



## Beam profile monitoring system for XFEL/SPring-8

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## Outline

- Introduction
- Image processing system for screen monitors
  - Configuration
  - GUI development
  - Image recording with synchronization data acquisition system
- System test with the SCSS prototype accelerator
- Summary

### Japanese X-ray Free Electron Laser (XFEL/SPring-8)



#### Beam commissioning will begin in March 2011

◆XFEL/SPring-8 ✓ 8 GeV,  $\lambda$  < 0.1 nm

- **SCSS** (SPring-8 Compact SASE Source)
  - ✓ 250 MeV,  $\lambda$  = 50 60 nm (EUV)
  - ✓ Utilized to establish XFEL technology

\* XFEL is via SASE (Self-Amplified Spontaneous Emission) process

### XFEL RF aging just has been started (5<sup>th</sup> October ~)



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## **XFEL Machine Layout**



- 8 GeV Linear accelerator with C-band acc. (400m)
- In-vaccum undulator (200m) to generate XFEL



Various/many/precise beam diagnostics tools are required

Beam radius : 40  $\mu$ m (RMS) in the undulator section  $\rightarrow$  Required < 10  $\mu$ m spatial resolution for SCM

	Number	Measurement
RF-BPM	57	Beam position
CT (Current Transformer)	30	Beam charge
SCM (SCreen Monitor)	49	Beam profile

## Screen Monitor (SCM)

- Transverse beam profile measurements
- Image data is taken with a digital CCD camera

Spatial resolution 10  $\mu$ m  $\rightarrow$  ~ 5 pix. at x 4 (1 pix ~ 7 x 7  $\mu$ m<sup>2</sup>)

\* Zoom range : 1-4

#### Purpose

- Optimization of beam transport
- Beam emittance measurements, etc.

→ Important role on beam commissioning

#### <u>Target screen</u>

- OTR (Optical Transition Radiation) target (>~100 MeV)
  - Thin stainless steel foil (0.1mm thick)
- Phosphor screen (<~ 100 MeV)</li>
  - Ce: YAG scintillator (0.1 mm thick)





### • Equipment control

- Zoom/Focus control
- Screen in/out, etc.
- → PLCs are used for the control



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### • Camera Link is used for

- Image data acquisition
- Provide external trigger
- Camera control

### Two types of CCD cameras



Monochrome, Digital (10 bit)

CV-A10CL: 0.46 M pixel, 60 fps
 CV-M4CL: 1.45 M pixel, 24 fps

→ Transfer rate : 0.35 Gbit/s (max)

#### <u>Camera Link</u>

- Serial communication protocol for image processing
- 4 LVDS lines
- Data throughput : 2.04 Gbit/s (Base configuration)

## Requirements on Beam Profile Monitoring System

Tuning	<ul> <li>Camera selection, Camera control,</li> <li>Screen operation</li> <li>Background subtraction</li> </ul>
lmage	<ul> <li>Online viewer at 5 Hz rate</li> <li>Beam profile Image analysis</li></ul>
viewer	(center, width, intensity)
Data	<ul> <li>Recording with synchronization</li></ul>
recording	data acquisition system <li>Remote data access, Web interface</li>

## Needs:

- High flexibility in the system to incorporate multi-functions
- To cope with additional requests in the beam commissioning on time
  - → Rapid GUI construction
- Developed Beam profile monitoring system for XFEL
- ✓ Performed tests with a prototype at SCSS
  - \* SCSS : Similar Camera Link system (with 14 CCD cameras)





























- Camera Link cables are extended with optical fibers (Max ~ 600 m)
- 46 CCD cameras  $\rightarrow$  11 Camera Link selectors, to select one

## Control equipments for image processing

- Commercial PCI Express boards with Linux driver support
- $\rightarrow$  Operating system for the image server : Cent OS 5.4

Image grabber board [AVALDATA APX-3312/1]



- Camera Link (Base configuration)
- External trigger input

<u>Counter board</u>

[Interface PEX-632102]



• Used to count trigger

Camera Link selector [Stack CLS-900A]



- 8 ch. selection with RS-232C
- Remote control with Serial-Ethernet converter

## Software configuration

#### Image server



#### Image server for XFEL/SPring-8

- Super Micro X8DAH
  - ✓ Dual CPU, 8 core (Intel 5520)

- Past data can be obtained via buffer area in the shared memory
- Multi processes should utilize the image data
- Image data other than Camera Link can be easily applicable



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   applicable
  - ex.) GbE camera image or test data without camera



## Beam profile monitor GUI @ SCSS : Tuning



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#### Background Threshold Beam profile monitor subtraction setting GUI @ SCSS : Tuning spa\_mon\_otr : Frame View File Background Camera Screen Mode : File @ /spaotr data1/data/Archive/data.18/un2010/oneshot/ID OTR 1/1275382900.img Wed Jul 28 10:11:11 2010 Source Camera O Memory File Camera Gain (soft) Screen ID OTR 1 Down All UP ¢ Jp Threshold (bkg) [OSLICE is selected] 10 Screen Camera X:1154 Y:372 Marking OFF Rainbow 🗘 Refrence operation selection Record Start Record stop One shot save xmean 780+/-21 ymean 432+/-17 intensity 5.207e+06 100 #Record Magnification Expand Up Left X range Right Zoom Down Y range Camera Control Gain, shutter speed



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 Online viewing with 5 Hz

Up to ~ 50 Hz for data recording (depend on camera spec.)

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**Online viewing** with 5 Hz

Up to ~ 50 Hz for data recording (depend on camera spec.)

#### Image for OTR screen monitor at SCSS





#### Image source selection (Camera, Memory, File)

## Beam profile monitor GUI @ SCSS : Image viewer



## Using Python for GUI construction

**Required Rapid GUI development** 

→ Python is applied for GUI application



Python modules

Available	PIL (Image processing), numpy (Matrix calculation , etc.)
Developed	MADOCA interface, etc.

Efficient development thanks to current existing modules

- $\rightarrow$  WxPython is used for GUI toolkit
- GUI frame is build with WxFormbuilder



# Synchronization data acquisition system for Image data (1)



- Image data are compared with BPM, CT data by a beam shot
- →Image data are saved with tag numbers
  - In DB and Files
  - Image data themselves are stored into files due to larger size
- Need to determine tag number
  - Trigger count is only available
  - →Offset count should be extracted

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# Synchronization data acquisition system for Image data (2)

#### Extraction of offset count

- Save a trigger count number with timestamp
- Refer tag number vs. timestamp in other CPU (from DB)
- Compare numbers in the closest timestamp

Sync. period ~ 16 ms (min)

 $\rightarrow$  NTP can be used for synchronization



Reasonable correlation between SCM and BPM data by a beam shot

## Summary

Beam profile monitoring system was developed for XFEL/SPring-8

- Camera Link system equipped with 46 digital CCD cameras
- An image server processes the selected image
- Tests were performed with a prototype at SCSS
  - Python based GUI can flexibly implement required functions
  - Image data can be recorded with a synchronization data acquisition system
  - → The system can be applied to XFEL/SPring-8
- Current status
  - Construction of the system for XFEL/SPring-8
  - Preparing for the beam commissioning in March 2011