Electron Beam Diagnostic System for the Japanese XFEL, SACLA

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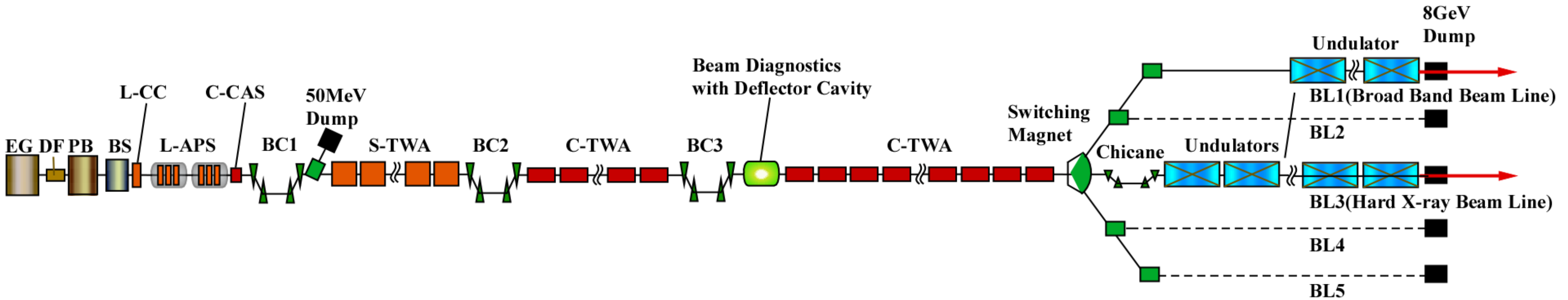
Outline

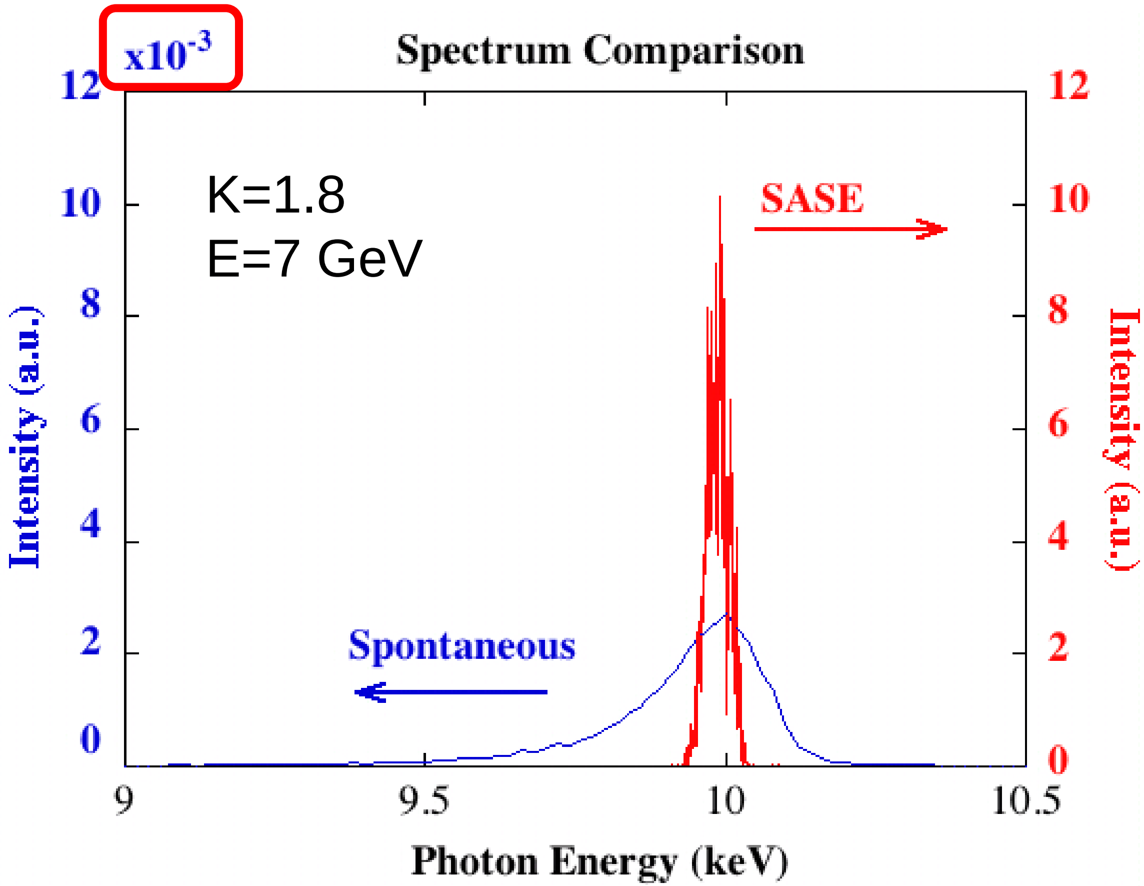
- Introduction
  - Current status of SACLA
- Design and Performance of Beam Diagnostic Instruments and their application for beam commissioning
  - RF-BPM and Multi-Strpline BPM
  - Screen monitor (OTR, YAG:Ce, Desmarquest)
  - Fast differential CT
  - Coherent radiation monitor to estimate the bunch length
  - Streak Camera
  - C-band Transverse deflector cavity
- Summary

Introduction



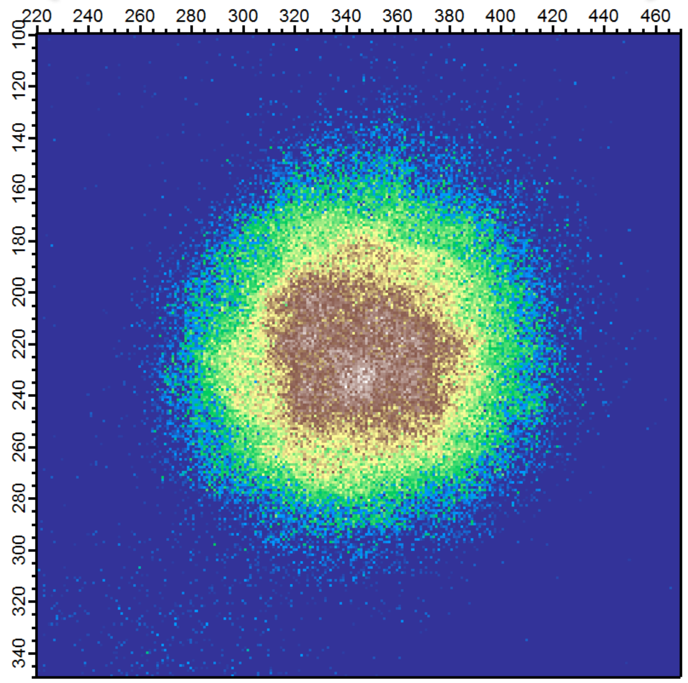
- SACLA
  - SPring-8 Angstrom Compact Free Electron Laser
  - XFEL is generated by Self-Amplified Spontaneous Emission (SASE)
- 8 GeV Linac and in-vacuum undulator beamline
  - CeB_6 thermionic electron gun (500 kV, ε_n: 0.6 mm mrad)
  - Velocity bunching and 3 bunch compressors to achieve > 3 kA peak current
  - C-band high-gradient accelerator (> 35 MV/m)
  - Short period in-vacuum undulator (λ_u : 18 mm)
  - Total facility length is 700 m.
- We started beam commissioning in March 2011 and observed the first XFEL radiation in June 2011.
- Public user experiments have been performed since March 2012.
  - Photon Energy: 5 – 15 keV
  - Wavelength: 0.08 – 0.25 nm

XFEL Spectrum and Profile



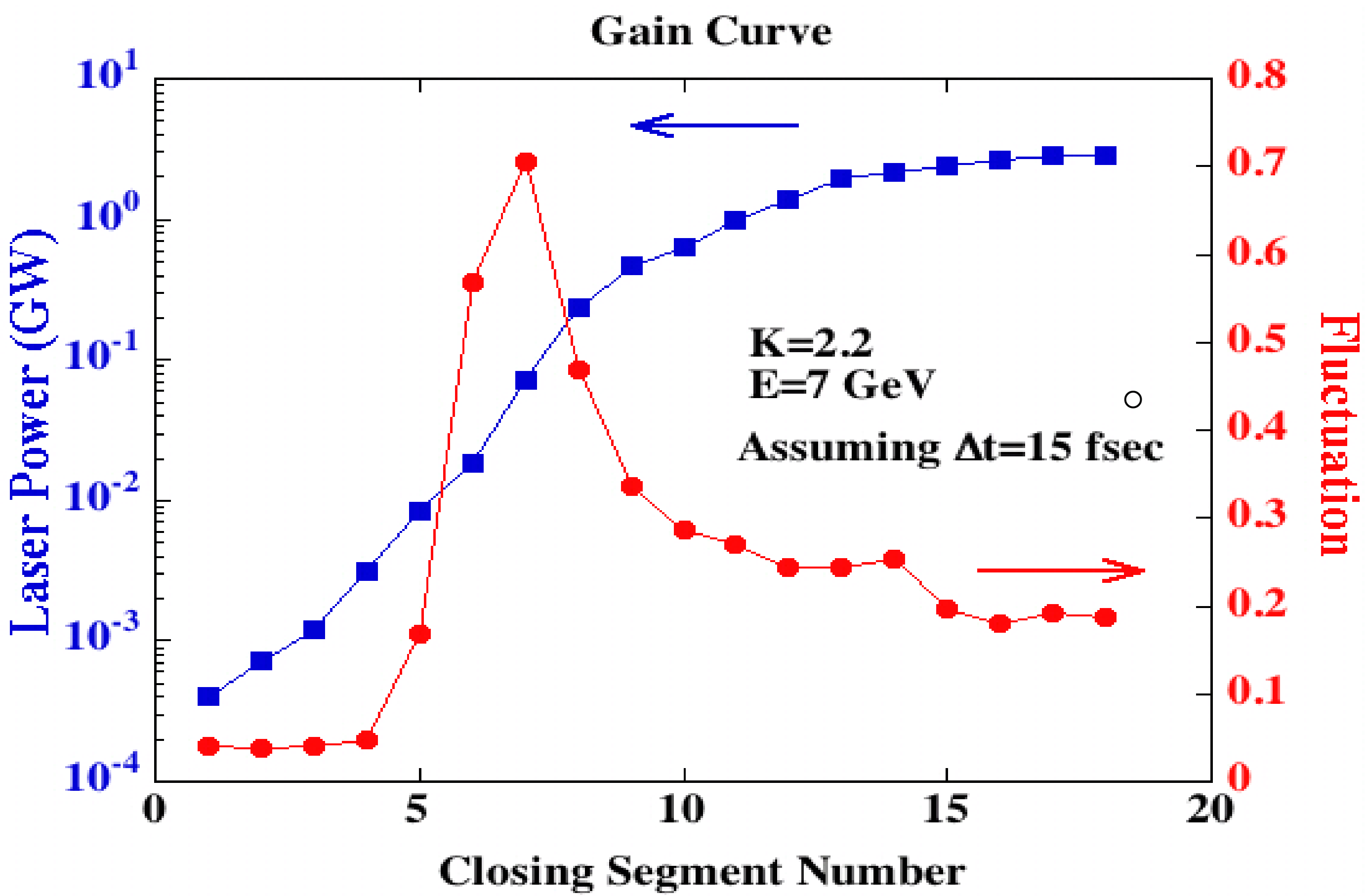
Narrow band width and high brightness

~ 0.5mm



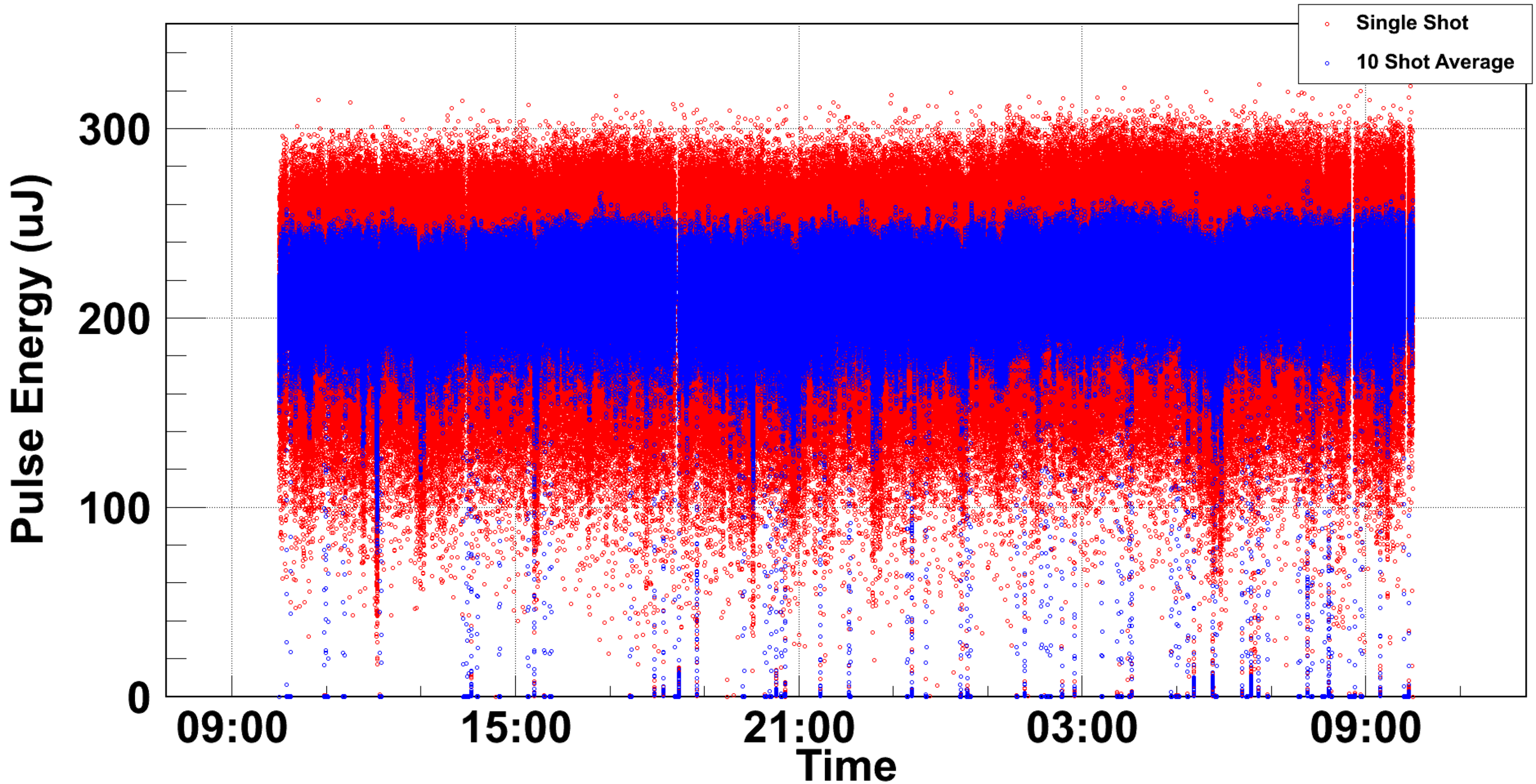
Transverse Profile

XFEL Gain Curve



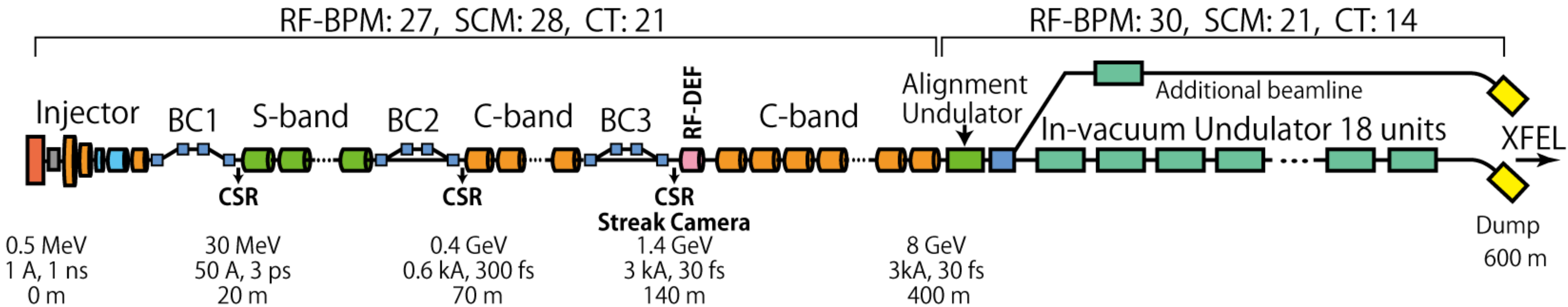
- Nonlinear amplification
- Large power fluctuation in the amplification stage
- Small power fluctuation after the saturation

XFEL Intensity Stability (24 hrs.)



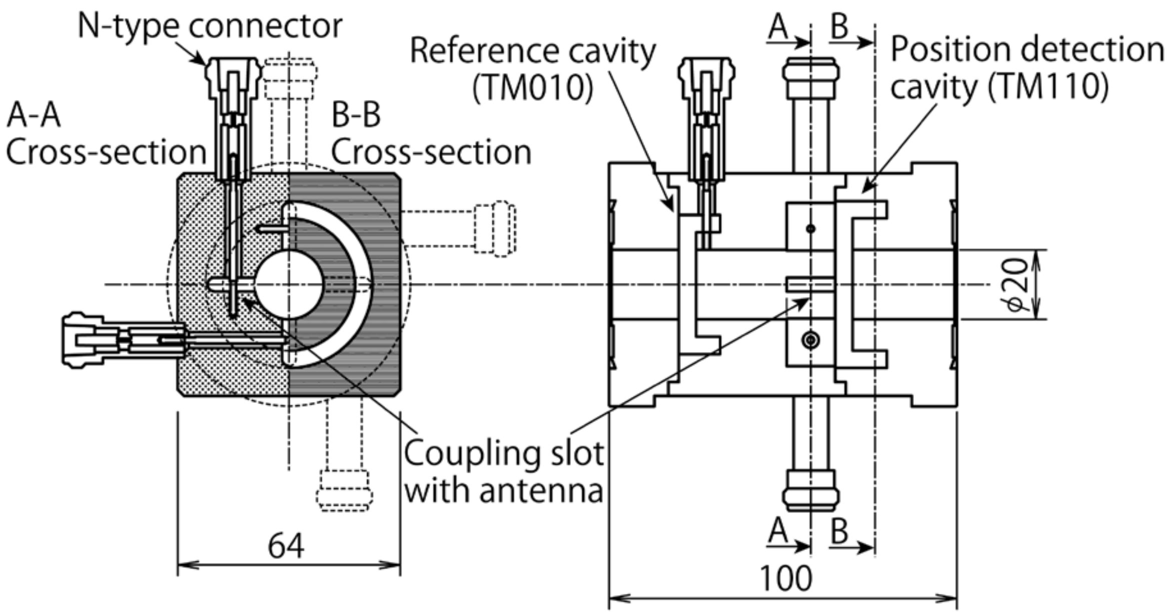
- Photon energy: 10 keV (Wavelength 0.124 nm)
- Electron beam energy: 7.8 GeV
- Bunch Charge: 0.2 nC

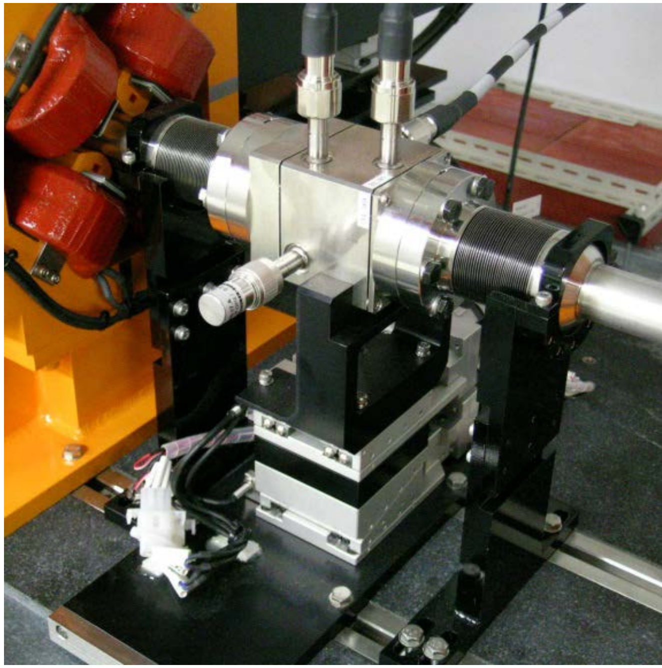
Beam Diagnostic System



- RF cavity BPM (RF-BPM) with position resolution < 1 μm.
  - Electron beam must be overlapped with x-rays within 4 μm in the undulator section.
- Multi-stripline BPM for dispersive part to monitor the beam energy
- Screen monitor (SCM) with less than 10 μm resolution.
  - Transverse beam profile measurement, emittance measurement etc.
  - OTR, YAG:Ce or Desmarquest screen with high-resolution imaging system.
- Fast differential current transformer (CT)
  - Bunch length measurement in the injector part
  - Bunch charge monitor without common-mode noise.
- Coherent radiation monitors
  - Coherent transition radiation (CTR) and coherent synchrotron radiation (CSR) monitor
- Streak Camera
  - Resolution: 300 fs
- C-band transverse RF deflector cavity system (RFDEF)
  - Resolution: 10 fs.
  - Bunch length is compressed to 30 fs.

RF Cavity BPM





- **TM110 dipole mode of Beam-induced RF field is used.**

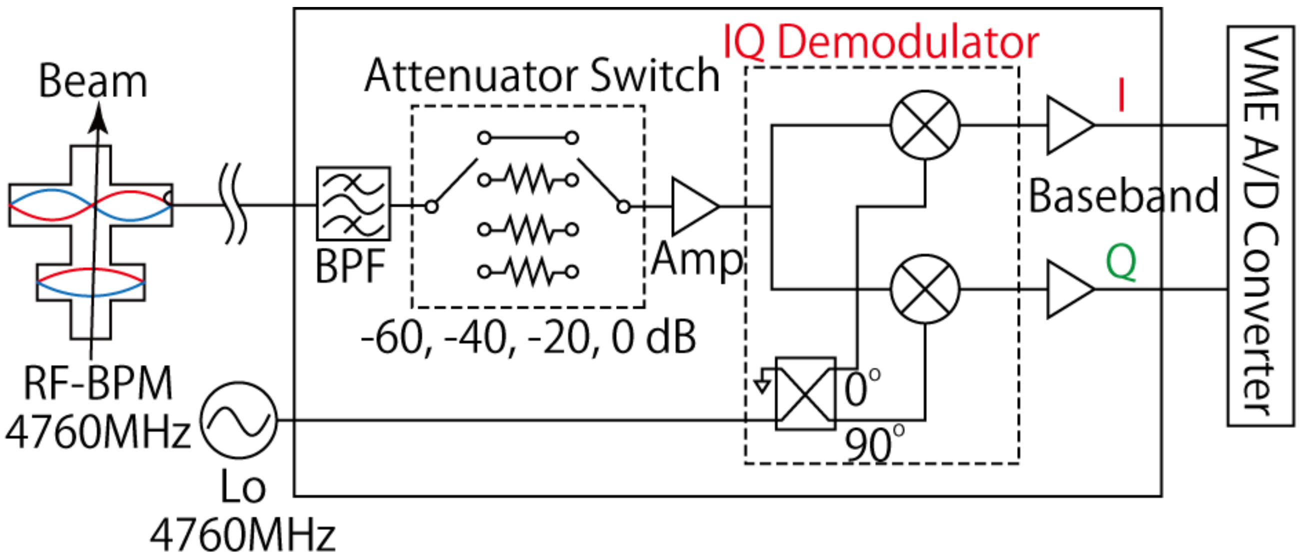
$$V = V_1 q x e^{j(\omega t+\phi)-t/T}$$

- **TM010 cavity determines the phase reference and the beam charge.**

$$V = V_0 q e^{j(\omega t+\phi)-t/T}$$

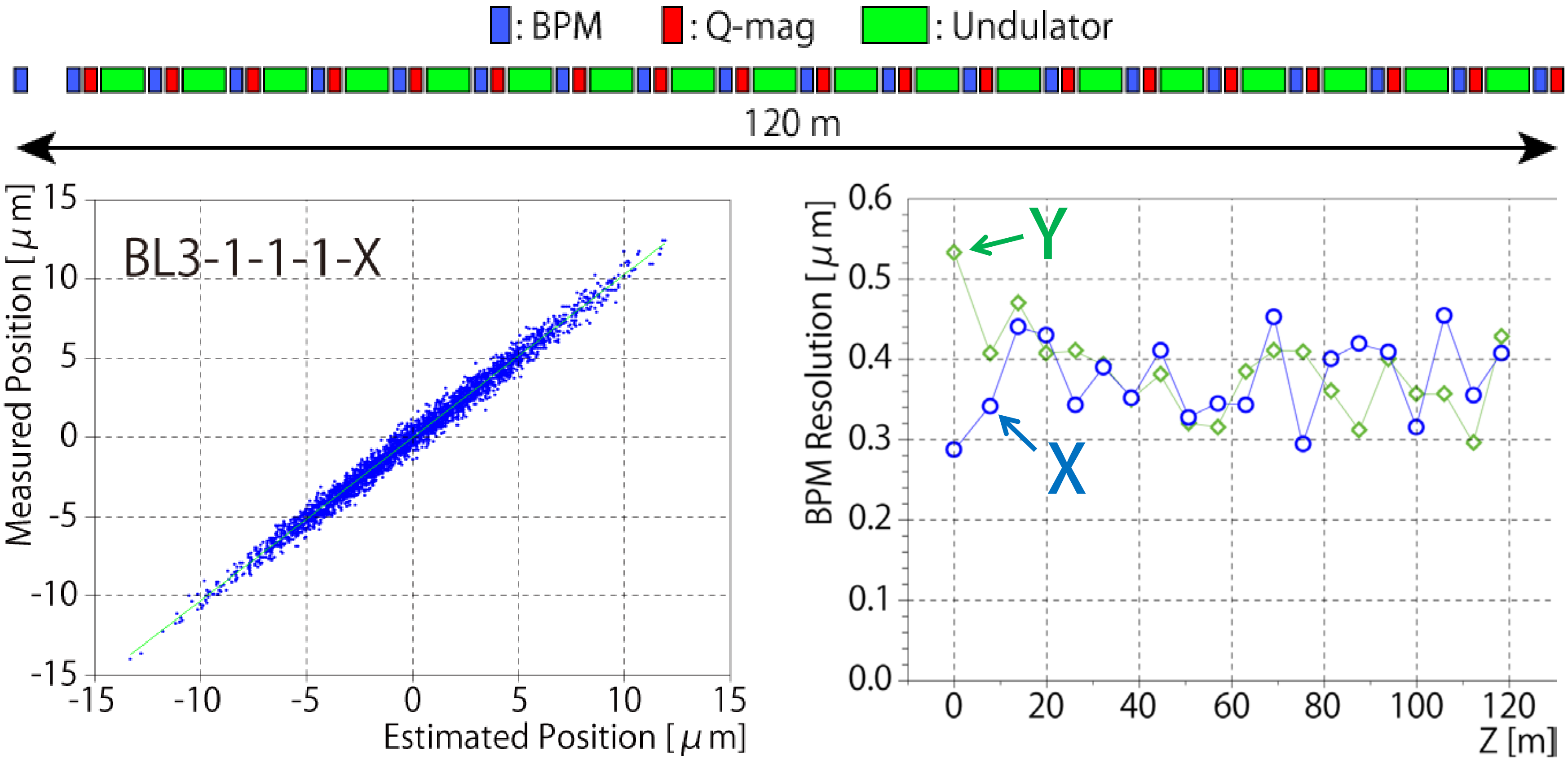
  - Beam arrival timing can be measured.
- **Resonant frequency：4.760 GHz (C-band)**
- **H. Maesaka et al., Nucl. Intrum. Meth. A 696, 66 (2012).**

RF-BPM Electronics



- IQ demodulator to obtain amplitude and phase
- Attenuator switch extends the dynamic range to 100 dB
  - From sub-μm to a few mm
- Baseband signals are recorded by a 12-bit or 16-bit VME waveform digitizer.

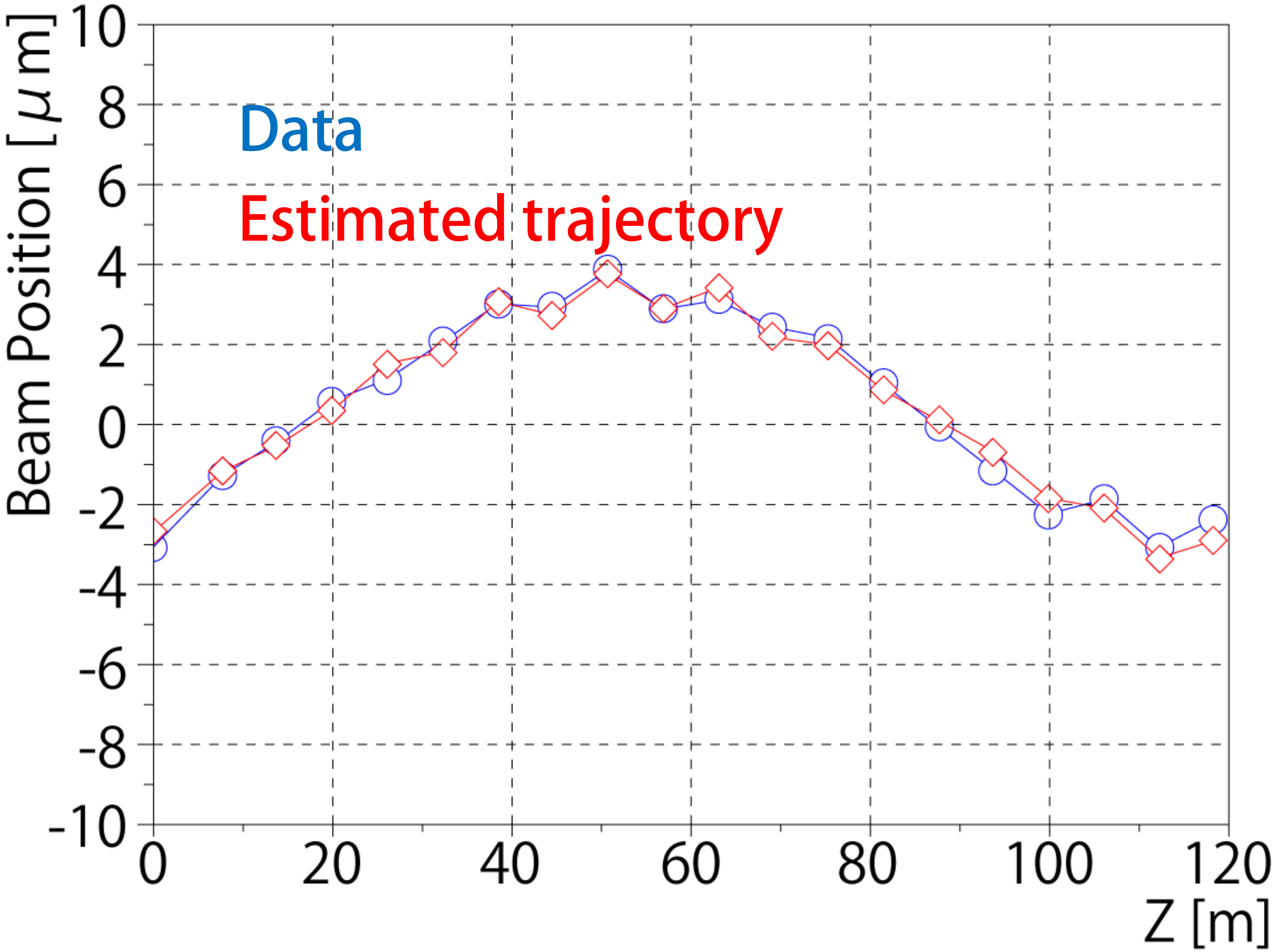
Position Resolution of RF-BPM



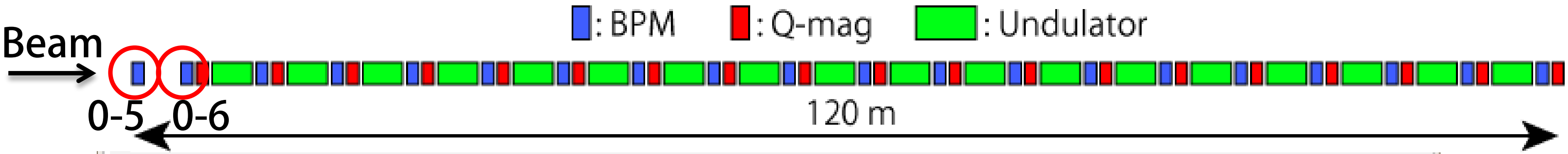
- Position resolution was analyzed for 20 RF-BPMs in the undulator section
- Estimated position at a given RF-BPM was estimated from the other BPMs.
- Measurement and estimation were almost same. (left plot)
- Resolution is defined as the rms of the difference between the measurement and the estimation.
- Position resolution < 0.6 μm (rms) (right plot)
  - 7 GeV, 0.1 nC

Beam Trajectory Monitored by RF-BPM

Single-shot beam trajectory

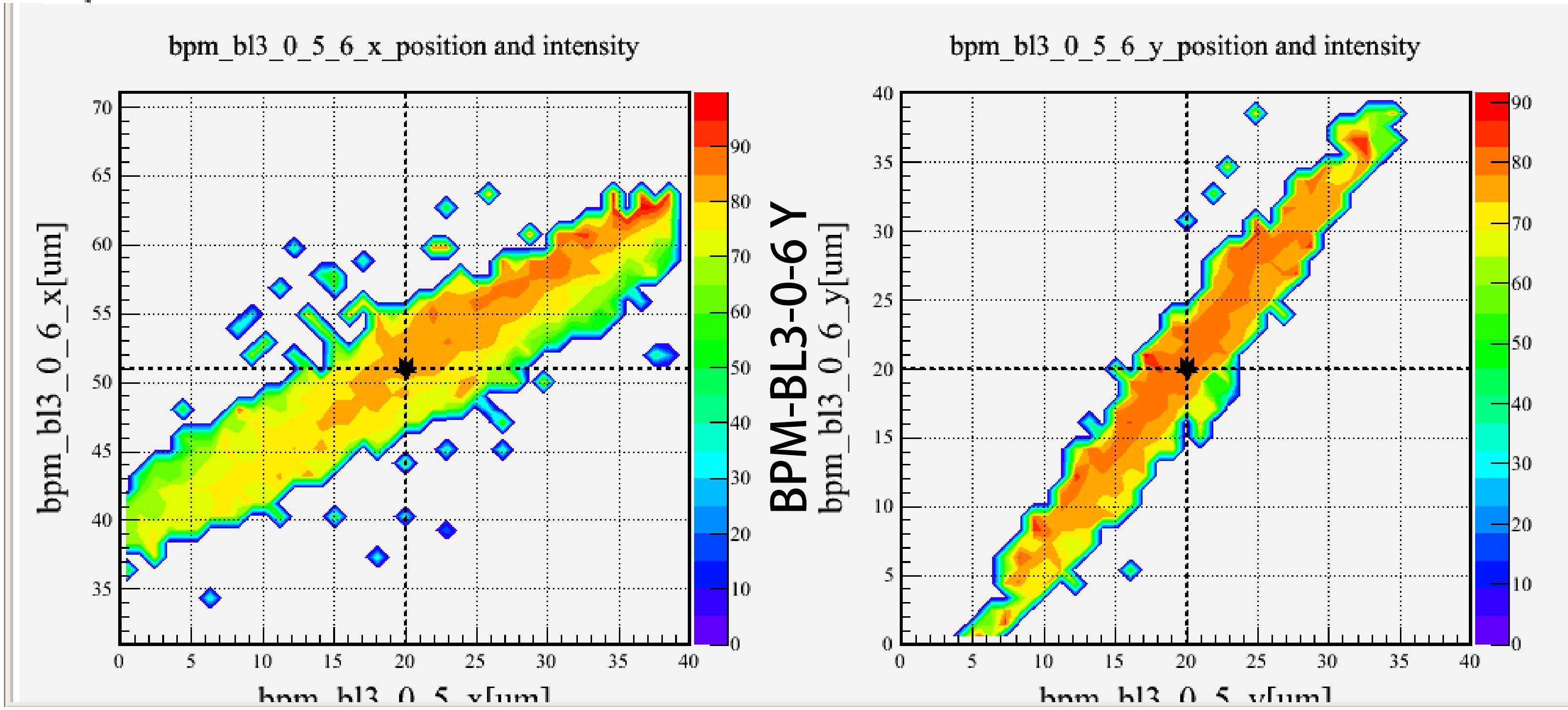


Correlation between Beam position and XFEL intensity



BPM-BL3-0-6 X

BPM-BL3-0-6 Y



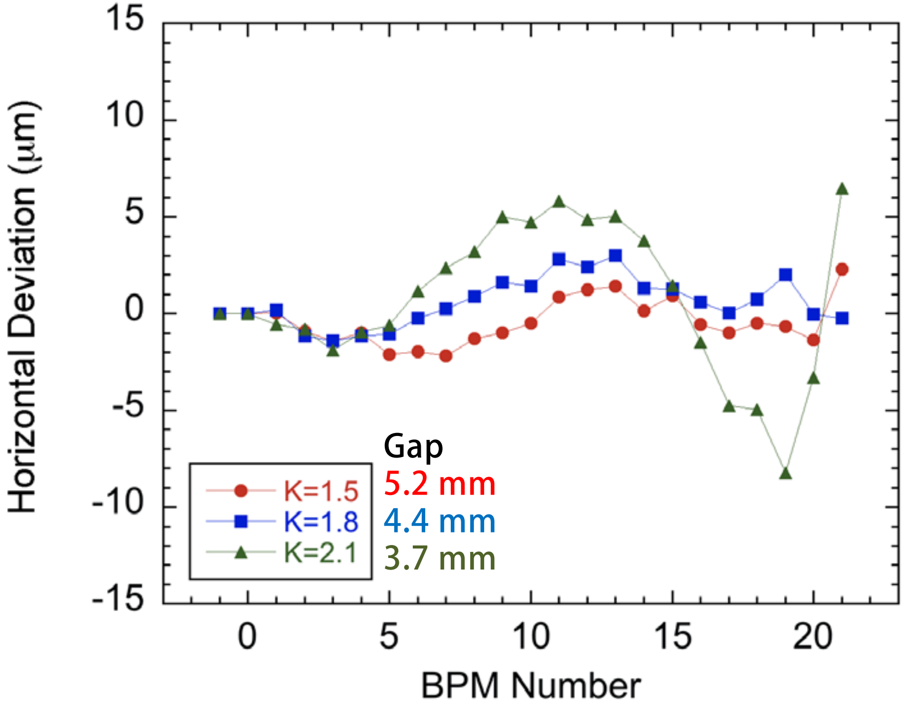
BPM-BL3-0-5 X

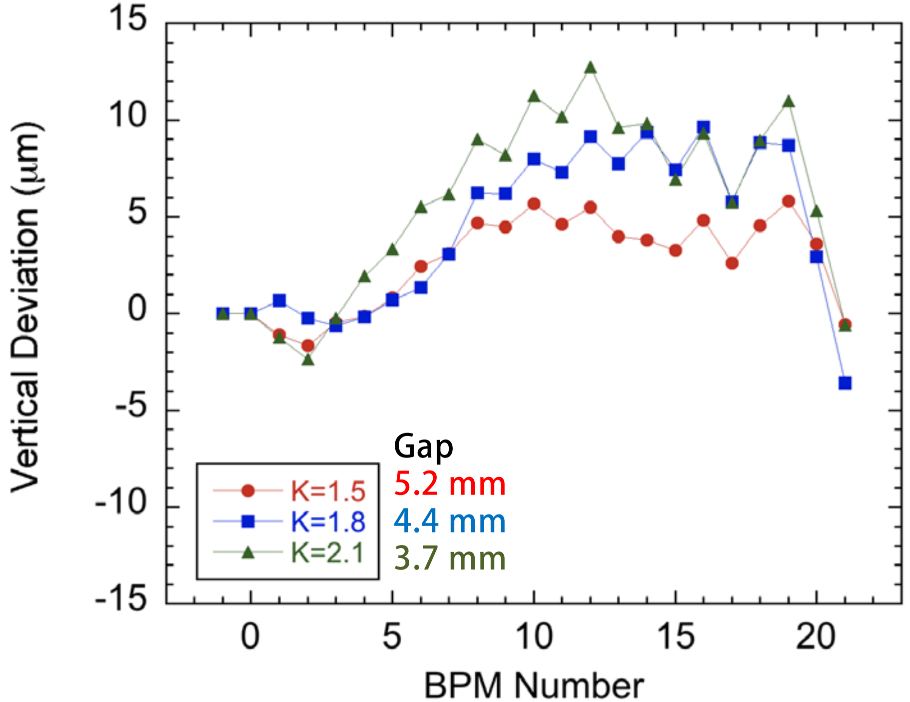
BPM-BL3-0-5 Y

- Correlation between the beam position (x,y-axes) and FEL intensity (z-axis)
- Easy to see what trajectory is the best.
- Injection orbit is locked to the best point by a feedback control.

Orbit Correction for Variable Gap Undulators

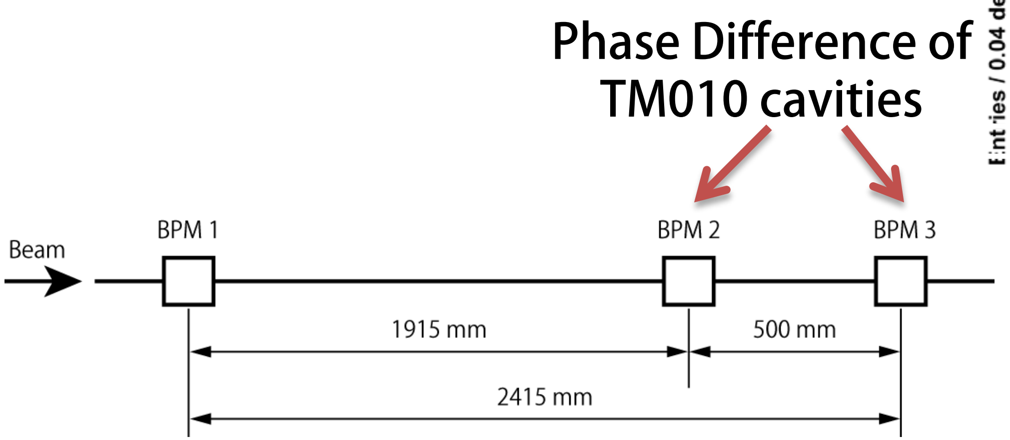
- RF-BPM data is used for the orbit correction for different undulator gap.
  - Beam orbit is corrected by steering magnets between undulators
  - Feed-forward table of steering magnets is prepared.
- Orbit reproducibility is within 10 μm.

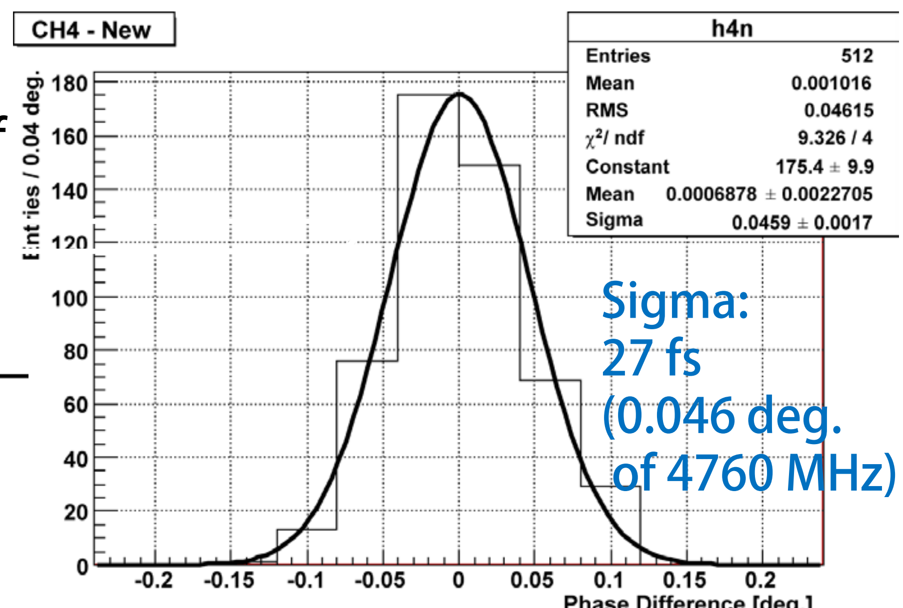




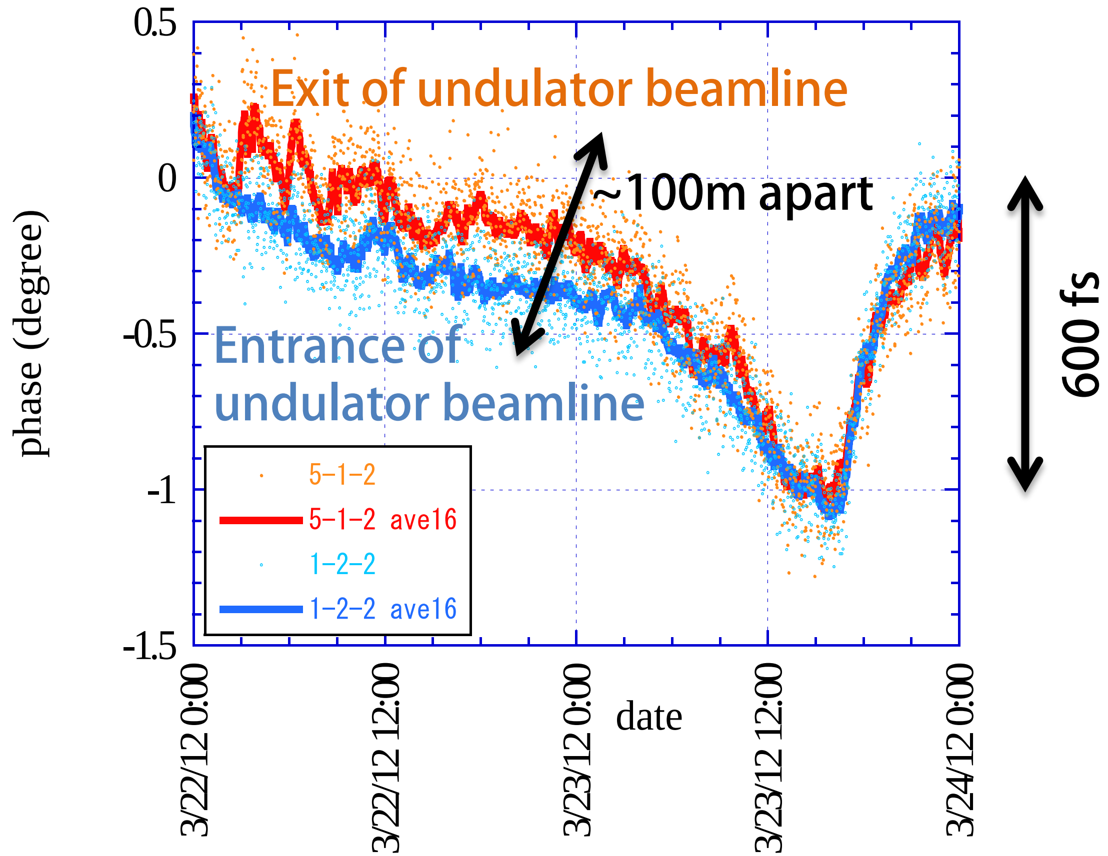
Beam Arrival Timing Resolution

- Beam arrival timing can be measured by the phase of the reference cavity (TM010).
  - Useful to monitor the timing drift of the machine
  - Experimental users can use this timing data
- Required temporal resolution: < 50 fs
- Arrival timing resolution: 27 fs (STD)
  - Measured by the reference cavities of two neighboring BPMs in the SCSS test accelerator.



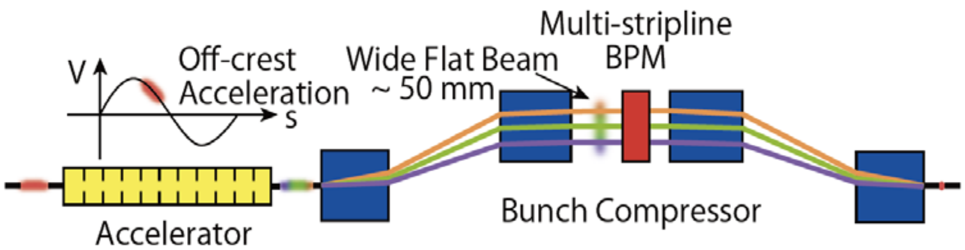


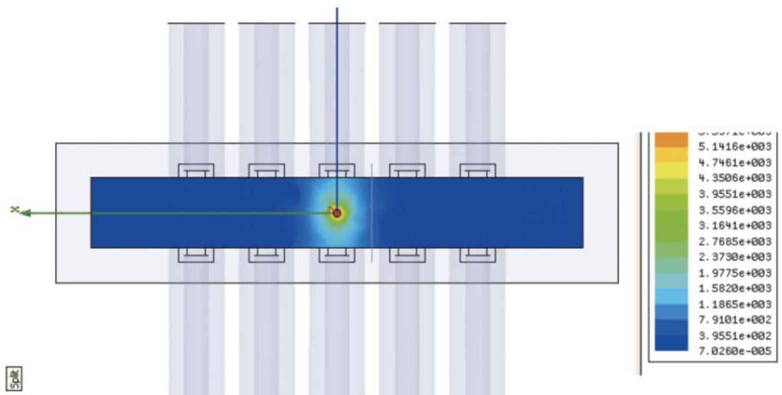
Trend of the Beam Arrival Timing



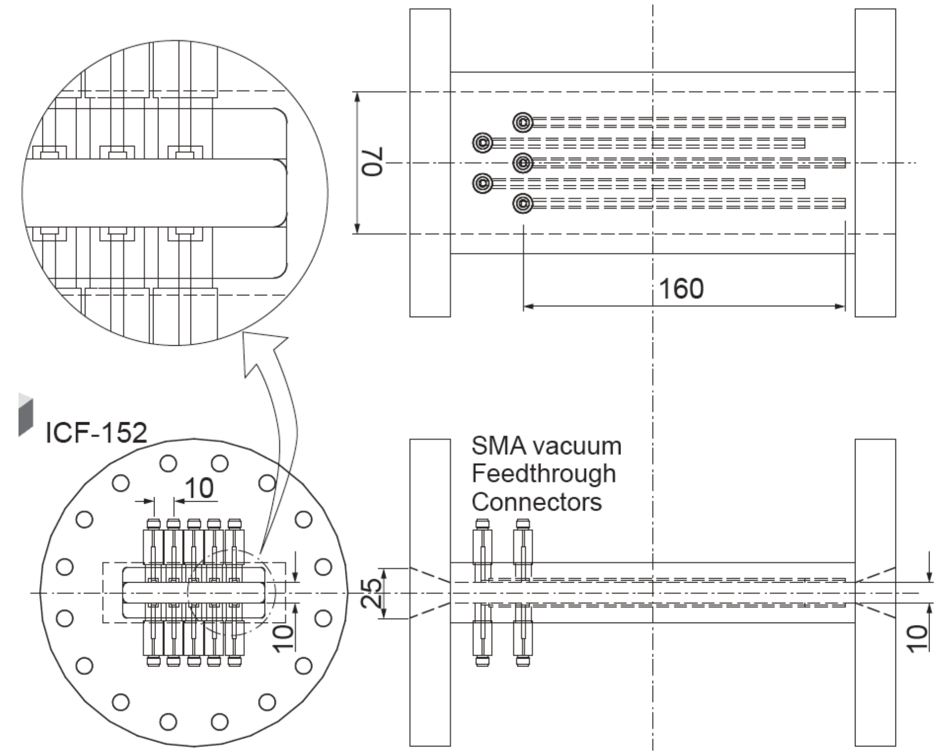
- Drift of the arrival timing is appropriately obtained.
- Large drift is due to the rf phase drift in the injector section.
- Time difference between the entrance and the exit of the undulator beamline is caused by the drift of the reference timing transmission line due to the ambient temperature drift.

Multi-stripline BPM



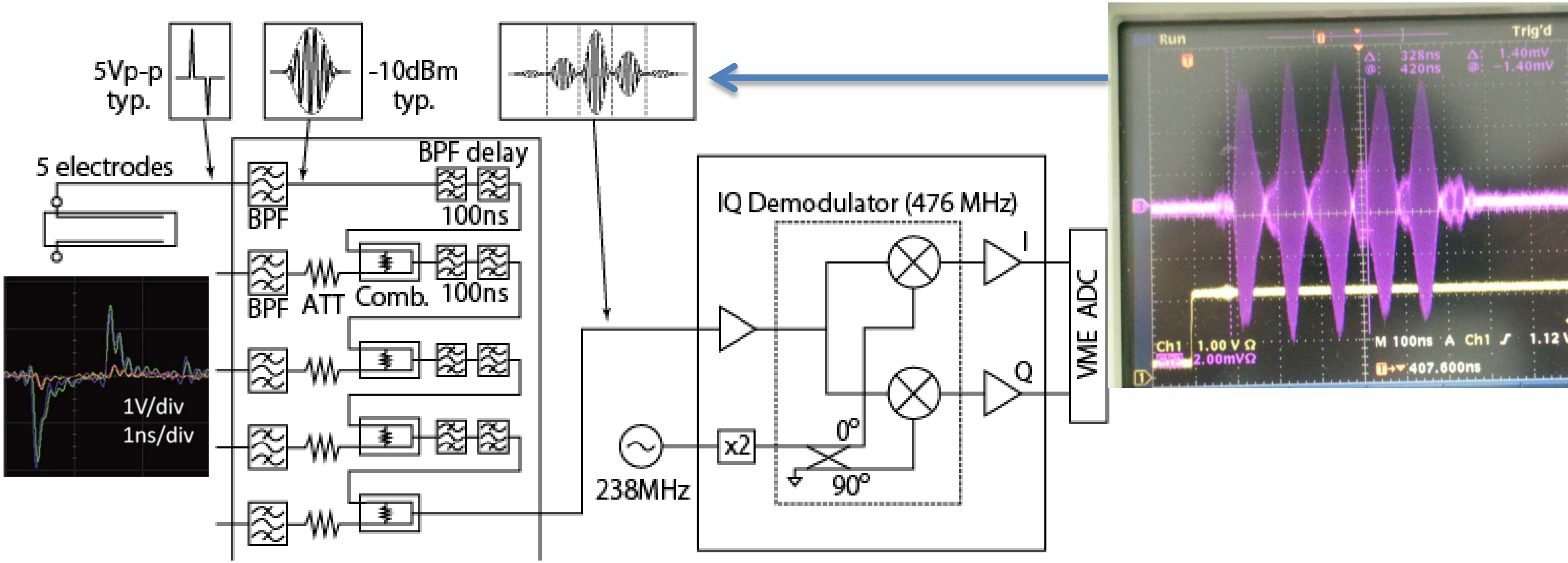


EM simulation



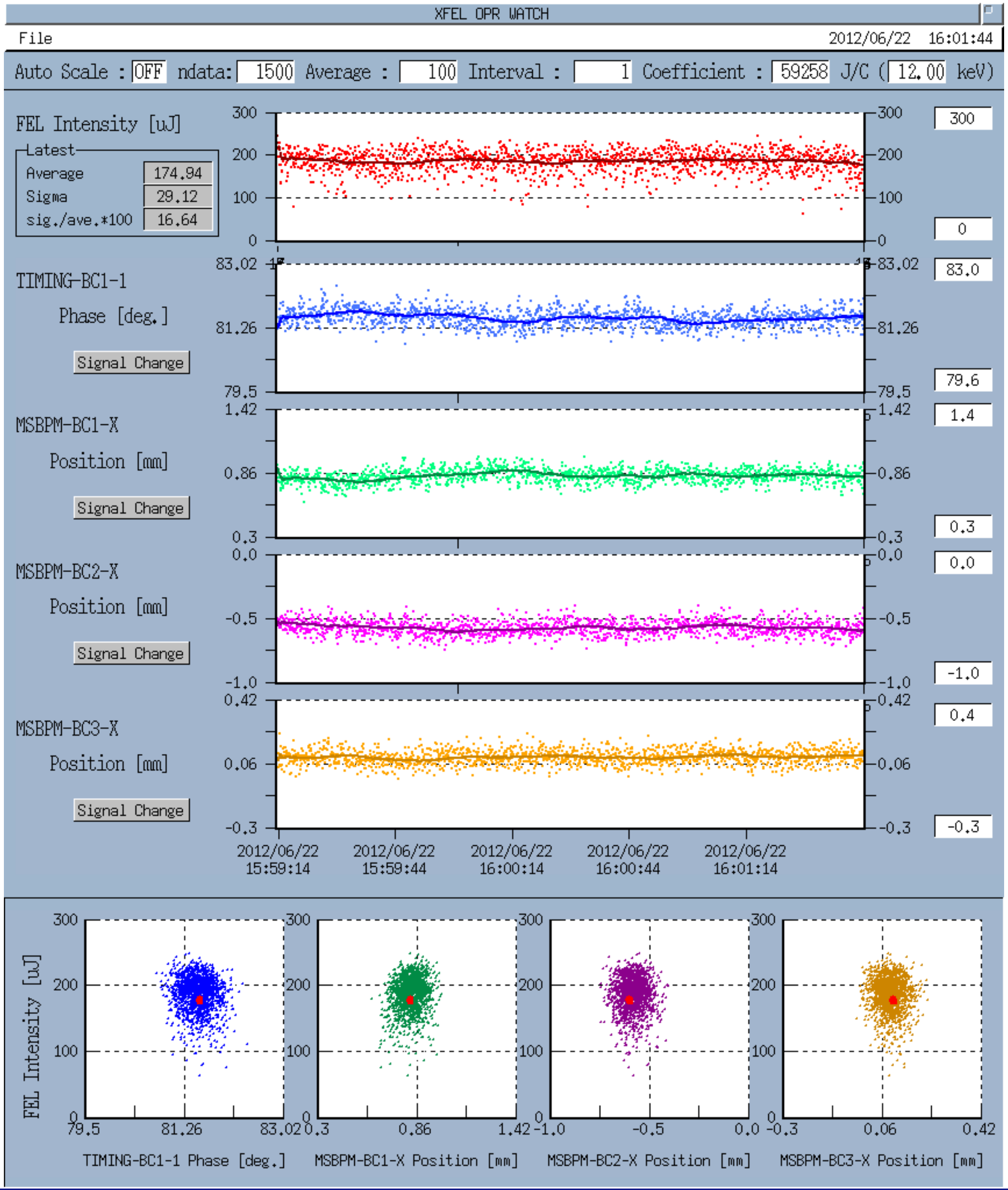
- Multi-stripline BPM is used at the dispersive part of a bunch compressor (BC), because the horizontal beam size is large.
- Beam position at BC is important for monitoring the beam energy.
  - 0.1 mm sensitivity is required for the beam energy measurement less than 0.1% resolution.
- Five stripline electrodes are equipped for each of top and bottom plane of the rectangular beam duct.
  - Characteristic impedance: 50 ohm
  - Stripline length: $\lambda/4$ of 476 MHz

Electronics for Multi-stripline BPM



- Impulse signal from the stripline electrode is converted to a wave packet of an rf signal by using a band-pass filter.
- Five signals are combined into one line by means of the group delay of other band-pass filters and rf power combiners.
- The rf signal is detected by an IQ demodulator and the baseband waveforms are recorded by VME waveform digitizer.
- Beam position is evaluated from the center of mass of the peak voltages of the pulse signals.

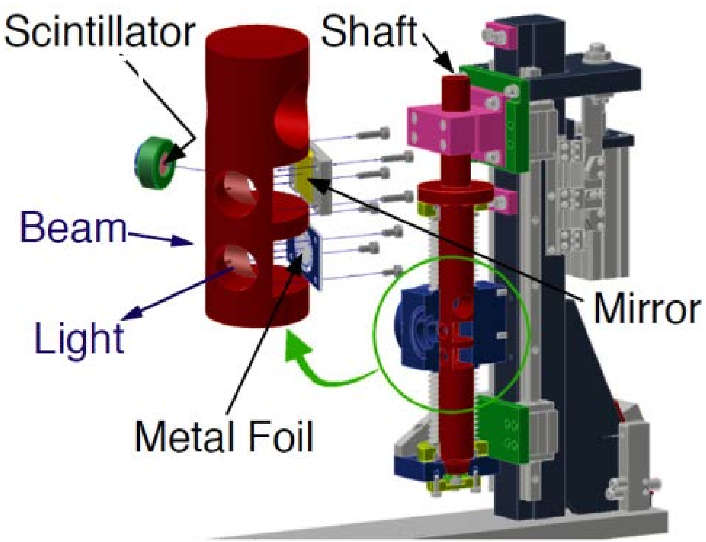
Arrival timing, beam energy and XFEL intensity



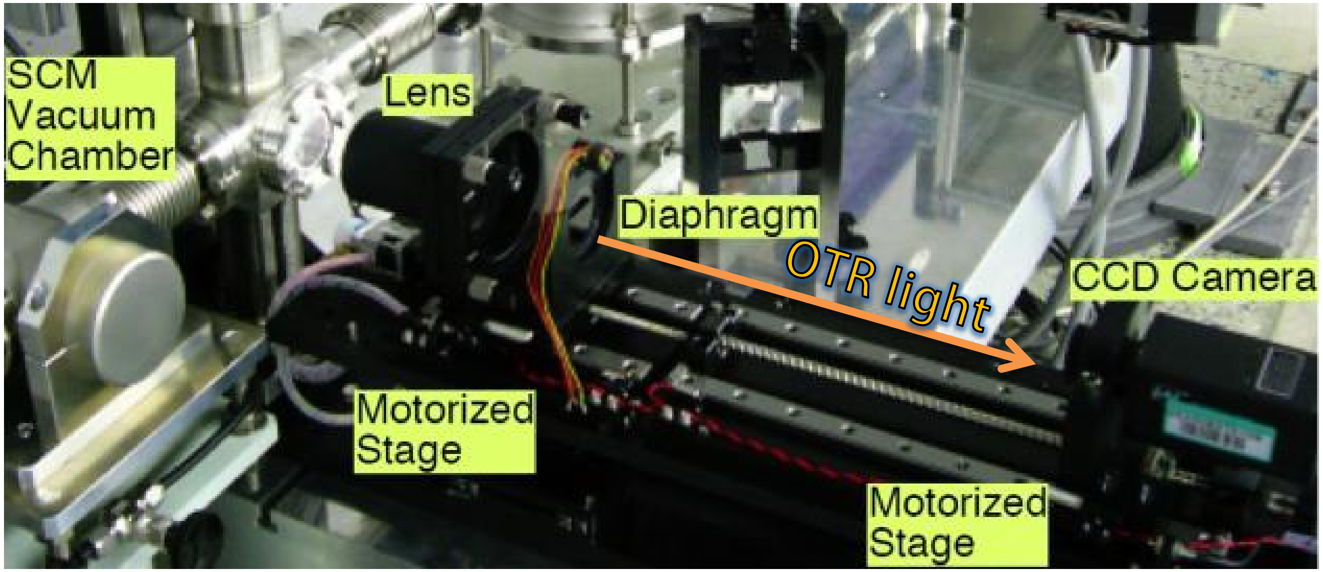
Trend graphs of the XFEL intensity, arrival timing and beam energy

Correlation plots with XFEL intensity

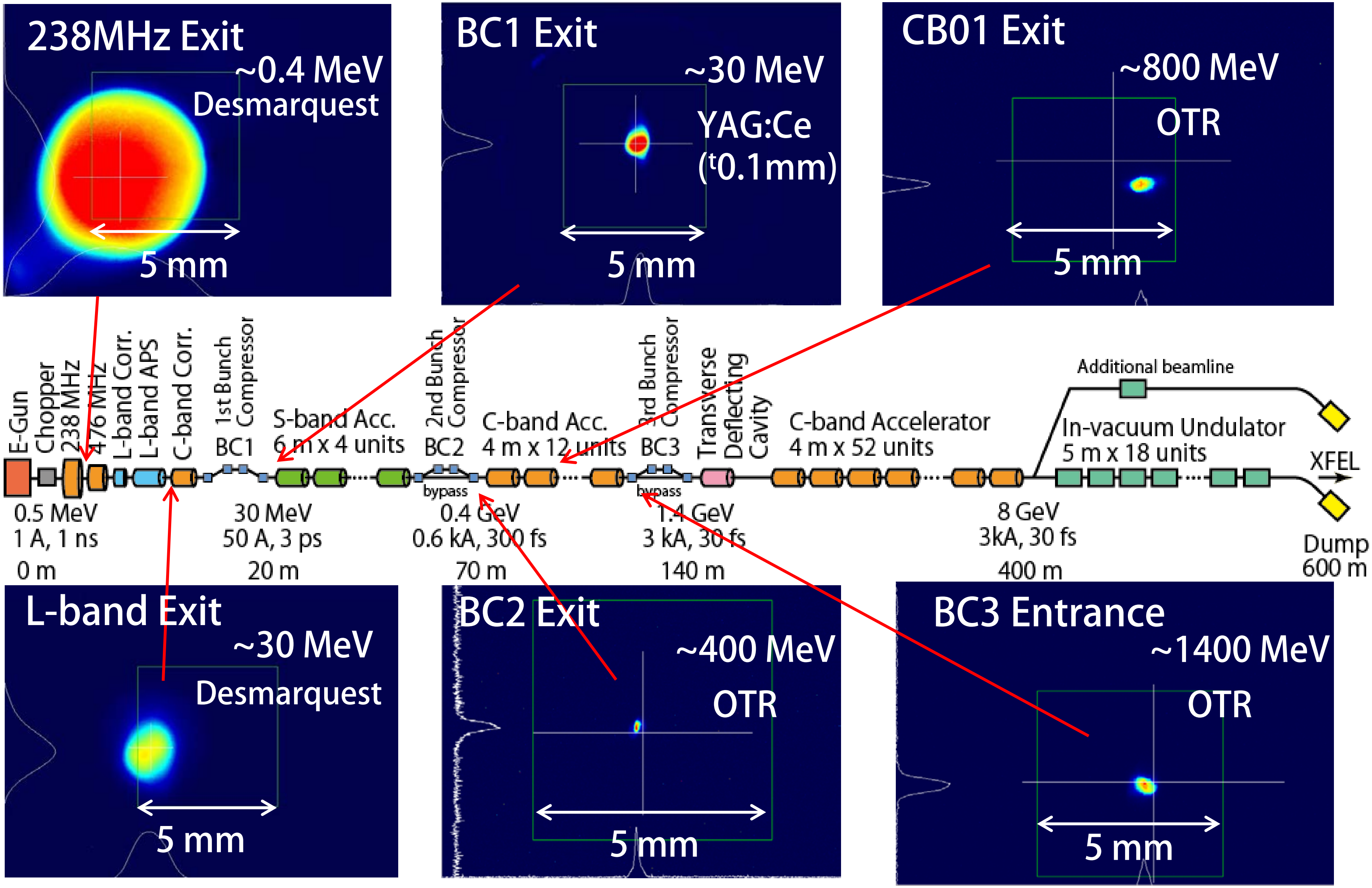
Screen Monitor



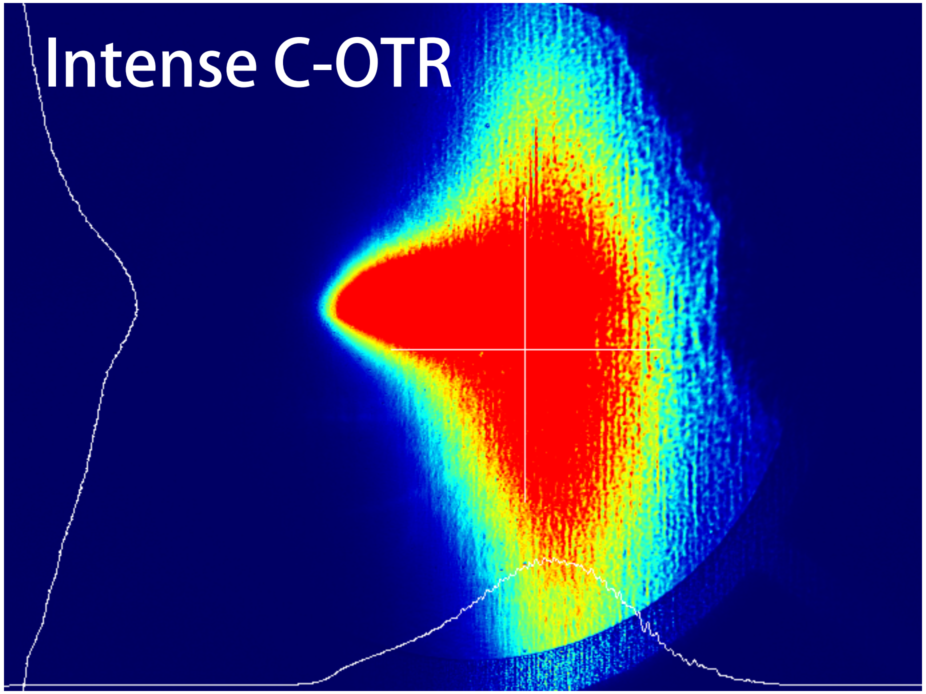
- OTR (stainless steel foil), YAG:Ce scintillator and Desmarquest targets were employed.
  - Target is mounted on a shaft driven by a pneumatic actuator.
- Custom-made lens system.
  - Some of the profile monitors are equipped with remote zoom system (x1 – x4).
- Resolution: 2 μm (x4 optics)
- Images are taken by a CCD camera and transferred by CameraLink.

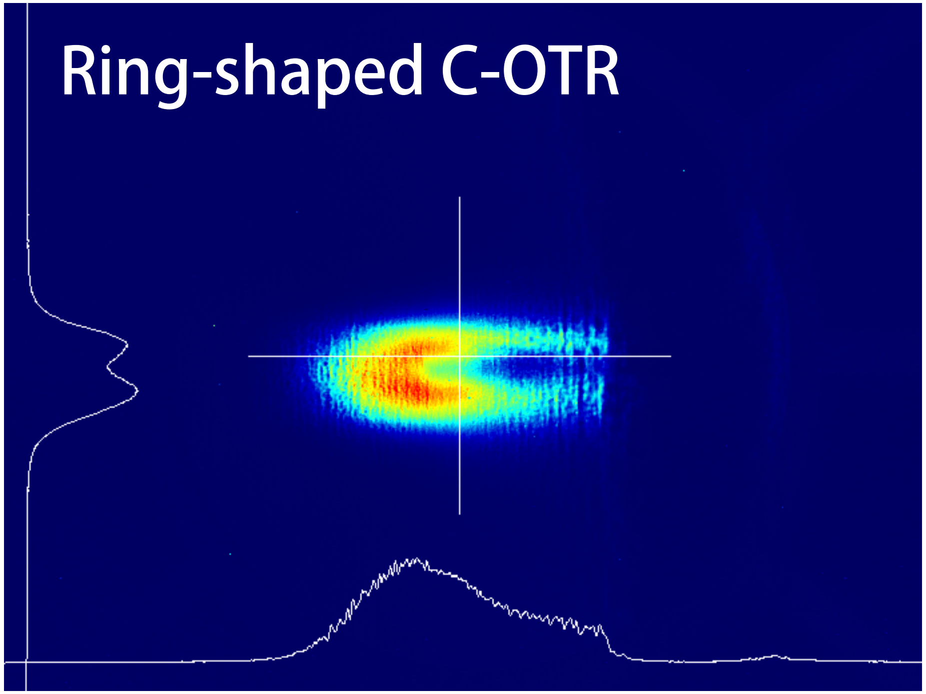


Beam Profiles before BC3



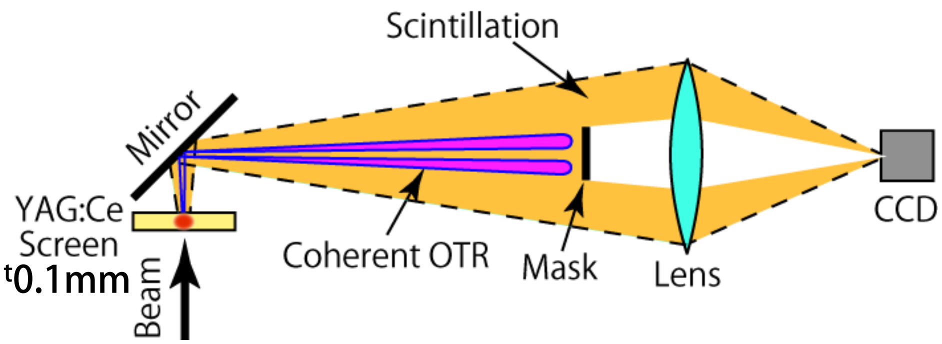
Coherent OTR after BC3

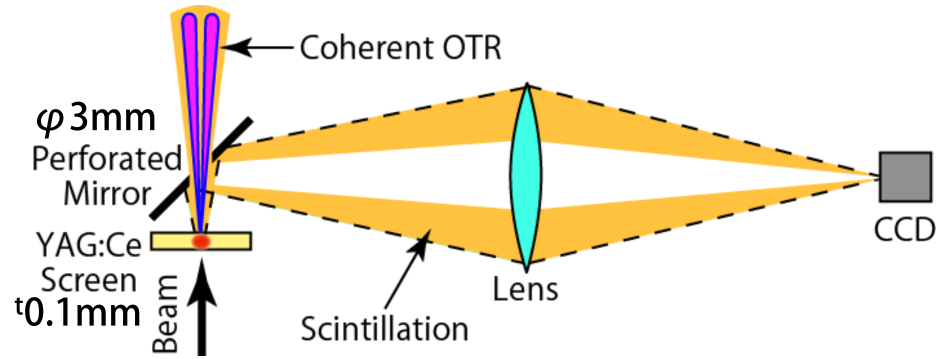


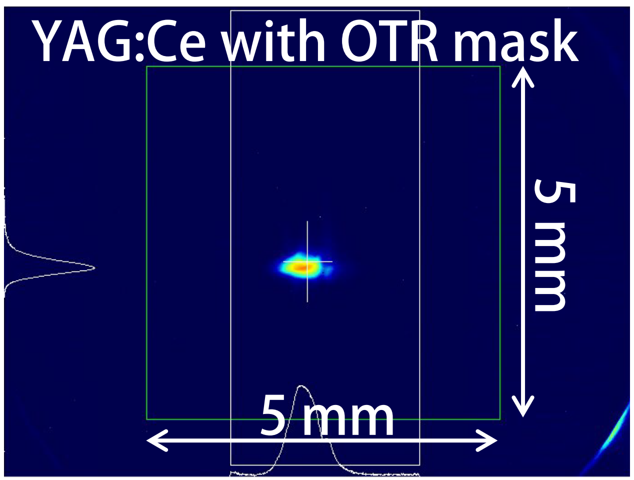


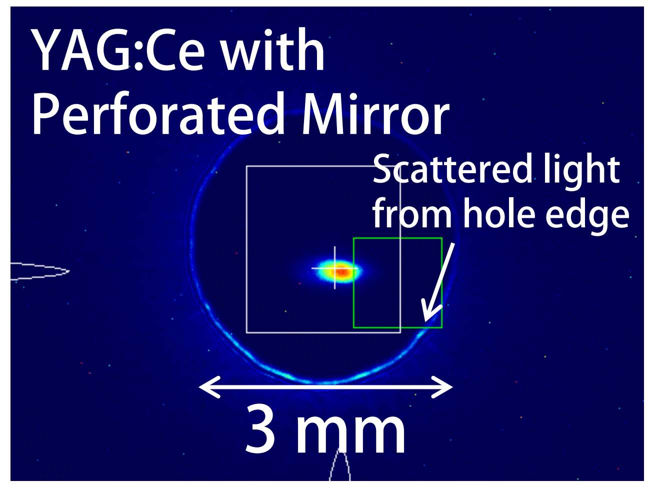
- Intense coherent OTR was observed after BC3
  - Bunch length < 100 fs
  - Stainless steel screen
- Target was changed to YAG:Ce
  - But, C-OTR was still observed from YAG:Ce

Mitigation of C-OTR Problem



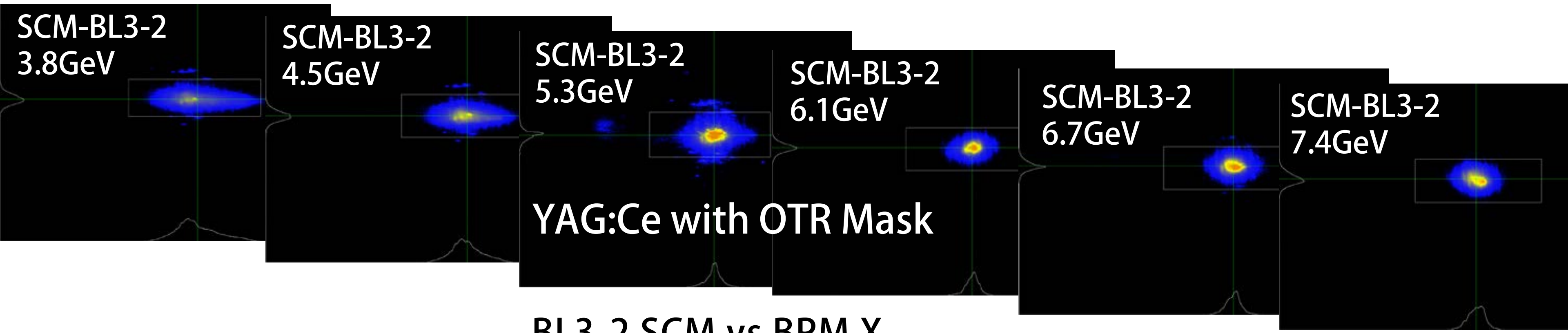


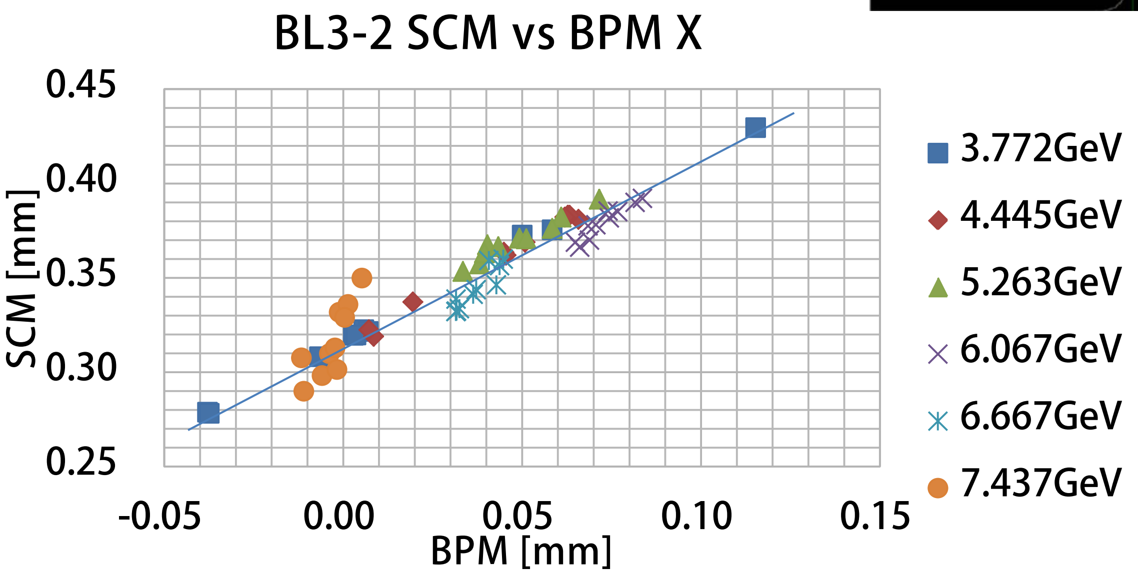




- OTR is emitted forward within ~$1/\gamma$ radian.
- Scintillation of the YAG:Ce has no directional dependence.
- An OTR mask and a perforated mirror were tried to mitigate the C-OTR problem.
- C-OTR from the YAG screen is removed from the mask or the hole on the mirror.
- Details will be presented later
  - MOCC04 by S. Matsubara

Comparison between RF-BPM and Screen Monitor



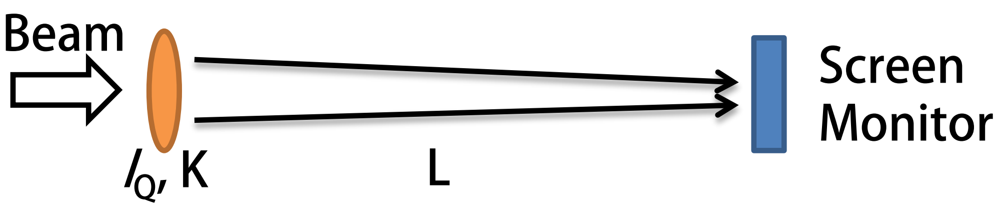


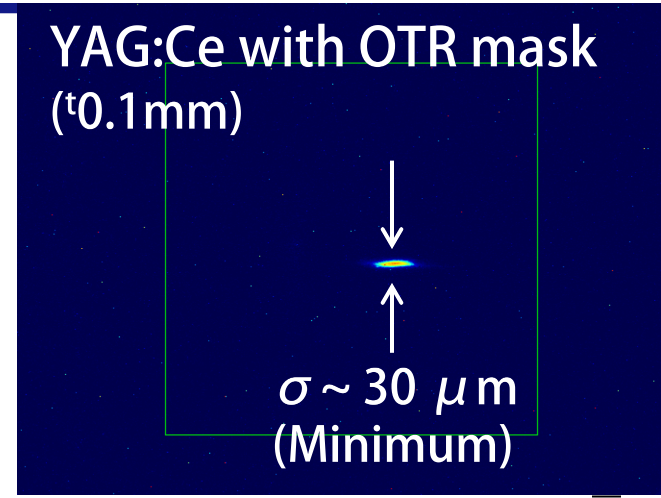
- Beam position from an RF-BPM is consistent with that from the adjacent screen monitor.
  - Even if the beam energy, profile were changed.
  - Error: < 10 μm (STD)

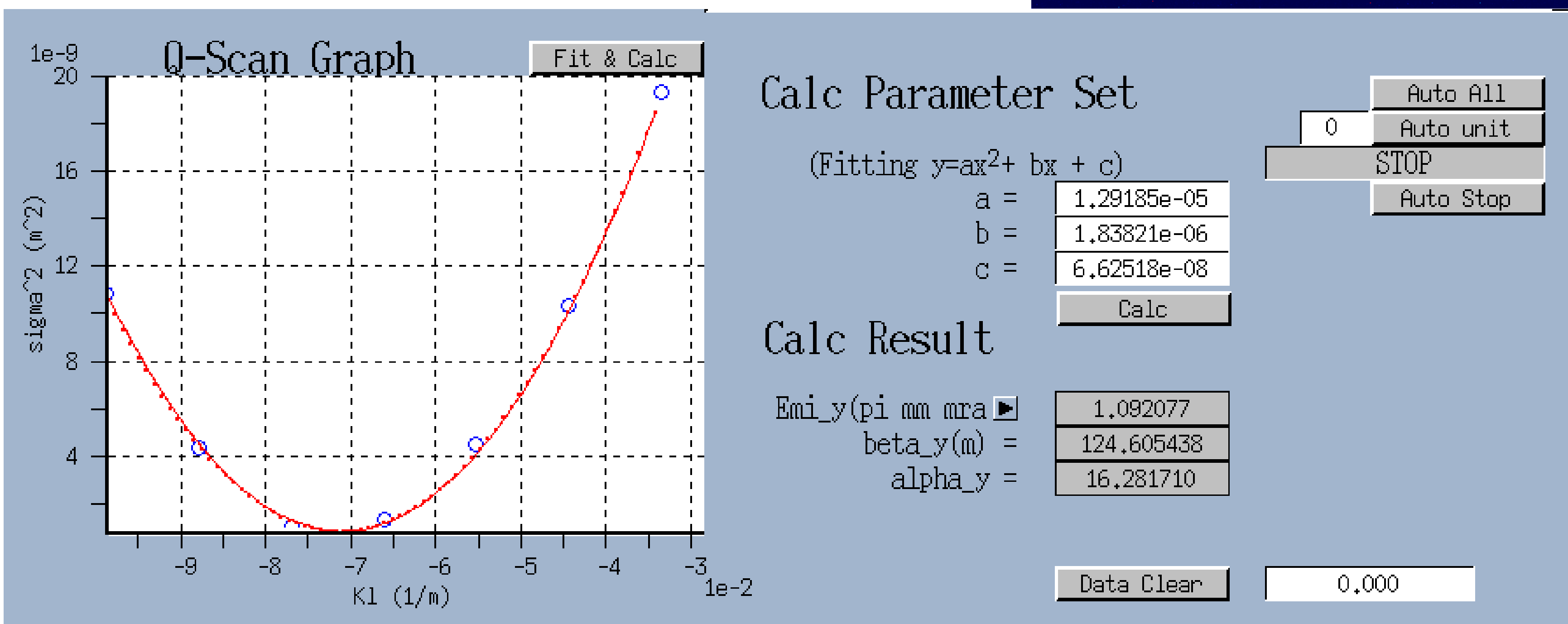
Emittance Measurement

- Q-scanning method

$$\sigma_x{}^2 = \beta\varepsilon\left(L l_Q K + \alpha L/\beta - 1\right)^2 + \varepsilon L^2/\beta$$

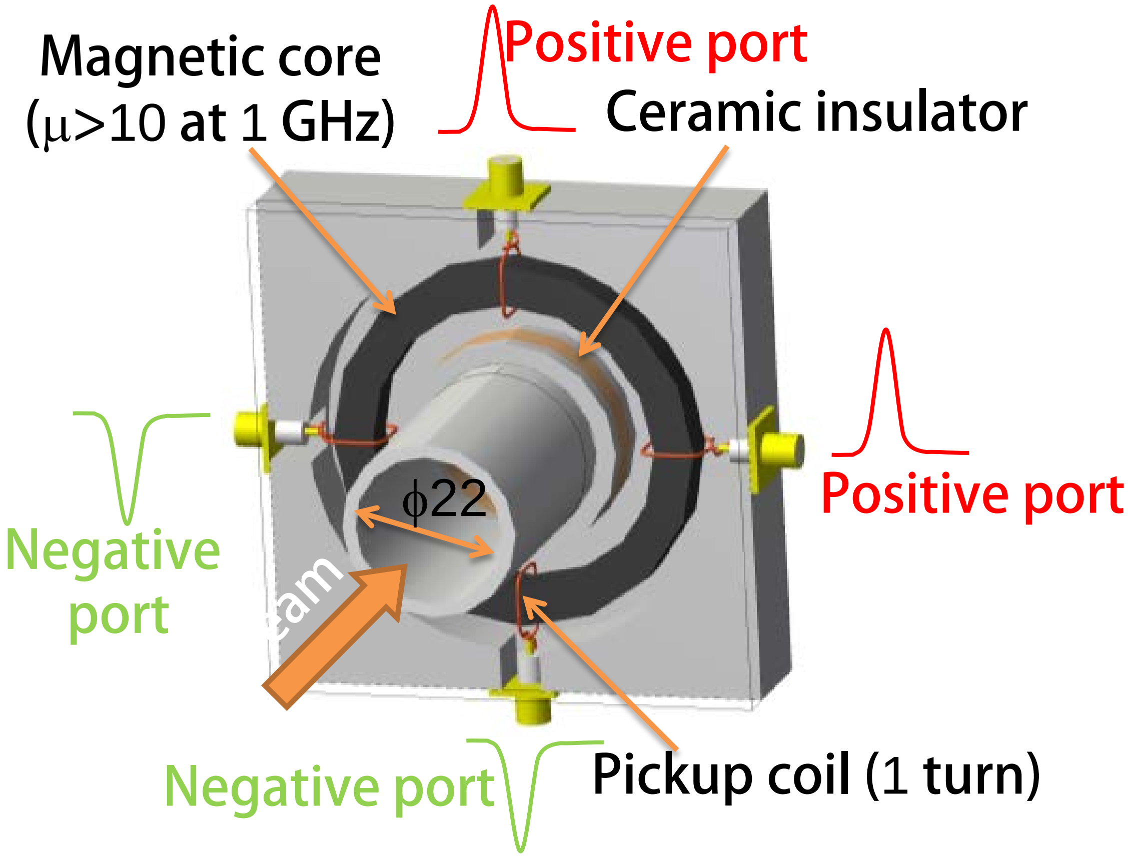


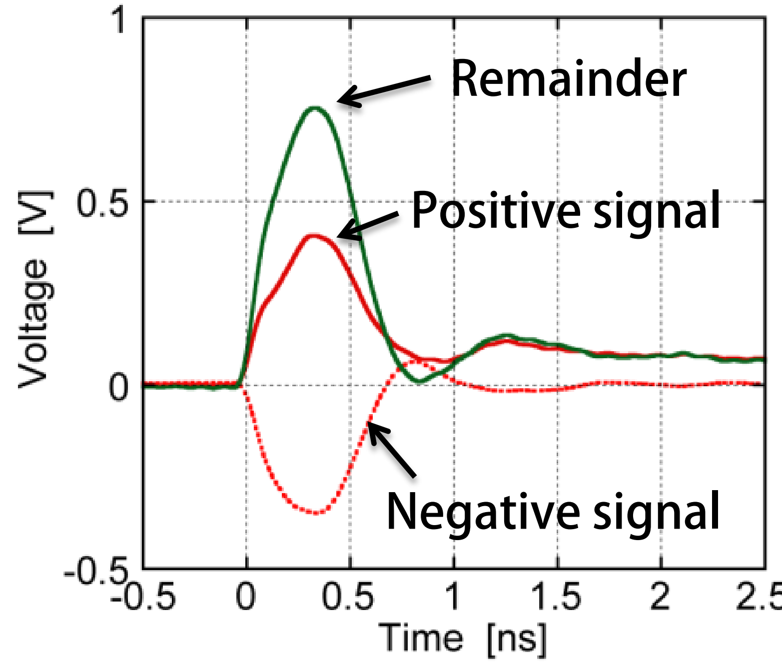


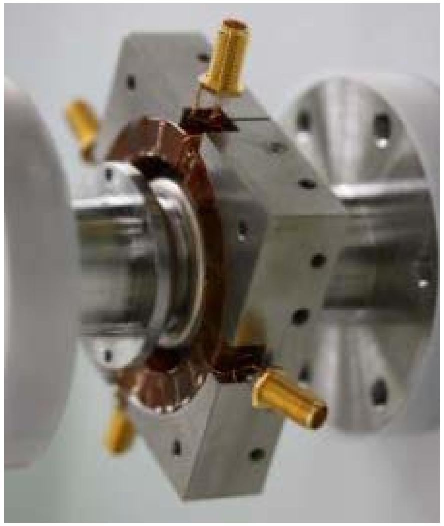


Normalized vertical emittance: 1.09 mm mrad after BC3 (1.4 GeV)

Fast Differential Current Transformer

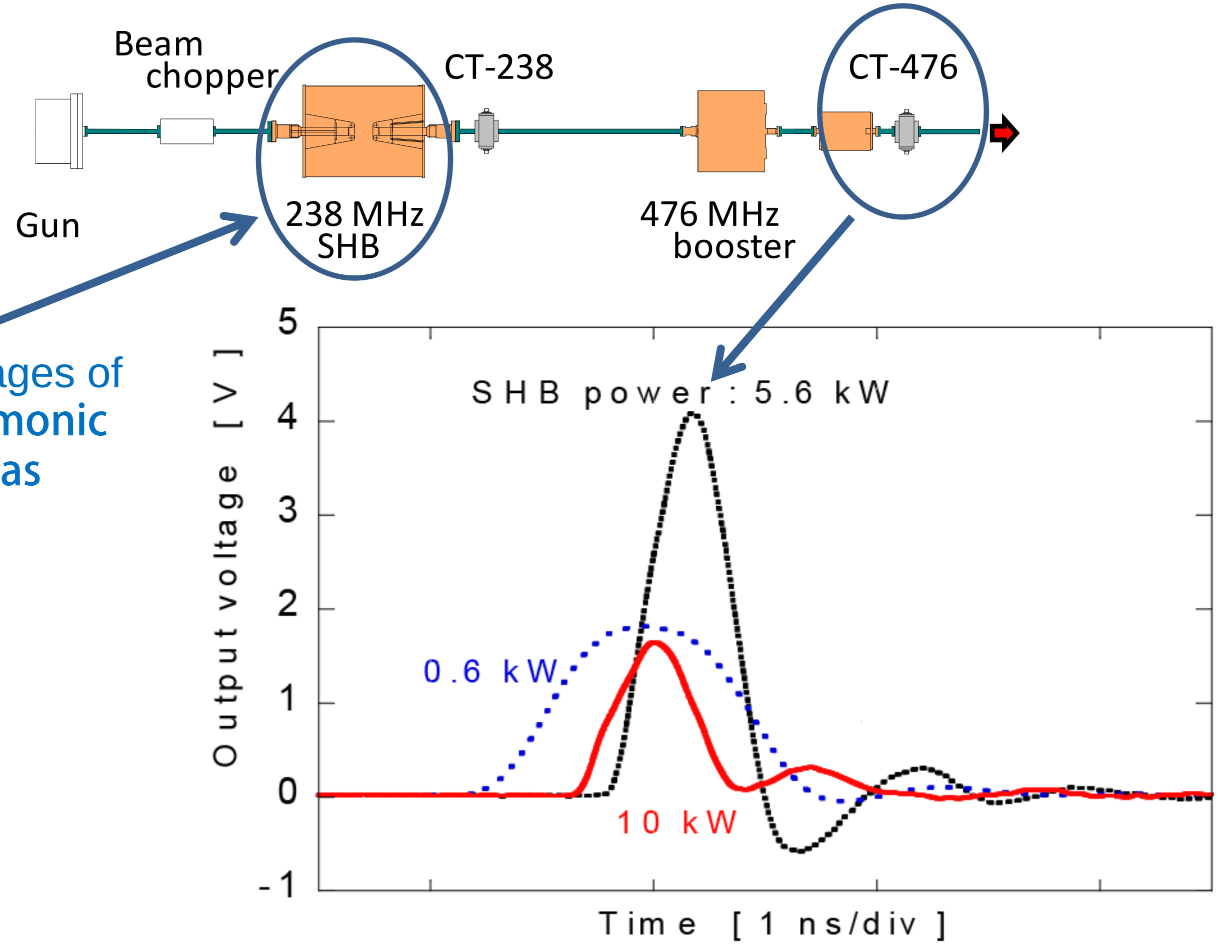






- 2 positive ports and 2 negative ports
- Oppositely coiled.
- Common-mode noise can be subtracted.
- Rise time: ~ 200 ps (10 – 90 %)

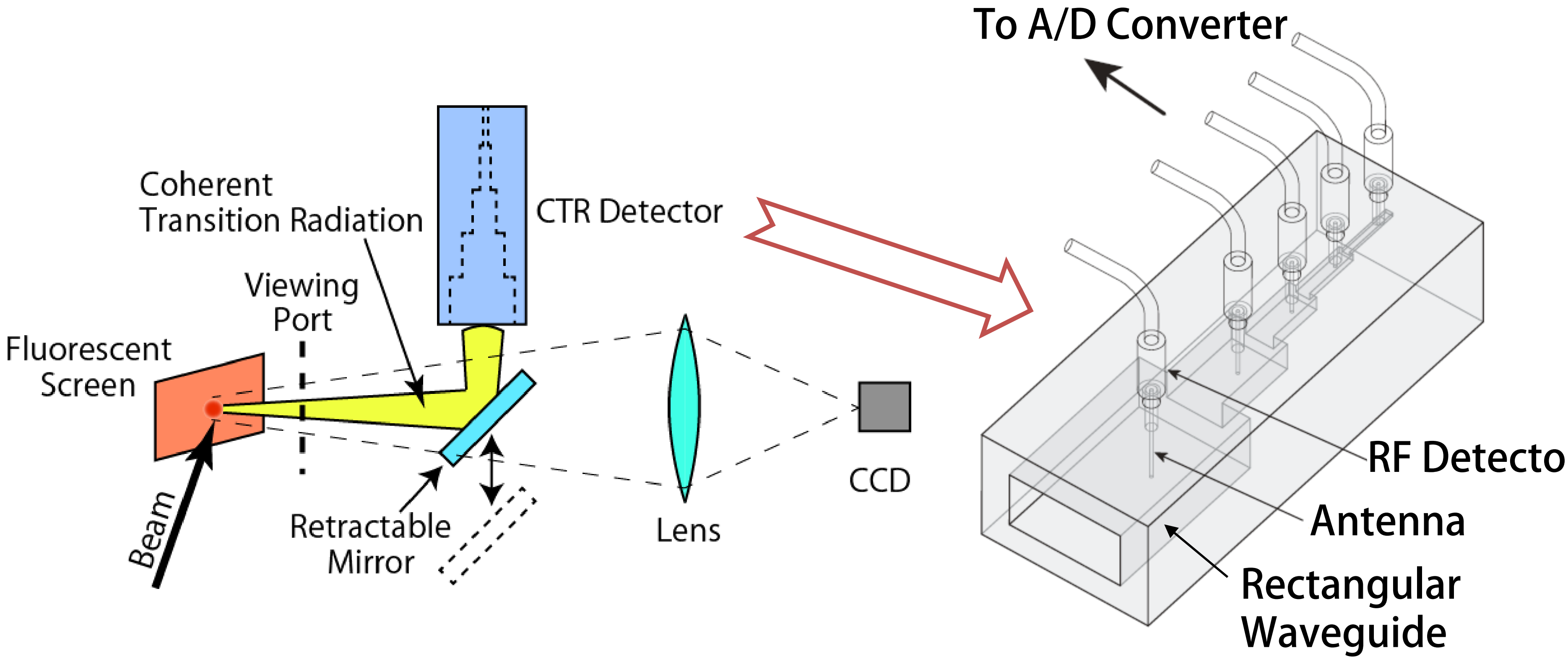
CT Data



Accelerating voltages of 238MHz sub-harmonic buncher cavity was scanned.

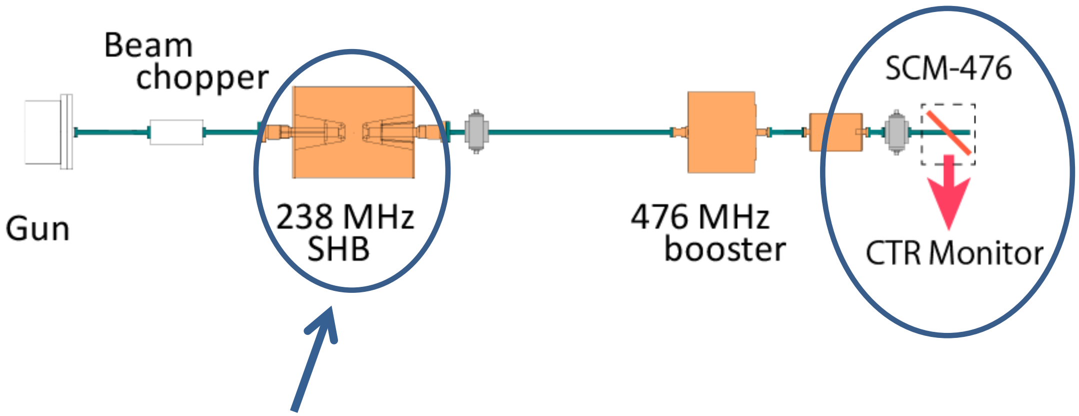
- Bunch length in the velocity bunching region can be measured by using raw signals from the CT.
- Bunch length: 400 ps (FWHM) minimum.

CTR Monitor

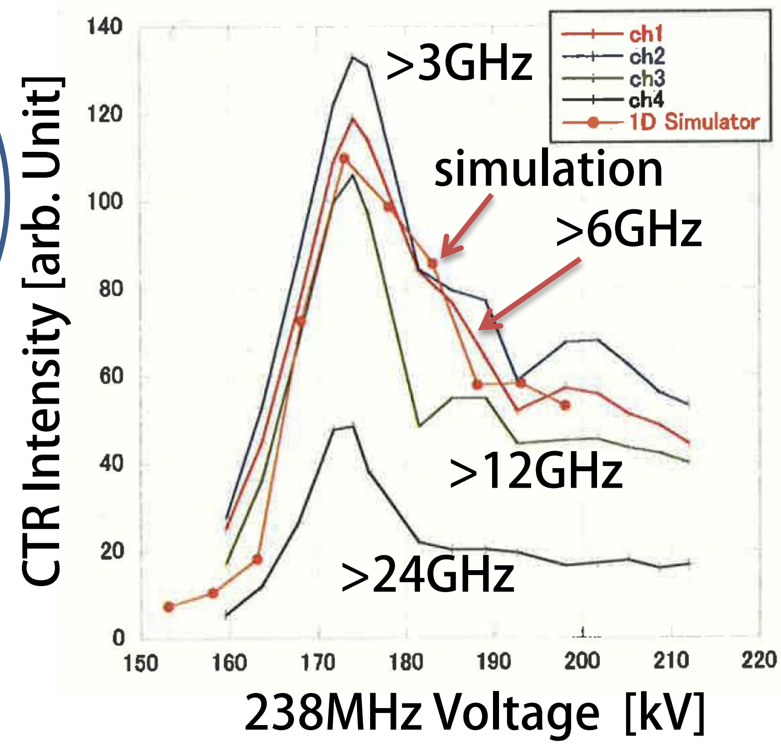


- Coherent transition radiation from a fluorescent screen is detected.
- By using a cut off of a rectangular waveguide, this works as a single-shot spectrometer.
- In the injector part, about 10 GHz rf signal is obtained.
  - Bunch length ~ 100 ps

CTR Monitor Data



Accelerating voltages of 238MHz sub-harmonic buncher cavity was scanned.
(476 MHz booster was turned off.)

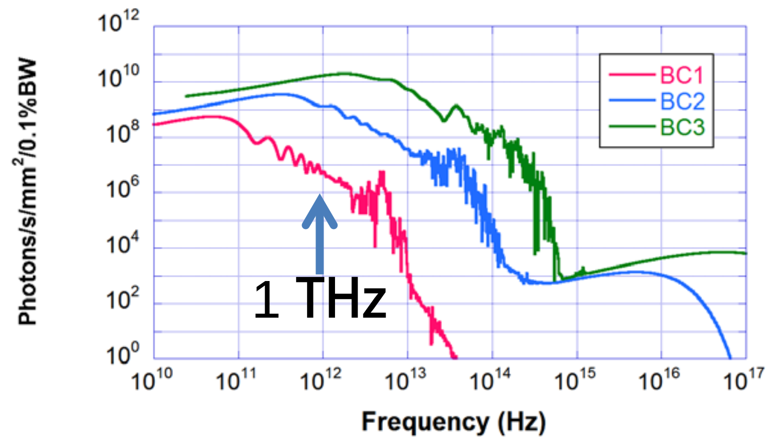


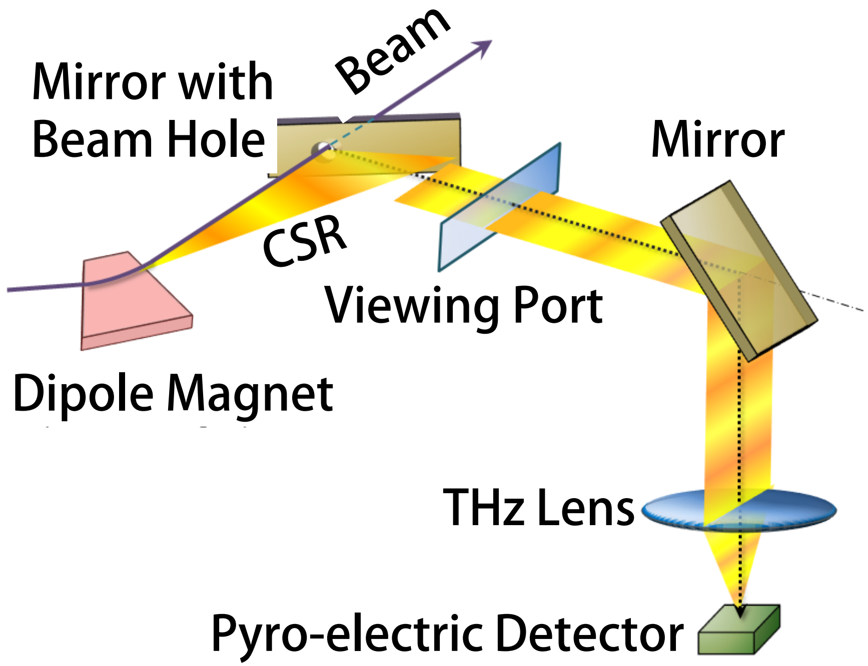
- The signal strength has a correlation with the bunch length.
  - Consistent with 1D simulation
  - Amplitude and phase of the sub-harmonic cavities can be determined

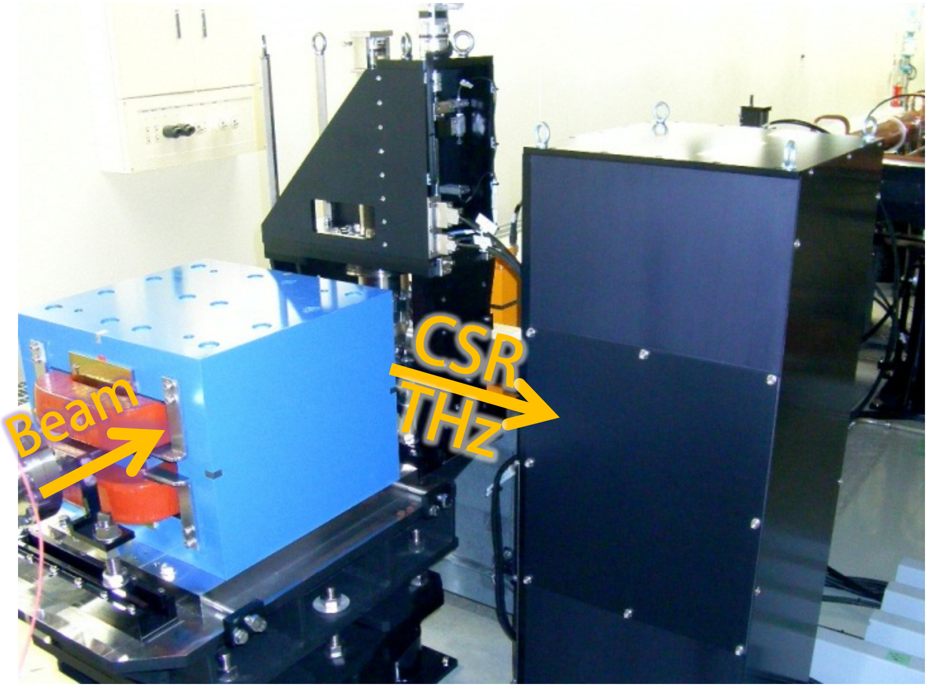
CSR Monitor

- CSR (Coherent Synchrotron Radiation) spectrum has a strong correlation with bunch length.
- CSR intensity was measured by a THz detector non-invasively.
- Pyro-electric detector or THz diode
- CSR from the 4th bending magnet of each bunch compressor is monitored.

CSR spectra (simulation)

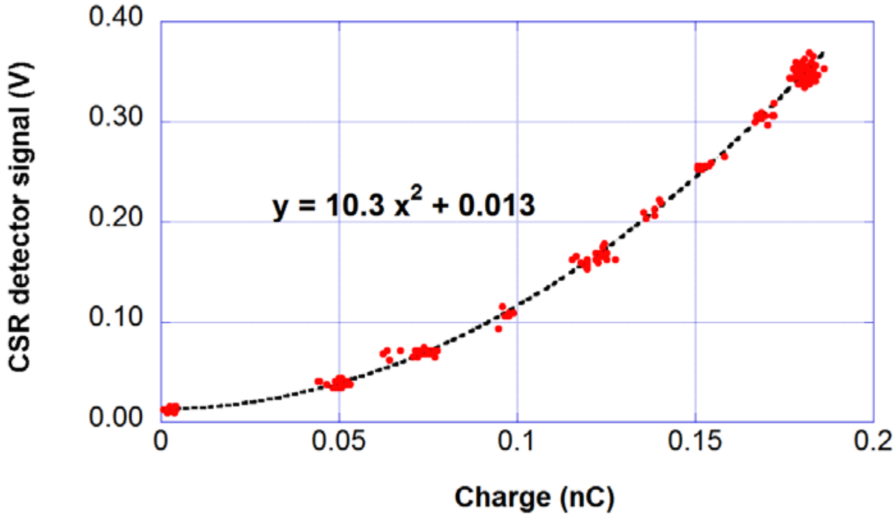




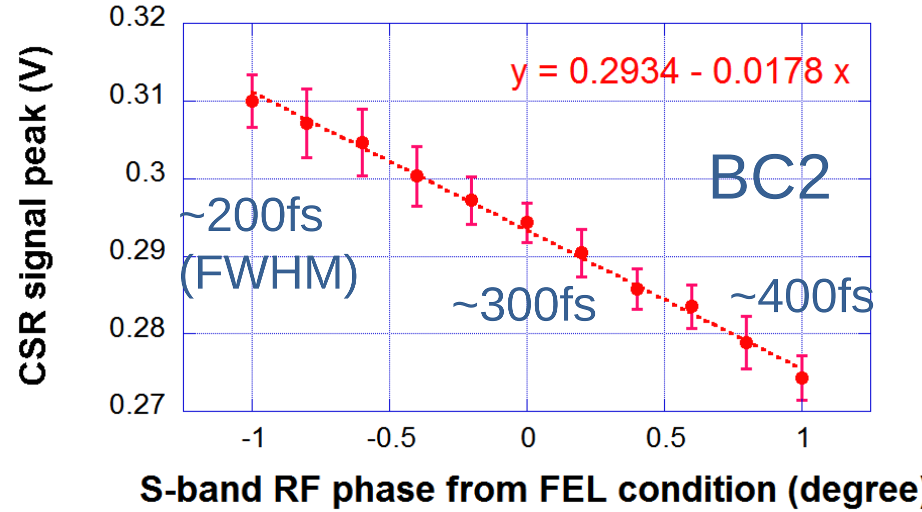


CSR Data

CSR intensity v.s. Charge

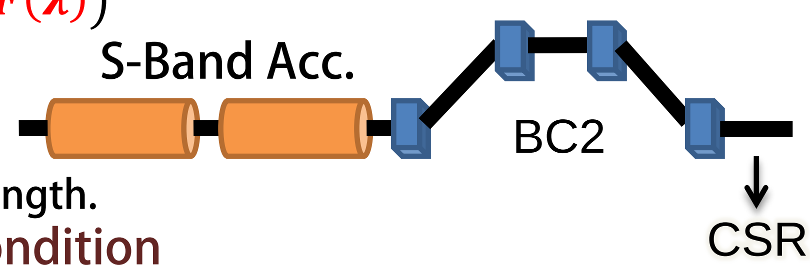


CSR intensity v.s. Bunch length



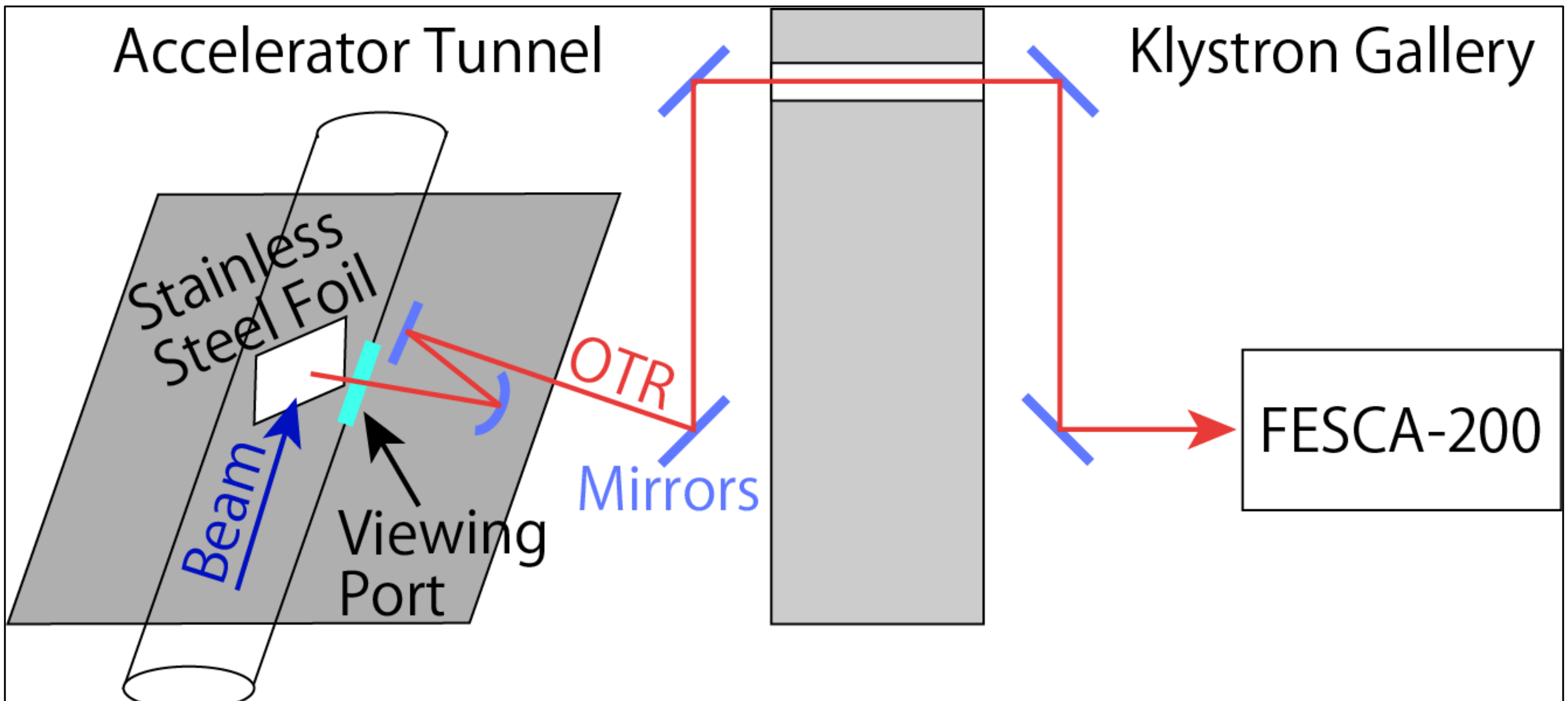
Error bar: STD of fluctuation

- CSR intensity at BC2 was plotted.
- Charge dependence $P(\lambda)\sim P_e(\lambda)\left(N_e + N_e^{\,2}F(\lambda)\right)$
  - CSR intensity is proportional to the square of the beam charge.
- Bunch length dependence
  - S-band phase was shifted to change the bunch length.
- Bunch length ~ 300 fs (FWHM) in the XFEL condition
- Phase shift 1deg. → Bunch length change ~ 100 fs
- Sufficient sensitivity to the bunch length.

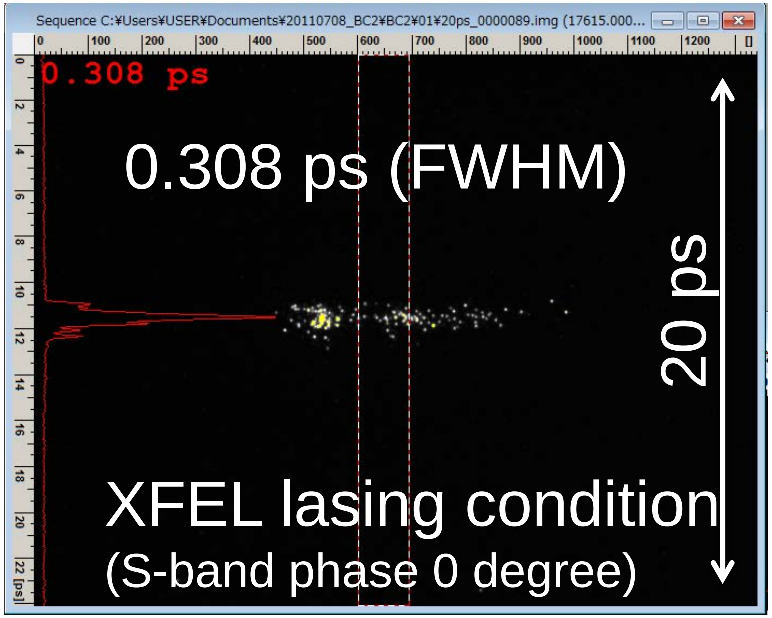


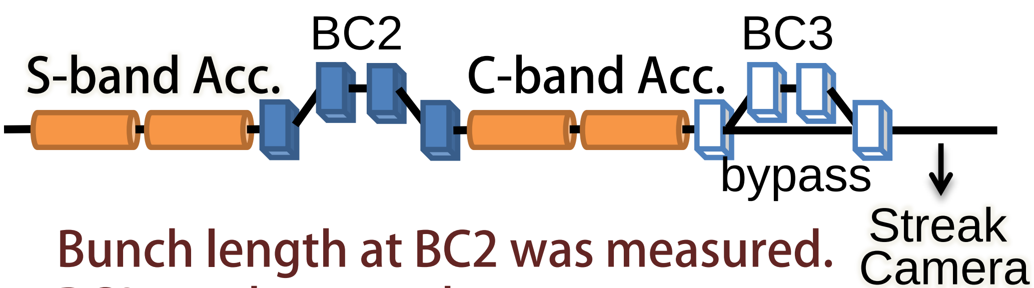
Streak Camera

- OTR light is transported to the klystron gallery and detected by FESCA-200 streak camera (Hamamatsu).
- For bunch length $\gtrsim$ 300 fs (FWHM)

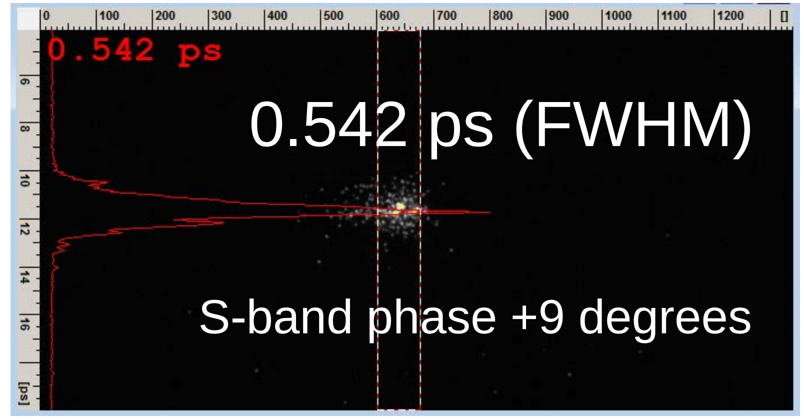


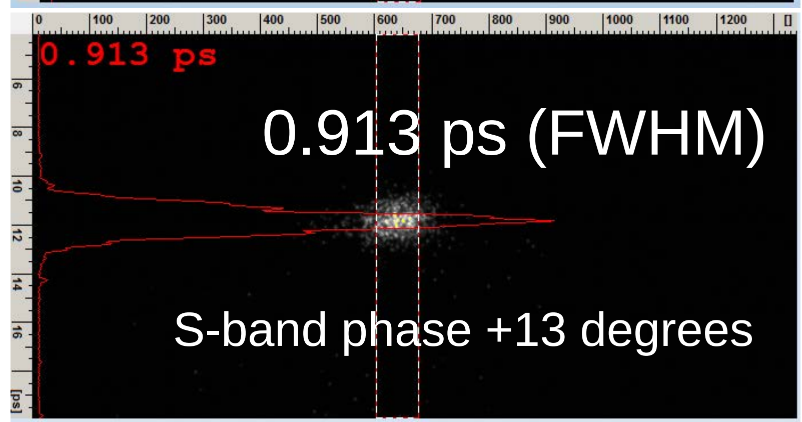
Streak Camera Data

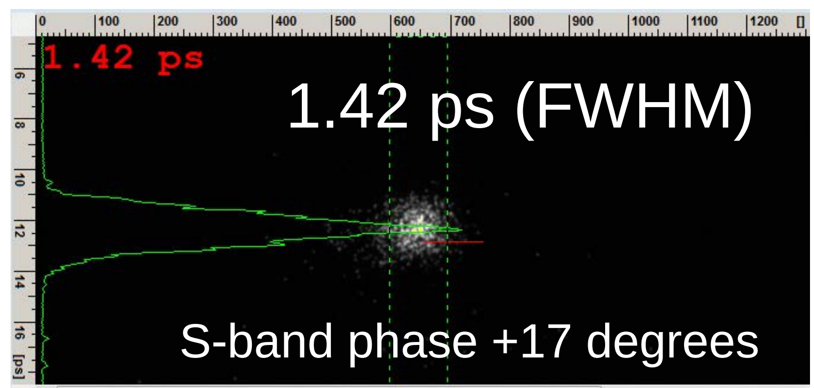




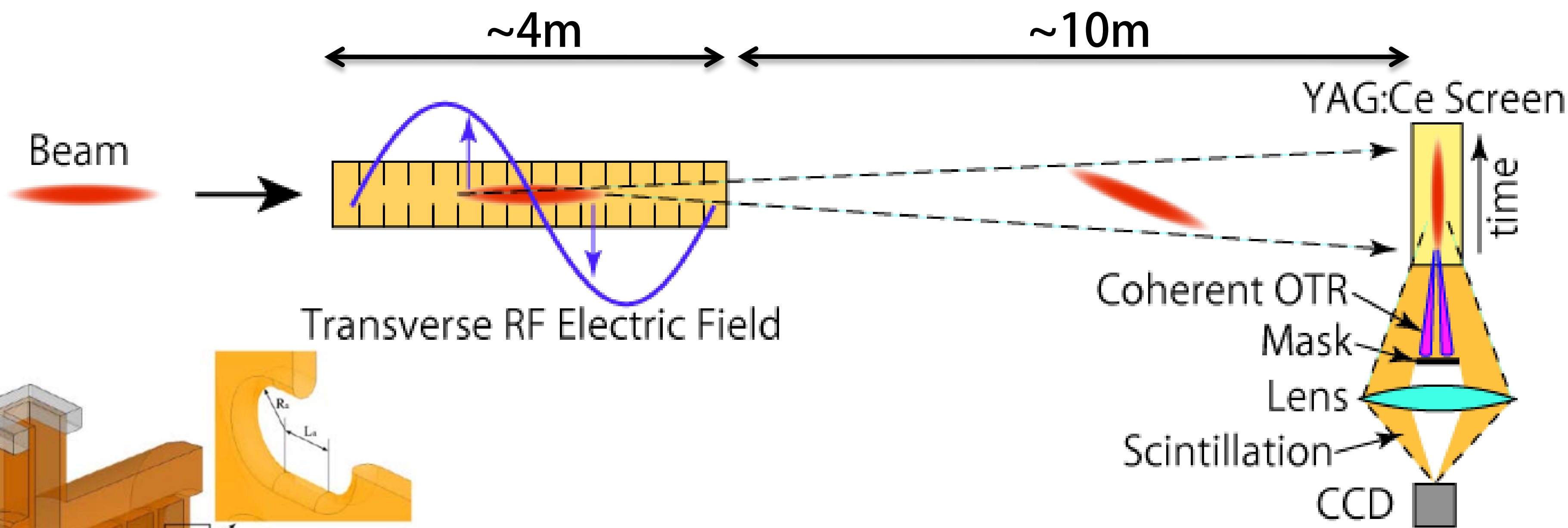
- Bunch length at BC2 was measured.
- BC3 was bypassed.
- S-band phase was shifted to change the bunch length.
- Each figure shows 50-shot integrated image.
- Bunch length of < 1 ps (FWHM) was obtained.

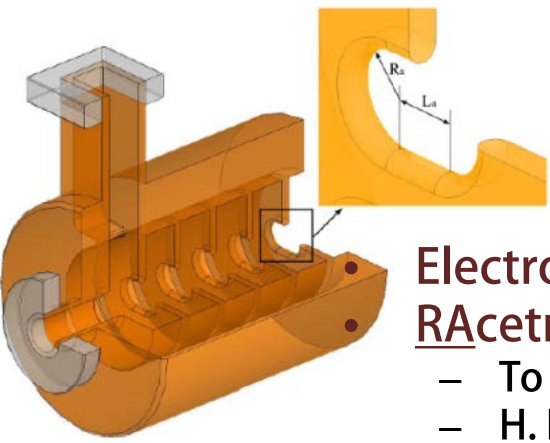






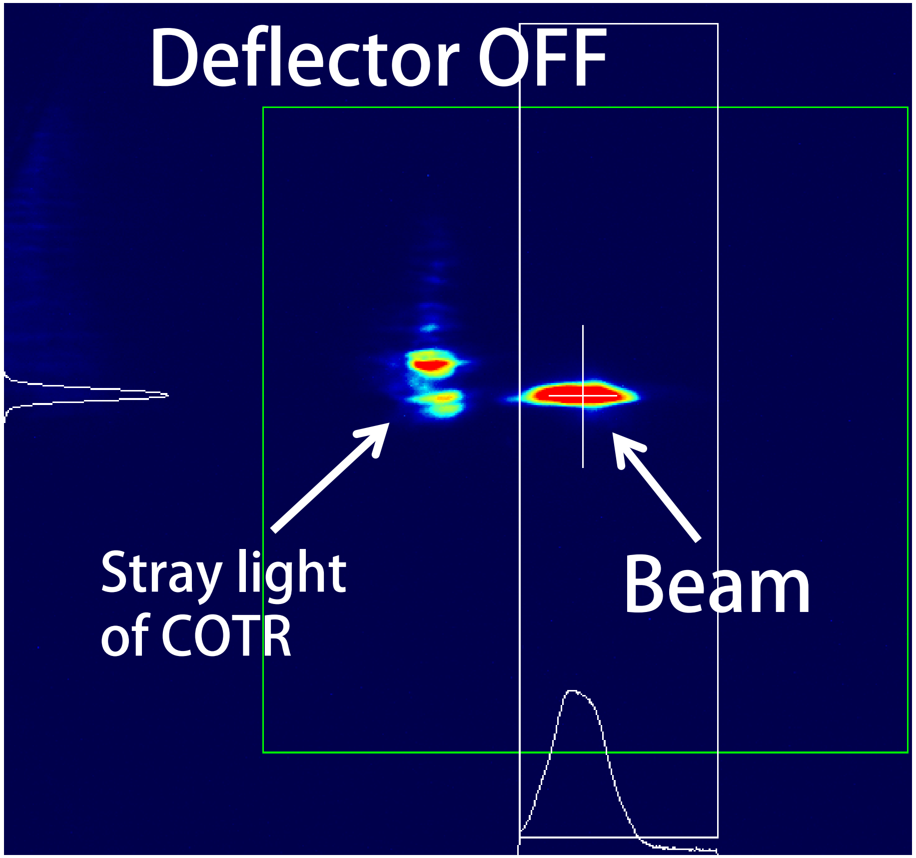
C-band Transverse Deflecting Cavity

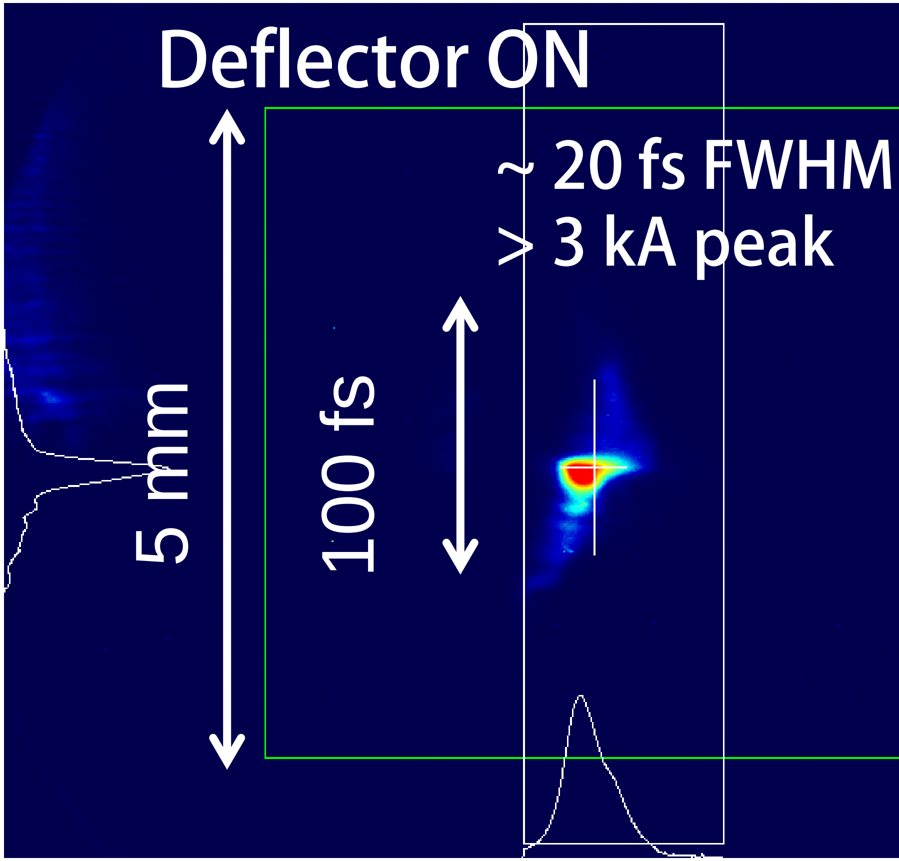




- Electron bunch is pitched by transverse RF field.
- RAcetrack-shaped Iris-coupling DEflectioN structure (RAIDEN)
  - To separate x- and y-mode
  - H. Ego et al., "Transverse C-band Deflecting Structure for Longitudinal Phase Space Diagnostics in the XFEL/SPring-8 "SACLA", Proceedings of IPAC'11.
- Resonant Frequency: 5712 MHz
  - To obtain higher kick voltage
  - To fully utilize the C-band accelerator resource
- Backward traveling wave of HEM11-5π/6 mode
- Deflecting voltage: 60 MV
  - When 1.7m x 2 cavities are driven by 50 MW klystron.

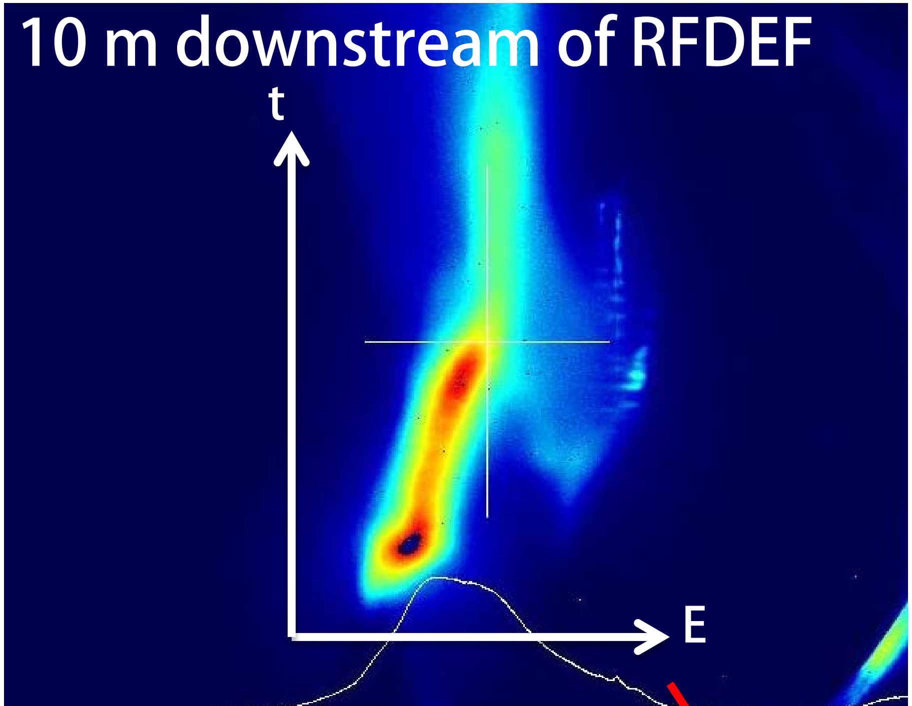
Performance of RF Deflector

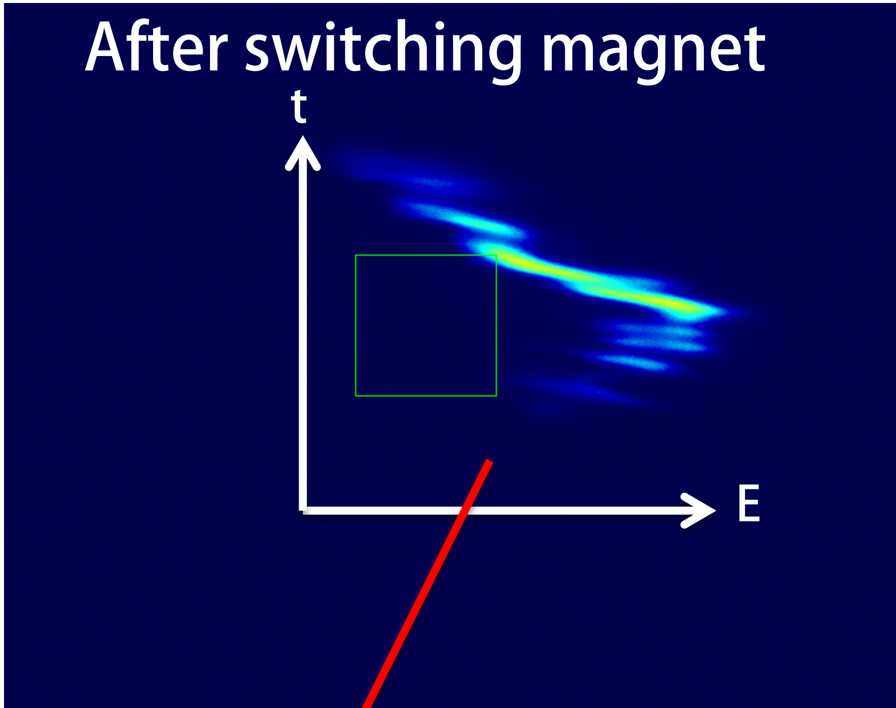


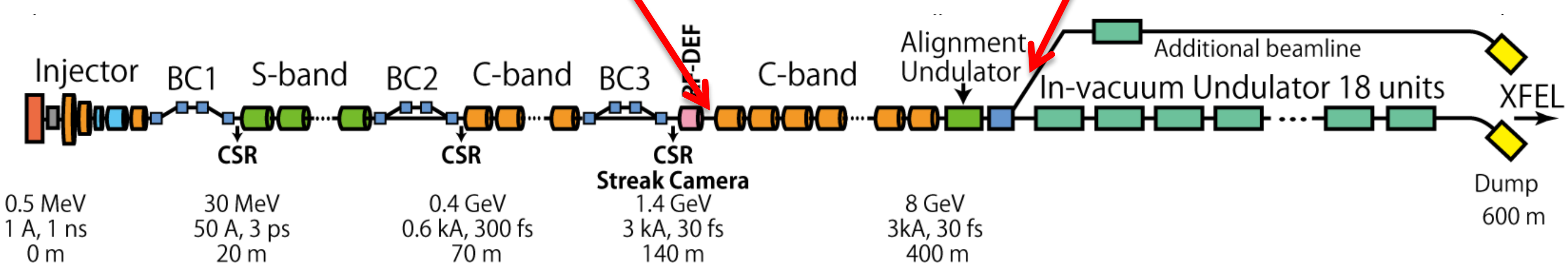


- Temporal structure of a 1.4 GeV beam was stretched to 50 fs/mm at 10 m downstream of the deflector cavity.
- Resolution: ~ 10 fs
- YAG:Ce and OTR mask are used in the profile monitor.

E-t Phase-space Measurement



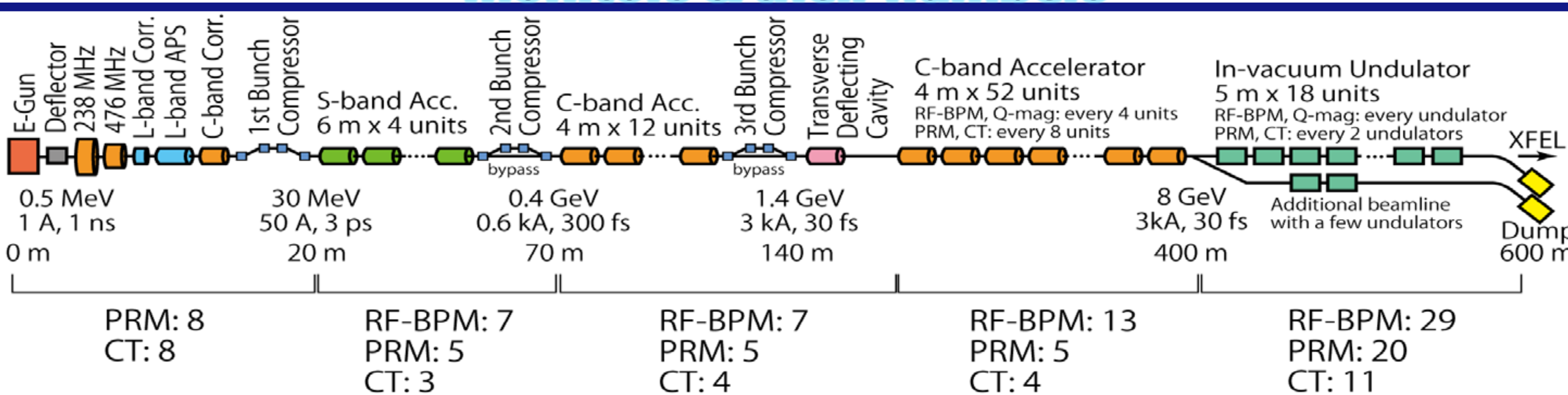




Summary

- RF Cavity BPM
  - Position resolution: 0.6 μm
- Multi-stripline BPM
  - Sufficient sensitivity to the energy measurement at BC
- Beam Profile Monitor
  - C-OTR was observed after BC3.
  - C-OTR was mitigated by YAG:Ce screen with a spatial separation method.
  - 1 mm mrad emittance was successfully measured.
- Fast Differential Current Transformer
  - Rise time: 0.2 ns
  - Bunch length measurement around 500 ps.
- CTR and CSR Monitor
  - Sufficient sensitivity to the bunch length
- Streak Camera
  - 300 fs (FWHM) bunch length was measured
- C-band Transverse RF Deflecting Cavity
  - Temporal structure measurement with 10 fs resolution
  - E-t phase space can be measured
- By using these instruments, X-ray lasing was achieved at SACLA.

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
Streak Camera by using OTR	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 mm for the undulator section, a 30 fs beam pulse width, and a beam arrival time of less than 30 fs after the BCs.

Detection Principle of RF-BPM

- TM110 dipole resonant mode of a pillbox cavity

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

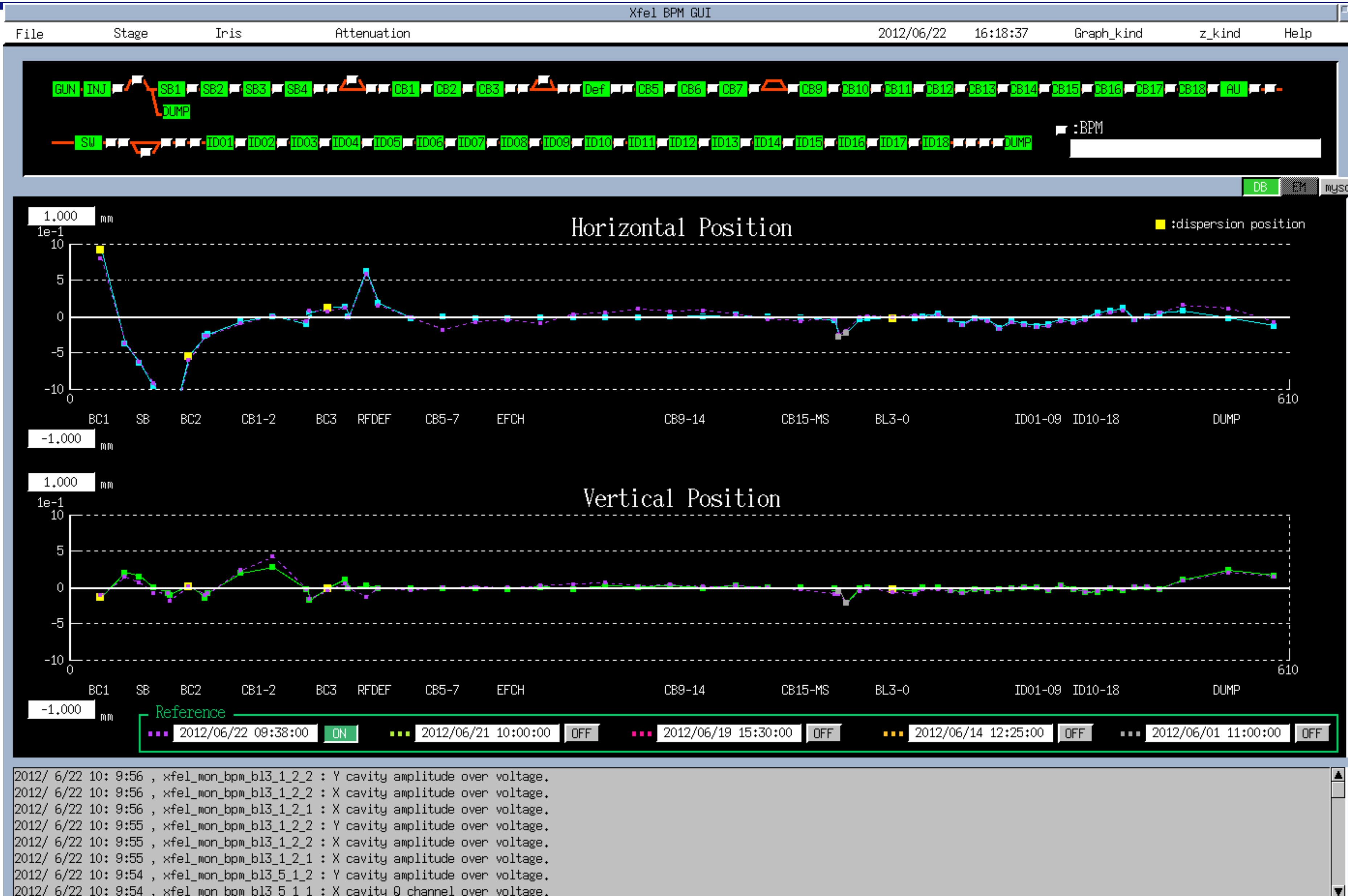
  – E-field is linear around the axis

- Output voltage

$$V = \underbrace{V_1 q x}_{\substack{\text{Position signal} \\ \text{In-phase}}} + \underbrace{j V_2 q x'}_{\substack{\text{Slope signal} \\ \text{Quadrature-phase}}} + \underbrace{j V_3 q}_{\substack{\text{Leakage of TM010 mode} \\ \text{Quadrature-phase}}} + \underbrace{V_n}_{\text{Noise}}$$

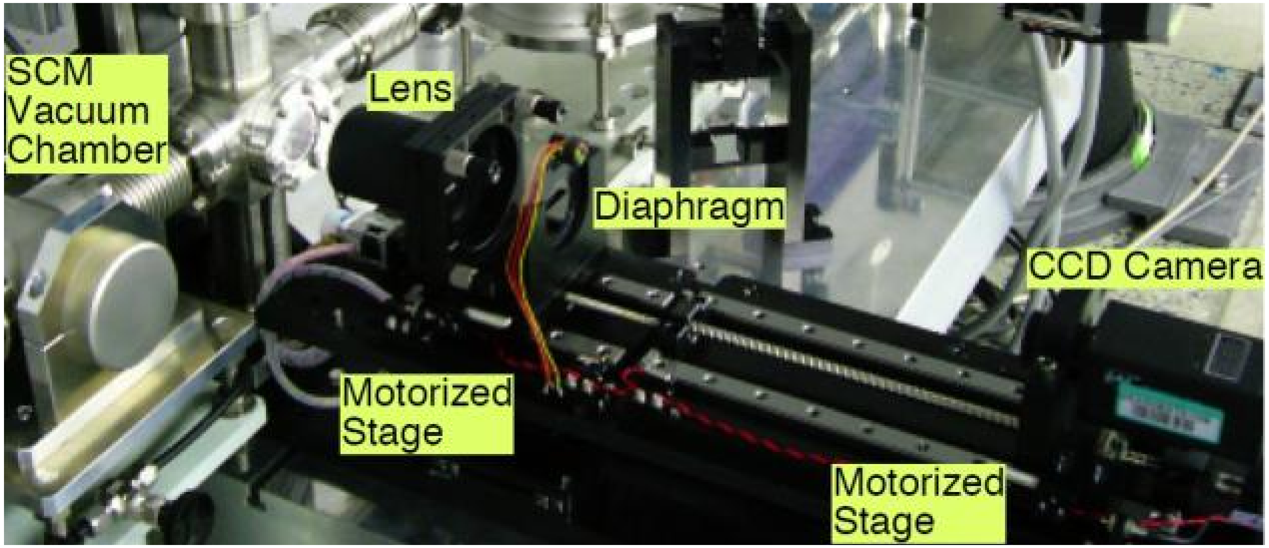
- Need to discriminate in-phase component from quadrature.

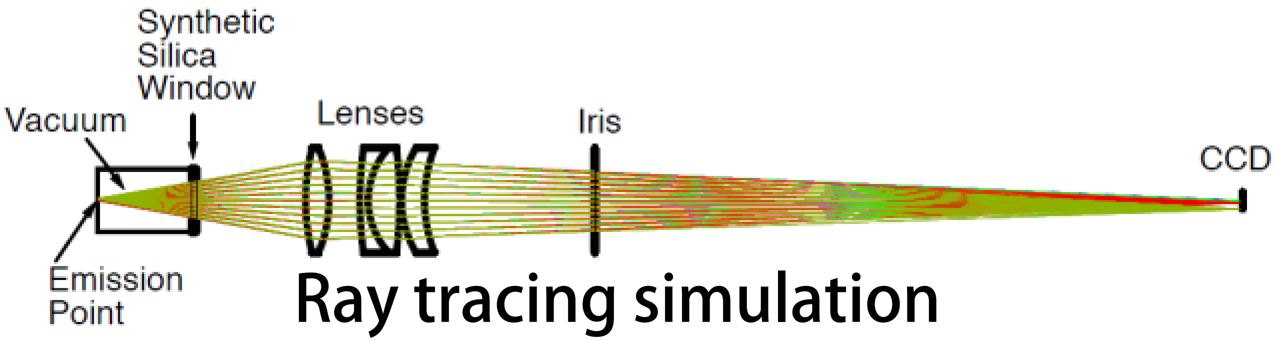
BPM GUI



Xfel BPM GUI
File
Stage
Iris
Attenuation
2012/06/22
16:18:37
Graph_kind
z_kind
Help
GUN INJ SB1 SB2 SB3 SB4 CB1 CB2 CB3 Def CB5 CB6 CB7 CB9 CB10 CB11 CB12 CB13 CB14 CB15 CB16 CB17 CB18 AU
DUMP
SW ID01 ID02 ID03 ID04 ID05 ID06 ID07 ID08 ID09 ID10 ID11 ID12 ID13 ID14 ID15 ID16 ID17 ID18 DUMP
:BPM
DB
EM
mysq
Horizontal Position
:dispersion position
1.000 mm
1e-1
-1.000 mm
0
610
BC1 SB BC2 CB1-2 BC3 RFDEF CB5-7 EFCH CB9-14 CB15-MS BL3-0 ID01-09 ID10-18 DUMP
Vertical Position
Reference
2012/06/22 09:38:00 ON
2012/06/21 10:00:00 OFF
2012/06/19 15:30:00 OFF
2012/06/14 12:25:00 OFF
2012/06/01 11:00:00 OFF
2012/ 6/22 10: 9:56 , xfel_mon_bpm_bl3_1_2_2 : Y cavity amplitude over voltage.
2012/ 6/22 10: 9:56 , xfel_mon_bpm_bl3_1_2_2 : X cavity amplitude over voltage.
2012/ 6/22 10: 9:56 , xfel_mon_bpm_bl3_1_2_1 : X cavity amplitude over voltage.
2012/ 6/22 10: 9:55 , xfel_mon_bpm_bl3_1_2_2 : Y cavity amplitude over voltage.
2012/ 6/22 10: 9:55 , xfel_mon_bpm_bl3_1_2_2 : X cavity amplitude over voltage.
2012/ 6/22 10: 9:55 , xfel_mon_bpm_bl3_1_2_1 : X cavity amplitude over voltage.
2012/ 6/22 10: 9:54 , xfel_mon_bpm_bl3_5_1_2 : Y cavity amplitude over voltage.
2012/ 6/22 10: 9:54 , xfel_mon_bpm_bl3_5_1_1 : X cavity Q channel over voltage.

Imaging System



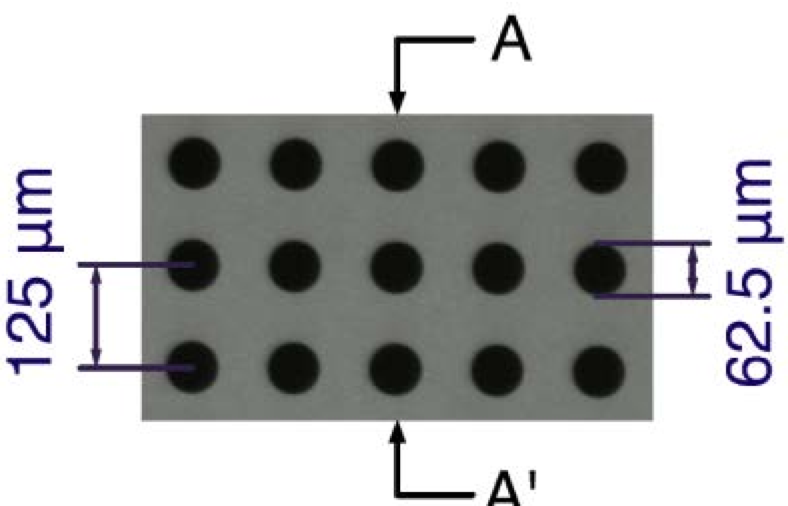


Ray tracing simulation

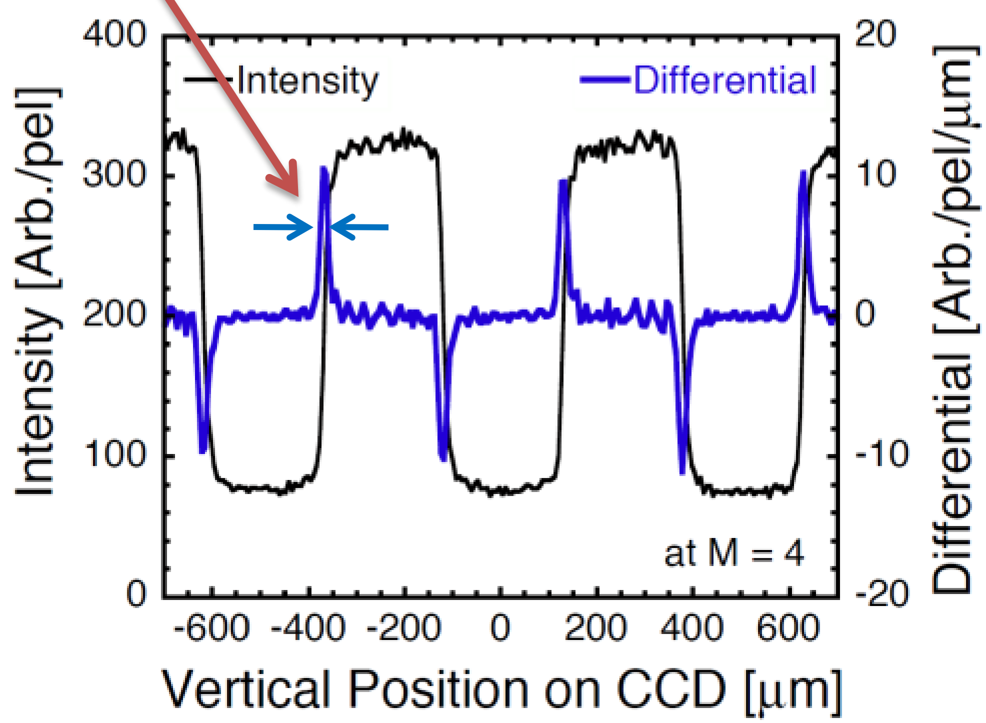
- Custom-made lens system
- Variable magnification: x1 – x4
  - Lens and CCD camera are mounted on a motorized stage
  - x1 optics: Beam finding
  - x4 optics: Precise measurement

Spatial Resolution

- Spatial resolution of the imaging system was measured by using a grid distortion pattern.
- Spatial resolution: 2.5 μm (HWHM)
  - x4 optics
  - Consistent with lens simulation



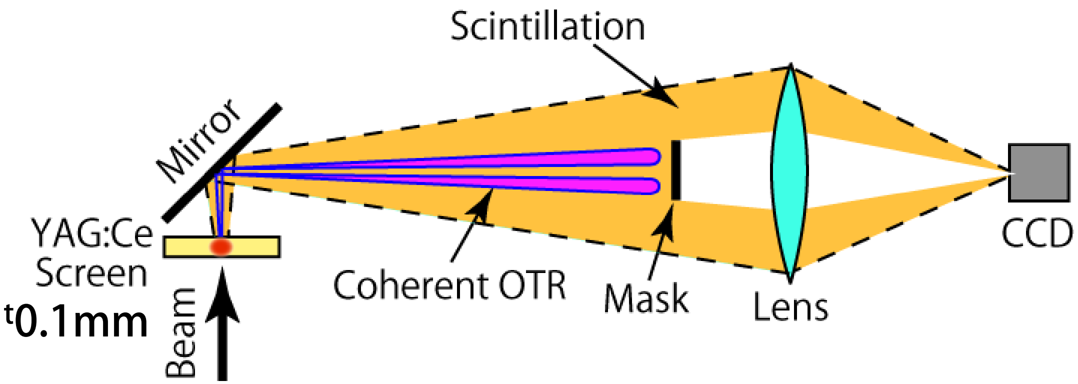
Grid distortion pattern



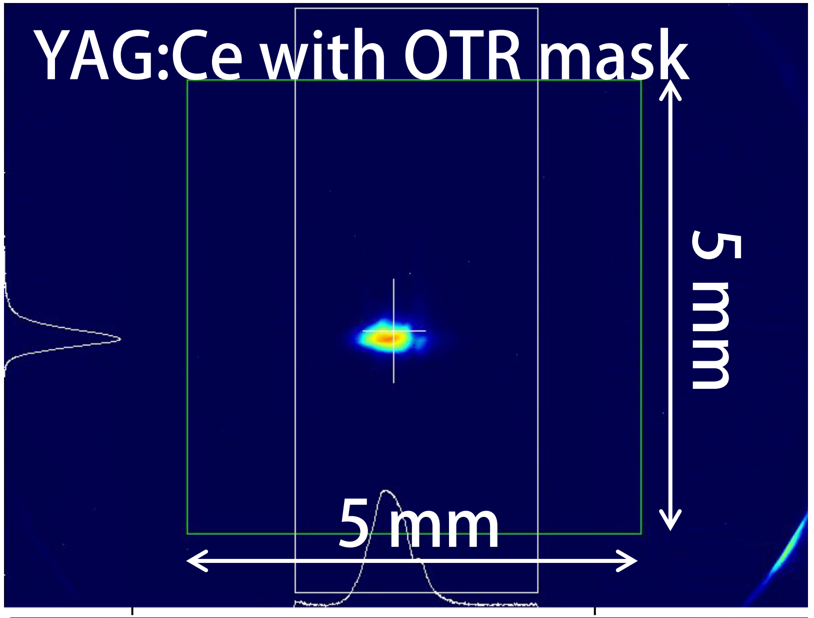
OTR Target

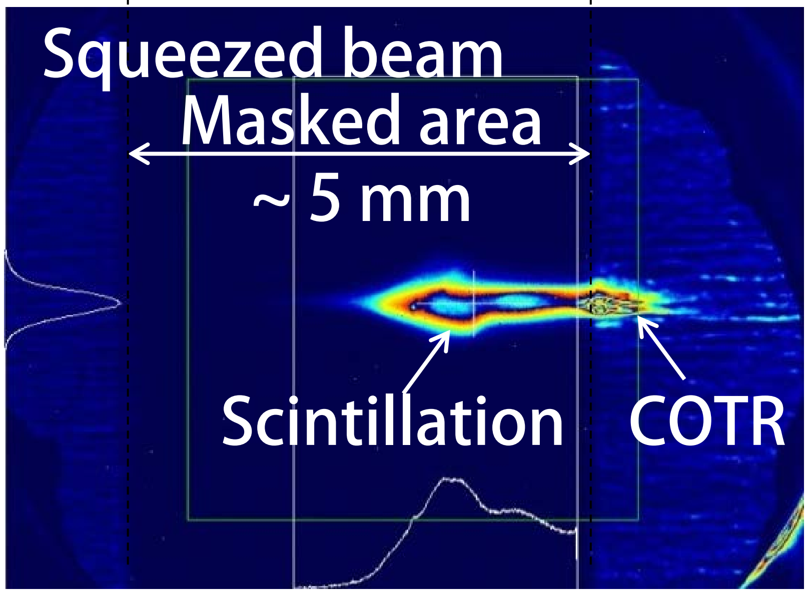
- Thin stainless steel foil
  - Thickness: 0.1 mm
  - To reduce radiation damage of other components.
- 1mm-thick frame to support the foil
  - Ten 0.1 mm thick foils are stacked and unified by a diffusion bonding technique.
- Surface roughness: several 10 nm
- Flatness: 3 μm

Mitigation of Coherent OTR

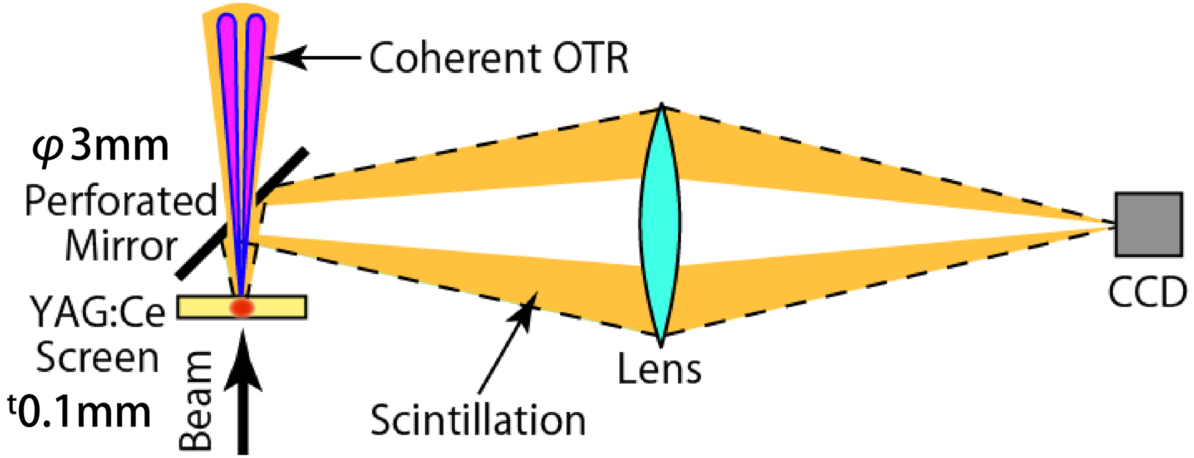


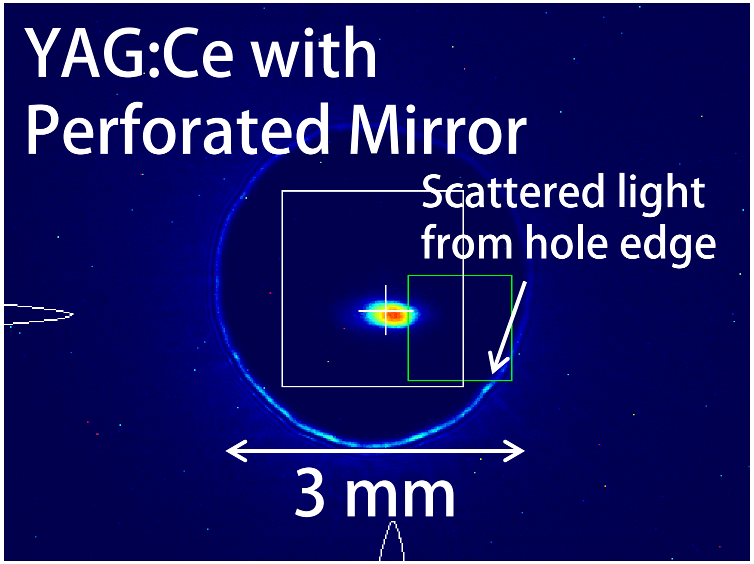
- Target was changed to YAG:Ce
  - C-OTR was still observed from YAG:Ce
  - Scintillation of the YAG:Ce has no directional dependence.
- OTR mask
  - 5 mm width
  - OTR is emitted forward within ~$1/\gamma$ radian.
- C-OTR problem was mitigated by YAG:Ce and OTR mask.
- Details are presented later
  - MOCC04 by S. Matsubara

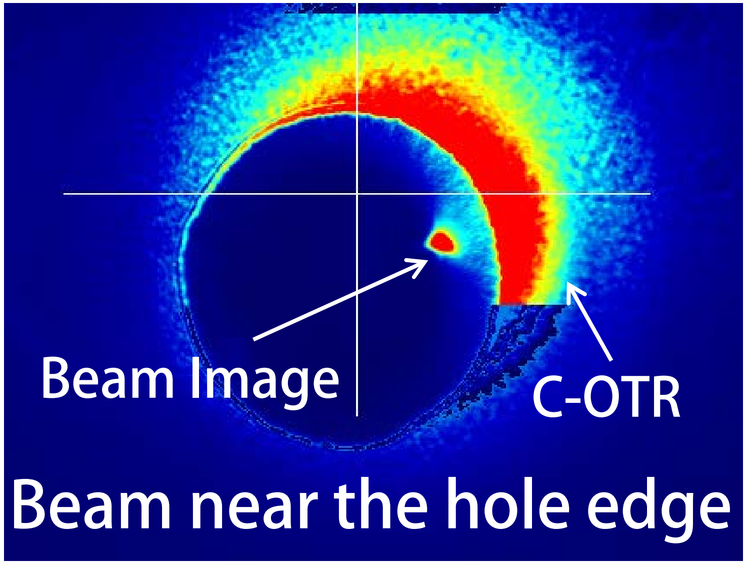




Perforated Mirror for COTR reduction

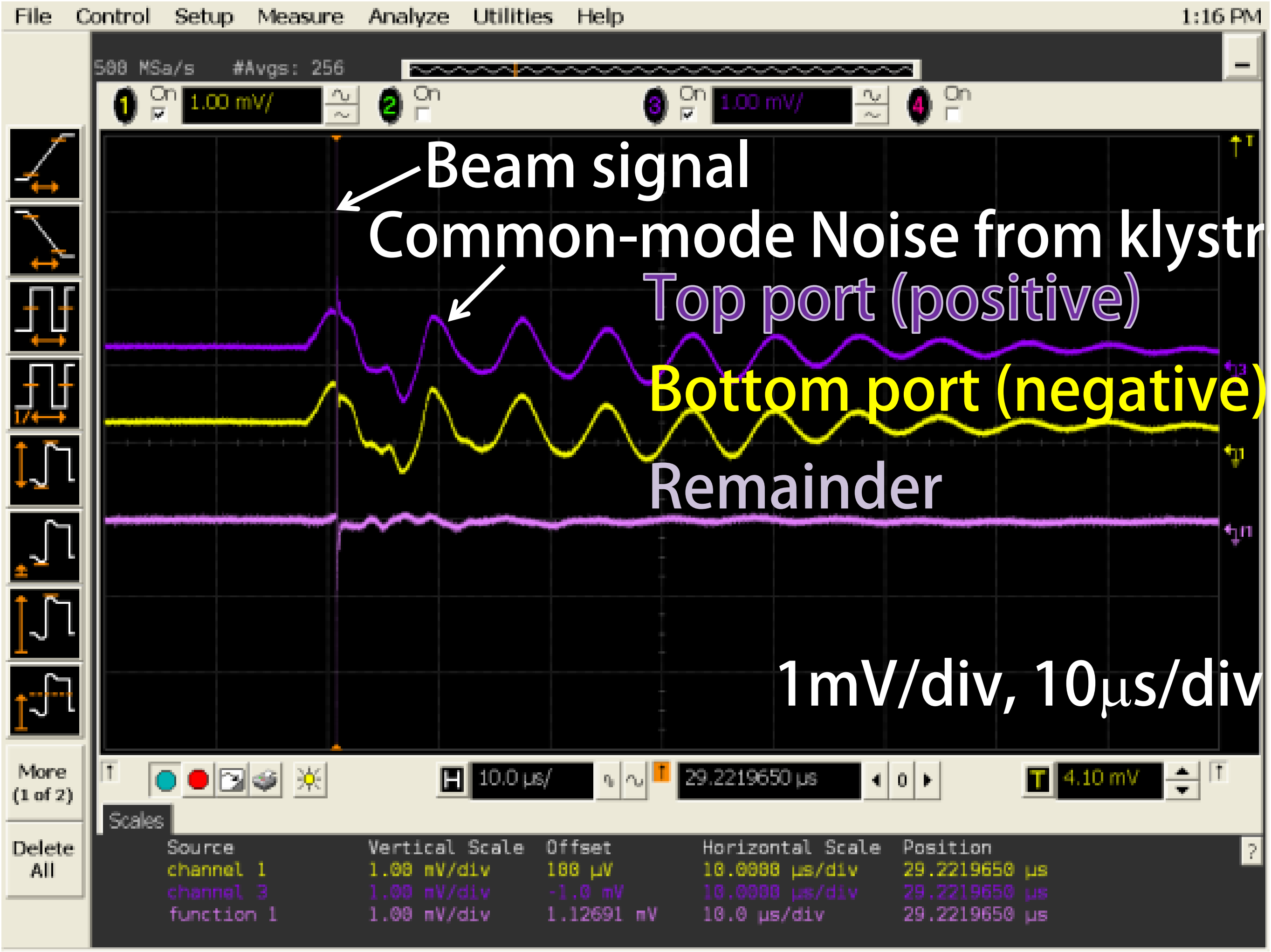






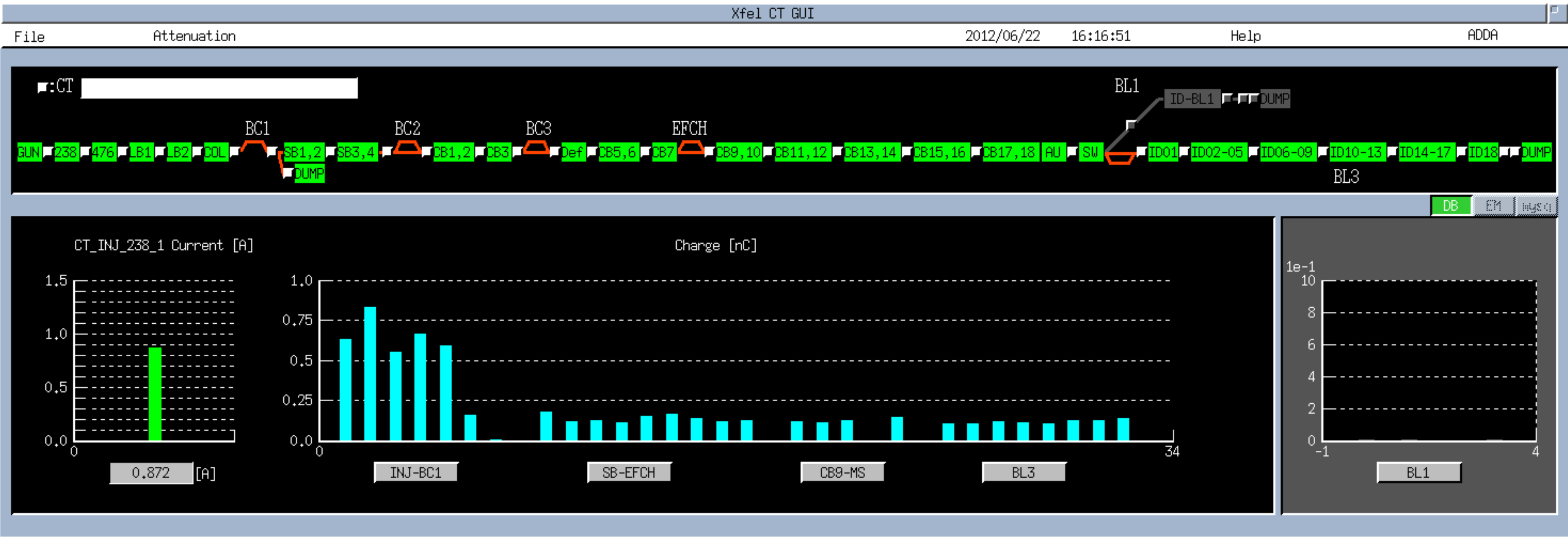
- C-OTR from the YAG screen is discarded through a hole in the mirror.
- Only scintillation light is reflected by the perforated mirror.
- When the beam is near the hole edge, C-OTR can be observed.

Common-mode Noise Reduction



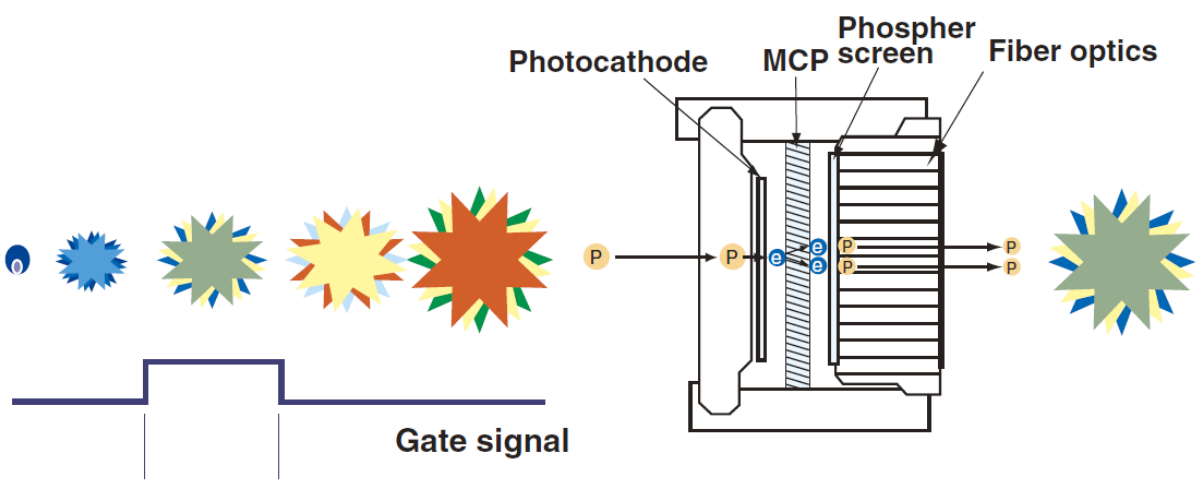
- Common-mode noise was reduced to 1/10.

CT GUI


Xfel CT GUI
File
Attenuation
2012/06/22
16:16:51
Help
ADDA
:CT
BL1
ID-BL1
DUMP
BC1
BC2
BC3
EFCH
GUN
238
476
LB1
LB2
COL
SB1,2
SB3,4
CB1,2
CB3
Def
CB5,6
CB7
CB9,10
CB11,12
CB13,14
CB15,16
CB17,18
AU
SW
ID01
ID02-05
ID06-09
ID10-13
ID14-17
ID18
DUMP
DUMP
BL3
DB
EM
CT_INJ_238_1 Current [A]
Charge [nC]
0.872
[A]
INJ-BC1
SB-EFCH
CB9-MS
BL3
1e-1
BL1

Fast Gate CCD to Remove C-OTR

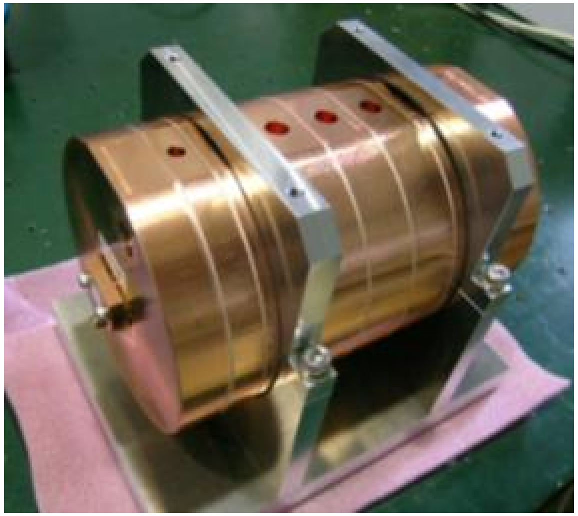
- C-OTR is prompt radiation.
- Decay time of YAG:Ce scintillation is ~ 70ns.
- Fast gated CCD camera can distinguish them.
- ~ 1 ns resolution. (but very expensive…)
- First developed at FLASH
- M. Yan et al., “Beam Profile Measurements Using a Fast Gated CCD Camera and Scintillation Screen to Suppress COTR”, Proceedings of FEL 11, THPB16 (2011).

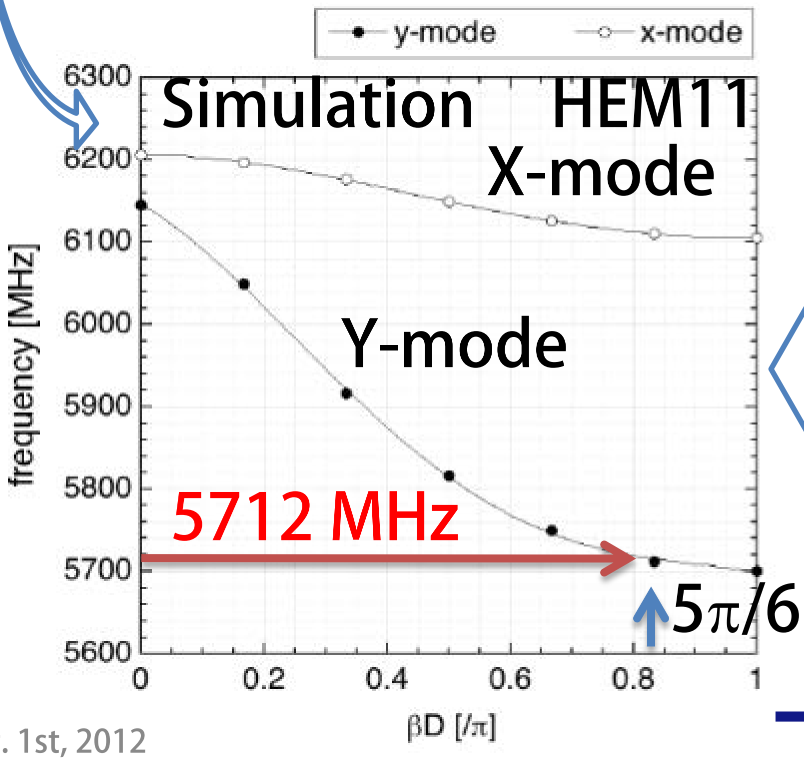


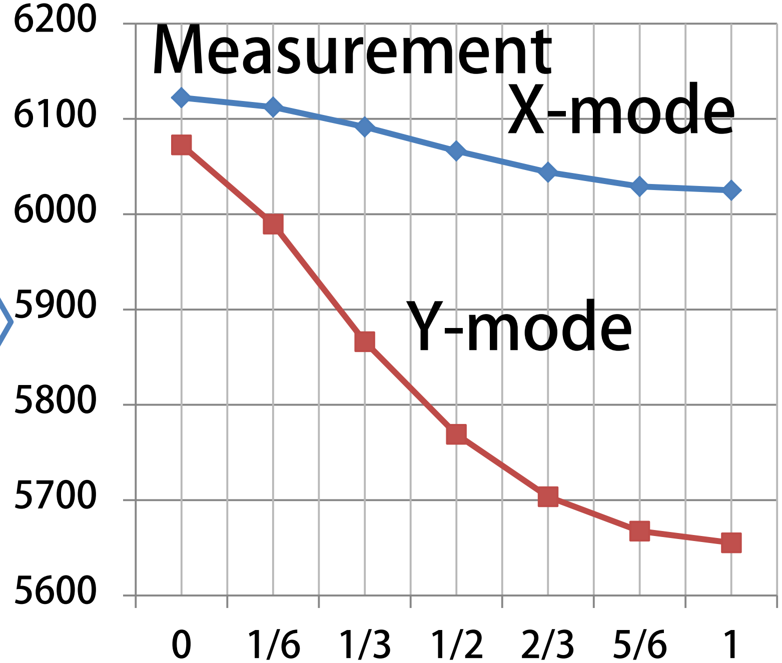
Fast Gate CCD Data

Low-level RF Measurements

- Measured with a 7-cell model.
- Pass band
  - Y-mode is clearly separated from x-mode.
- Shunt impedance
  - Bead perturbation measurement
  - Simulation: 13.9 MΩ/m
  - Measurement: 13.7 MΩ/m

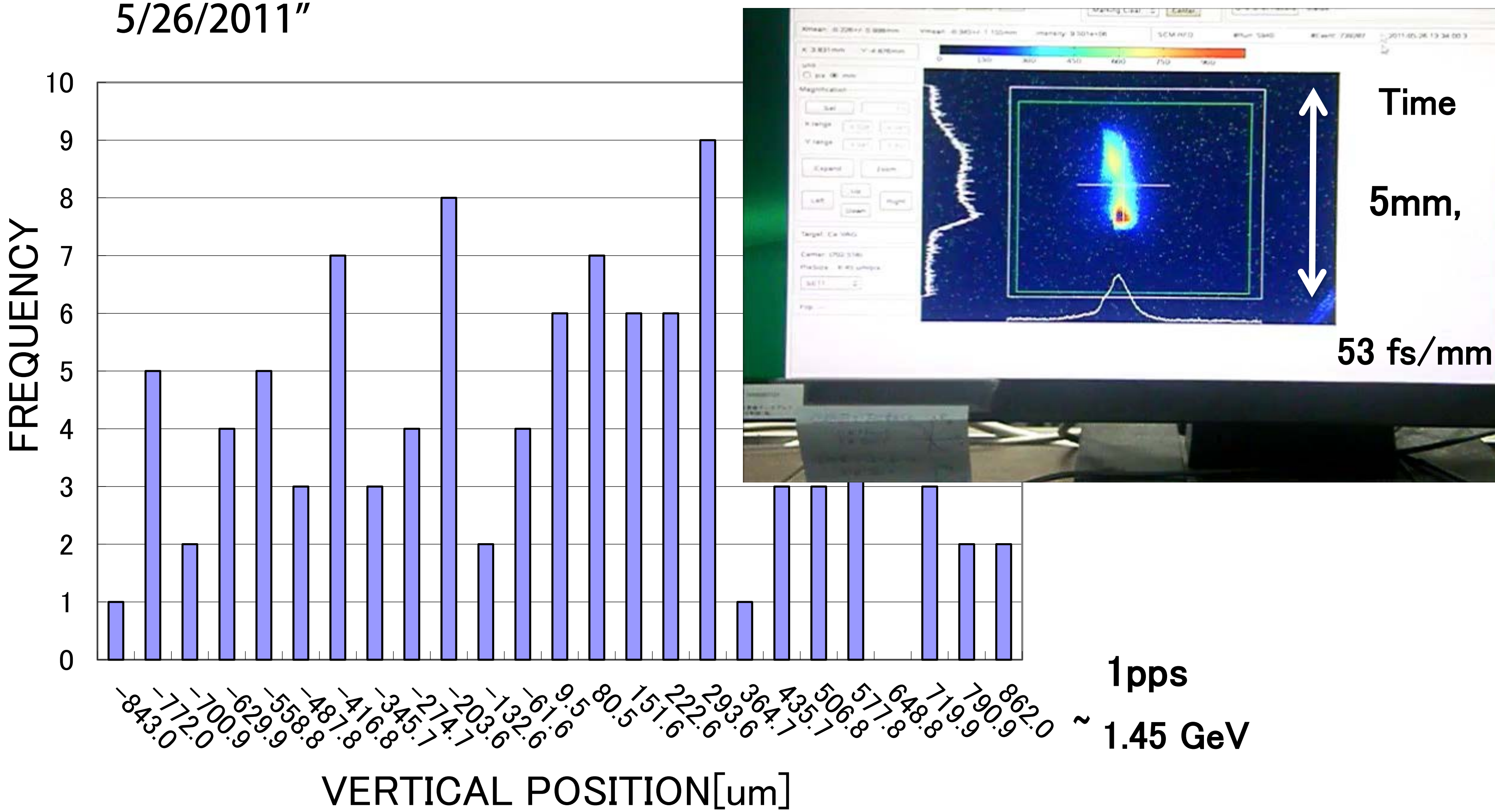






Beam Arrival Time Jitter observed by the RF Deflector

5/26/2011”



HISTOGRAM OF VERTICAL POSITION, 100 shots

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

Parameters of RAIDEN Cavity

Design

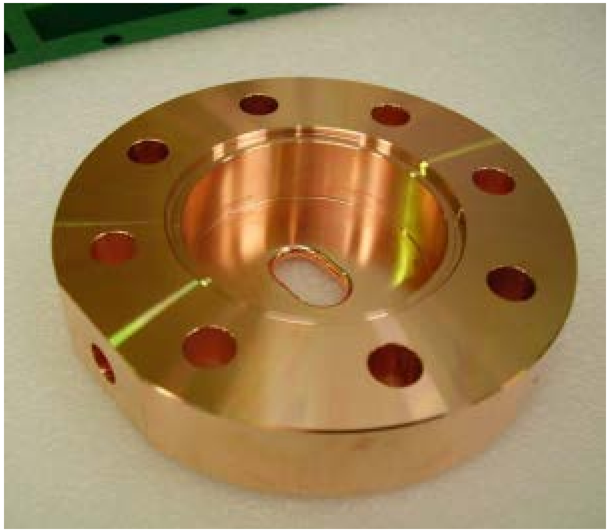
Total Deflecting Voltage	V_y	60	MV
RF deflecting phase	φ_a	0	degree
Fractional bunch length for X-ray oscillation	σ_z	200	fs
Beam energy at the deflector	p_z c	1.45	GeV
Resonant frequency	f_a	5712	MHz
Type of structure		CZ	
Resonant mode		HEM11	
Phase shift per cell	βD	$5\pi/6$	rad
Group velocity	v_g /c	-2.16	%
Filling time	T_f	0.27	µs
Unloaded Q	Q_a	11500	
Transverse shunt impedance	z_y	27.8	MΩ/m

Data

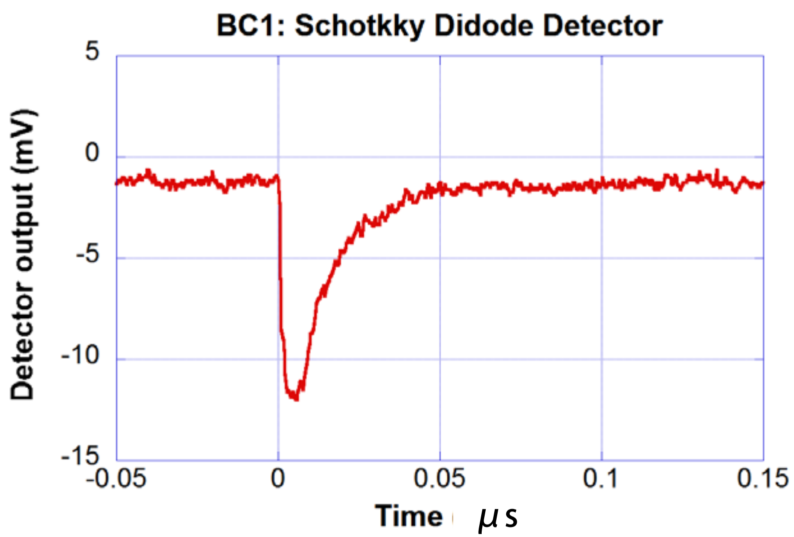
		#1	#2
Operation frequency [MHz]	f_a	5712	
Resonant mode		HEM11-5π/6	
Unloaded Q	Q_a	8809	8948
Group velocity	v_g /c	-0.0213	-0.0213
Filling time [µs]	T_f	0.269	0.269
Attenuation parameter	τ	0.548	0.539
Transverse shunt impedance [MΩ/m]	r	20.8	21.0
VSWR		1.12	1.09
Maximum accumulation of errors in phase-advance [º]		±7.5	±2.8

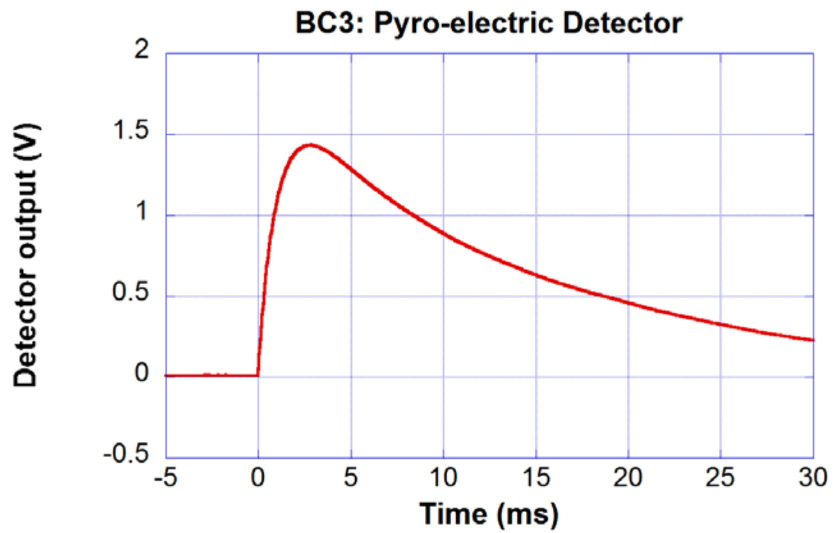
Machining of the Cell

- Race-track iris
  - Made by a precise milling machine
  - Electrochemically polished
  - Surface roughness: 1 μm pk-pk
- Other part
  - Machined by a precise lathe with a diamond bit
  - Roughness < 1 μm pk-pk



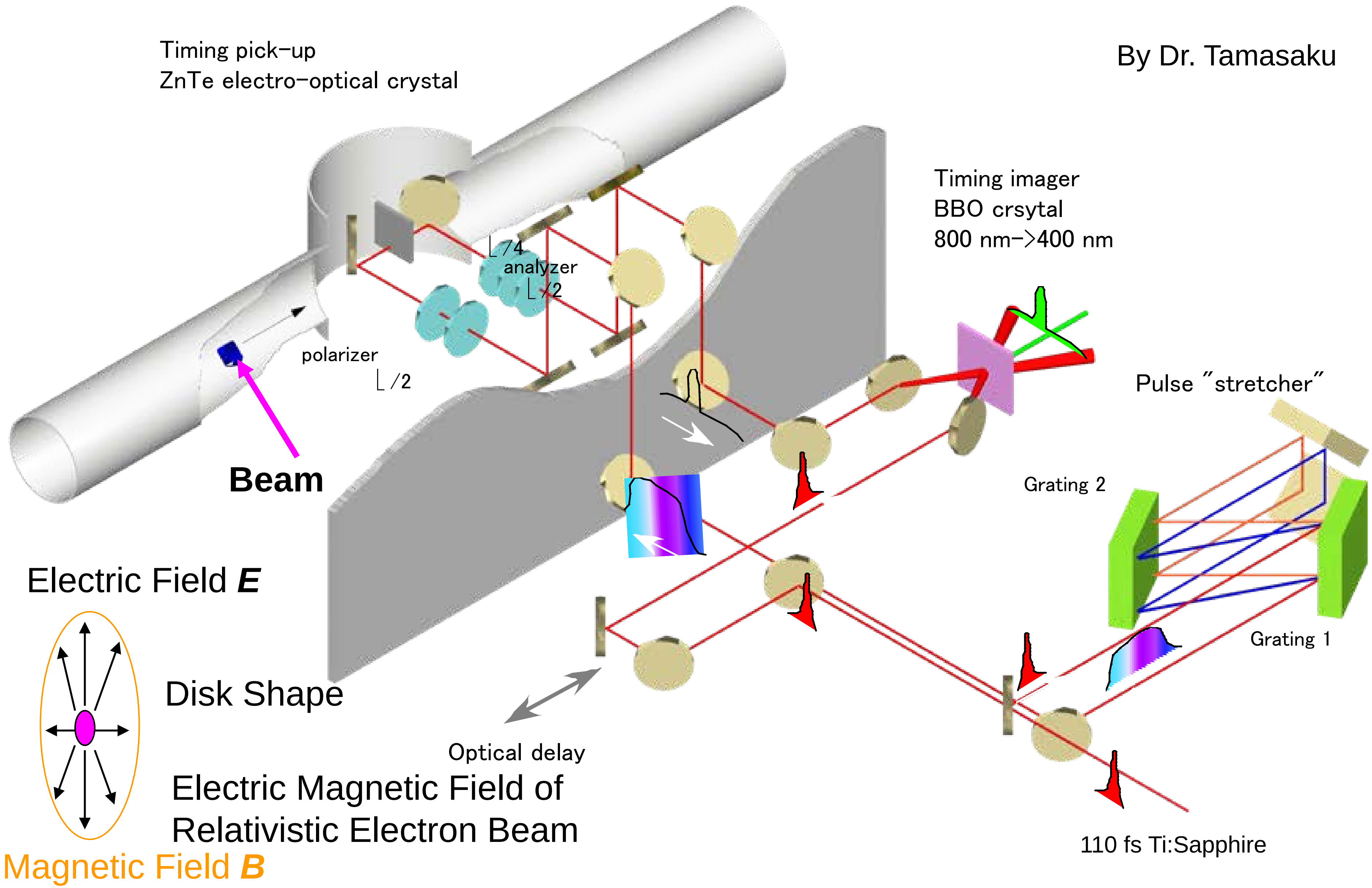
Waveform of CSR Monitor





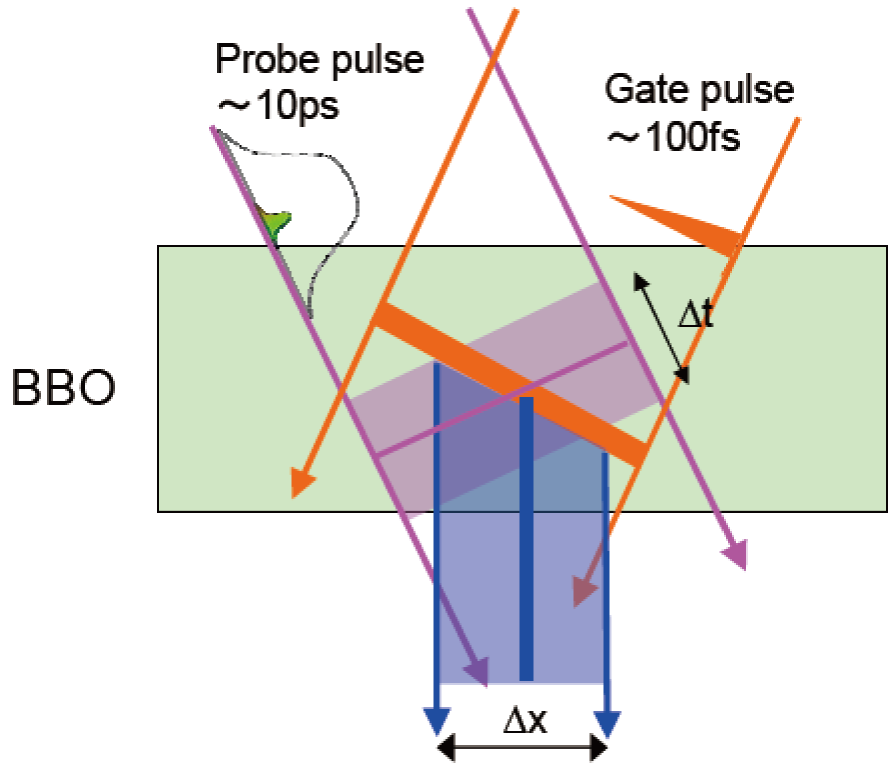
- THz diode detector: ~10 ns
- Pyroelectric detector: ~10 ms

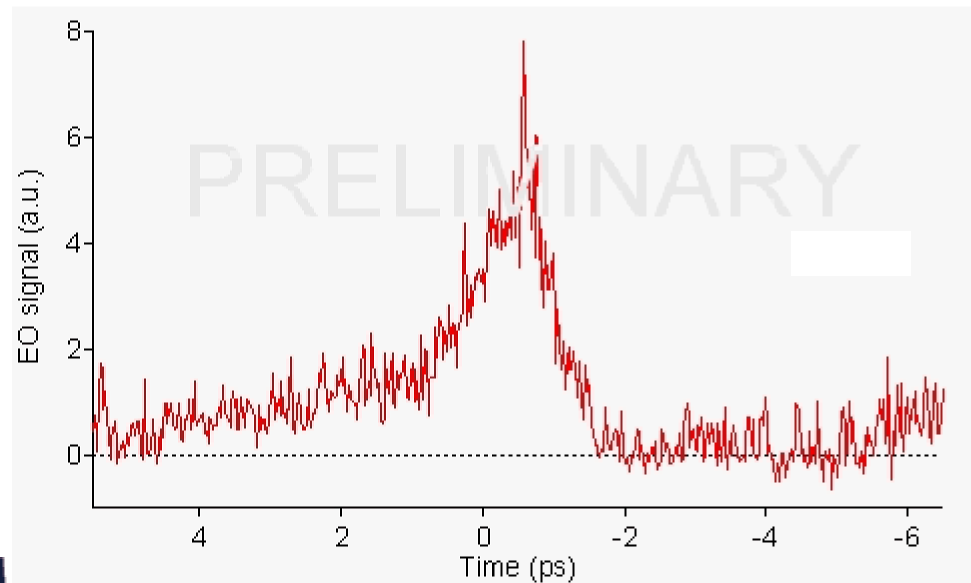
Electron Beam Timing Pick-up using EO Crystal

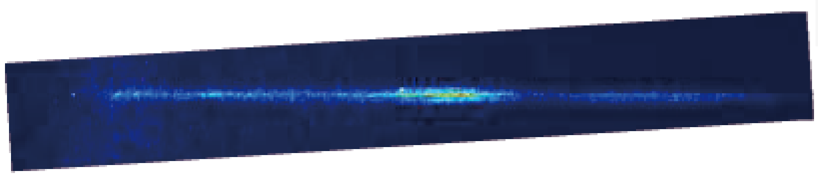


EO Sampling Results

Courtesy of K. Tamasaku and T. Togashi

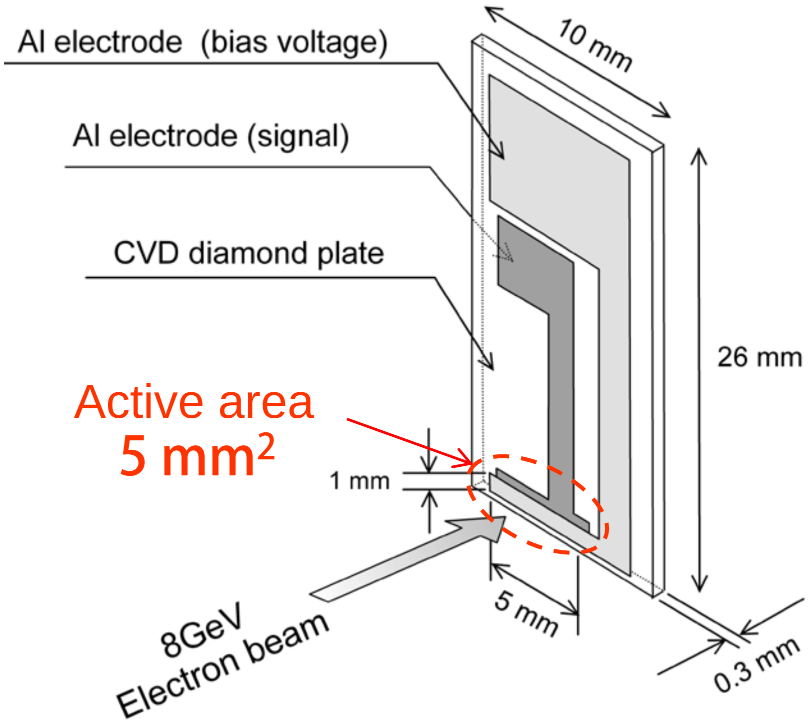


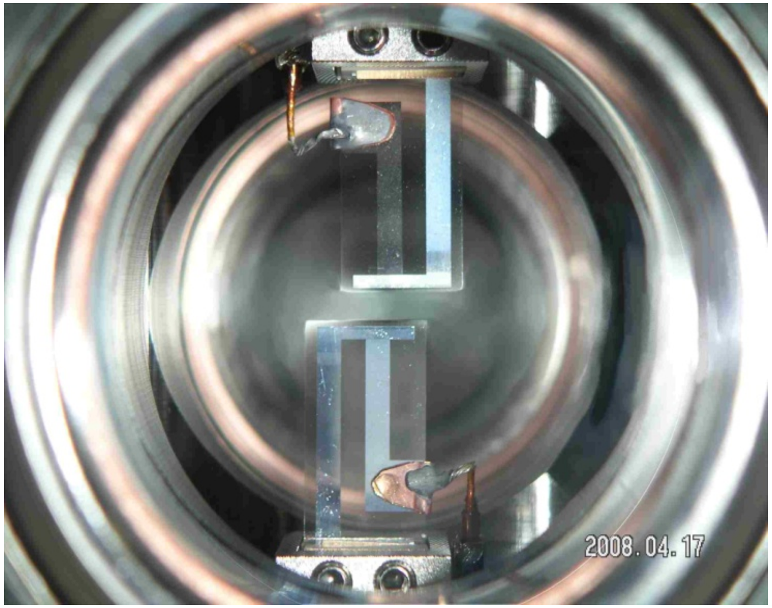




- ~100 fs resolution is expected

Halo Monitor

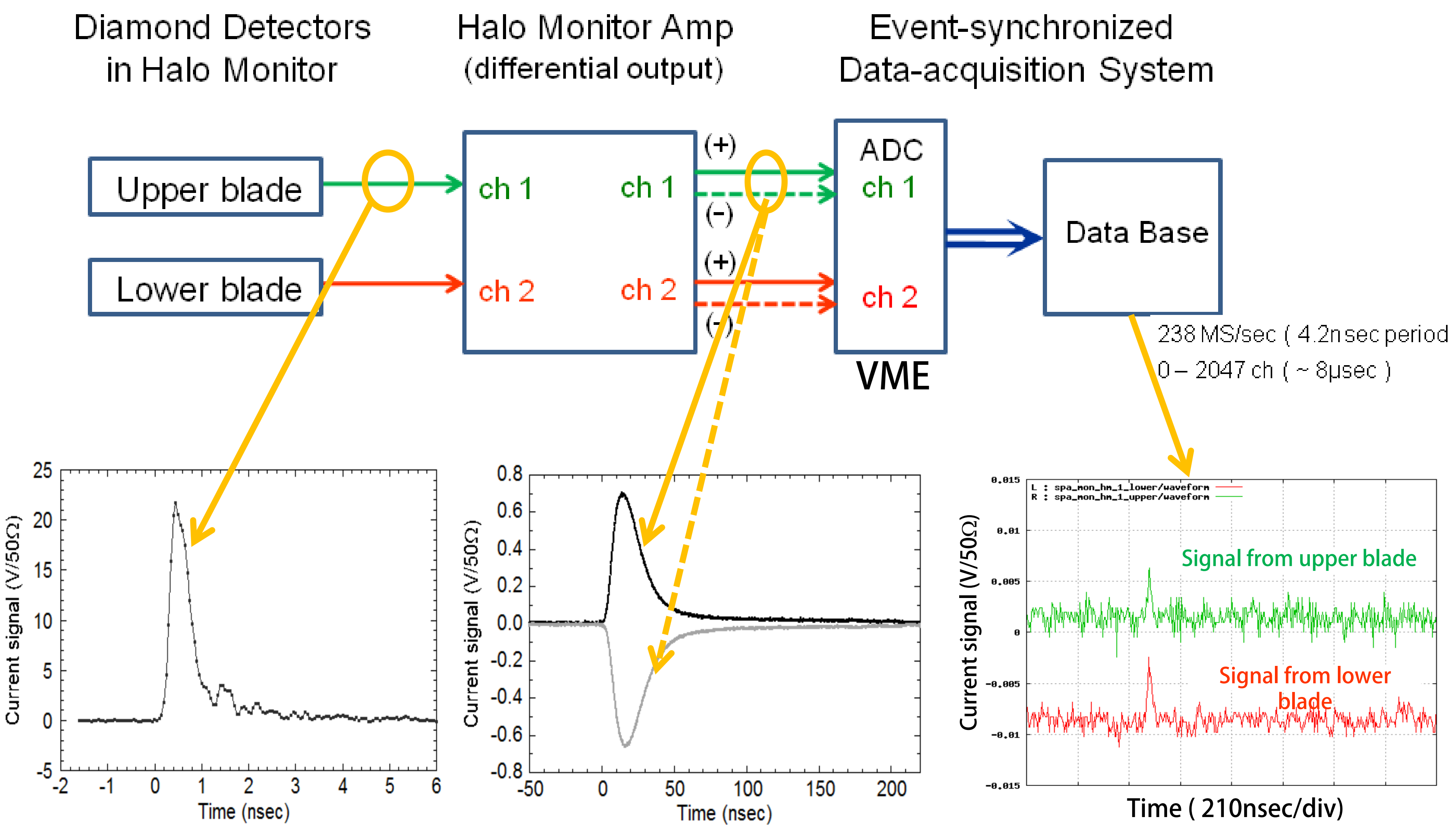




Seen from on the axis

- To reduce the demagnetization of the undulator magnet.
  - Undulator magnet can be damaged by beam halo.
- Diamond detector is employed.
  - Sensitivity: 10 fC (10^{-14} C)
- Installed into the upstream of the undulator beamline.

Electronics of the Halo Monitor

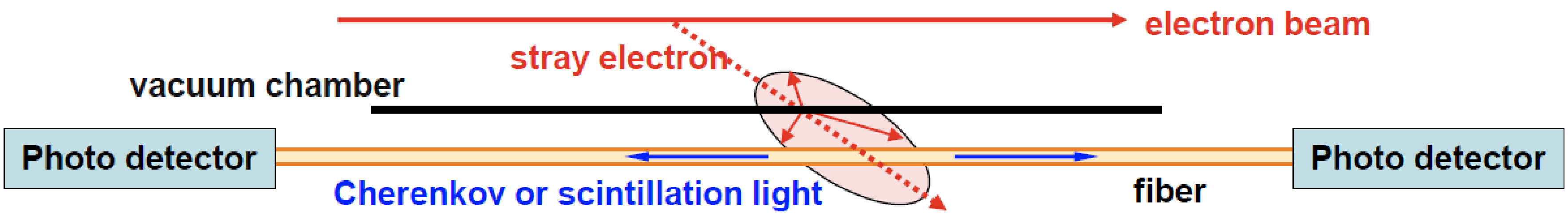


(a) The output signal from the diamond detector

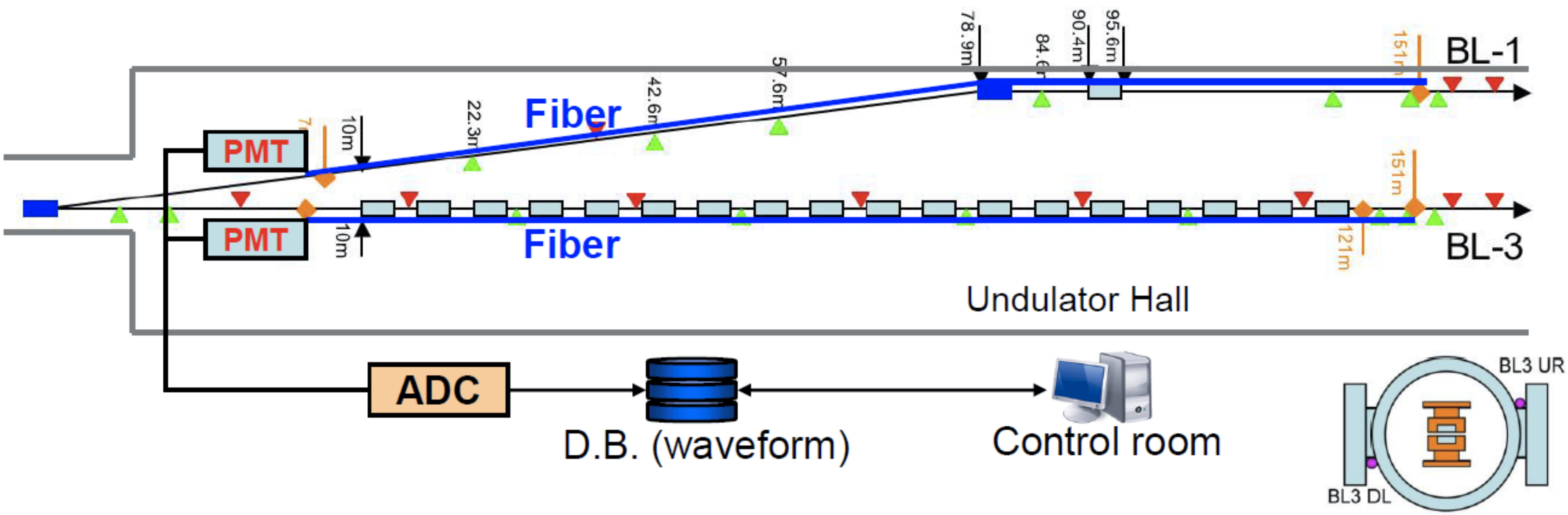
(b) The output signal from the pre-amplifier.

(C) The waveform stored at data base.

Optical Fiber Beam Loss Monitor

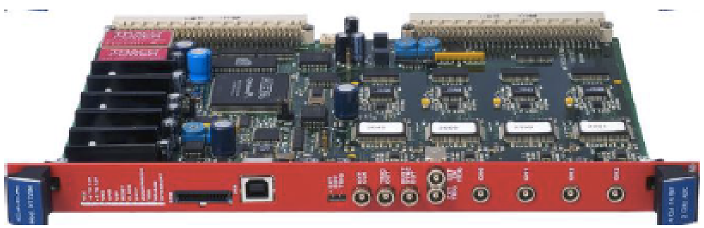


- Scattered electrons emit Cherenkov radiation in an optical fiber.
- The Cherenkov light is detected by a photo-multiplier tube.
- Signal intensity → Amount of beam loss (1pC sensitivity)
- Signal timing → Position of beam loss



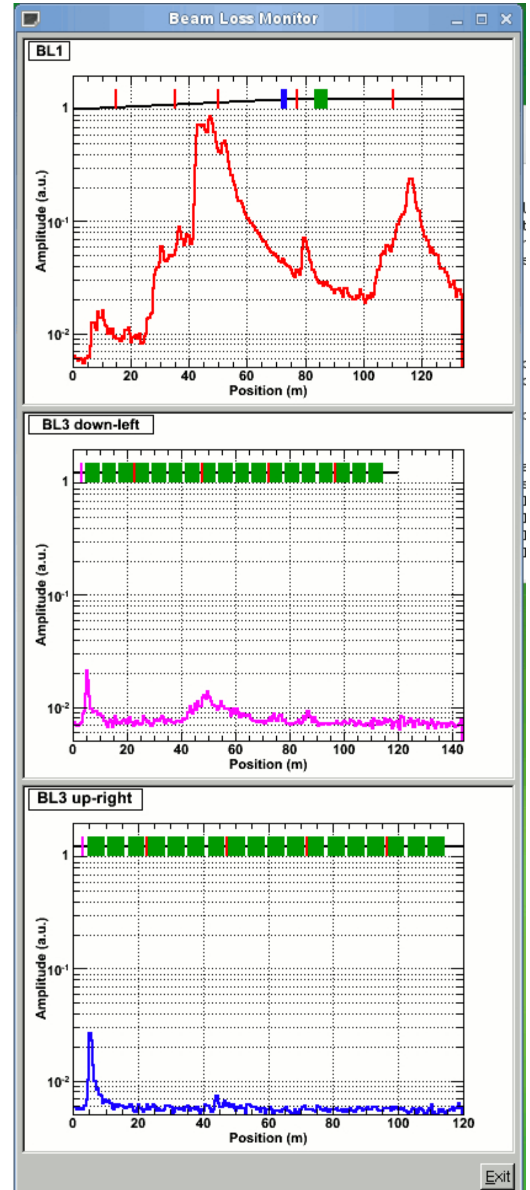
Electronics of Beam Loss Monitor

PMT: Hamamatsu H6780-02
with FC connector

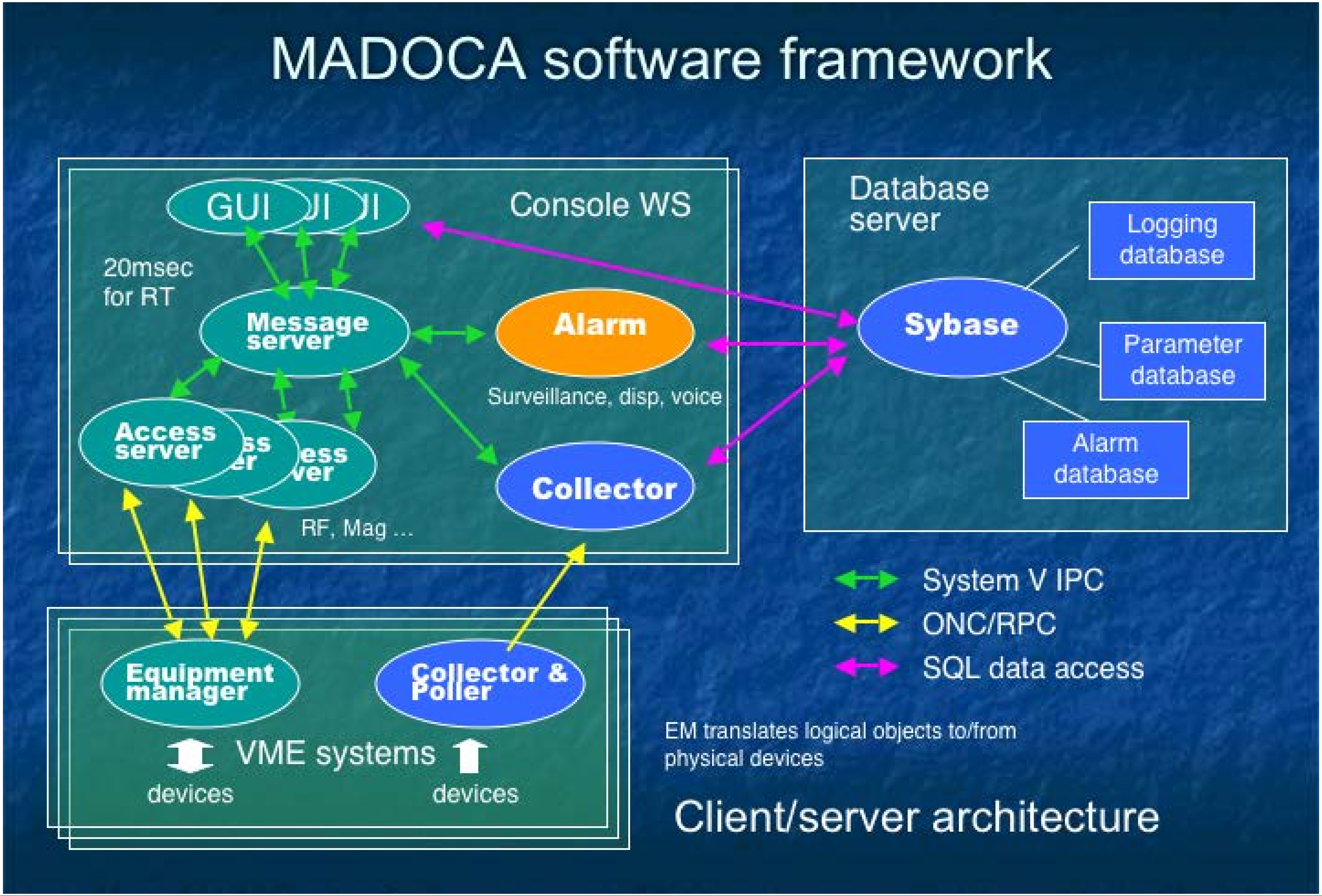


ADC: CAEN V1729A Switched-Capacitor Digitizer
4 Channel, 14 bit, 2 GS/s (300 MHz bandwidth)

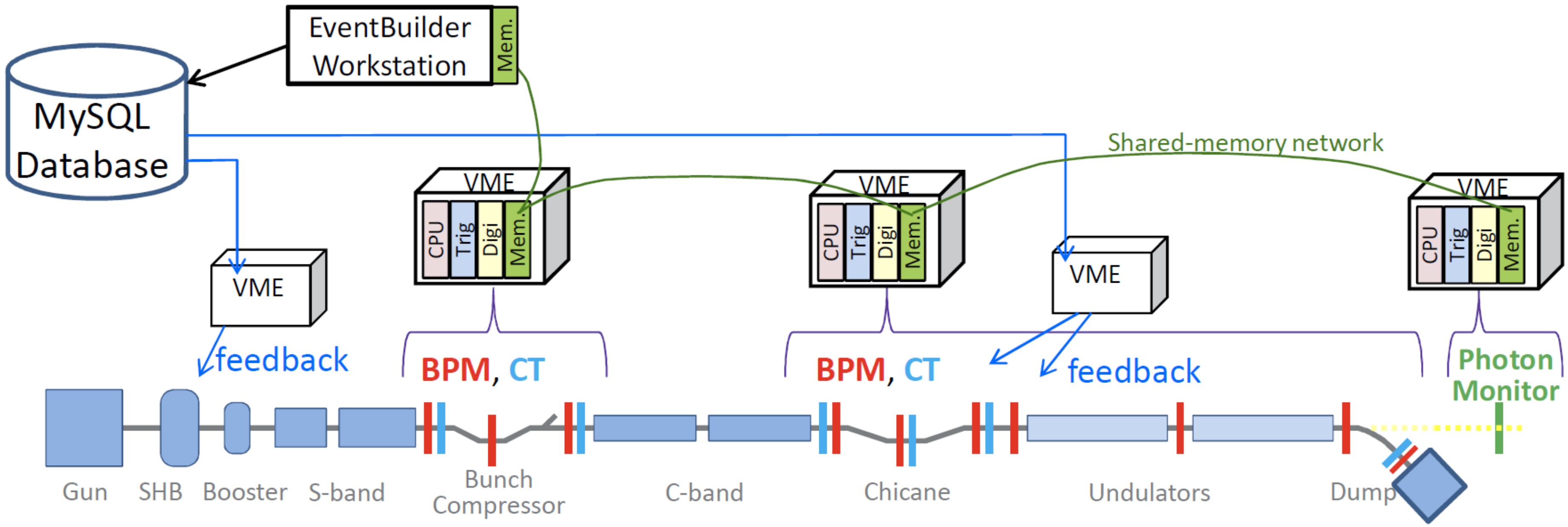
- Waveform is recorded by a VME AD board
- Beam loss is plotted as a function of the position.



MADOCA

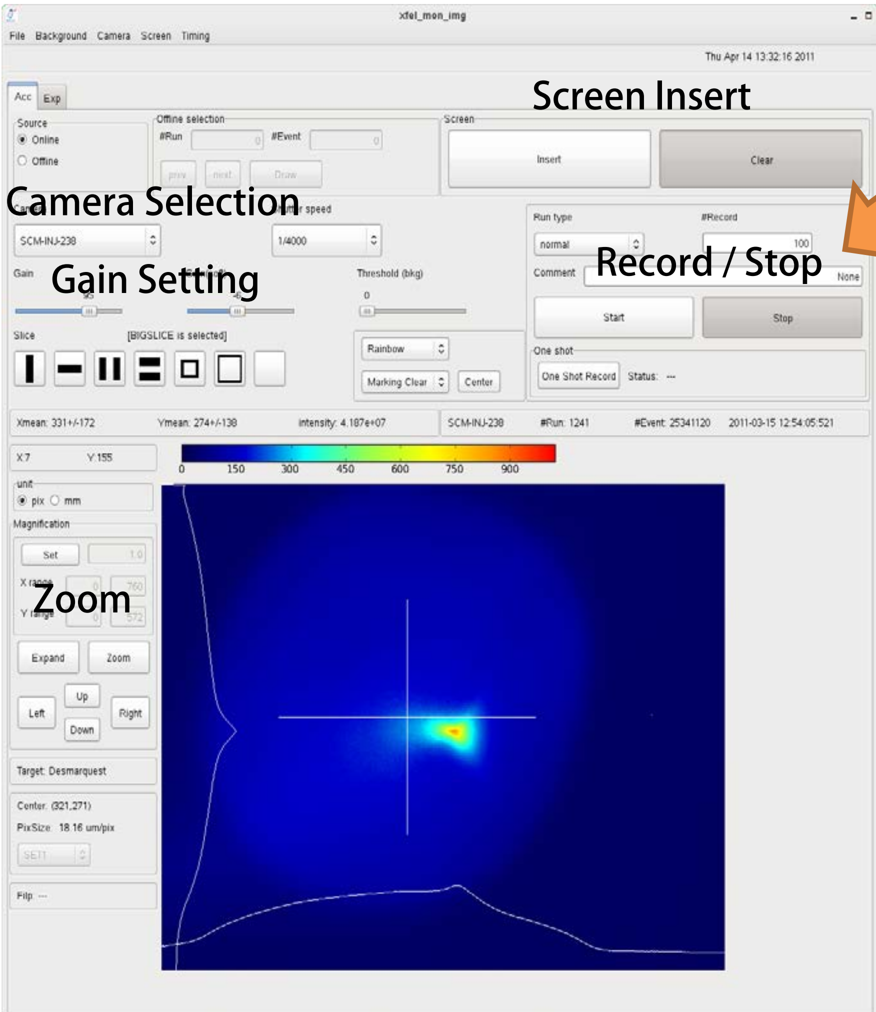

MADOCA software framework
GUI
GUI
GUI
Console WS
20msec
for RT
Message server
Alarm
Surveillance, disp, voice
Access server
Access server
Access server
Collector
RF, Mag ...
Database server
Logging database
Sybase
Parameter database
Alarm database
System V IPC
ONC/RPC
SQL data access
Equipment manager
Collector & Poller
VME systems
devices
devices
EM translates logical objects to/from physical devices
Client/server architecture

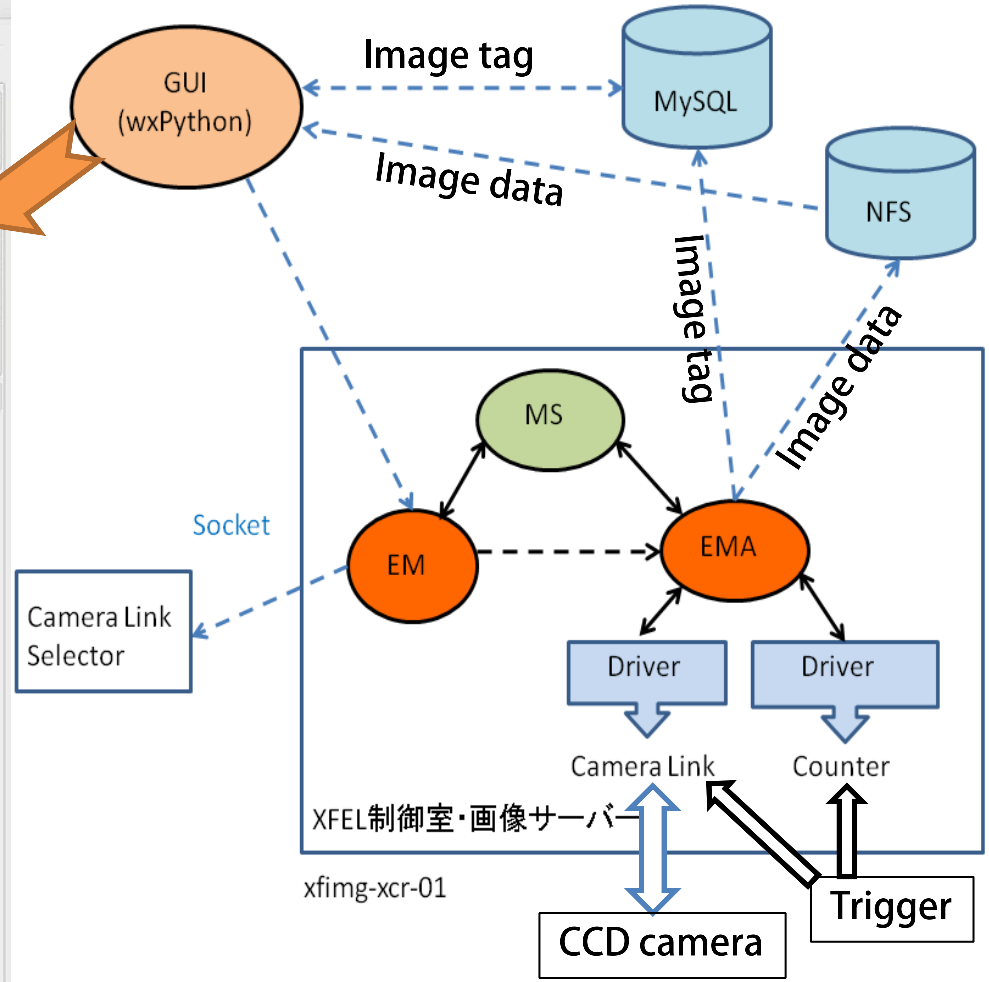
Event Synchronized Data Acquisition



- VME reflective memory board is used.
- In each VME crate, trigger number is counted and the data is synchronized by using this number.
- MySQL database is used.
- Capable of 60 Hz operation

Image Data Acquisition





- Image data is stored in a NFS storage and image tag information is recorded by MySQL.
- Realtime image is monitored by a GUI