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A Soft X-ray Free-electron Laser Beamline at SACLA

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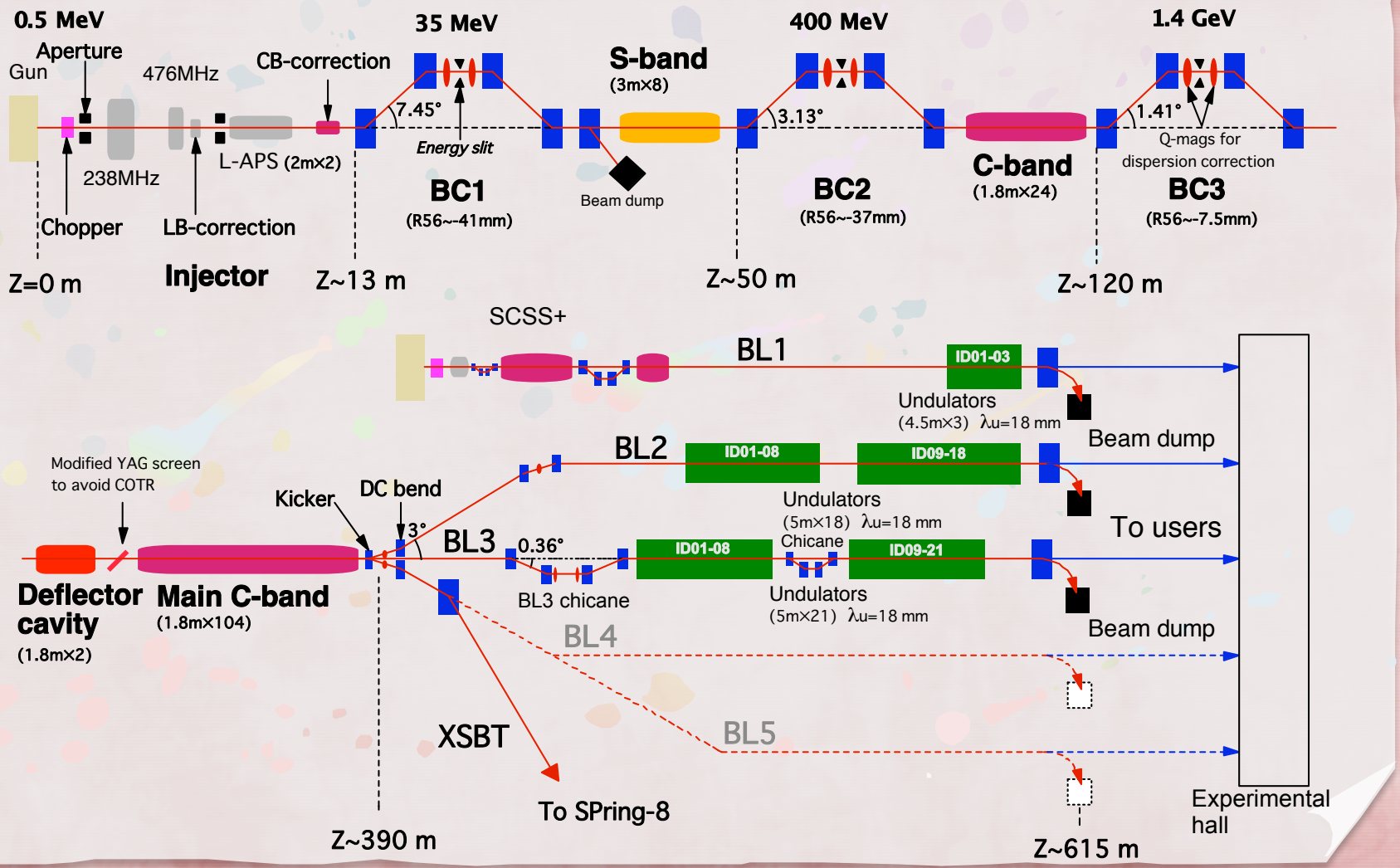
Japanese X-ray Free-electron Laser Facility SACLA

Features of SACLA

- Provide stable high-intensity short-pulse XFEL lights for AMO physics, chemistry, biology, solid-state physics, material science, etc.
- Cover wide wavelength range from soft x-ray to hard x-ray.
- Simultaneous operation of plural FEL beamlines.
- As injector linac for SPring-8 SR ring.

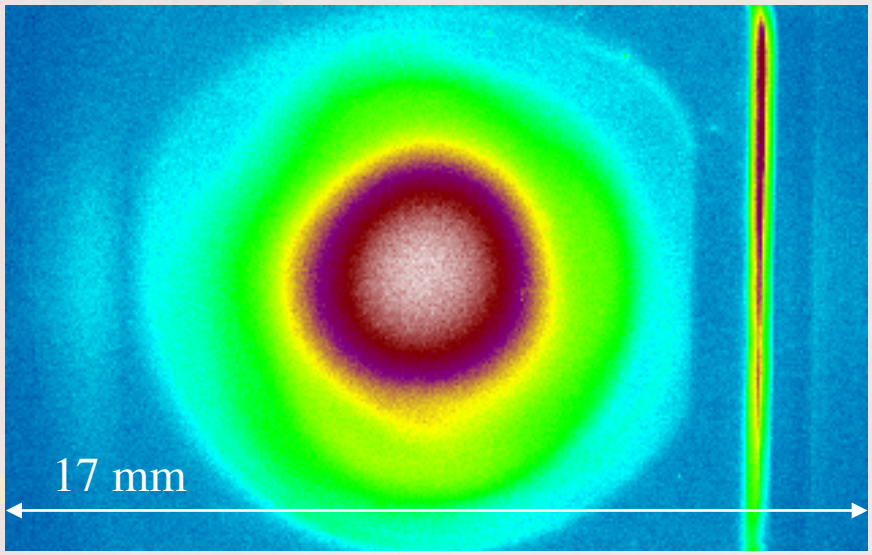
Schematic of SACLA Accelerator

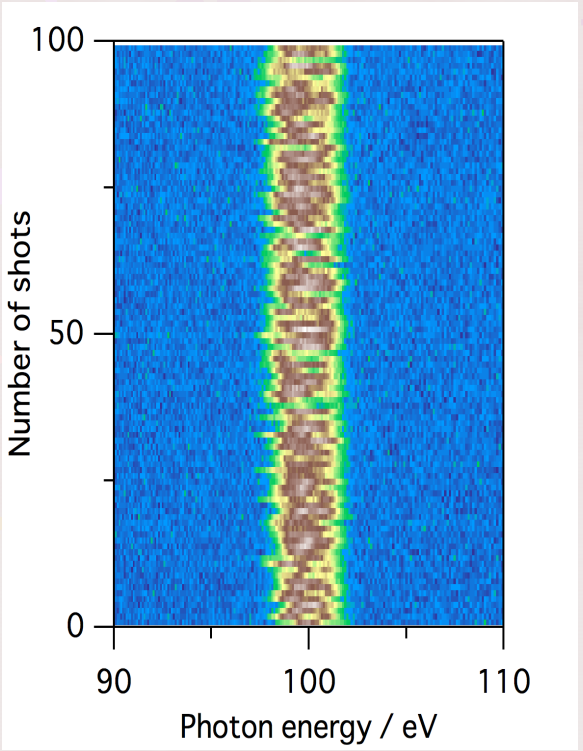


Brief History of SACLA Soft XFEL Beamline (BL1)

- 2012: SACLA begun user operation.
- 2013: The SCSS test accelerator (250 MeV, prototype) was shut-downed.
- 2014: The SCSS test accelerator was moved to the SCALA undulator hall and used as a dedicated accelerator of the soft x-ray beamline BL1 (500 MeV).
- 2015: First SASE lasing at 37 eV.
- 2016: Energy was upgraded to 800 MeV and power saturation at 100 eV (λ=12 nm) was accomplished.
- 2016: Experimental user operation started (20 eV-150 eV).

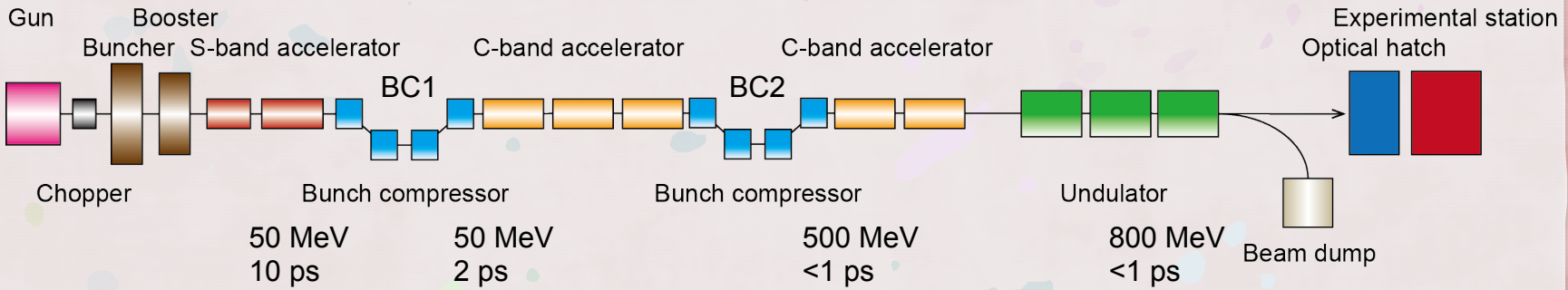
Soft XFEL Beam at Optical Hatch





- FEL photon energy: 100 eV.
- Ce: YAG screen located 50-m downstream of the undulator.
- Symmetric Gaussian profile.
- Stable SASE spectrum.

SACLA-BL1 Accelerator



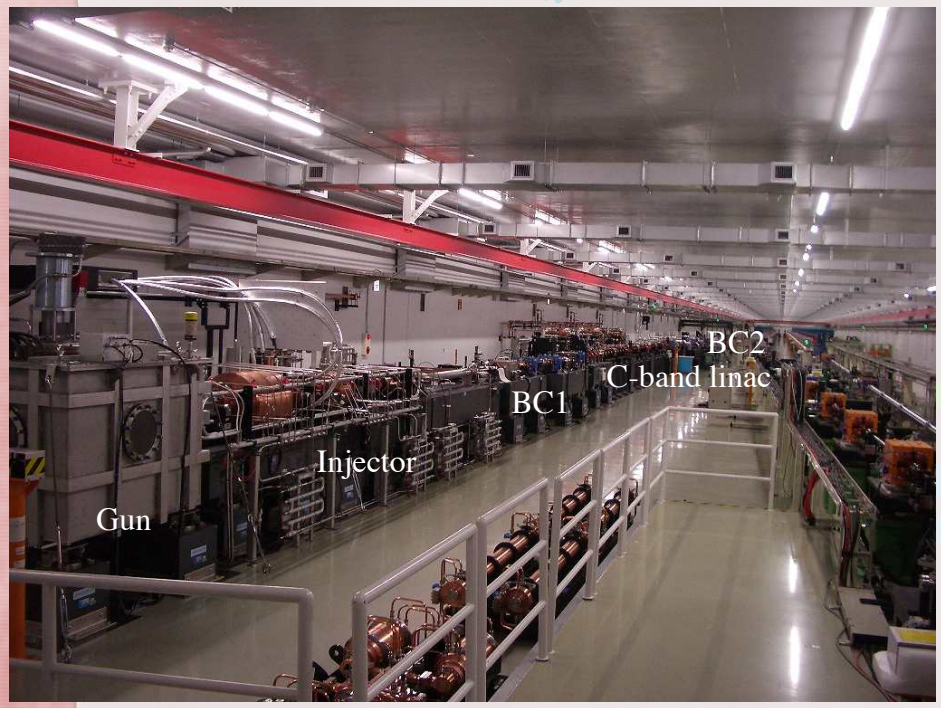
Electron beam

Beam energy	300-800 MeV
Bunch charge	0.2-0.3 nC
Peak current	300 A (simulation)
Bunch width	<1 ps
Energy spread (projected)	0.6% (fwhm)
Normalized emittance (projected)	3 mm mrad
Repetition rate	60 Hz

Undulator

Periodic length	18 mm
Number of undulator modules	3
Total number of period	777
Maximum K-value	2.1
Minimum gap	3.8 mm
FEL Photon energy range	20-150 eV
FEL pulse energy	several-100 μJ

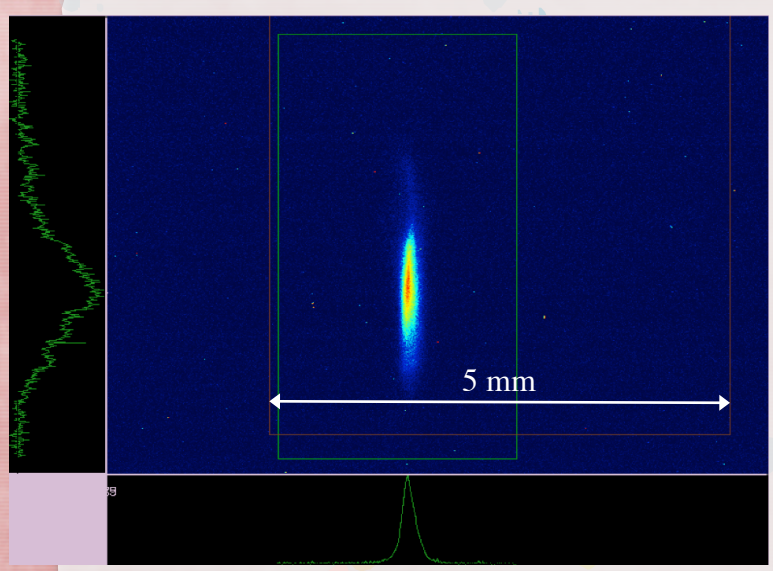
SACLA-BL1 Accelerator



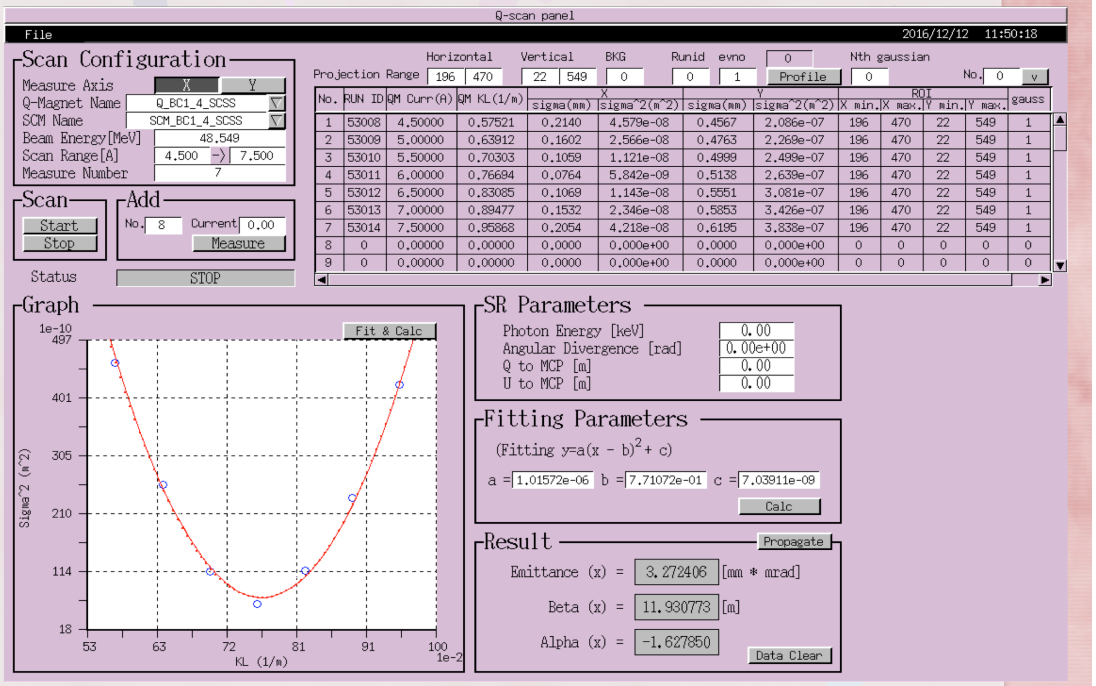
Upstream of SACLA undulator hall

Downstream of SACLA undulator hall

Emittance Measurement

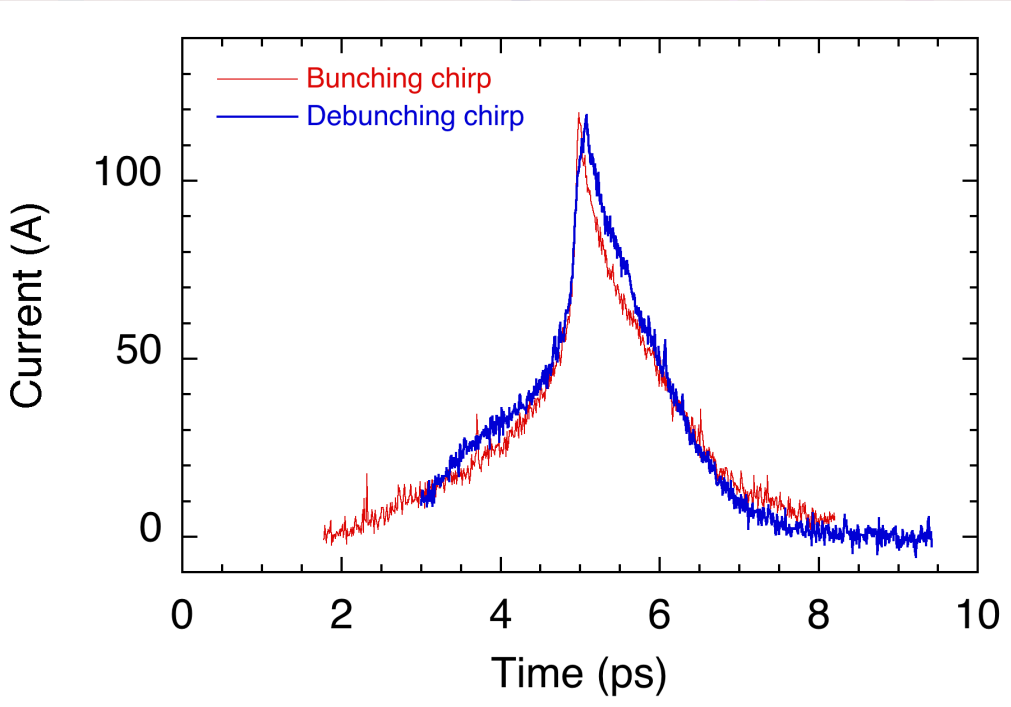


Horizontally-focused beam



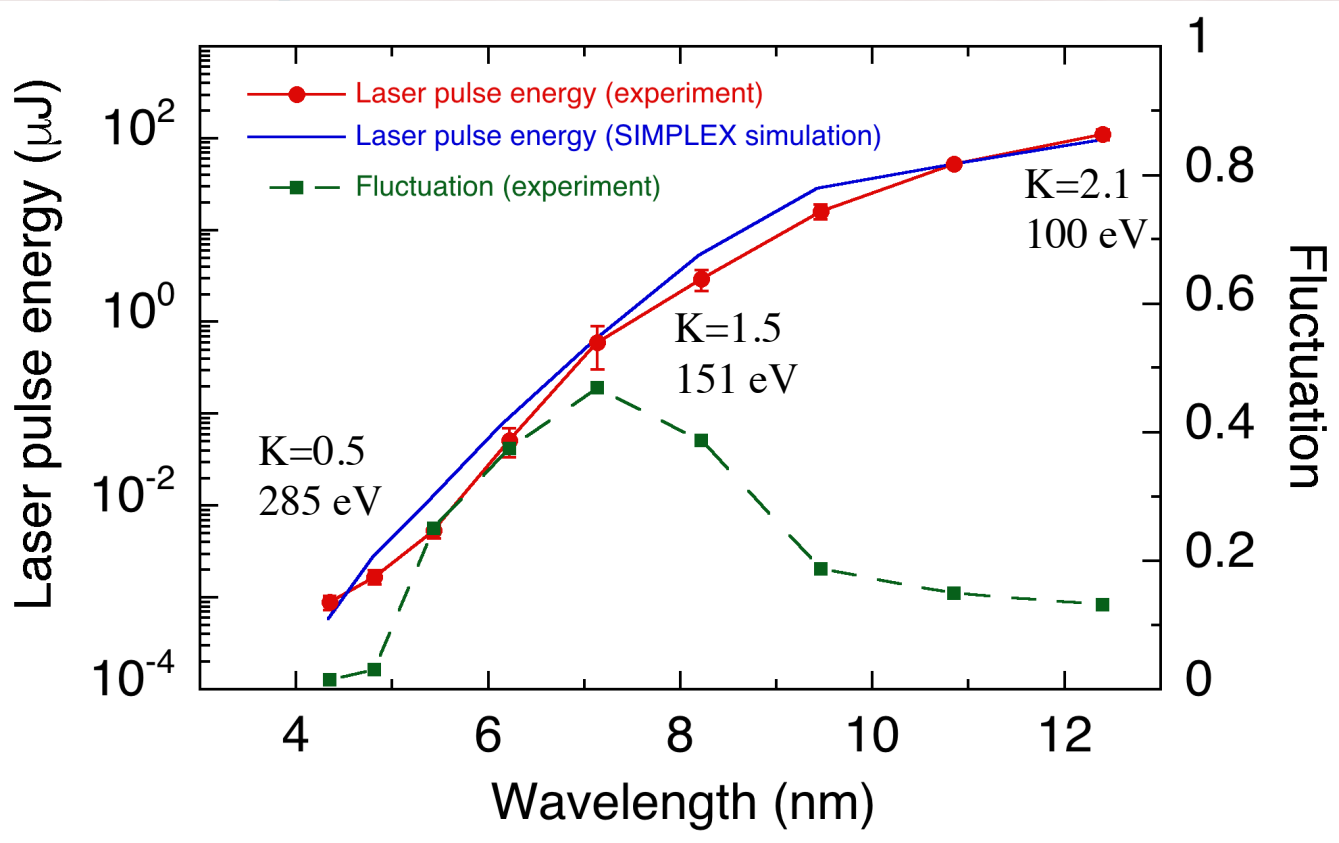
- Quadrupole-magnet-scan method.
- Measured at the first bunch compressor exit (50 MeV).
- Normalized-rms-projected emittance: 3 mm mrad.
- Reproduced the original SCSS test accelerator.

Longitudinal Beam Profile after BC1



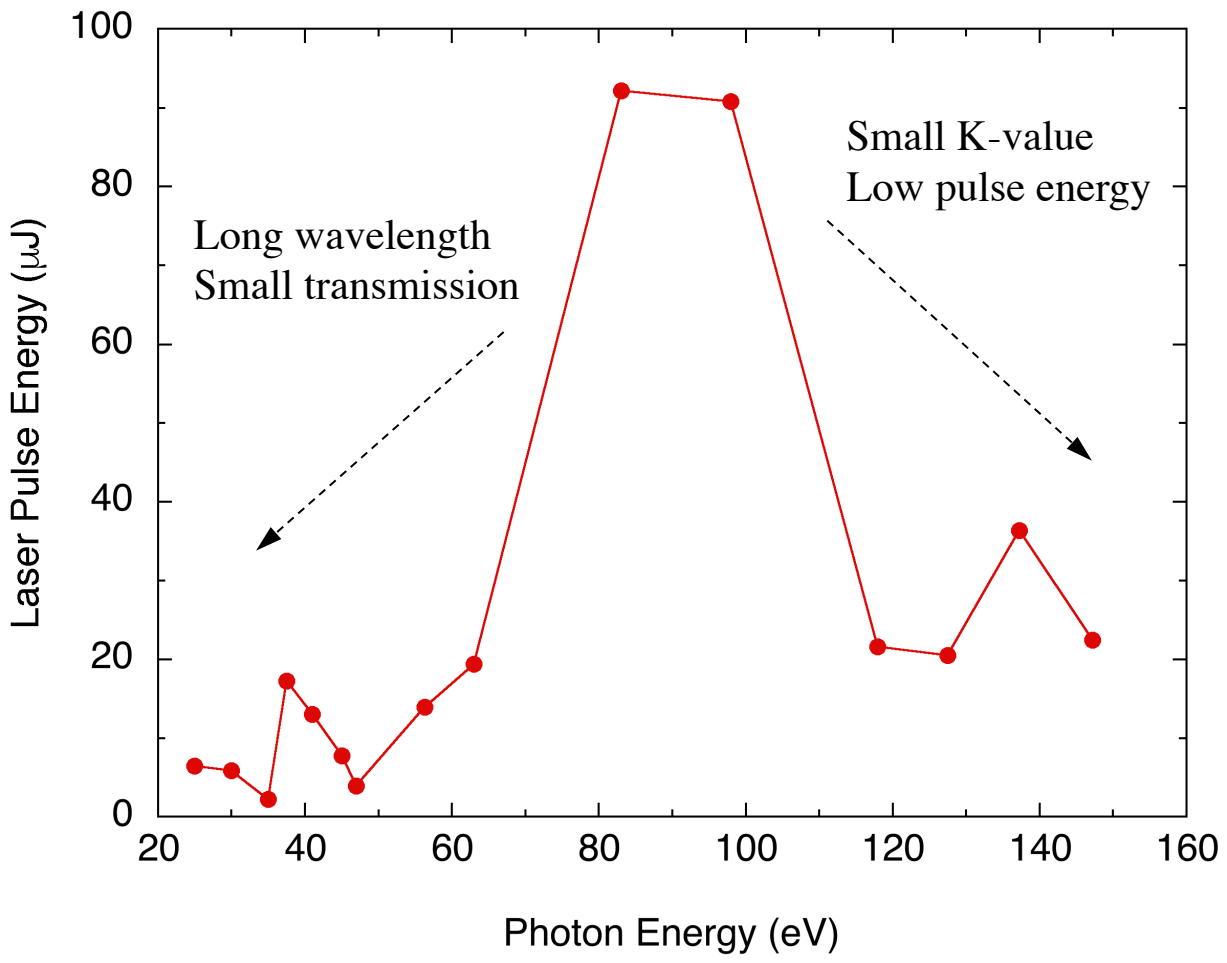
- Rf zero-phasing method (after BC1).
- Add linear energy chirp at the 3rd C-band unit then energy analyzed at BC2.
- Peak current: 120 A, Bunch width: 0.8 ps.
- Profile at the undulator section has not been measured so far.

FEL Gain Curve

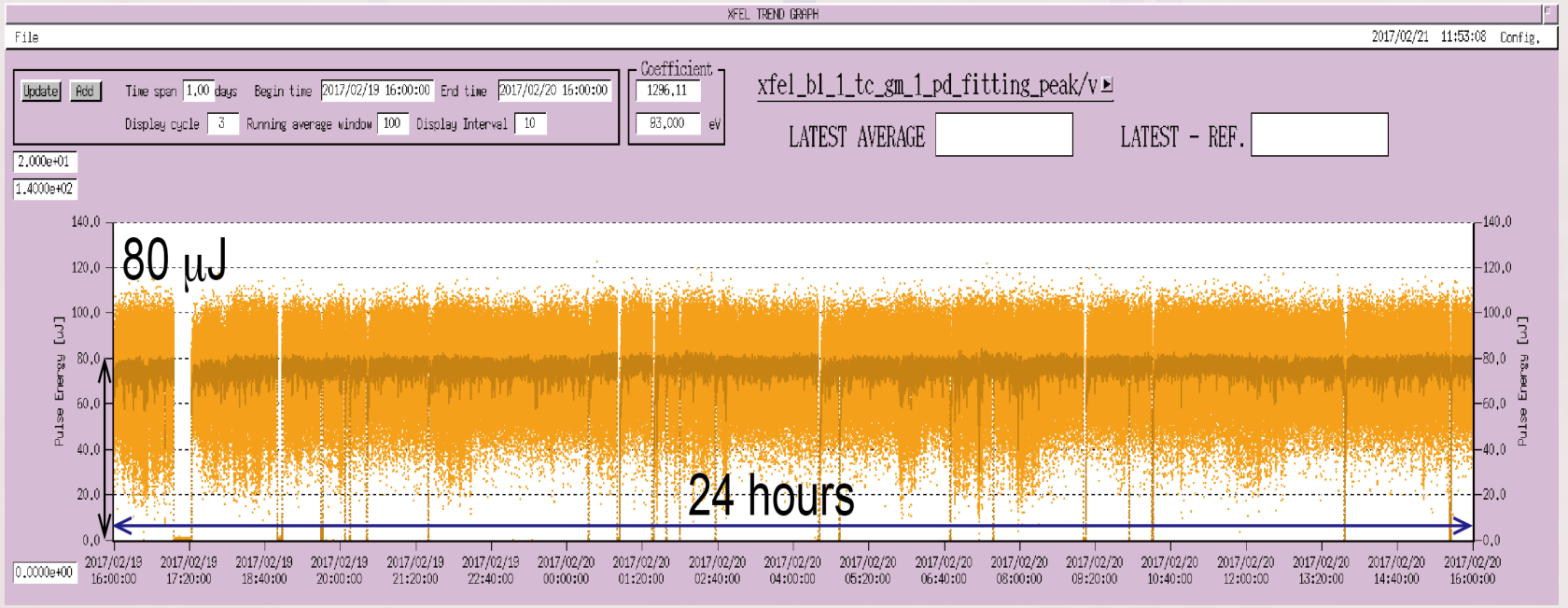


- Scan undulator gap (K=0.5 to 2.1).
- Calorimeter (>1 μJ), photodiode with N_2 attenuator (<1 μJ).
- Good representation by SIMPLEX simulation.
  (Gaussian, I_p=300 A, t=0.7 ps (fwhm), $\varepsilon_{n,\,rms}$=0.5 mm mrad).

Available FEL Pulse Energy



User Operation



- FEL photon energy: 93 eV.
- Yellow: single shots, Brown: 100-shots averaged.
- Stable laser pulses are delivered to experimental users.

Next and Future Upgrades

- Increase pulse energy by nonlinear energy chirp correction using a higher-harmonic rf cavity or higher-order multipole magnets.
- Energy upgrade from 800 MeV to 1.8 GeV. The fundamental FEL wavelength can reach water-window region (2-4 nm) at BL1.
- The other soft x-ray FEL beamline (BL5) will cover the blank wavelength between 1 keV to 4 keV.

Summary

- The SACLA-BL1 has been upgraded to deliver intense soft XFEL beams to experimental users.
- Currently, several to one hundred μJ pulses with a photon energy range from 20 to 150 eV can be provided at 60 Hz.
- We will try to increase the laser pulse energy by a nonlinear energy chirp corrector.