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# Progress of the SCSS Test Accelerator for XFEL/SPring-8

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SPring-8 Joint Project for XFEL

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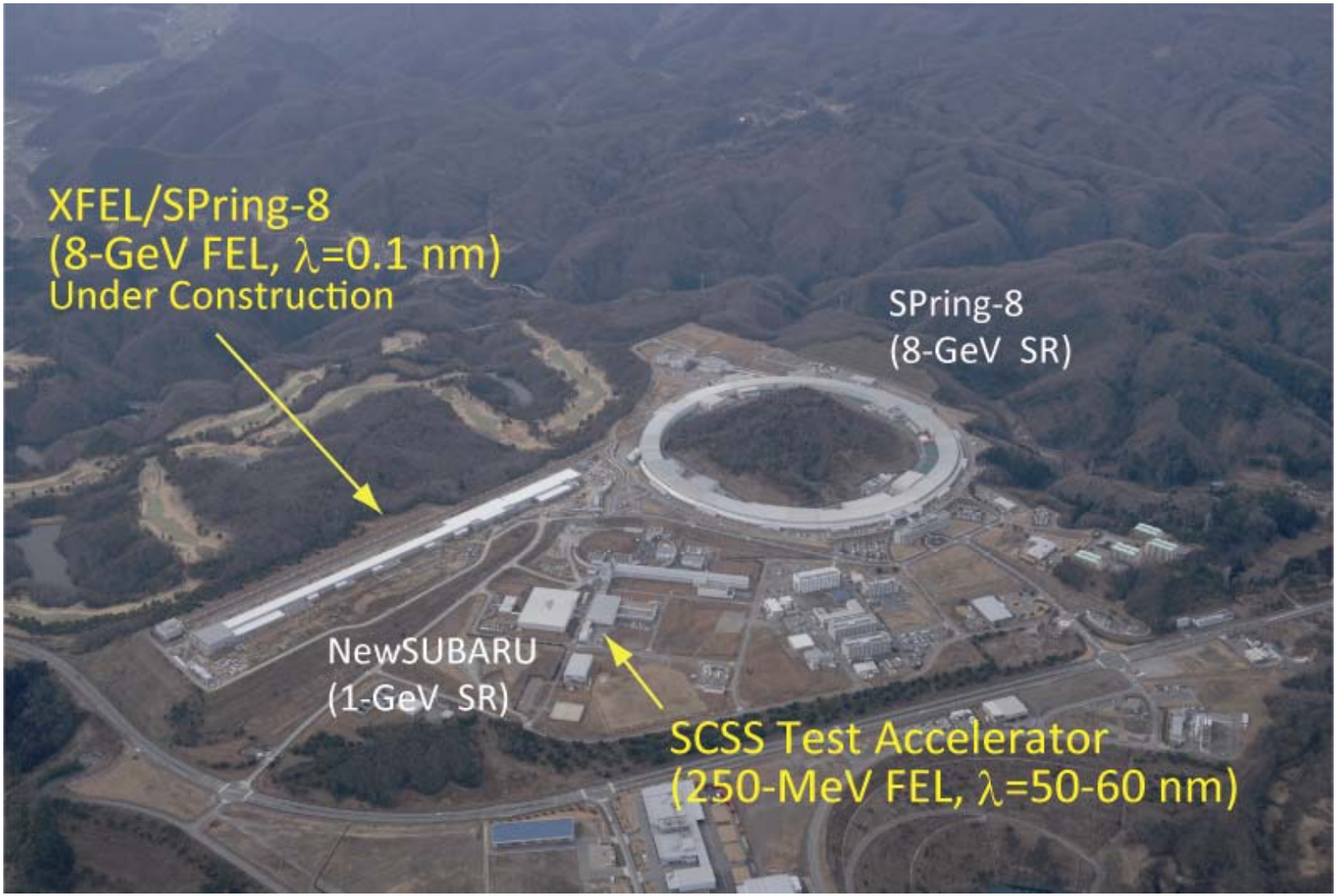
# Light Sources at SPring-8



# Outline

- Overview of the SCSS Test Accelerator
- Stable EUV-SASE for User Experiments
- Resent Topic on the SCSS Test Accelerator
- Construction Status of the XFEL Project at SPring-8

# Overview of the SCSS Test Accelerator

# SCSS Concept for Compact XFEL

## Lower beam-energy is essential !!

### 1) Short-period Undulator

Radiation Wavelength

$$\lambda = \lambda_u \left(1 + K^2/2\right)/2n\gamma^2$$

$\longrightarrow$ In-vacuum Undulator

### 2) High-gradient Linac

Higher Frequency $\longrightarrow$ C-band Linac (5712 MHz)

### 3) Low-emittance Electron Injector

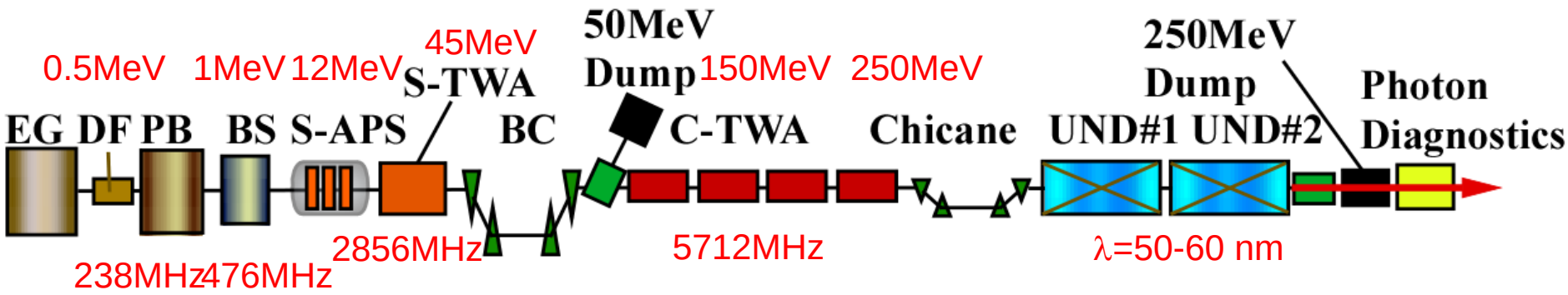
Need for short gain-length of SASE-FEL.

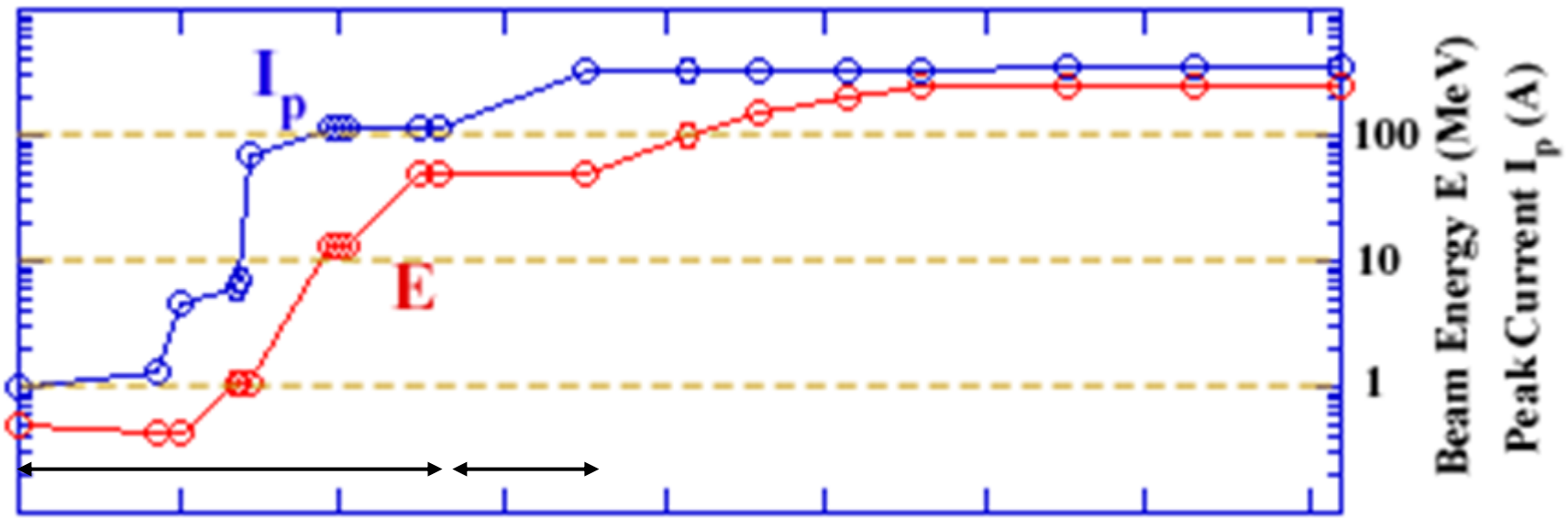
$$\varepsilon = \frac{\varepsilon_n}{\beta\gamma}$$

$\longrightarrow$ Single-crystal Thermionic Gun
+Stable Buncher

T. Shintake et al, Proc. SPIE 4500 (2001) p.12

# SCSS Test Accelerator



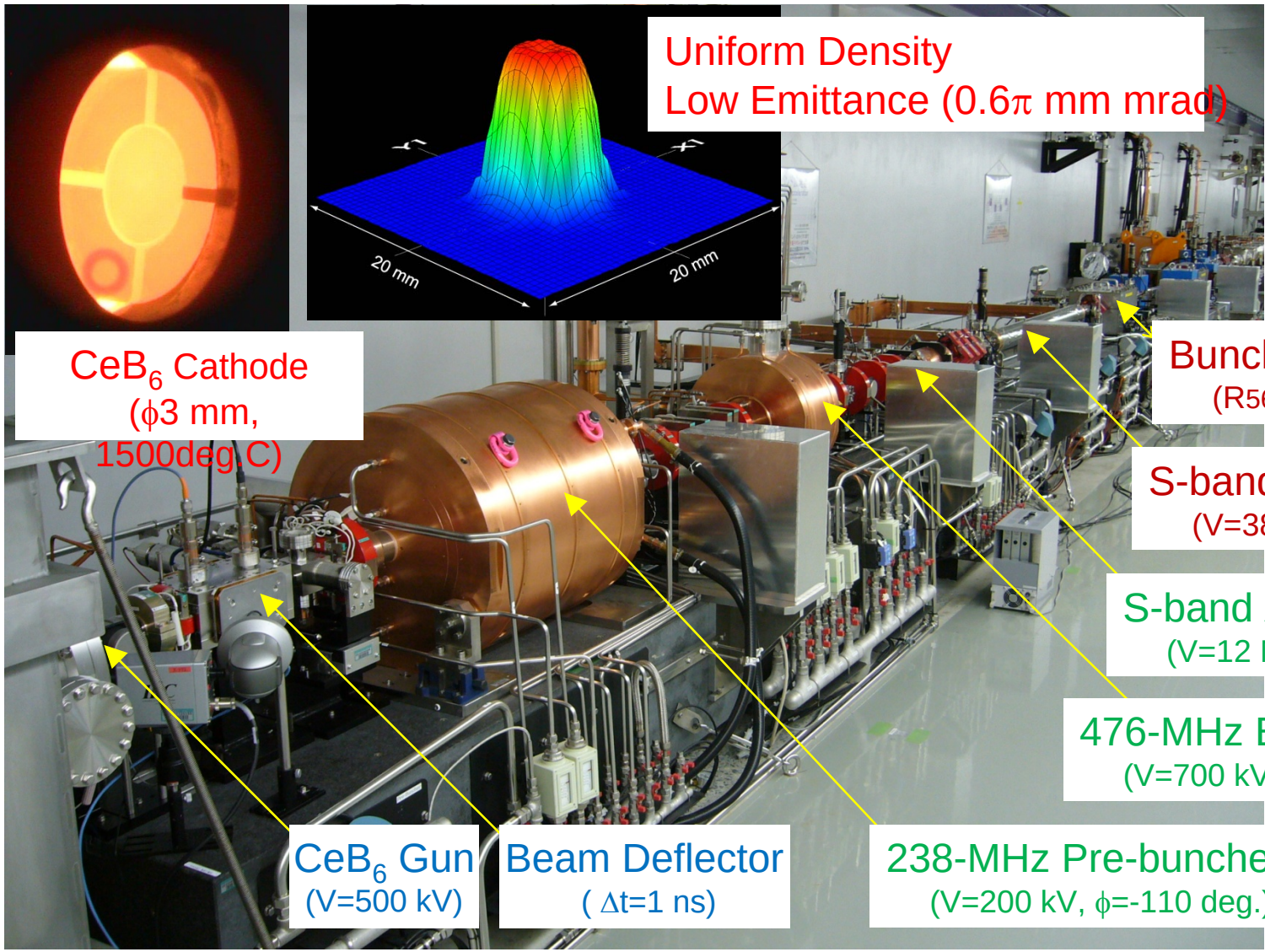




Velocity Bunching (CB~100)

Magnetic Compression (CB~3)

H. Tanaka et al, Proc. EPAC08 (2008) p.1944

# Low-emittance Thermionic Injector



# C-band Linac and In-vacuum Undulator

## C-band Linac

Choke-mode Structure (HOM-free)
Structure Length : 1.8 m X 4
#2 unit is operating at 37 MV/m.

## In-vacuum Undulator

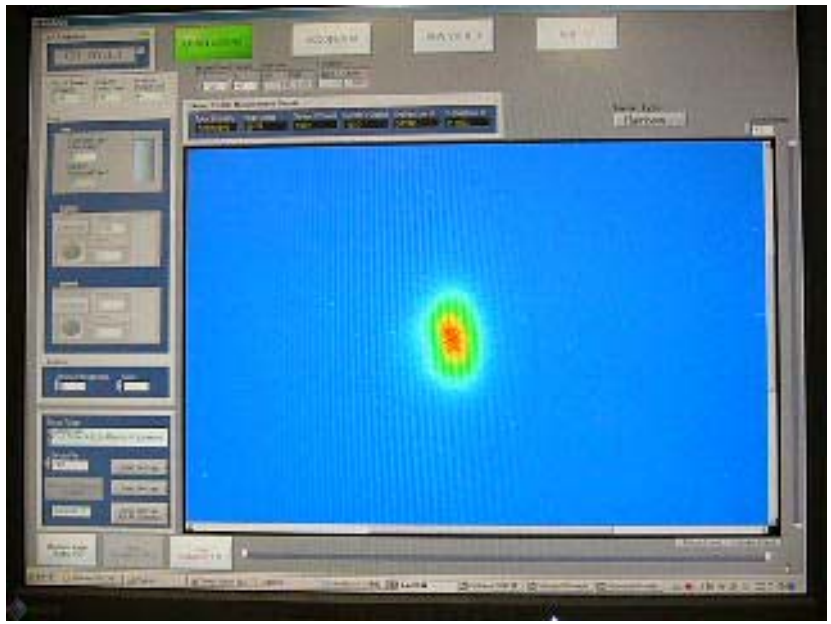
Magnet Period : 15 mm
Period Number : 300 X 2
Gap : 3 mm (min.), variable
K-value : 1.5 (max.), variable

# Characteristics of Electron Beam

## Electron Beam

| | |
|---|---|
| Energy | 250 MeV |
| Charge | 0.3 nC |
| Peak Current | 300 A |
| Bunch Width | 0.7 ps |
| Rep. Rate | 60 pps (max.) |
| Initial Emittance (normalized, rms) | 0.6π mm mrad (90%-core) |

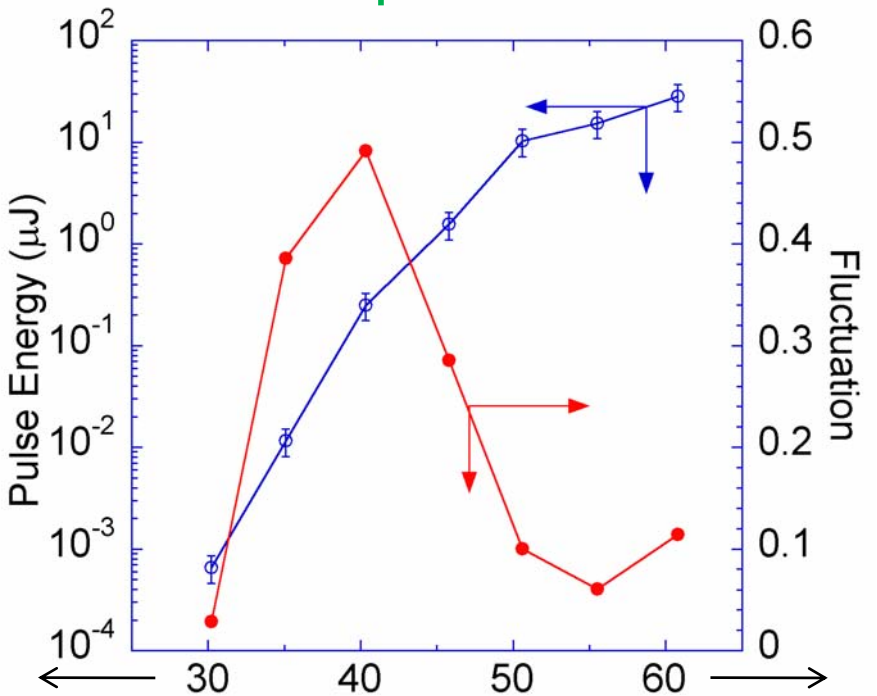
## Transverse Profile



OTR monitor at C-band linac exit

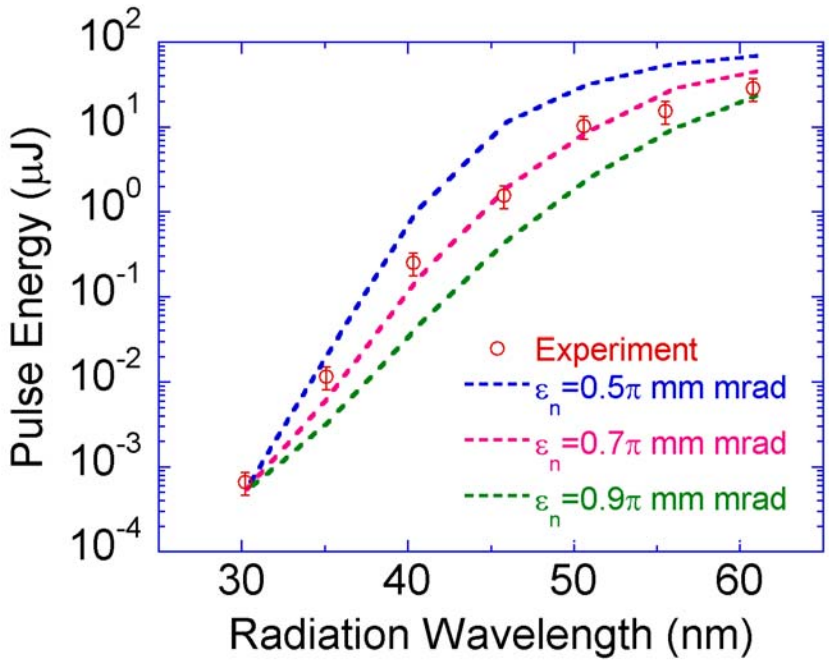
# EUV-SASE Saturation

Experiment




T. Shintake et al, Nature Photonics 2 (2008) p.55

Experimental data analyzed




T. Tanaka
http://radiant.harima.riken.jp/simplex/index.html

Normalized Emittance = 0.7π mm mrad !!

# Stable EUV-SASE for User Experiments

# Stable EUV-SASE for User Experiments

In 2008FY, SCSS successfully delivered stable EUV-SASE light through a year.

- 11 research groups used the SCSS facility.
  - Atomic-molecular Science
  - Coherent Imaging
  - Solid-state Physics
  - Etc.
- Total Operation Time : 95-days (840-hours)
- Downtime Rate : 4%
- 80-days was used for improvements and R&Ds.

# Characteristics of EUV Photon Beam

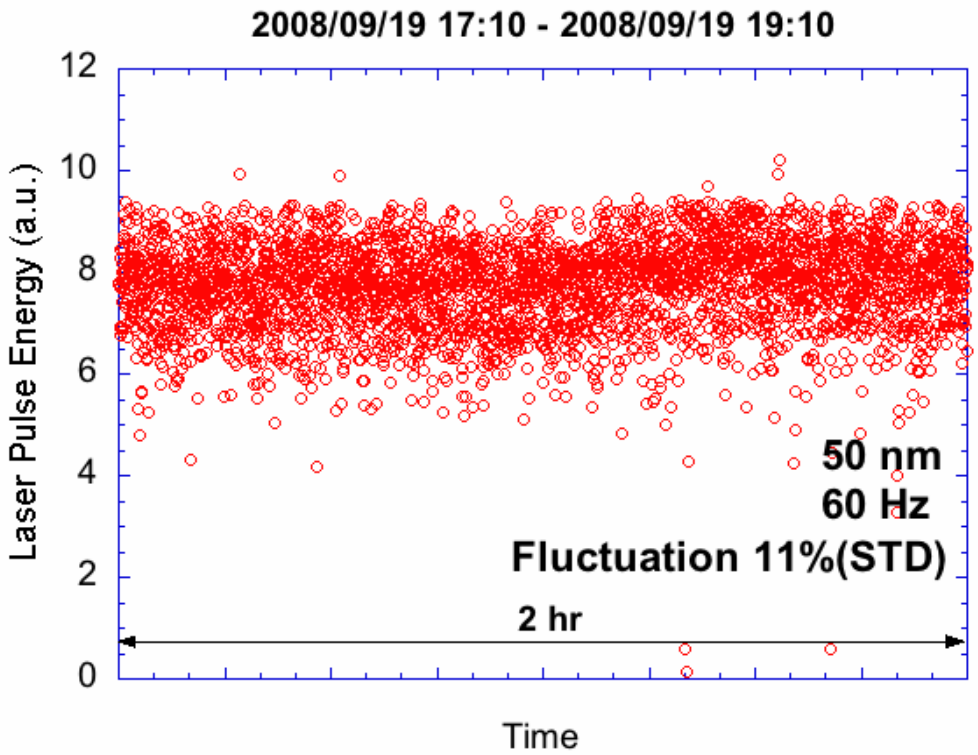
## EUV Photon Beam

| | |
|---|---|
| Wavelength | 50-60 nm |
| Pulse Energy | 30 μJ typical |
| Power Fluctuation | ~10% |
| Spot Size* | 3 mm (FWHM) |
| Pointing Stability* | 5% of spot size |
| Averaged Spectrum Width | 0.6% (FWHM) |

* 10m downstream from the udulator

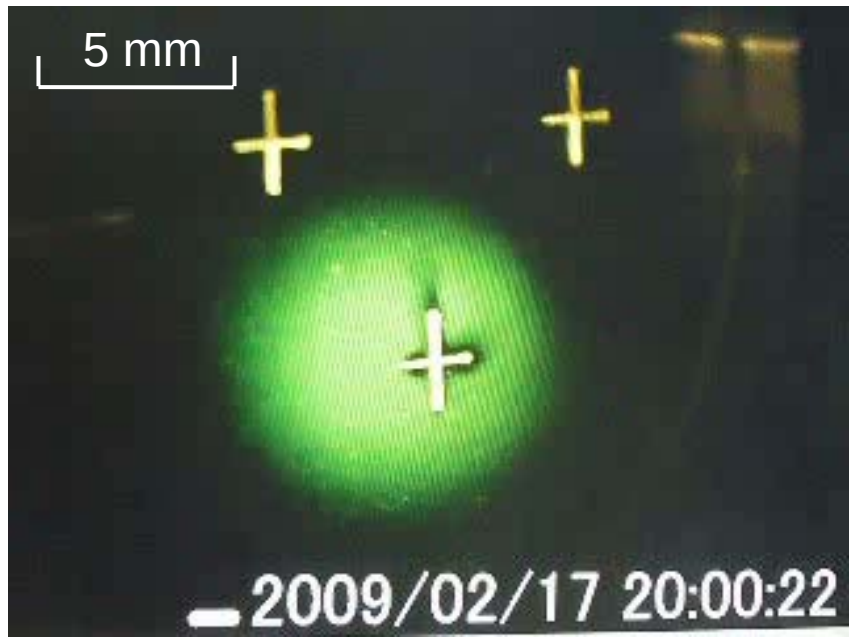
# Stability of EUV Photon Beam

## Trend Graph of Pulse Energy




measured by Si photodiode

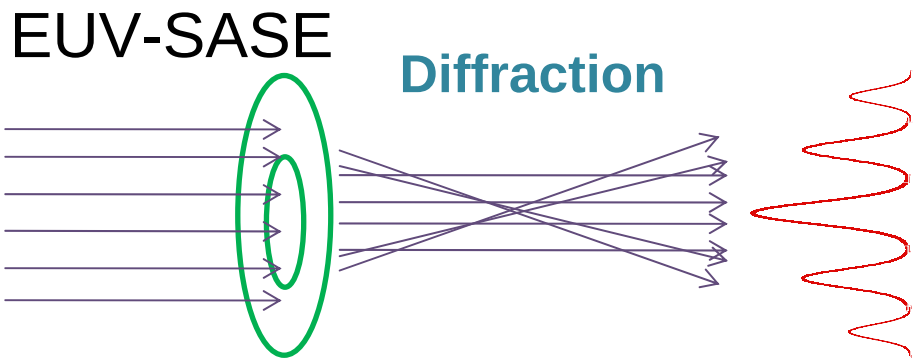
## Transverse Profile




measured by Ce:YAG screen

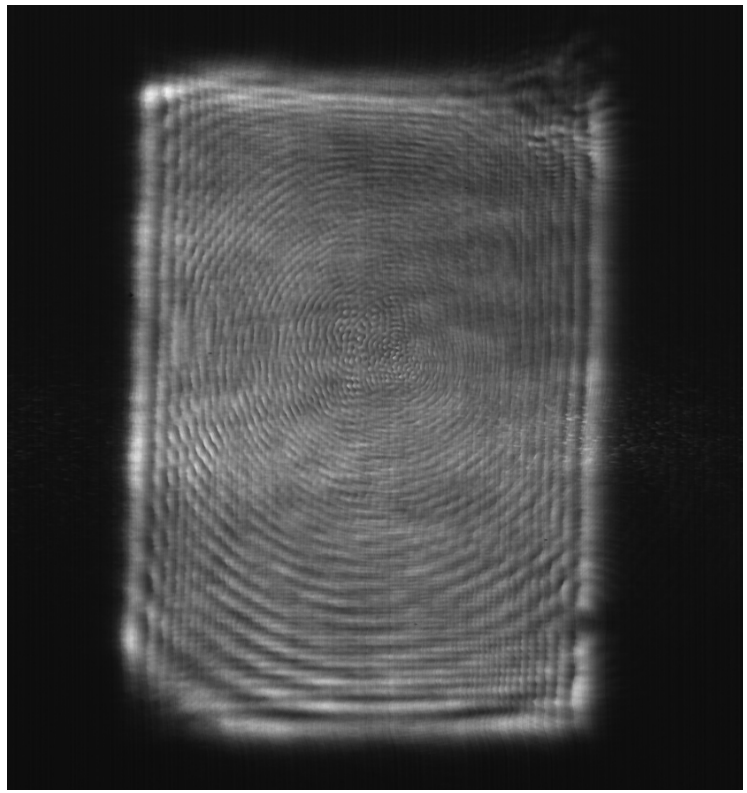
Stable EUV photon beam is routinely delivered !!

# Evidence of Full Spatial Coherence




Iris: ϕ10 mm

CCD image



Good Spatial Coherency !!

by courtesy of Dr. Yoshinori Nishino of RIKEN Harima Institute

# Recent Topic on the SCSS Test Accelerator

# Longitudinal Electron Beam Property

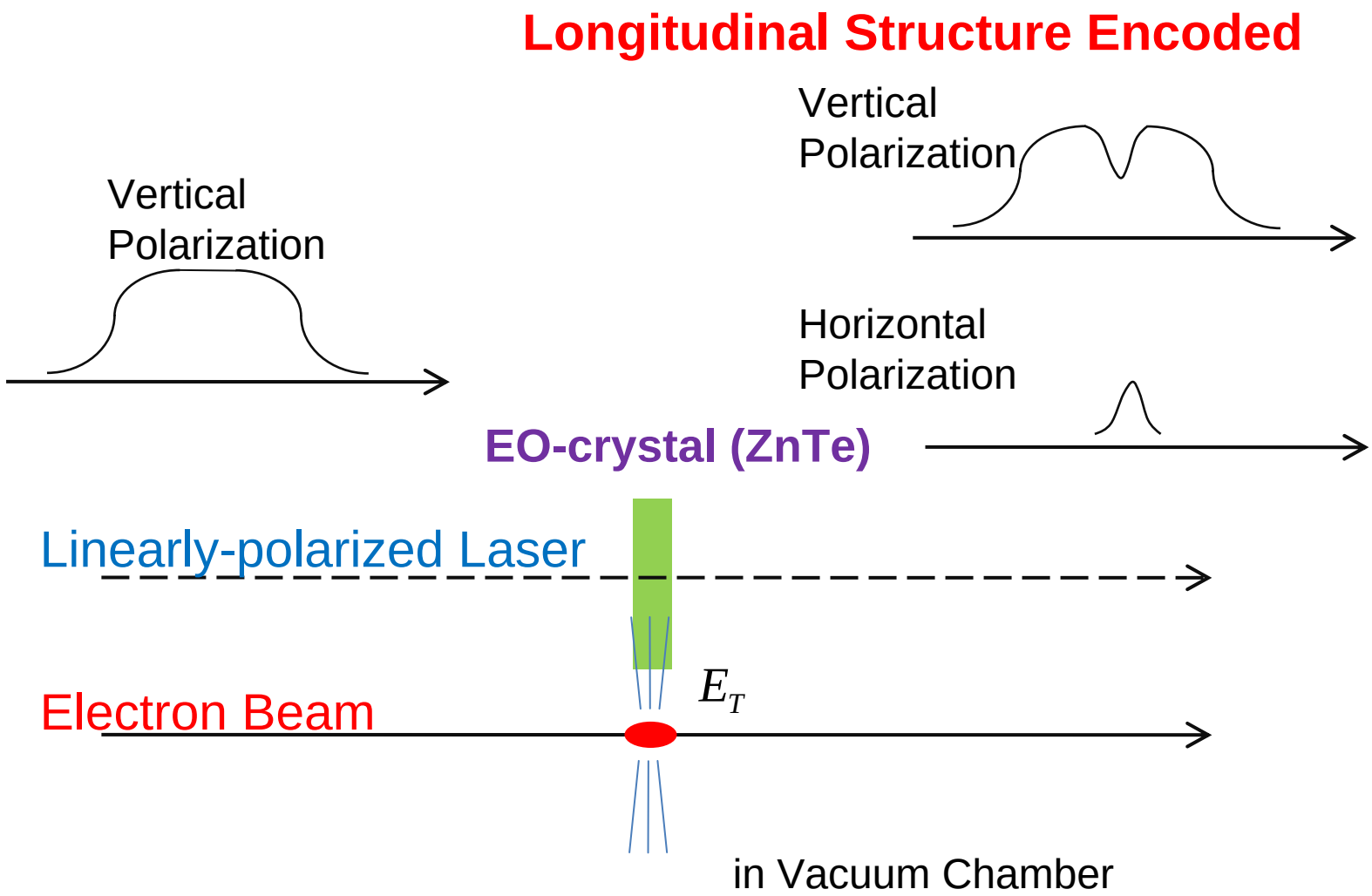
Shot-by-shot Electron Bunch Timing ⇨ Need for precise experiments.

Longitudinal Bunch Structure ⇨ Need for reliable commissioning.

Non-destructive and real-time measurement can be done by Electro-Optical sampling method.

G. Barden et al, Phys. Rev. Lett. 93, 114802 (2004)

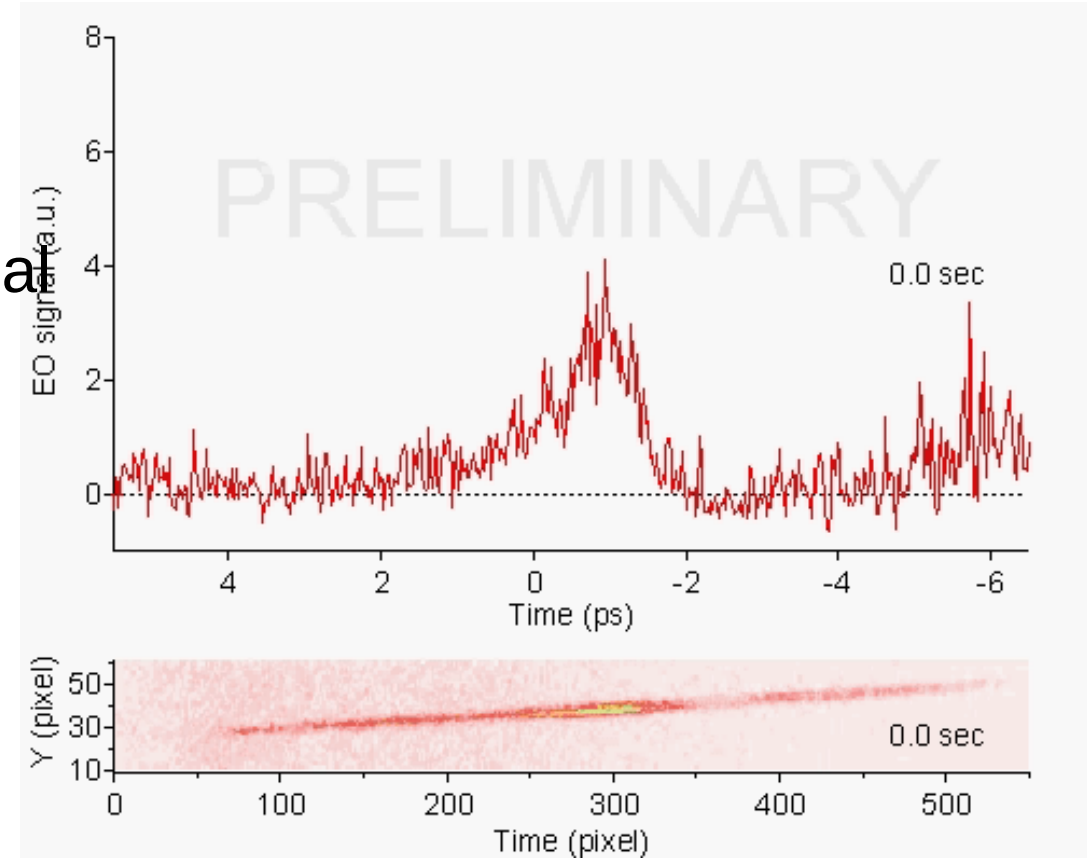
# Electro-optical Sampling Method



# Preliminary Result at SCSS

Reconstructed EO-signal

Spatially Decoded Signal by BBO-crystal



# Construction Status of the XFEL Project at SPring-8

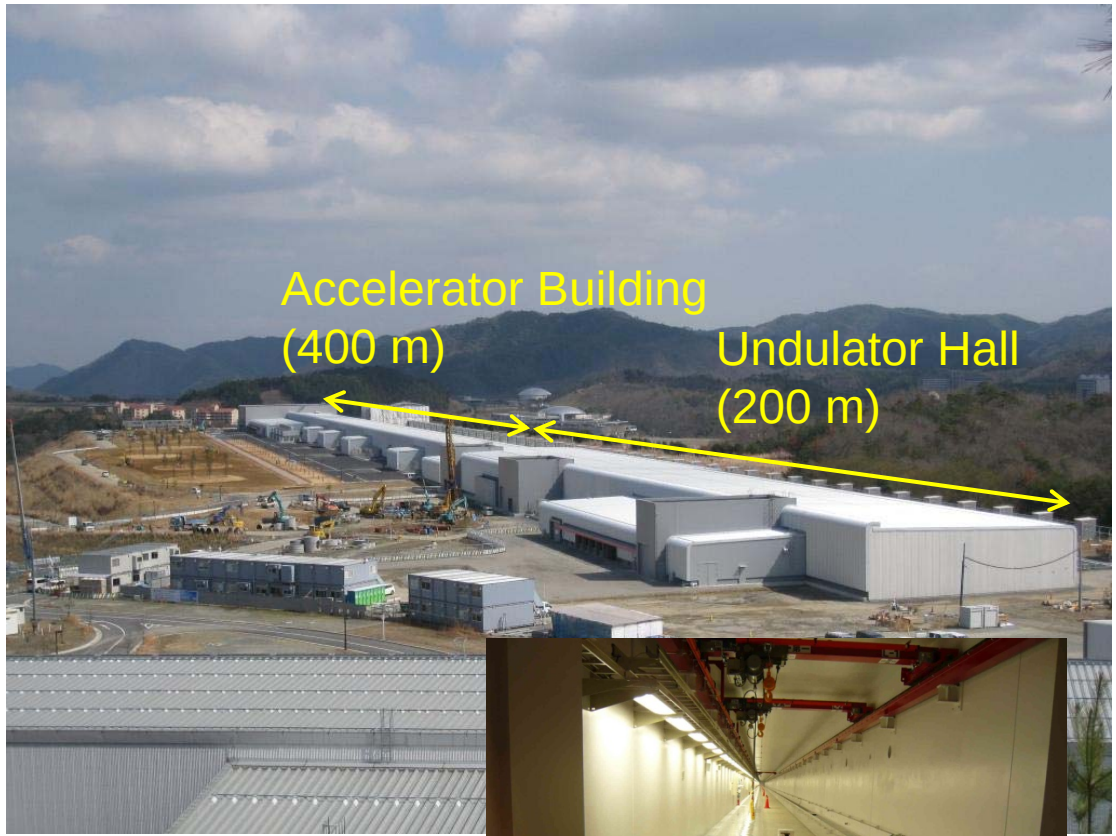
# XFEL/SPring-8

## Electron Beam

| | |
|---|---|
| Energy | 8 GeV |
| Peak Current | 4.4 kA |
| Bunch Width | 55 fs (FWHM) |
| Repetition rate | 60 pps |

## Photon Beam

| | |
|---|---|
| Wavelength | 0.1 nm |
| Peak Power | >20 GW |
| Pulse Energy | 0.8 mJ/pulse |
| Bandwidth | 9 X $10^{-4}$ |




Accelerator Tunnel

# Schedule

March 2009

Building construction was completed. 70% of the main rf components were fabricated.

Summer 2009

Installation of the C-band main linac will be started.

Fall 2010

Equipment installation will be finished. Rf-aging, beam commissioning.

2011~

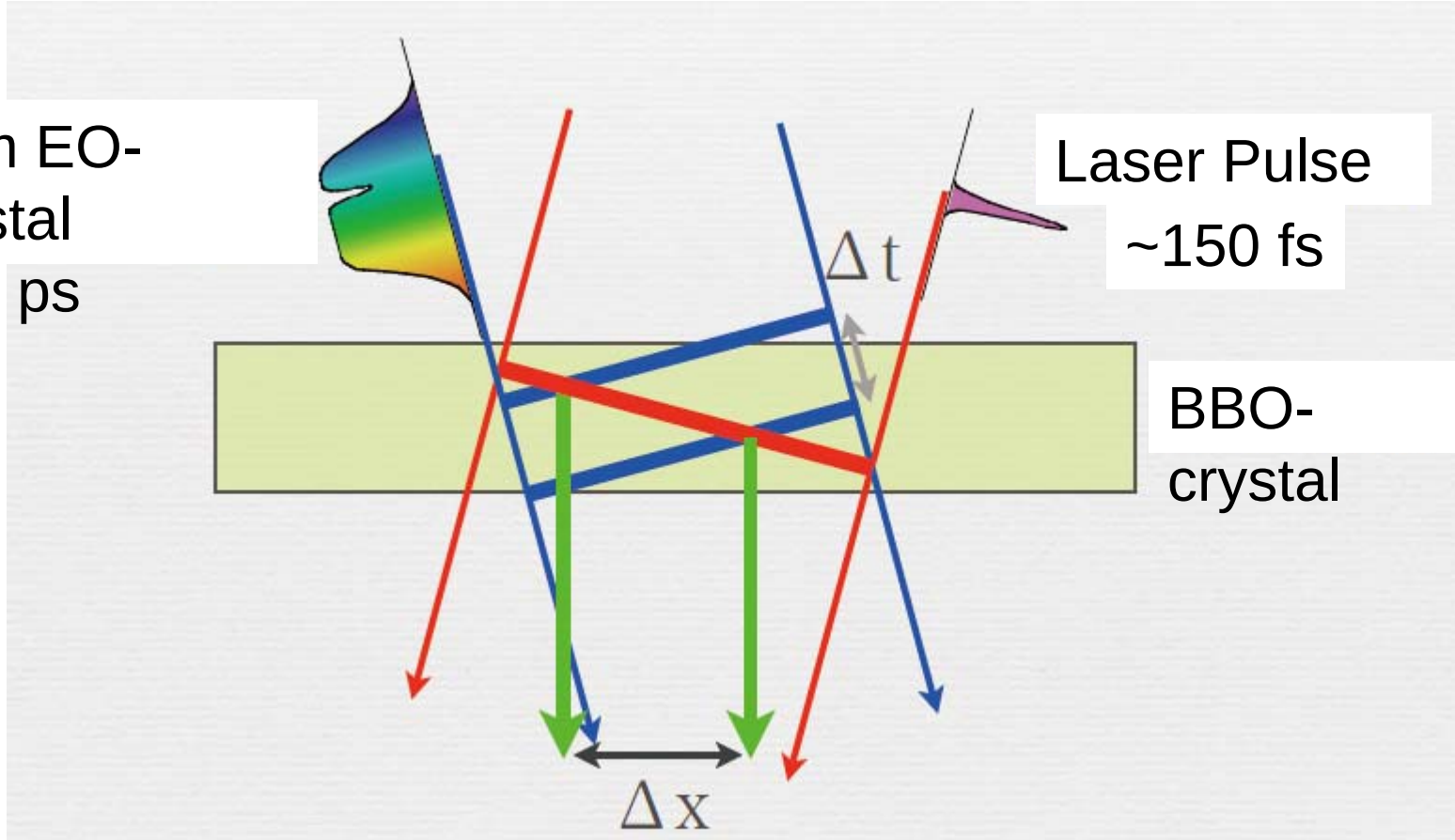
User operation will be started.

# Summary

- The SCSS test accelerator has successfully delivered stable EUV-SASE laser pulses, whose fluctuation is kept in 10% during the experimental period, for various experiments through a year.
- The experience of the machine operation is being fed back to the construction of the 8-GeV XFEL/SPring-8.
- User experiments at the XFEL/SPring-8 will be started in 2011.

# Spare

# Spatial Decoding



# History of the XFEL Project at SPring-8

- 2000 : Concept of the SPring-8 compact SASE source.
- 2001-4: R&D of machine components.
  (Thermionic Gun, C-band Linac, In-vacuum Undulator)
- 2005 : 250-MeV SCSS test accelerator constructed.
- 2006 : First lasing at 49 nm at SCSS.
  : Design and construction of 8-GeV XFEL/SPring-8 started.
- 2007 : Saturation at 50-60 nm. User operation started at SCSS.
- 2008 : Building construction of XFEL/SPring-8 completed.
- 2011 : User operation (~0.1 nm) will start at XFEL/SPring-8.