COMMISSIONING AND PERFORMANCE OF THE BEAM MONITOR SYSTEM FOR XFEL/ SPRING-8 "SACLA"

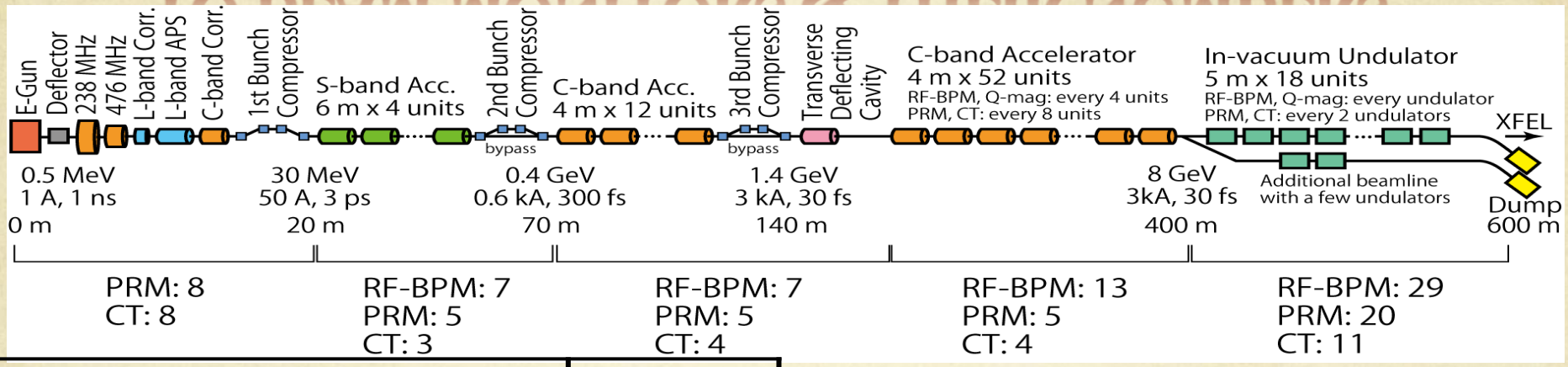
Y. Otake*, H. Maesaka, S. Matsubara,
S. Inoue C. Kondo, T. Sakurai, K. Yanagida,
H. Ego, T. Matsumoto and H. Tomizwawa

RIKEN, SPring-8 Center, XFEL Research & Development Division.

JASRI, XFEL Division

SPring-8 Service Co. Ltd.

DEMANDED SPATIAL AND TEMPORAL RESOLUTION TO BEAM MONITORS & THEIR NUMBERS

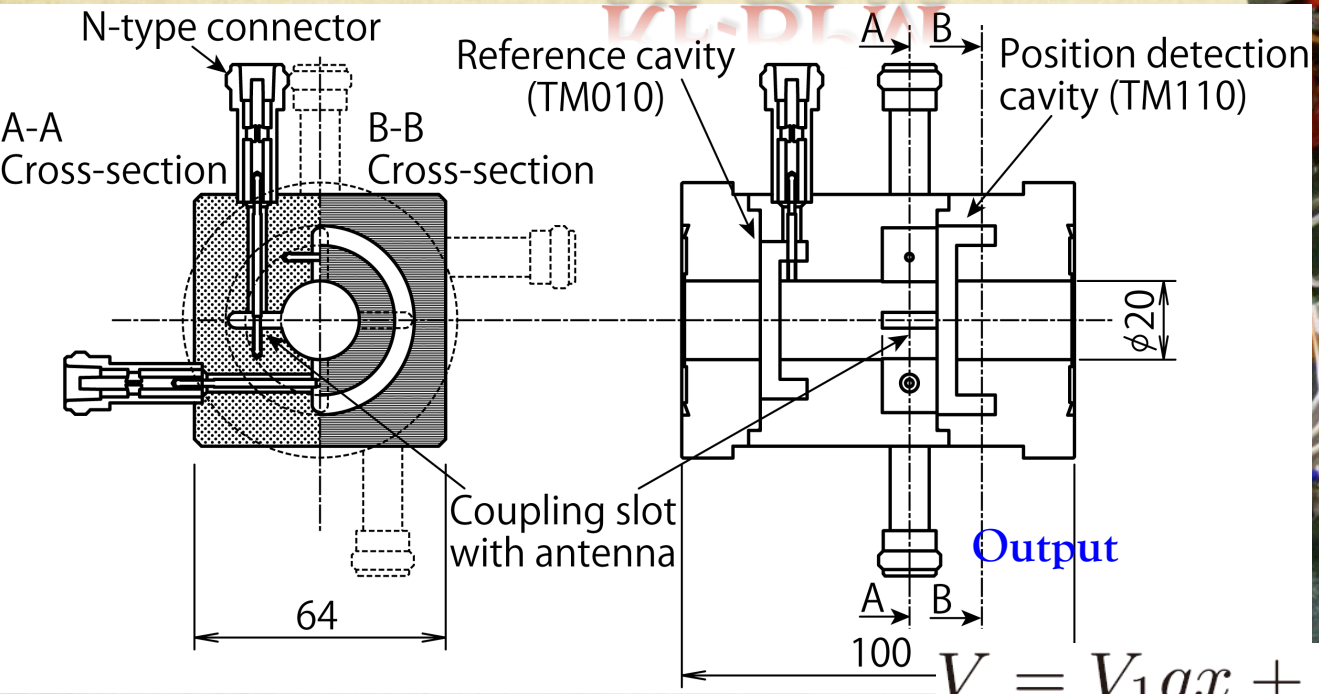


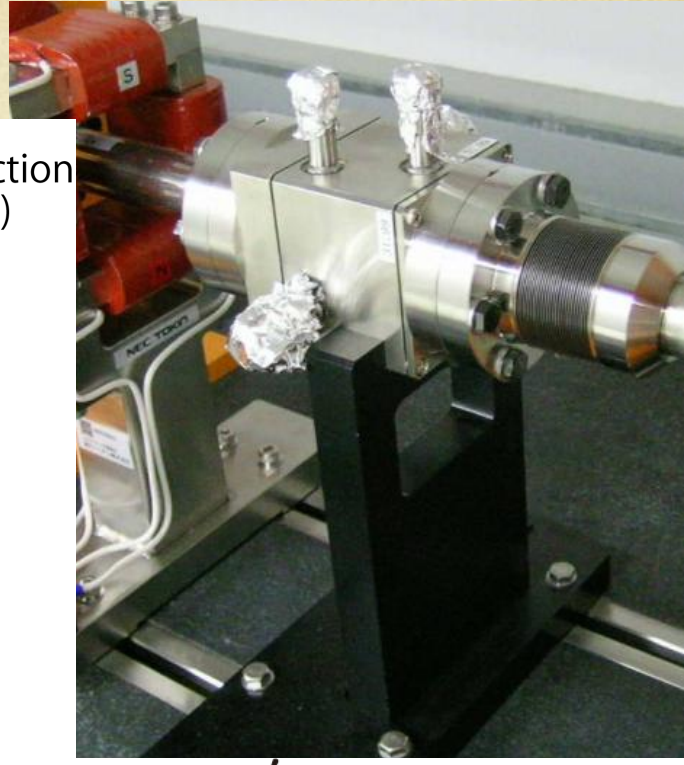
Kinds of Monitor	Number
RF cavity BPM	57
Multi-stripline BPM	4
Screen Monitor	43
Differential Current Transformer	30
Transverse rf Deflector	1
OTR Bunch Length Monitor using Streak Camera	3
EO Sampling	1
Waveguide Spectrometer	4 ~ 5
CSR Pyro-detector	3

To keep stable lasing, the beam monitors must measure a spatial resolution of less than 1 μm for the undulator section, a 30 fs beam pulse width, and a beam arrival time of less than 30 fs after the BCs.

SACLA RIKEN SPring-8

RF-BPM





$$V = V_1 qx + jV_2 qx' + jV_3 q + V_n$$

Noise

Position signal
In-phase

Slope signal
Quadrature-phase

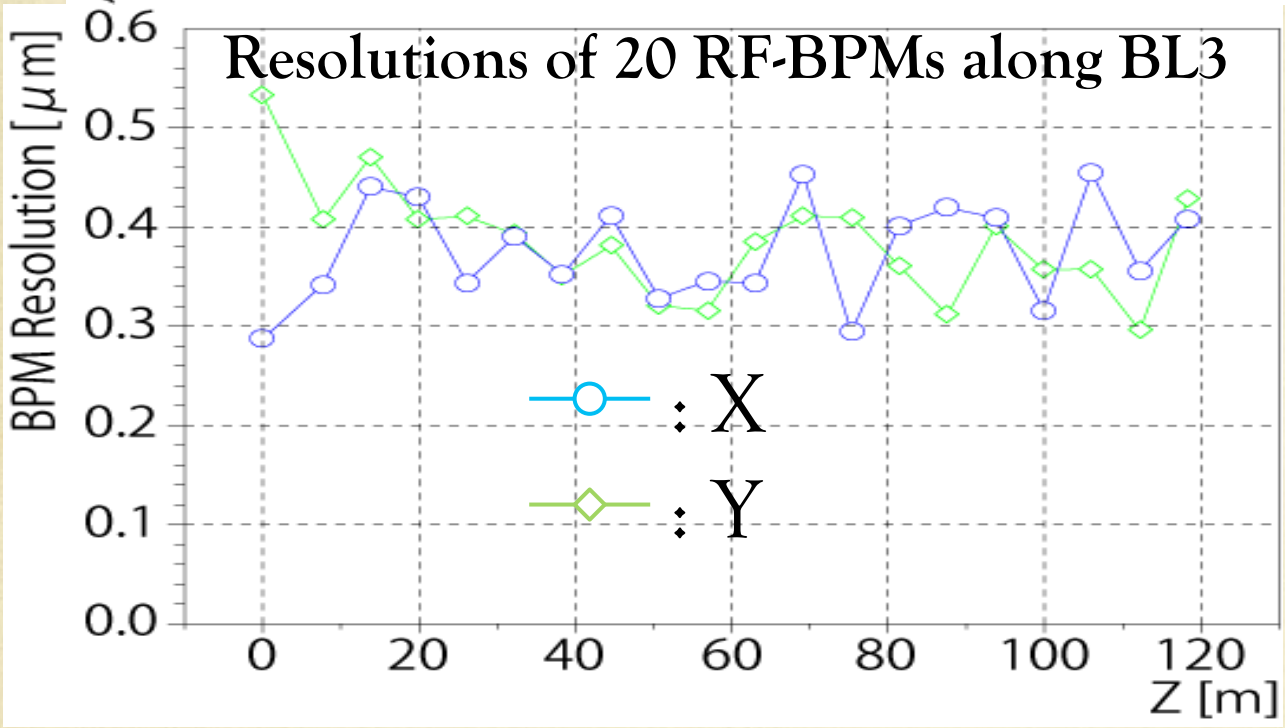
Leakage of TM010 mode
Quadrature-phase

Excited E field

$$E_z = E_0 \, J_1\left(\frac{\chi_{11} r}{a}\right) \cos\phi \; e^{j\omega t}$$

- The beam position is measured with a TM110 cavity.
- The beam intensity and phase are also measured with a TM010 reference cavity.
- Cavity resonant frequency : 4760 MHz
- This BPM can also measure a beam arrival time.

ESTIMATED RF-BPM RESOLUTION USING MEASURE DATA



- RF-BPM Resolution: RMS of the difference between the measured position and the estimated one.
- Resolution is less than 0.6 μm.

RF-BPMs

- 20 BPMs around IDs of the BL3 beamline (120m-long)

Electron beam

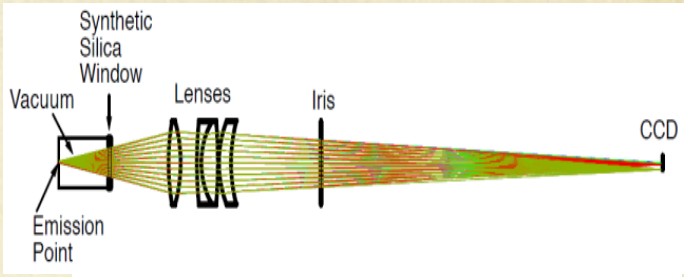
- Energy: 7 GeV
- Charge: 0.12 nC
- Repetition: 10 Hz

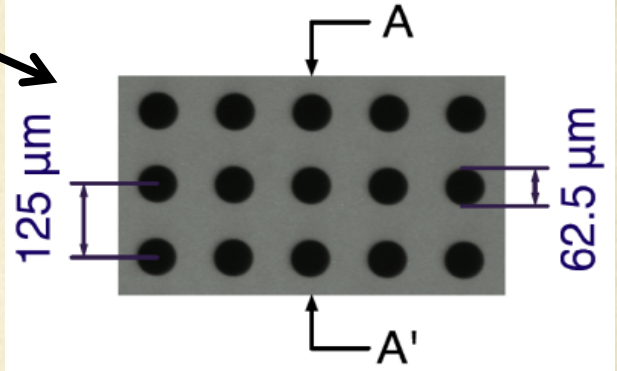
Data

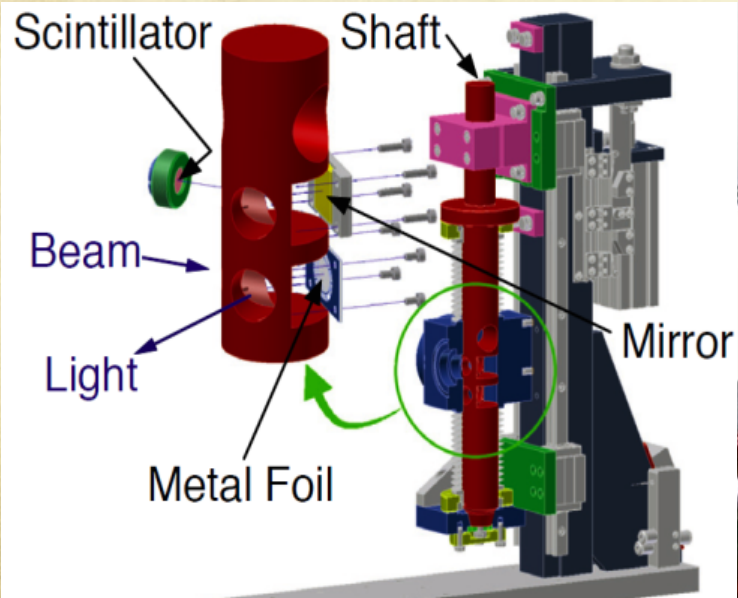
- # of shots: 3000
- Time duration: 5 minutes

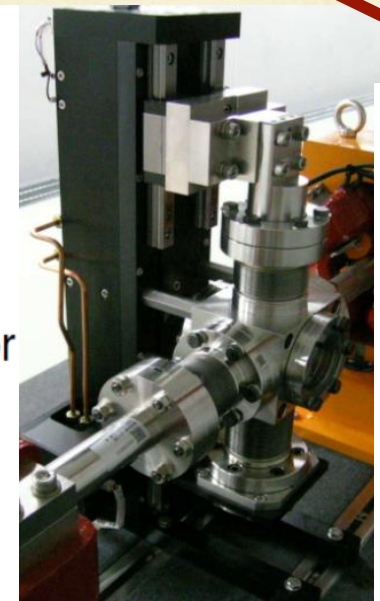
SCREEN MONITOR

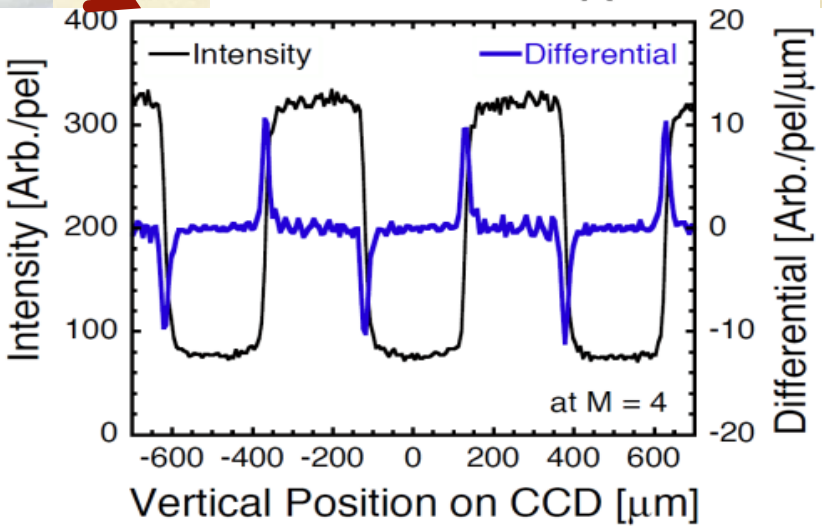
- Use OTR (SUS Foil), YAG:Ce, and Desmarquest (Al_2O_3: Cr_2O_3 0.5% doped) target screens.
- Use a custom-made optical lens equipped on the optical bench.
- Spatial resolution of the imaging system was measured by using a grid distortion pattern.
- The bench has a 1~4 X zooming mechanism at the highest resolution demanded observation point. The optical resolution of the bench is 2.5 μm at 4 X magnification case.



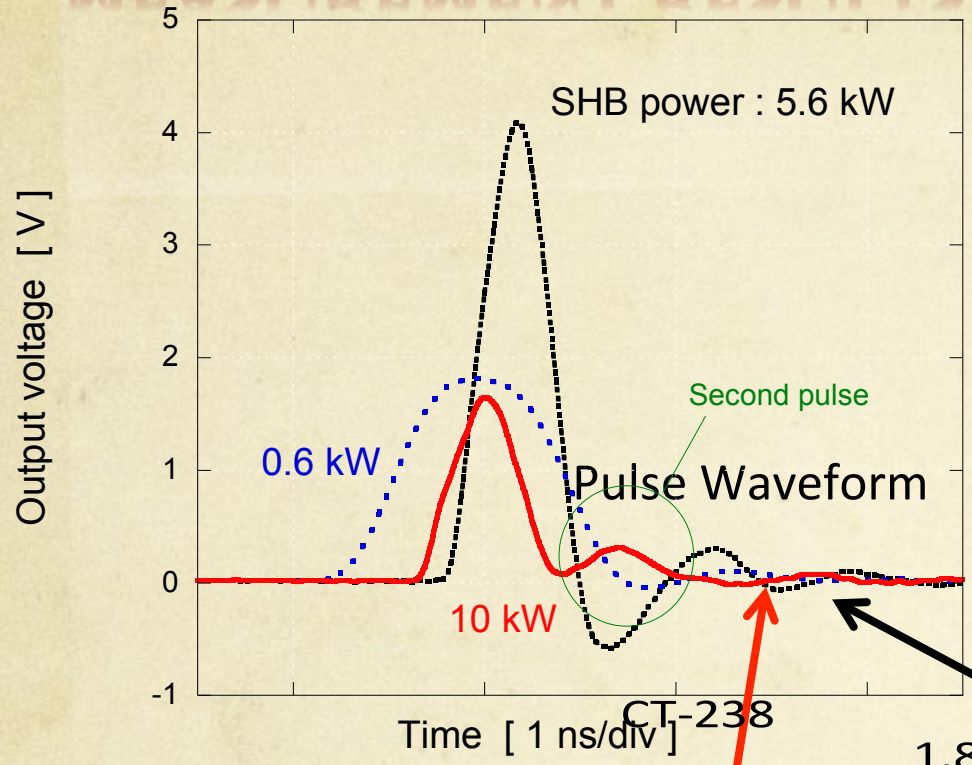








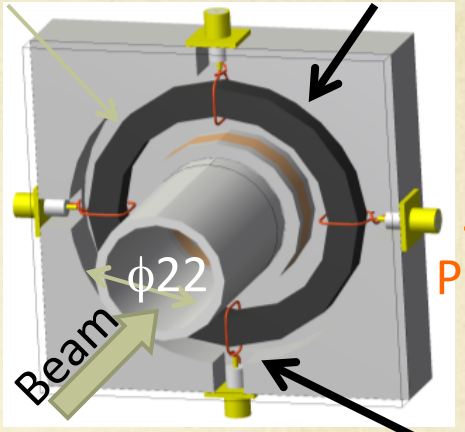
MEASUREMENT RESULTS WITH DIFFERENTIAL CT



Magnetic core
(μ>10 at 1 GHz)

Positive port

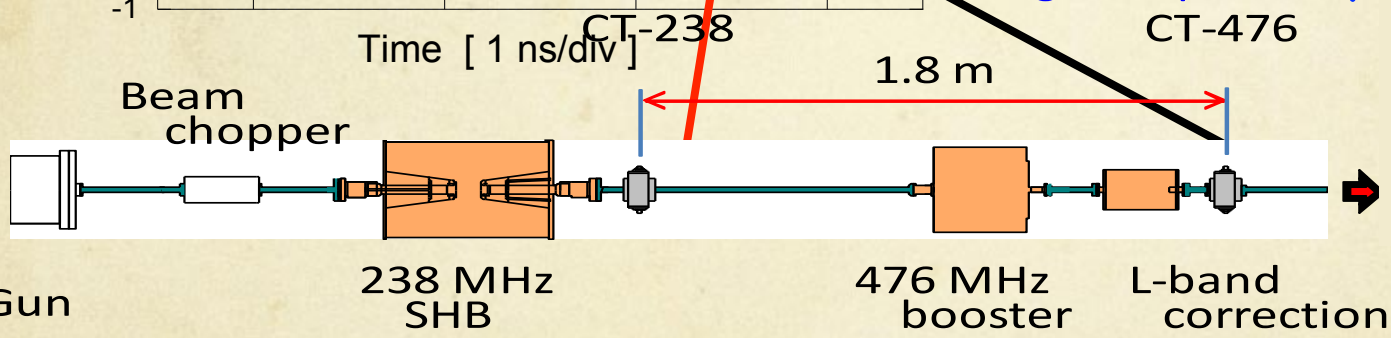
Ceramic insulator



Positive port

Negative port

Pickup coil (1 turn)

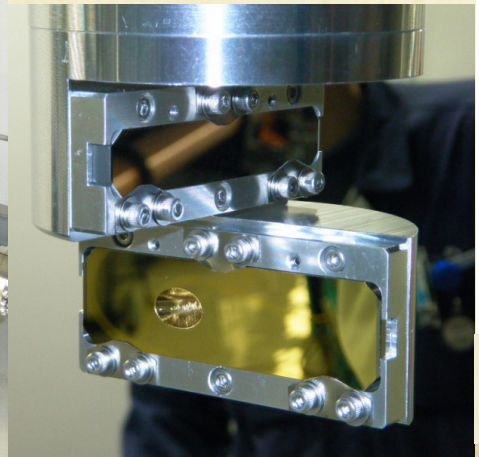


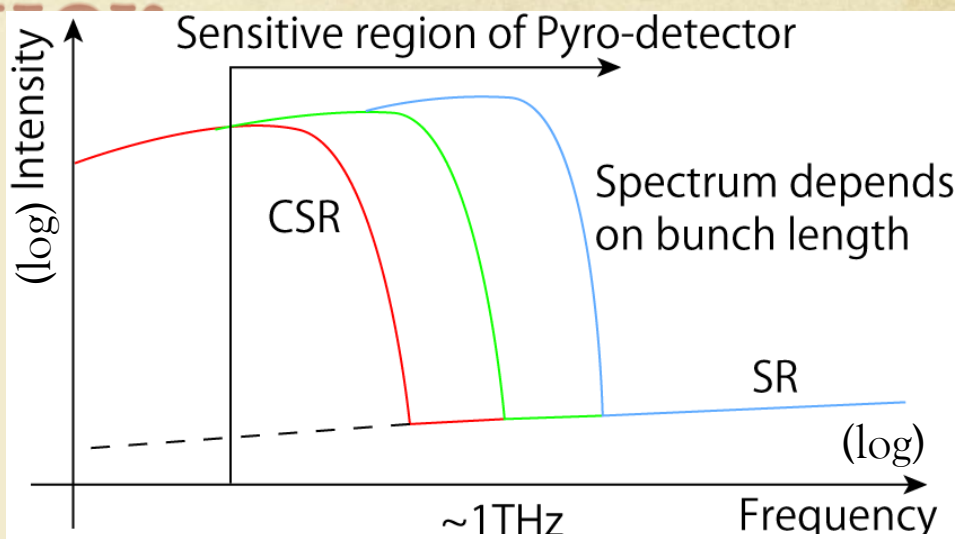
Shin-ichi Matsubara et al., Development of High-speed Differential Current-transformer Monitor, TUPC094

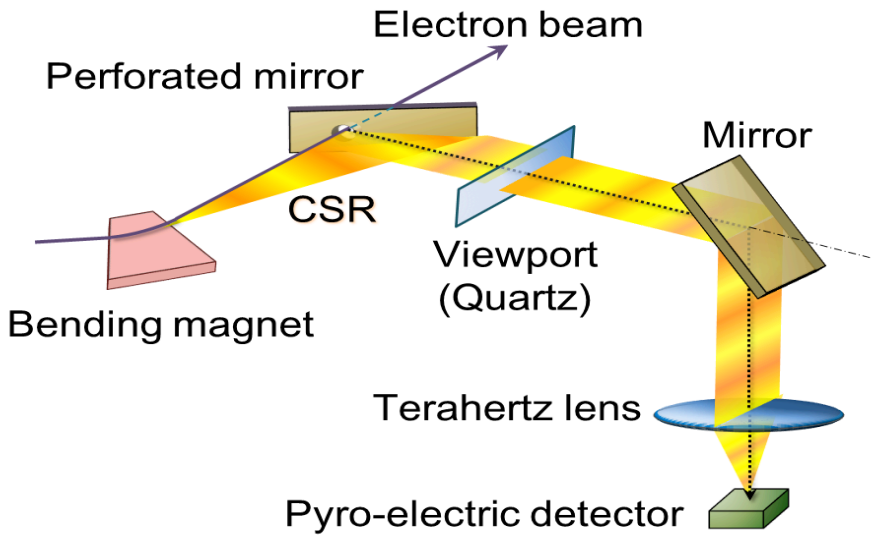
- Pulse rise time: 0.2 ns (10-90%)
- The peak voltage of the pulse is proportional to the charge amount of a beam
- This CT can measure a bunch length around the SHB.

BUNCH LENGTH MEASUREMENT USING CSR MONITOR

- CSR (Coherent Synchrotron Radiation) intensity has strong correlation to an electron bunch length.
- The CSR light is picked up by using a pyro-detector at a bending magnet of a bunch compressor.

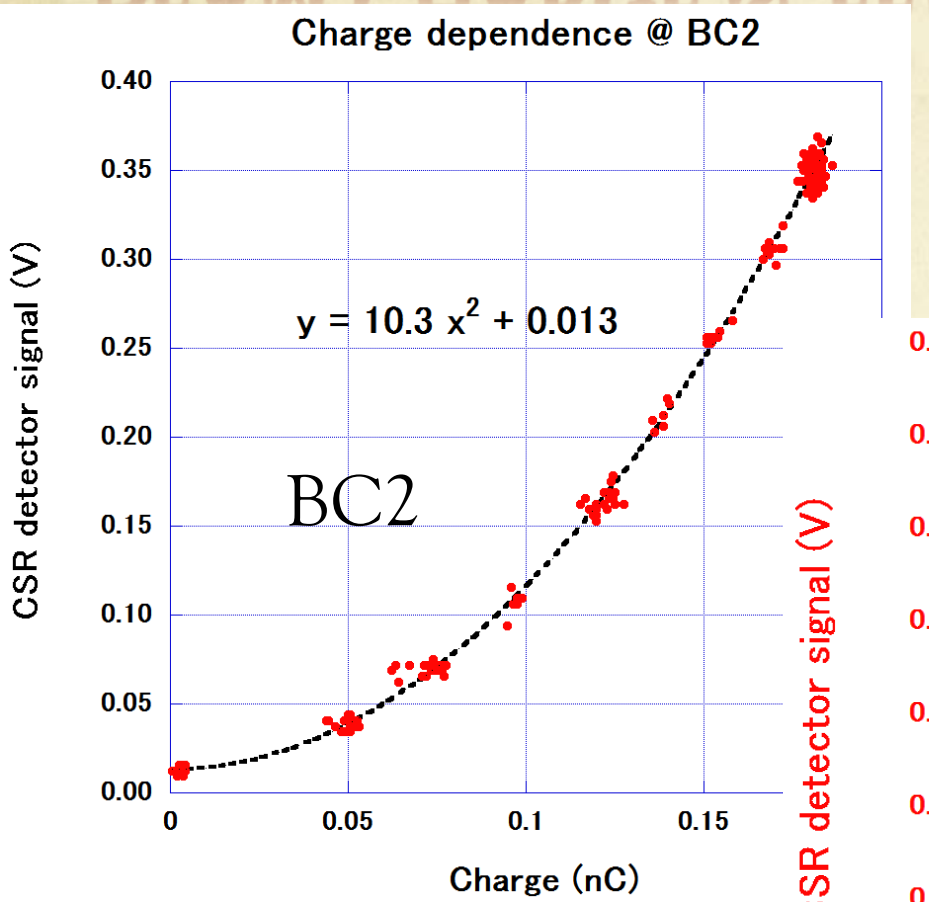


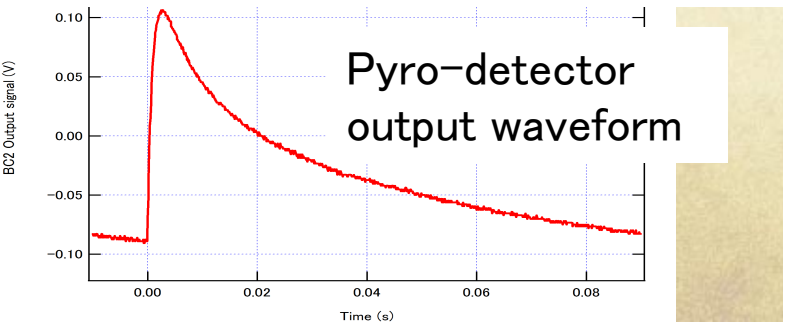




Chikara Kondo et al. CSR Bunch Length Monitor for XFEL/SPring-8 – SACLA, TUPC093

CSR DETECTOR SIGNAL INTENSITY VS. BEAM CHARGE & FEL INTENSITY AT SACLA

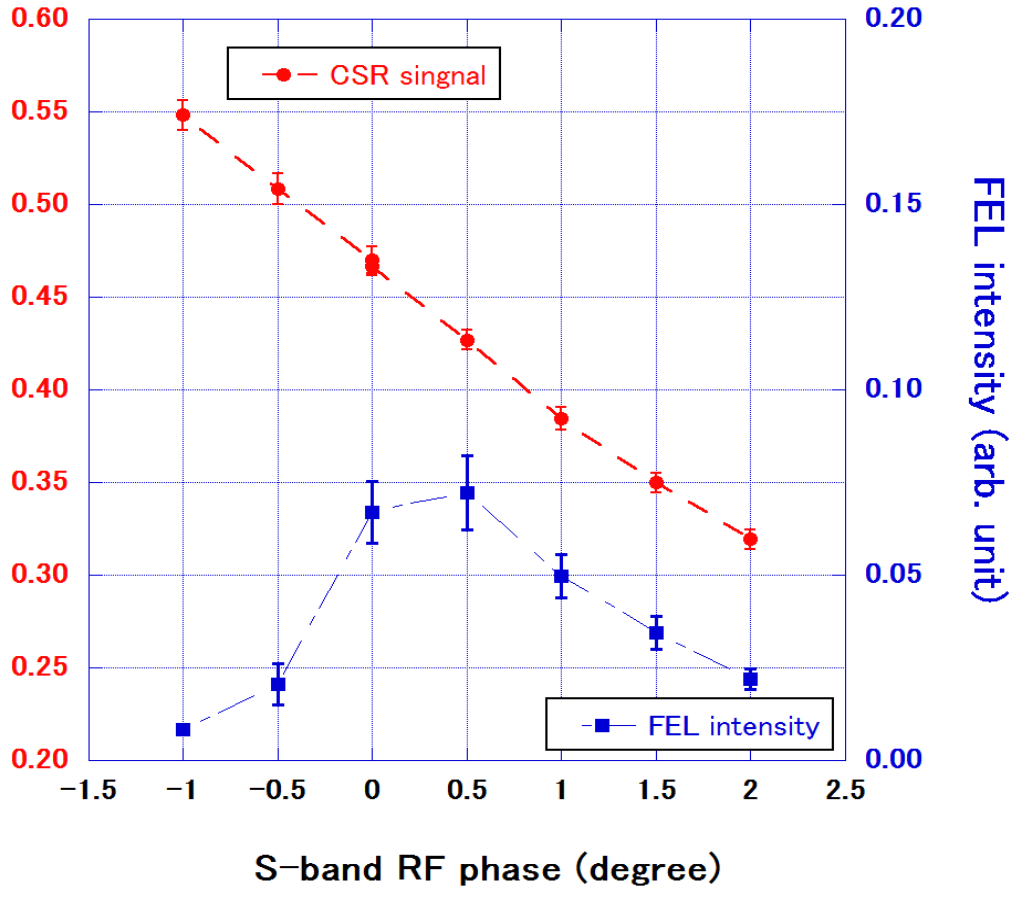




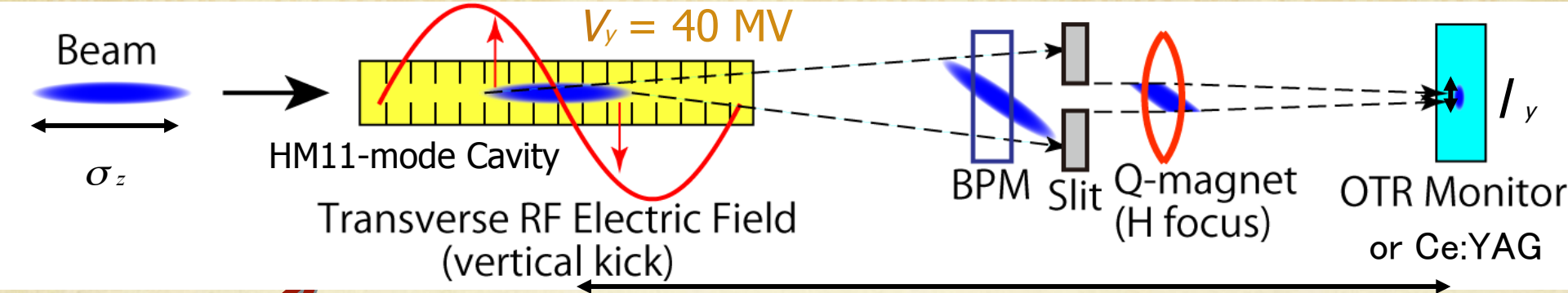
CSR flux intensity $P_{csr}(I)$

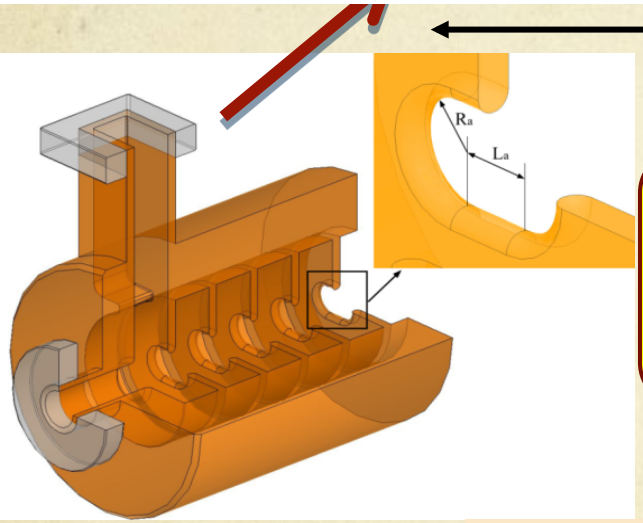
$$P_{csr}(\lambda) \sim P_c(\lambda)\{N_c + N_c^2 F(\lambda)\}$$

Preliminary Results

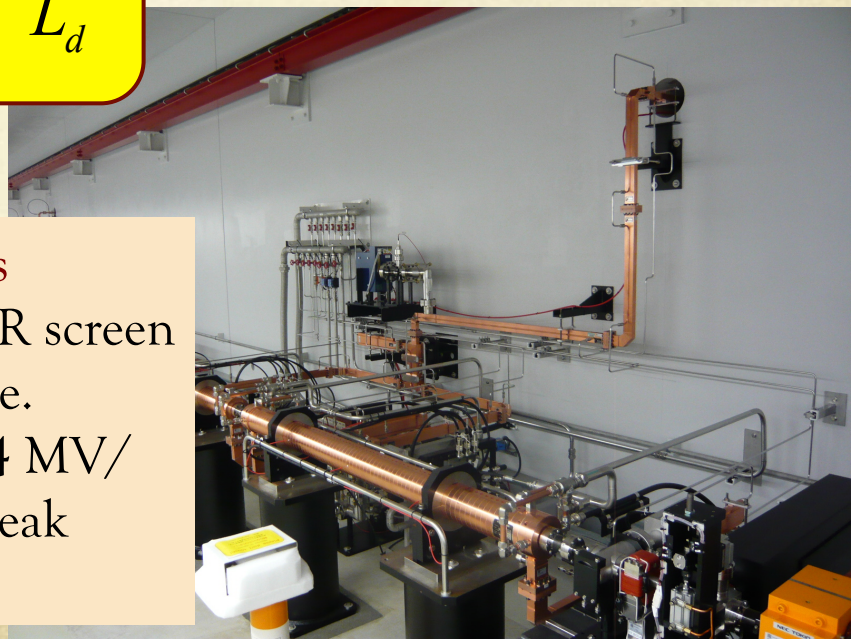


Method to measure Bunch Length by using RF Deflector





$$\Delta y' = \frac{ek_a V_y \sigma_z}{cp_z} = \frac{l_y}{L_d}$$



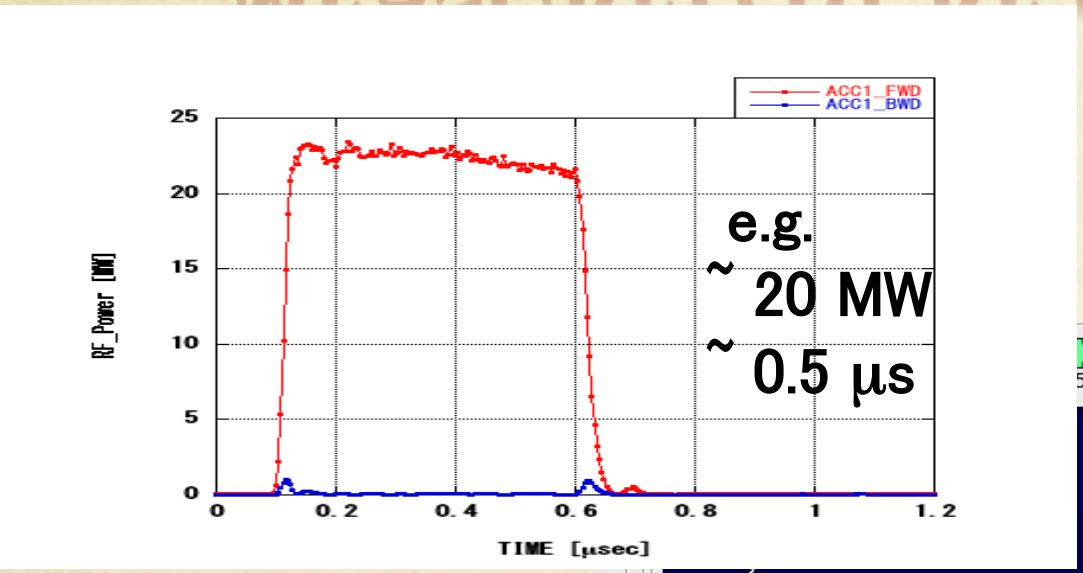
5/6π HEM11-mode Backward Wave Cavity (RFDEF)

Temporal resolution: < 20 fs

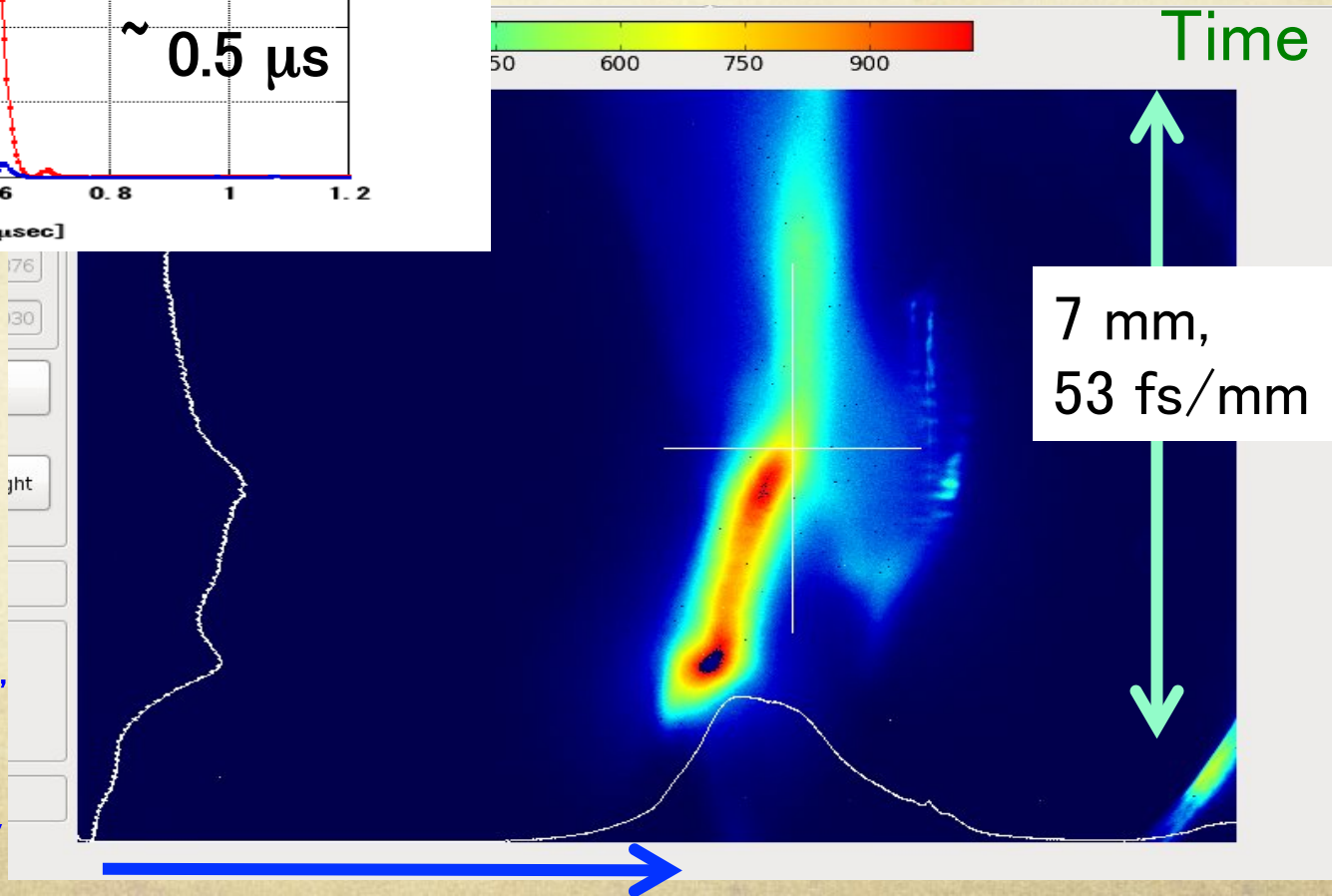
100 fs/mm on the OTR screen after a 12.5m drift space.

RF voltage gradient: 1.4 MV/ps (Ultra high-speed streak camera).

E-T SPACE BEAM IMAGE MEASURED BY RF DEFLECTOR



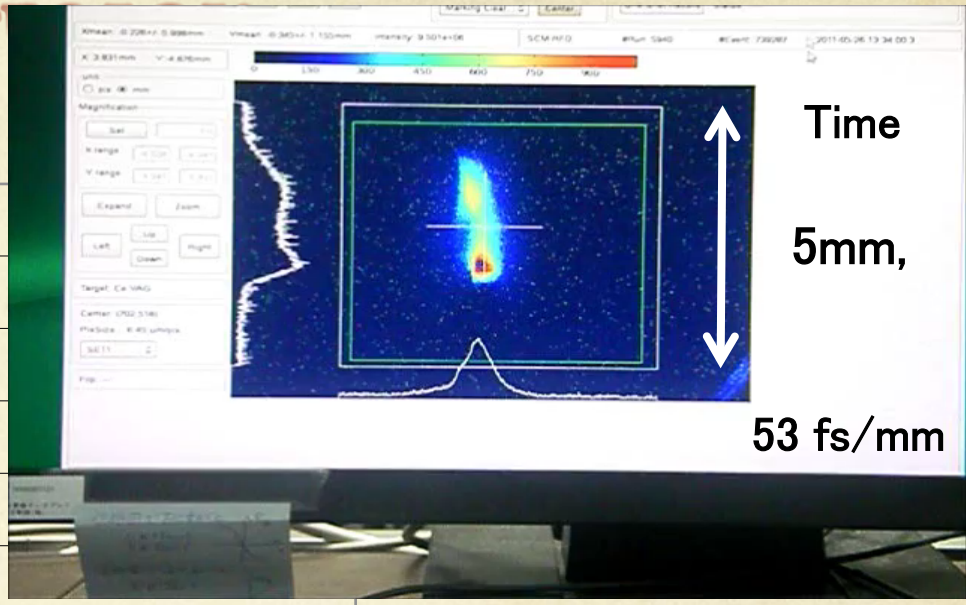
Rf input wave form to the rf deflector cavity from the klystron

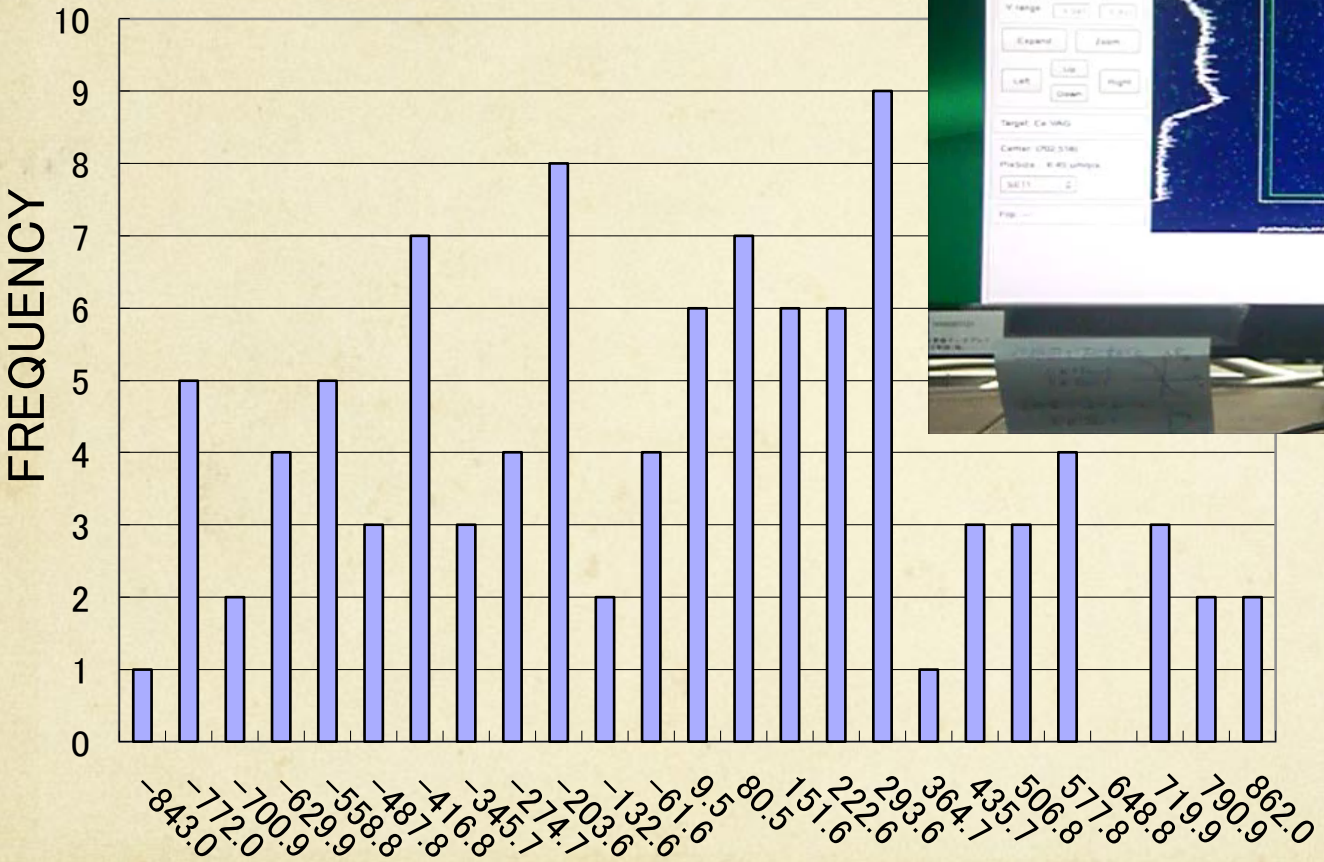


H. Ego et al., TRANSVERSE C-BAND DEFLECTING STRUCTURE FOR LONGITUDINAL PHASE SPACE DIAGNOSTICS IN THE XFEL/SPRING-8 “SACLA”, TUPC092

BEAM ARRIVAL TIME JITTER OBSERVED BY THE RF DEFLECTOR

5/26/2011”





1pps

~ 1.45 GeV

HISTOGRAM OF VERTICAL POSITION, 100 shots

436.81[um, STD] = 22.7 fs, 53 fs/mm

SUMMARY

- We finally realized beam monitors at SACLA with a spatial resolution of less than 1 μm for the undulator section, a 30 fs ~ 1ns beam pulse width observation, and a beam arrival time resolution of less than 22 fs.
- The beam monitor system works well for tuning the beam transport and lasing of SACLA.