Demonstration of Two-color XFEL Operation and Autocorrelation Measurement at SACLA

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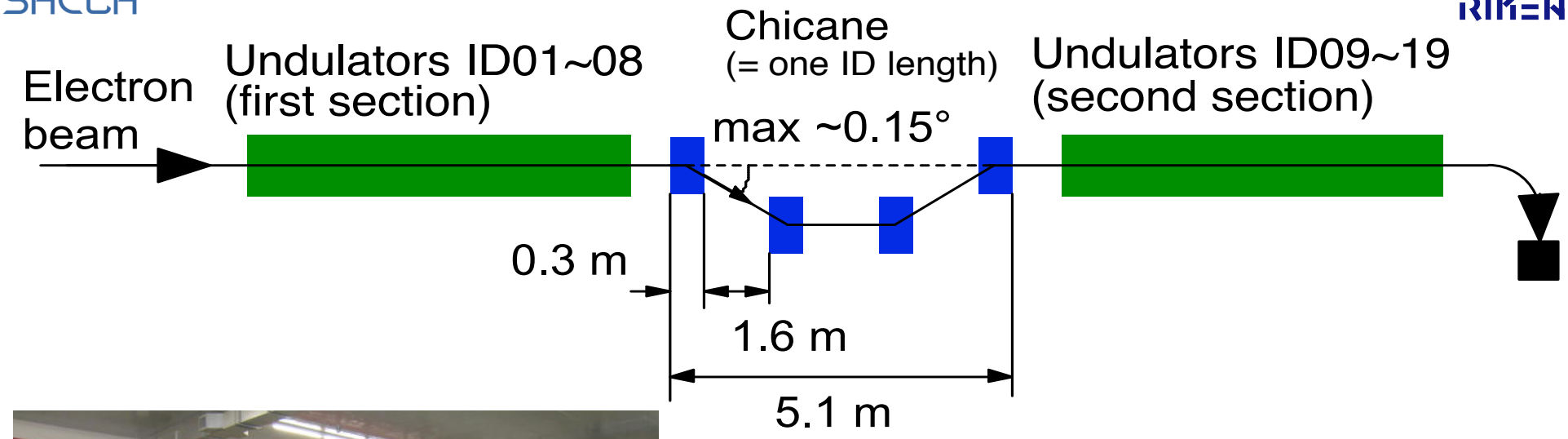
Contents

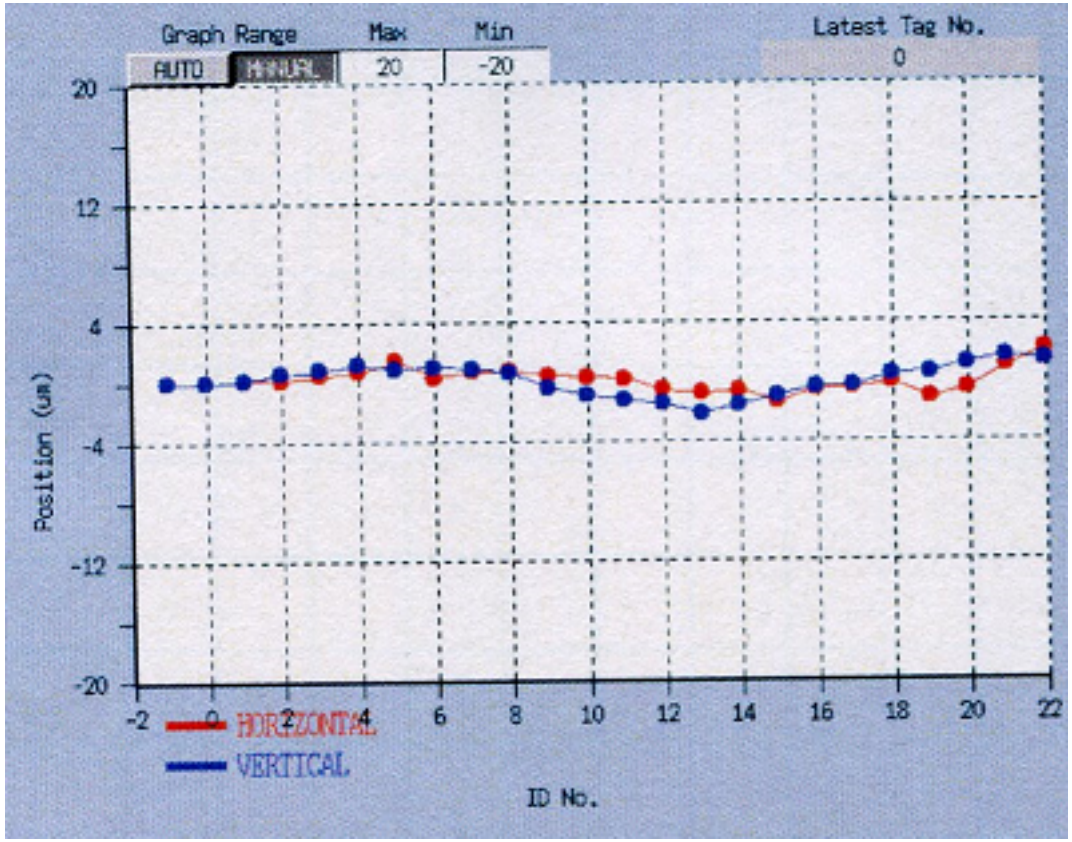
- Laser pulse length measurement with an autocorrelation method.
- Two-color XFEL operation.
- Bunch by bunch multi-energy operation of a linear accelerator.
- Future upgrade plans.

Installation of a chicane in SACLA BL3



- Self-seed experiments.
- Laser pulse length measurements using an autocorrelation technique.
- Time delay for two-color operation.
- Maximum time delay 45 fs for 8 GeV with sub-fs resolution.

Orbit correction of chicane

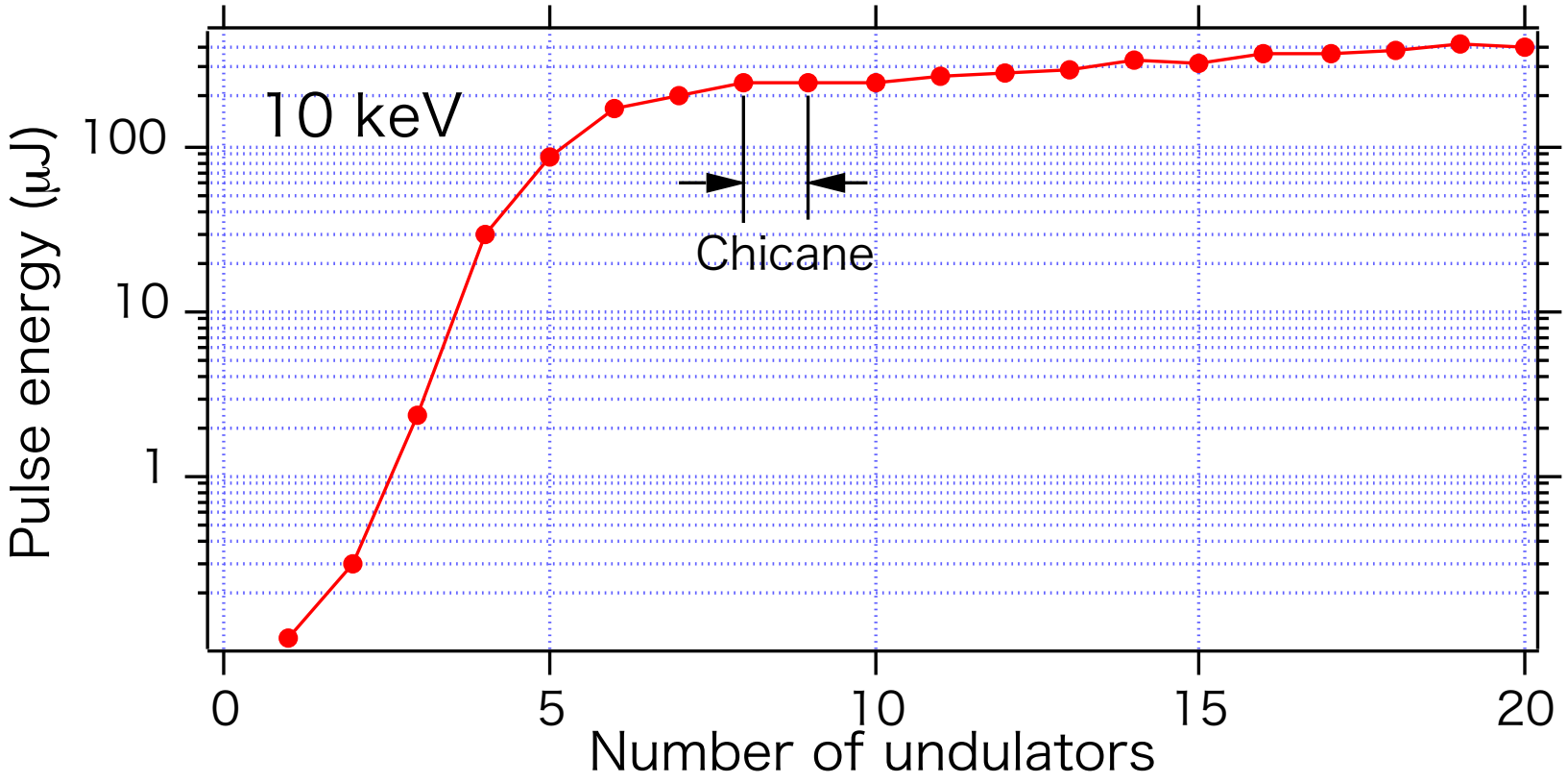


Orbit deviation at maximum delay with respect to 0 delay.

Beam orbit deviations are within±2 μm.

Feed forward orbit correction as a function of the chicane current using a pair of steering magnets.

Gain curve at 10 keV



Measured gain length indicates a laser pulse length around 2-3 fs.

Laser pulse length measurement autocorrelation technique

Gaussian pulse assumed.

Laser pulse length measurement spectral spike width

Single shot spectrum measurement using Si (660) with a resolution ~70 meV.

Normal operation

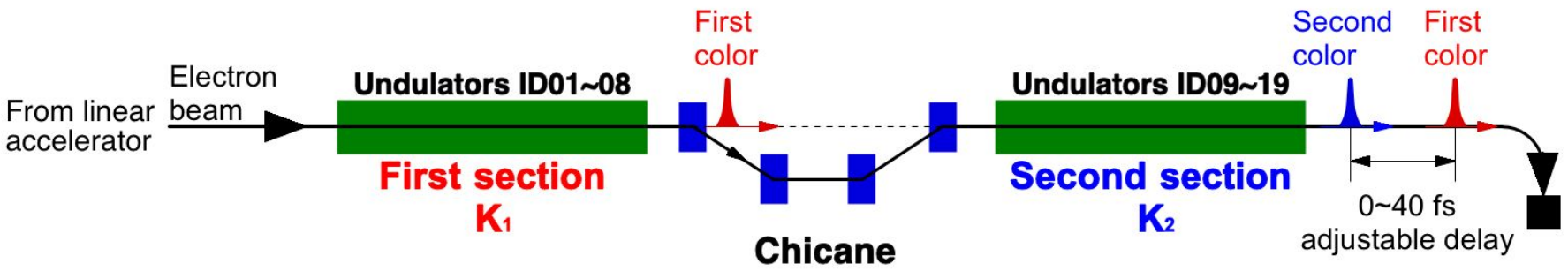
Long bunch with smaller compression factor.

Laser pulse length measurement
spectral spike width

The laser pulse length of SACLA is less than 10 fs (FWHM).
Some current spikes exist?

Two-color XFEL operation in SACLA

- First two-color operation in hard x-rays.
- Simple scheme: 19 undulators of of BL3 are divided into 2 sections with different K-values.
- Two-color FEL is already open to the user experiments.



- Two wavelengths are tunable with maximum separation of ~30 %.
- Time delay between two pulse can be adjusted between 0~40 fs with a sub-femtosecond resolution.

Unpublished data

Averaged spectrum of 2-color operation

- K=1.92 (9 keV) for the first half of undulators (ID01-08), K=2.1 (8 keV) for the last half (ID10-19).
- Total pulse energy is about 130 μJ.
- No delay dependent output change.

Unpublished data

Averaged spectrum of 2-color operation

- To equilibrate two outputs, the lasing of the first color was stopped well before saturation.

Two-color XFEL operation in SACLA

Correlation between the first- and second-color intensities.

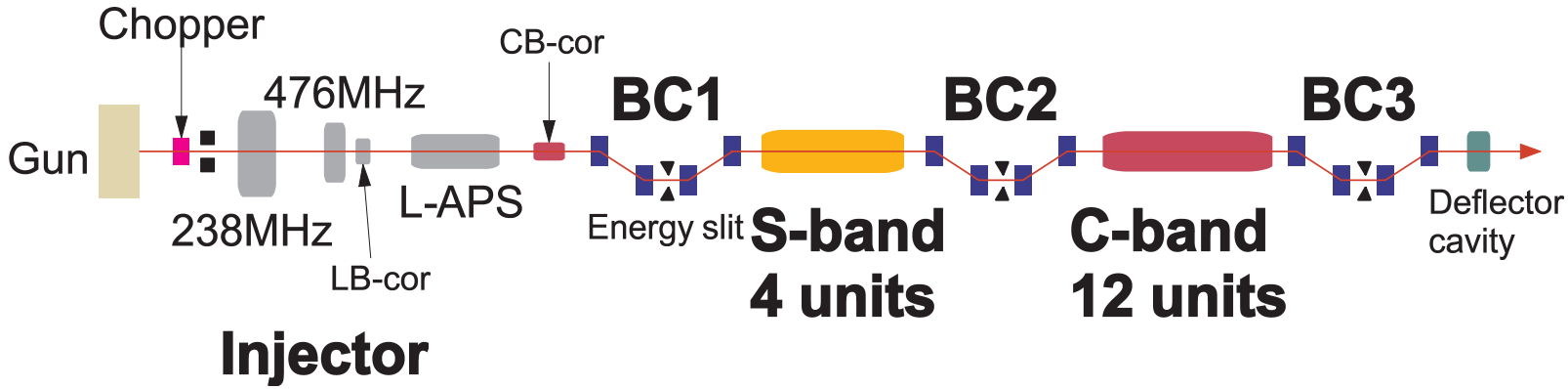
Two-color XFEL operation in SACLA

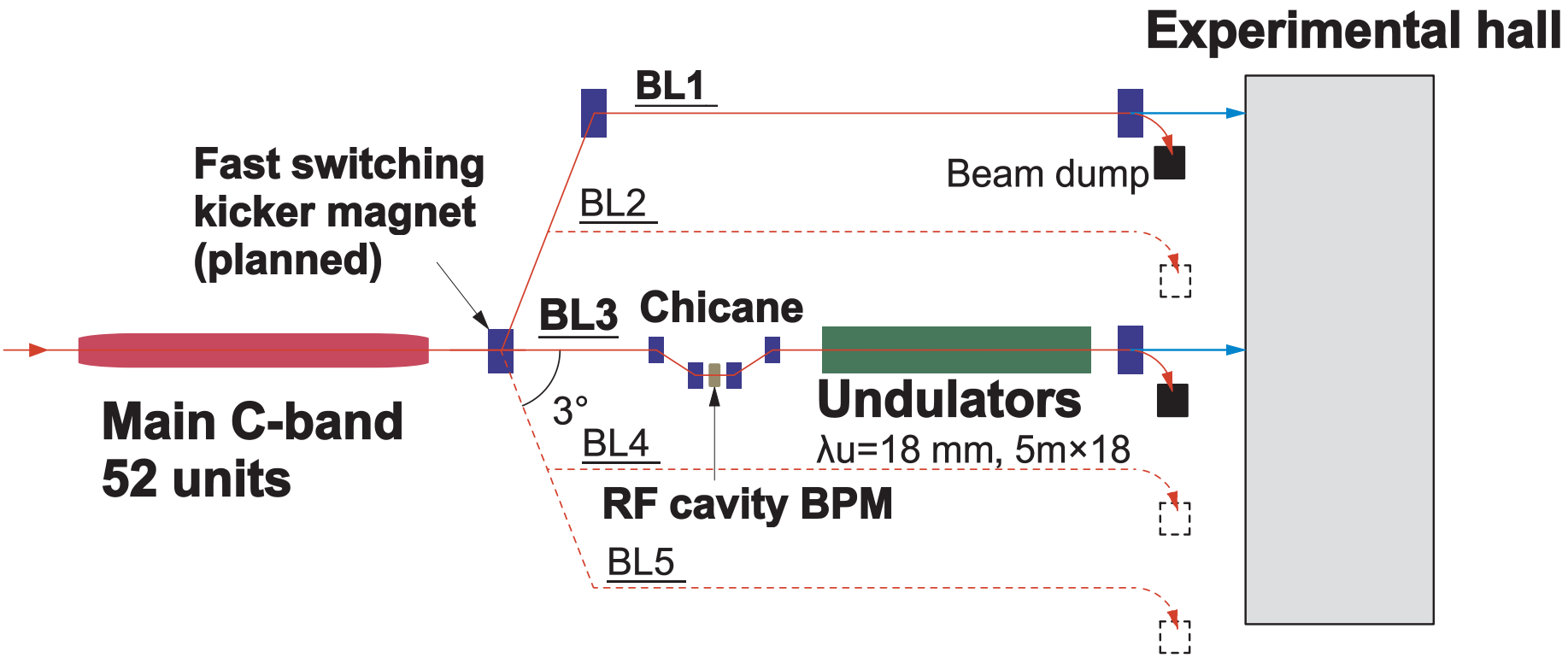
- The maximum separation of two wavelengths is about 30 %.
- Peak power of the laser pulse reaches several GW.

Two-color XFEL operation in SACLA

- Spatial separation of two-color pulses.
- Electron beam is deflected by 10 μrad at chicane.
- Undulators and Q-mags are realigned along the deflected orbit (2-3 mins).

Multi-beamline operation of SACLA





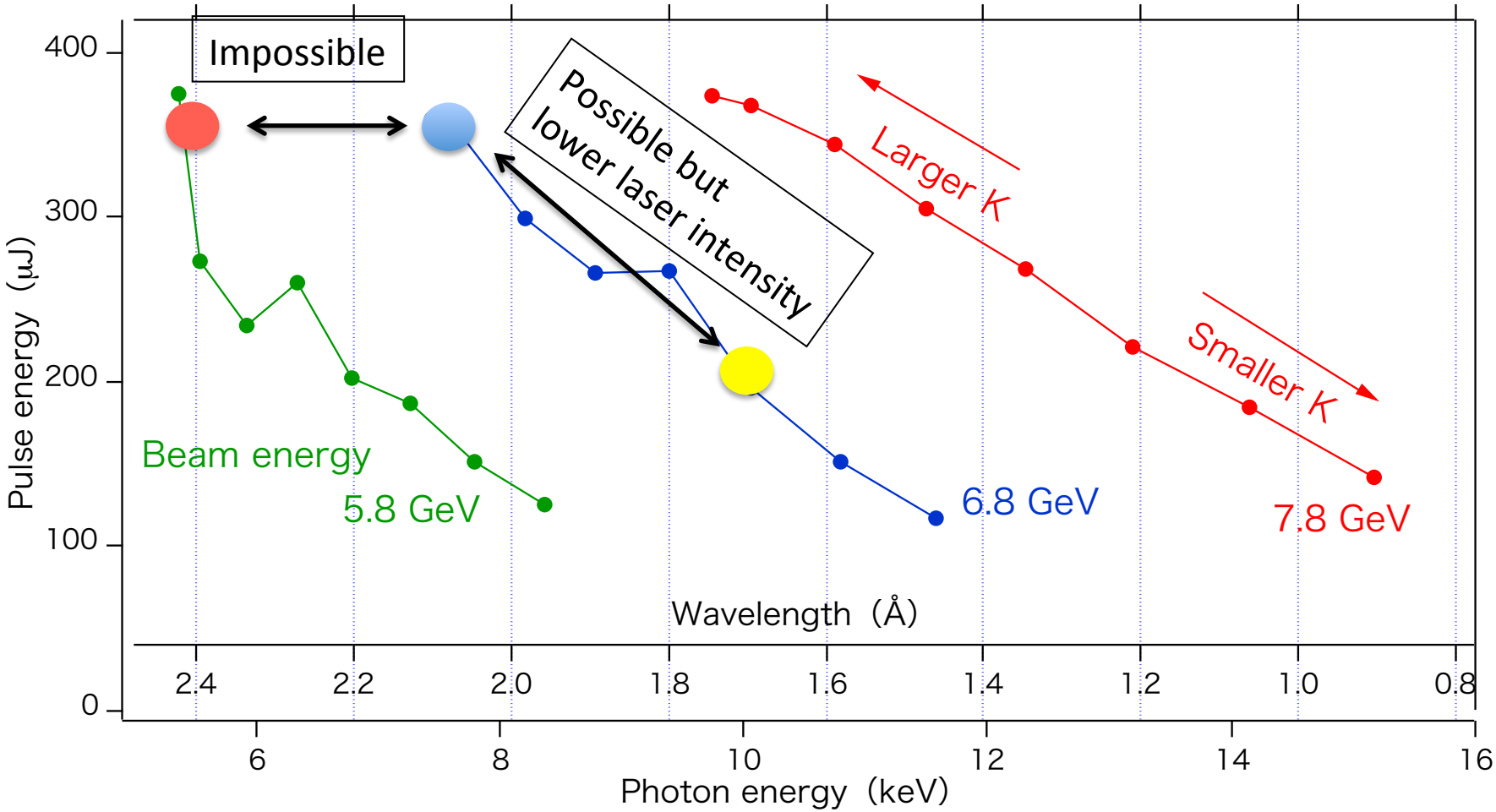
How to adjust the beam energy?

Laser wavelength

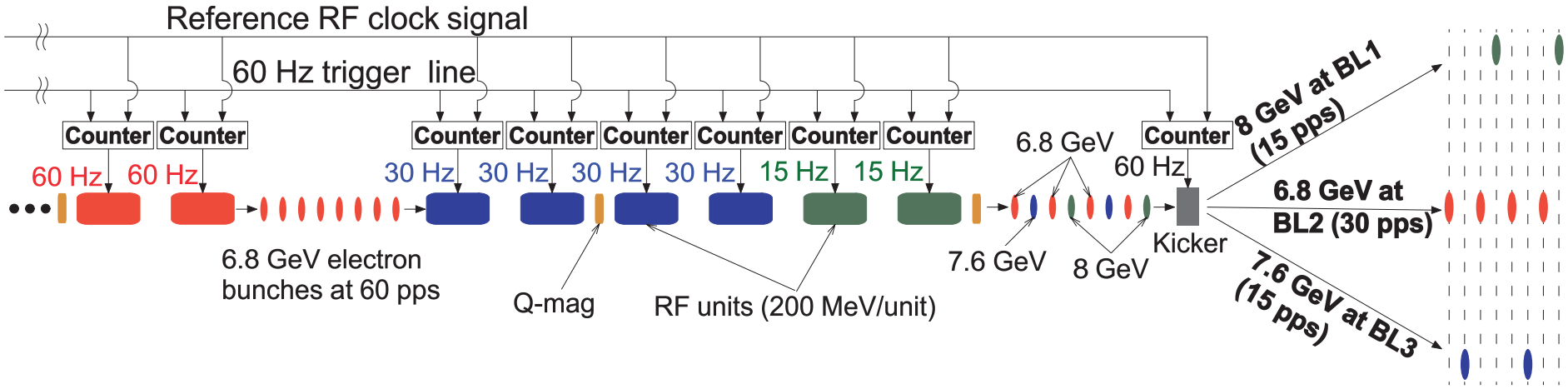
Electron beam energy

Undulator gap

$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1+\frac{K^2}{2}\right)$$



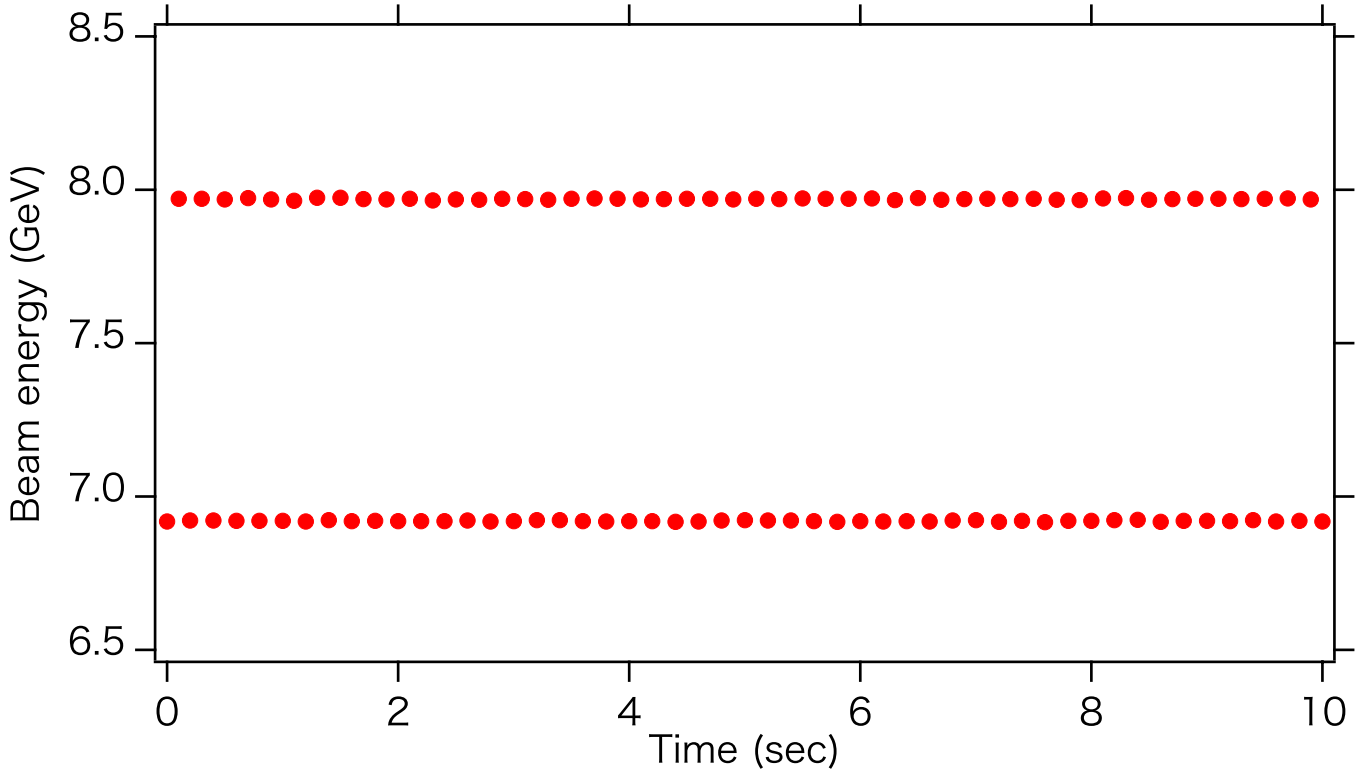
Beam energy control from bunch to bunch



- Bunch to bunch distribution to multi-beamline using a fast switching magnet (kicker + DC septum).
- Electron beam energy needs to be changed from bunch to bunch.
- Fast parameter change from bunch to bunch leads to instable operation of RF.
- Since all RF systems operate under steady condition, the developed method does not degrade the accelerator stability.

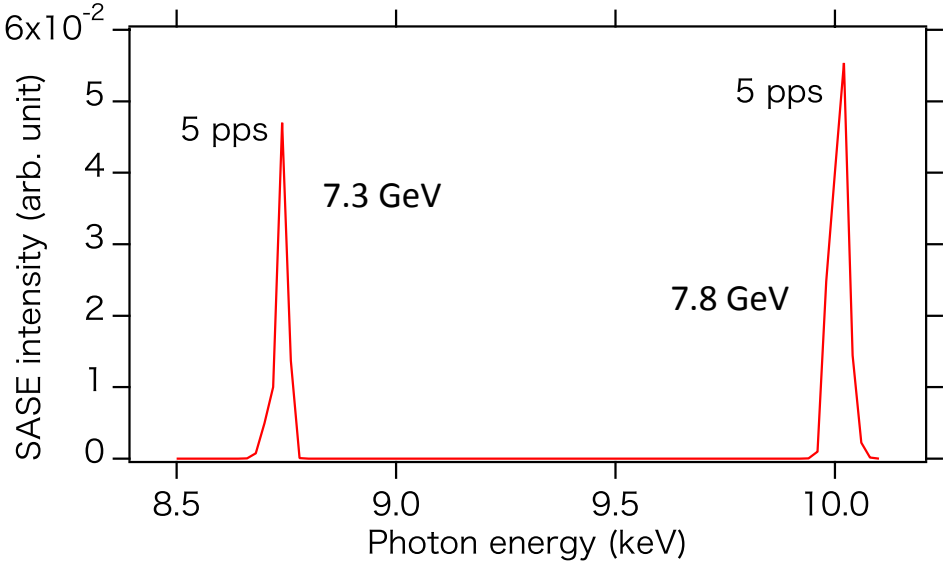
Demonstration of the multi-energy acceleration

Since a fast switching magnet has not yet installed, all bunches are sent to BL3.
The beam energy is measured at upstream chicane of BL3 undulators.

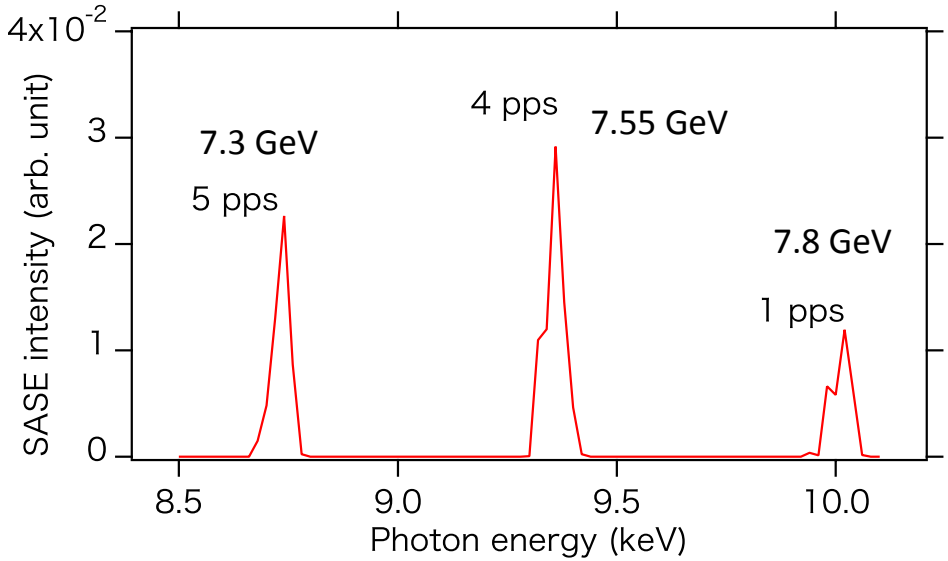


- Bunch repetition 10 Hz.
- 8 C-band RF units (16 accelerator structures) are operated at 5 Hz.

Demonstration of the multi-color lasing from bunch to bunch

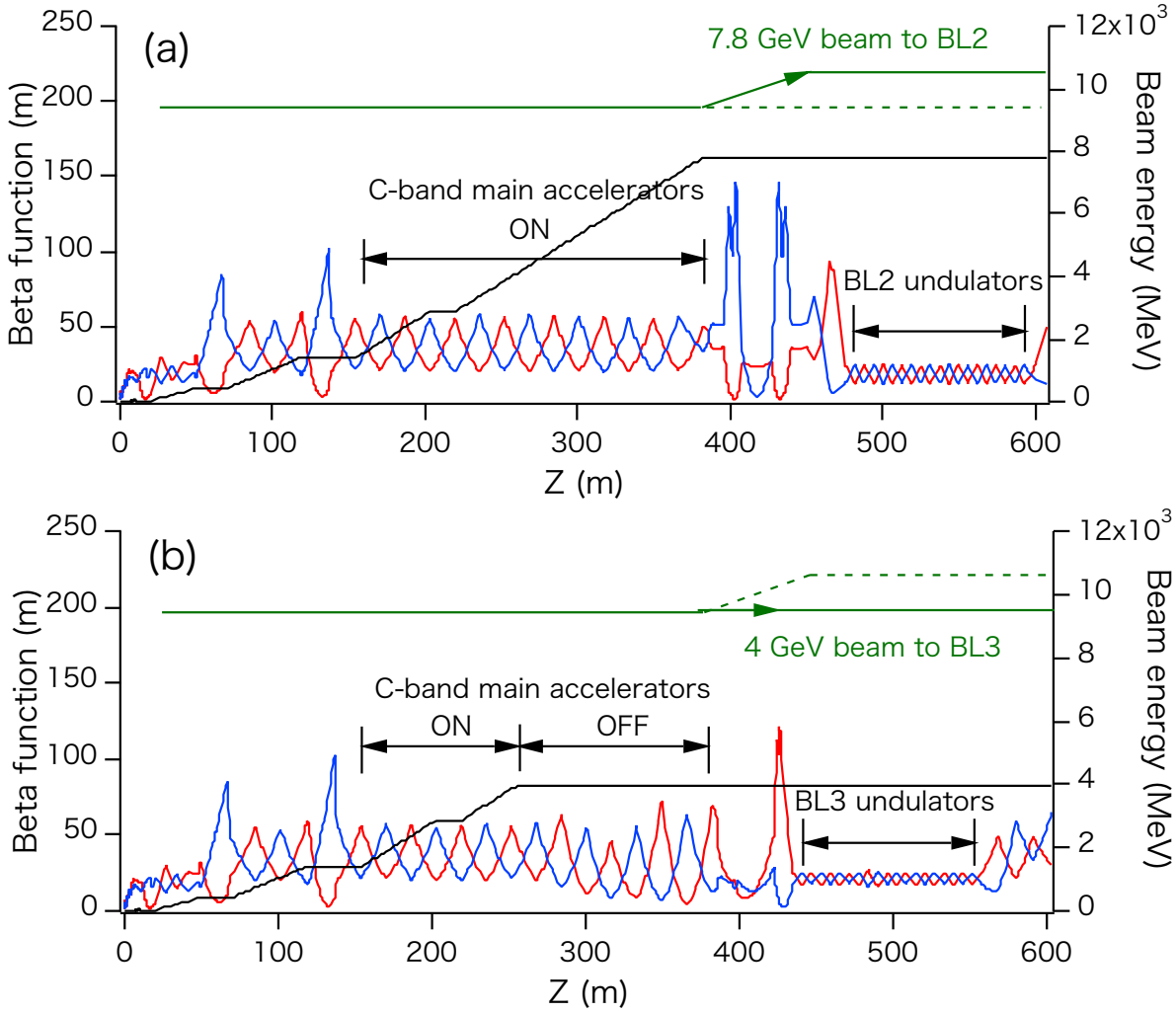


Bunch repetition 10 Hz
C-band 4 RF units 5 Hz



Bunch repetition 10 Hz
C-band 2 RF units 5 Hz
C-band 2 RF units 1 Hz

Multi-energy operation from bunch to bunch



Beam envelope and orbit can be readjusted after the switching magnet .

Expected energy range, for example 4~8.5 GeV.

Beam envelop can be matched to the undulator FODO.

Future upgrade plans of SACLA

- Self-seed experiments to generate Fourier transform limited pulses (autumn 2013).
- Beam injection to SPring-8 (SACLA to booster synchrotron, autumn 2013)
- Installation of the second beamline BL2 (summer 2014)
- Move SCSS test facility to SACLA undulator hall (from 2013 to 2014)
- Development of a fast switching magnet.

Near future plans of SACLA