelerator cavity (planned 2020 ~)
TiN coating to suppress multipactor discharge.



Add 2 units of C-band accelerator

- ### For SPring-8 beam injection
- C-band accelerator unit: 52 → 54
 - Electron beam energy 7.8 GeV → 8 GeV.
 - Enough back-up RF units for emergency.
 - Intensity increase for high energy XFELs.

- ### Schedule
- Aug. 2018 Install accelerator cavities.
 - Nov. 2018 Install klystron & modulator
 - Dec. 2018 Connect waveguides
 - Jan. 2020 Conditioning of RF cavities
 - Apr. 2020 Use for beam acceleration



We made a new cavity with TiN coating. We plan to test and replace in next year.