Early Days of SACLA

March 15th , 2019

@APS, ANL

Tetsuya Ishikawa

Director

RIKEN SPring-8 Center

齊 ： ordered, coherent

光 ： light

光齊 Kwang-Je

First International Review Committee for SCSS Project

February 3, 4, 2005

Spring-8, Kouto, Harima, Japan

Won Namkung, Shin-ichi Kurokawa,
Marie-Emmanuelle Couprie, John Galayda,
Jochen Schneider, Jerry Hastings, ***Kwang-Je Kim***

SCSS Review Comments

1. Summary
2. Scientific case
3. Uniqueness of projects
    1. Thermionic-gun-buncher based injector
    2. Accelerator system
    3. Undulator system
    4. Diagnostics and commissioning
    5. Synergy with Spring-8
    6. X-ray optics
4. Schedule and milestones
5. International collaboration

Summary

- SCSS is an innovative project for generation and use of intense, coherent, short pulse x-ray beams
- SCSS is a unique due to its compactness and its co-location with Spring 8, the leading third generation x-ray facility
- Spring 8 site and facility is very well-suited for this project
- Success of the SCSS will be a milestone event in the advance of technology for x-ray FEL, stimulating progress in x-ray science worldwide
- Members of the SCSS project team are well-known for their successes in innovative solutions of difficult problems
- The project schedule of the SCSS is ambitious but feasible in view of the competence of the project team and accumulated knowledge in the Spring 8 site
- The 60 nm FEL using 250-MeV accelerator is a major step toward the success of the project. We strongly recommend provision for full scientific utilization of this unique source.
- The Committee strongly recommends the prompt start of the SCSS project.

SPring-8 XFEL Status

March 16th , 2007

@NSLS, BNL

Tetsuya Ishikawa

Leader, SPring-8 XFEL Project

On behalf of the Joint XFEL Project Team

RIKEN

SPring-8

Japan launched XFEL Project

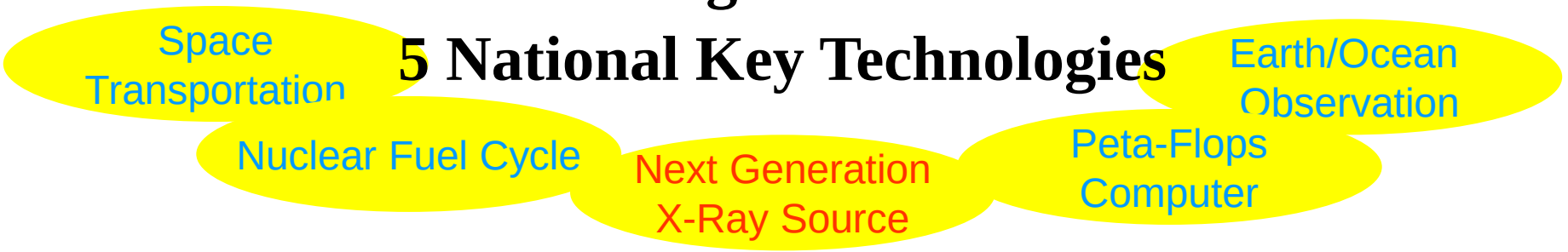
Japanese 3rd Science and Technology Basic Plan (2006-2010)

“Selection & Concentration”

273 Important R&D items

62 Strategic R&D items

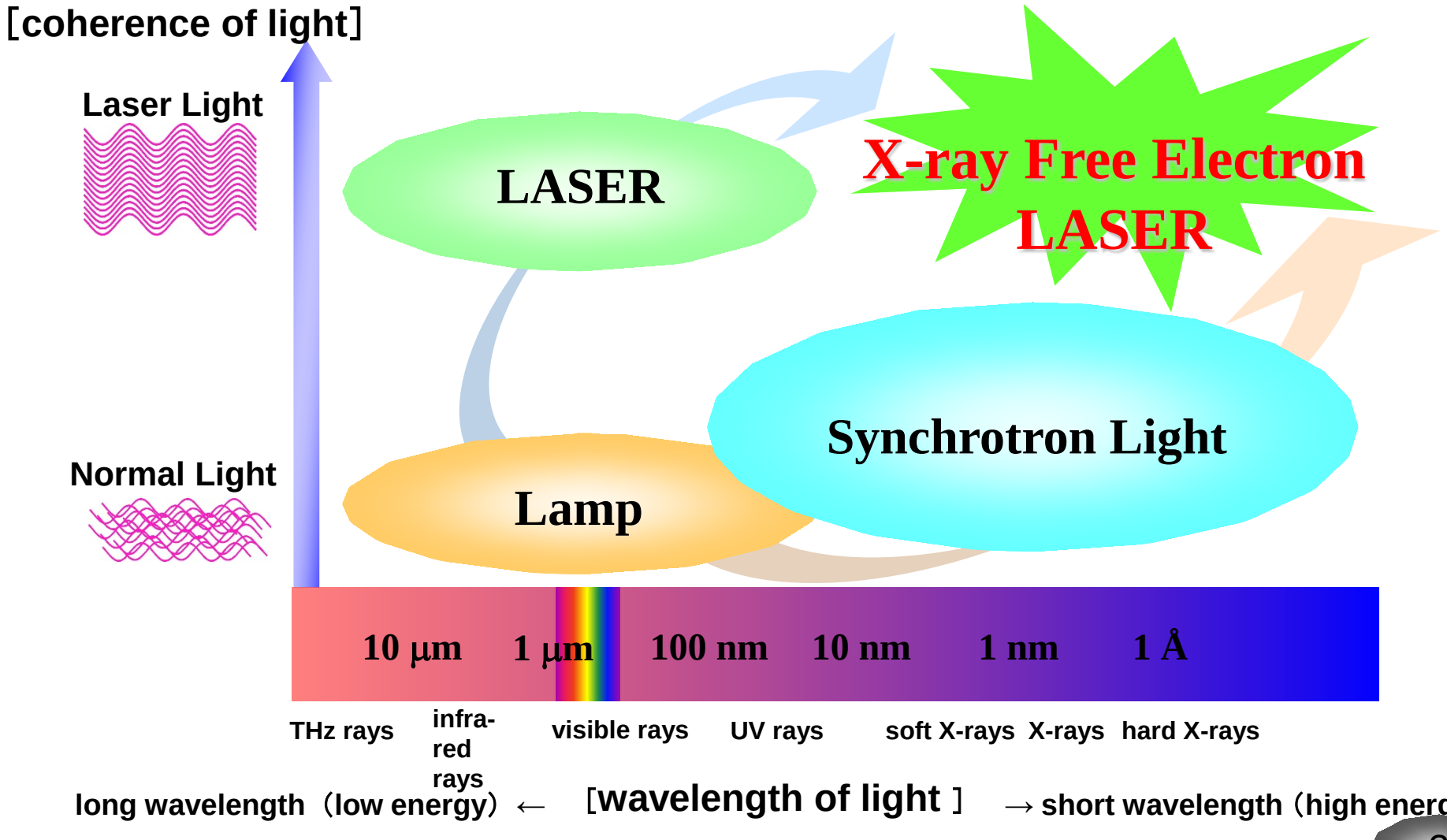
5 National Key Technologies



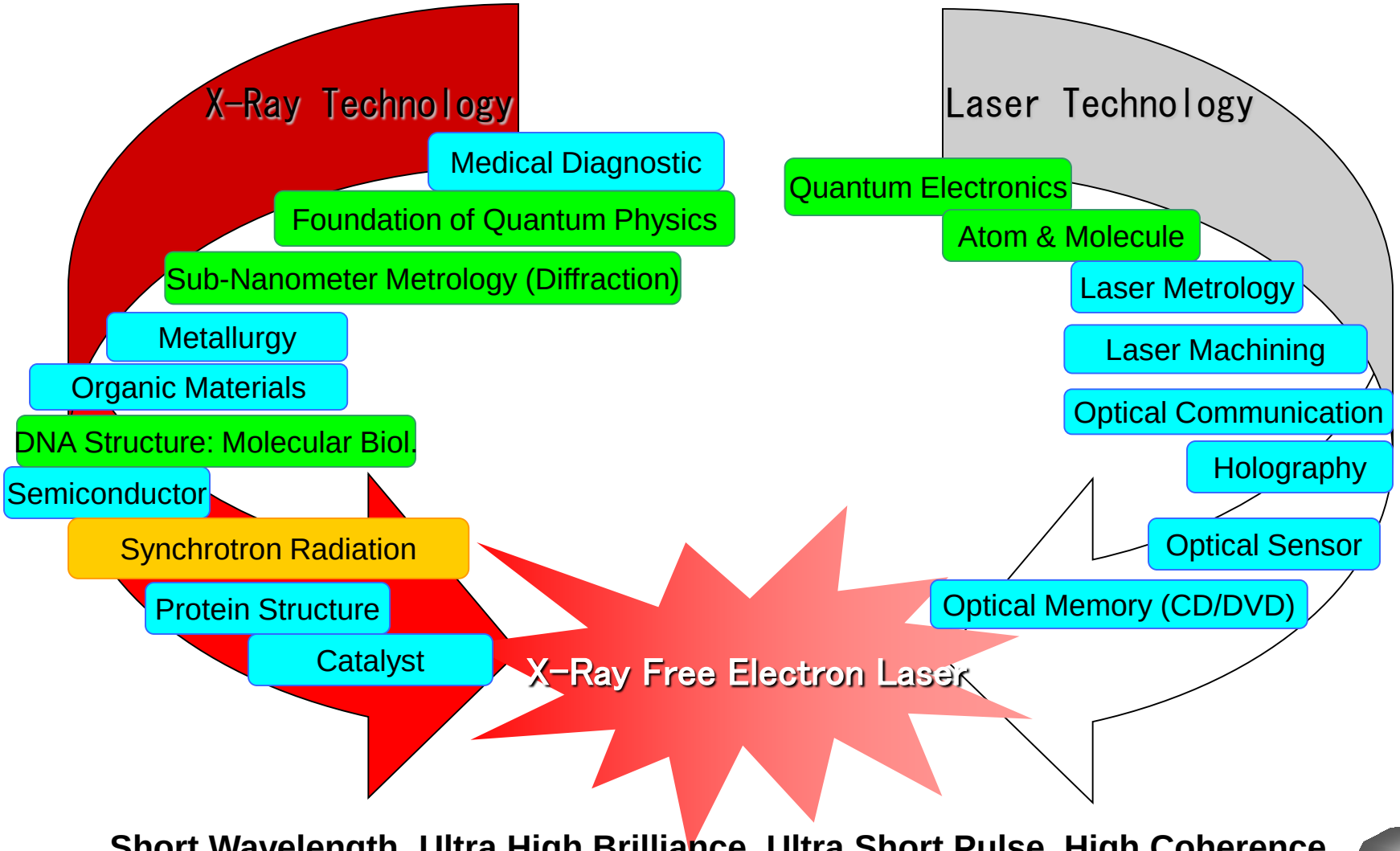
X-Ray Free Electron Laser was selected as one of the National Key Technologies.

“X-ray Free Electron Laser, XFEL”

provides a perfectly-coherent X-rays with a miraculous intensity.

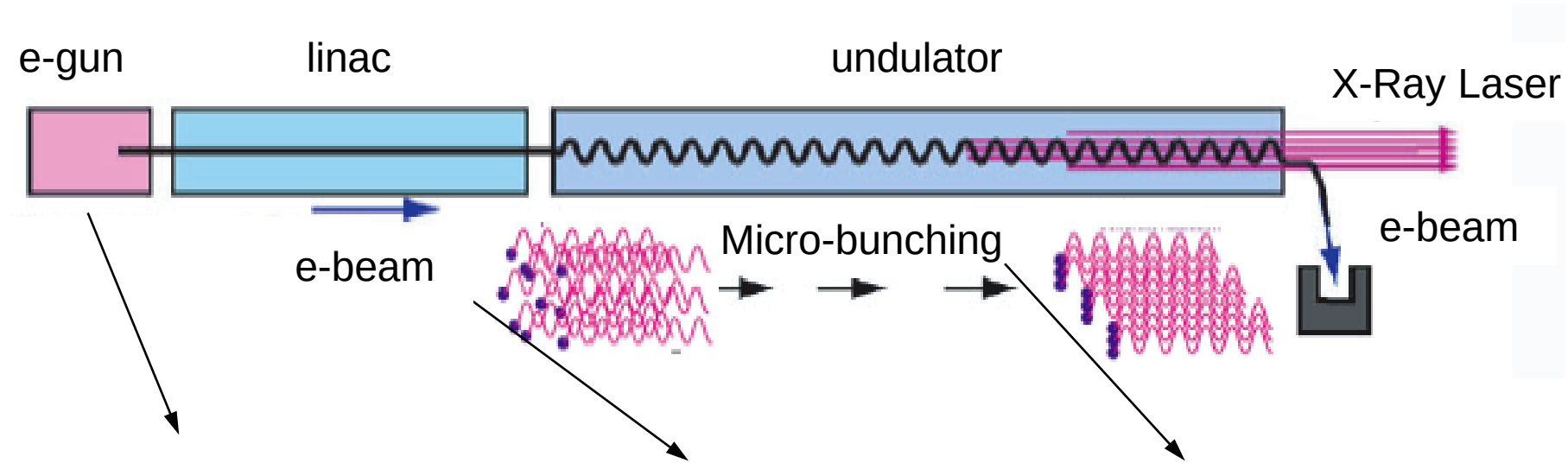


Photon Technology for 21st Century by Fusion of Two Greatest 20th Century Photon Technologies

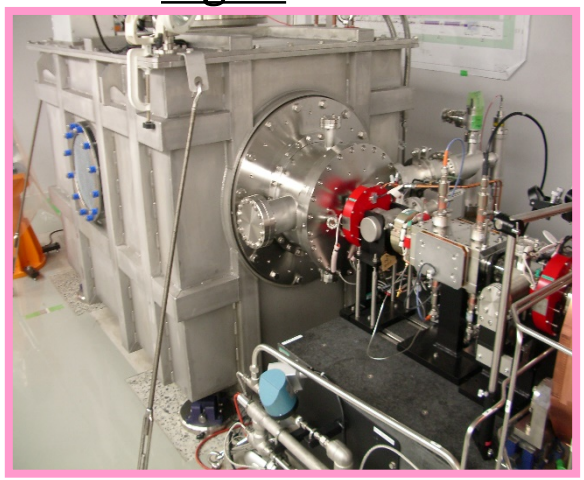


Short Wavelength, Ultra High Brilliance, Ultra Short Pulse, High Coherence

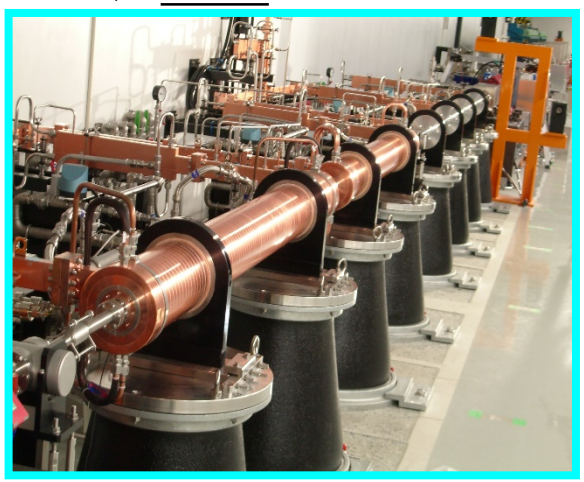
Linac-Based Free Electron Laser
Self-Amplified Spontaneous Emission (SASE)



◆ e-gun

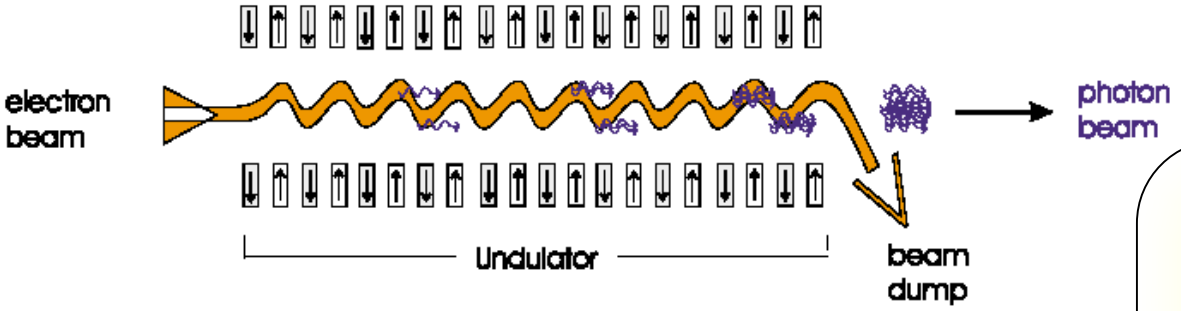


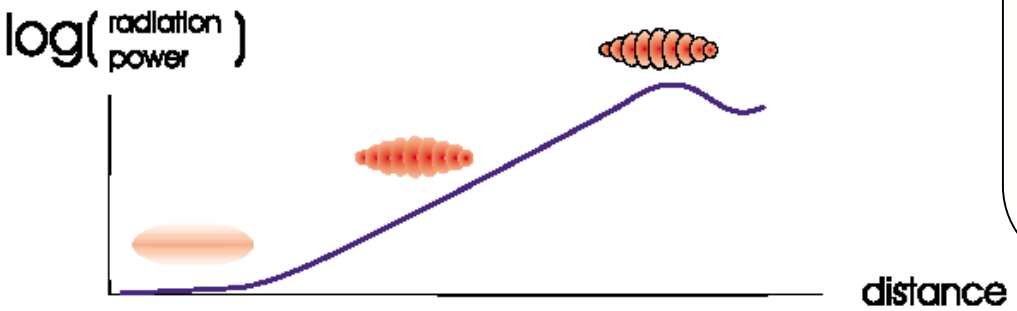
◆ linac



◆ undulator

Self Amplified Spontaneous Emission (SASE)

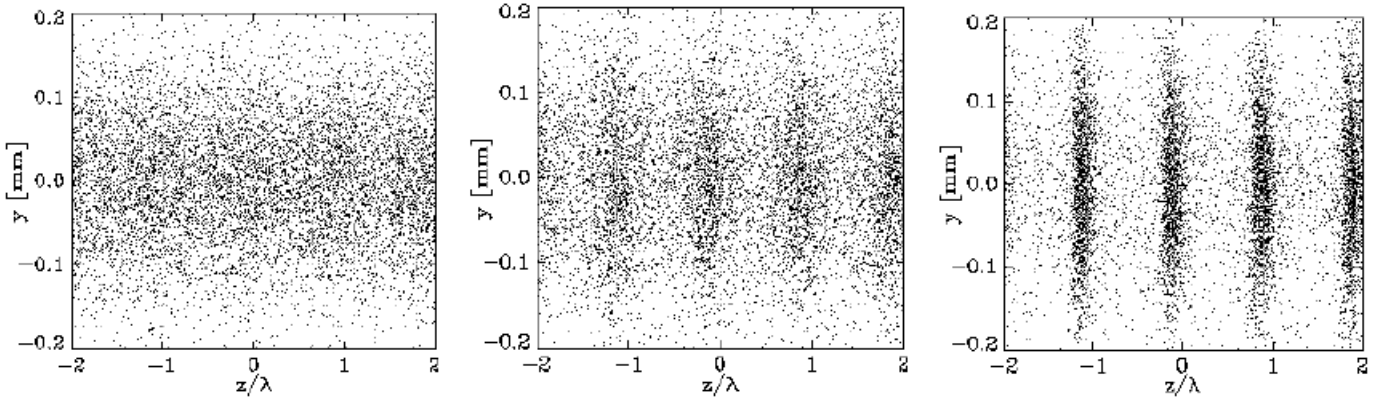




Requirements for e beam

- Low Emittance
- High Density in 6D Phase Space

> nC in 0.05x0.05x0.03 mm^3 volume



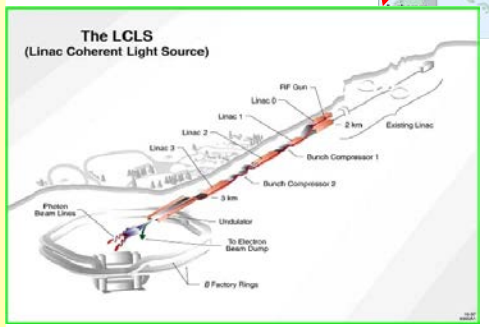
US and European XFEL Projects

【US】 SLAC：Stanford Linear Accelerator Center

Liniac Coherent Light Source : LCLS

- Use Existing 2 mile Liniac
- Project Cost: 315 M US$
- Size: 2 km long
- Shortest Operating Wavelength: 0.15 nm
- To Start Operation in 2009
- RF gun/Normal Conducting Liniac/Out-of-Vacuum Undulator
- 3rd Priority in DOE's Future Facility Plan

Stanford, CA



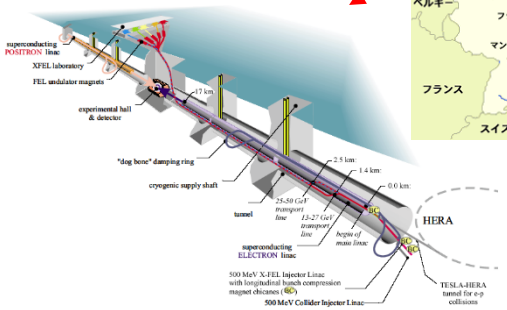
LCLS

【EU】 DESY：Deutsches Elektronen-Synchrotron

European X-Ray Free-Electron Laser

- Collaboration among 12 EU Countries + China
- Project Cost 908M Euro
- Size: 3.4 km long
- Shortest Operating Wavelength: 0.085 nm
- To Start Operation in 2013
- RF gun/Superconducting Liniac/Out-of-Vacuum Undulator

Hamburg, Germany



European XFEL

SPring-8 Compact SASE Source (SCSS)

- SPring-8 Compact SASE Source (SCSS) is a linac-based X-ray Free Electrom Laser to emit $\lambda < 0.1$ nm radiation.
- The project was born from a discussion of how we could reduce the size of an XFEL by combining a SPring-8 in-vacuum & mini-pole undulator and a high-energy-gradient linear accelerator.
- To achieve the downsizing, we had to develop high-performance injection system, which was recently addressed by DC gun.

Compact SASE Source

Undulator Radiation

$$\lambda_{photon} = \frac{\lambda_{magnet}}{\gamma^2}$$

$$\gamma = \frac{E}{m_0 c^2}$$

With smaller λ_{magnet} , shorter wavelength is achievable with smaller electron beam energy E.

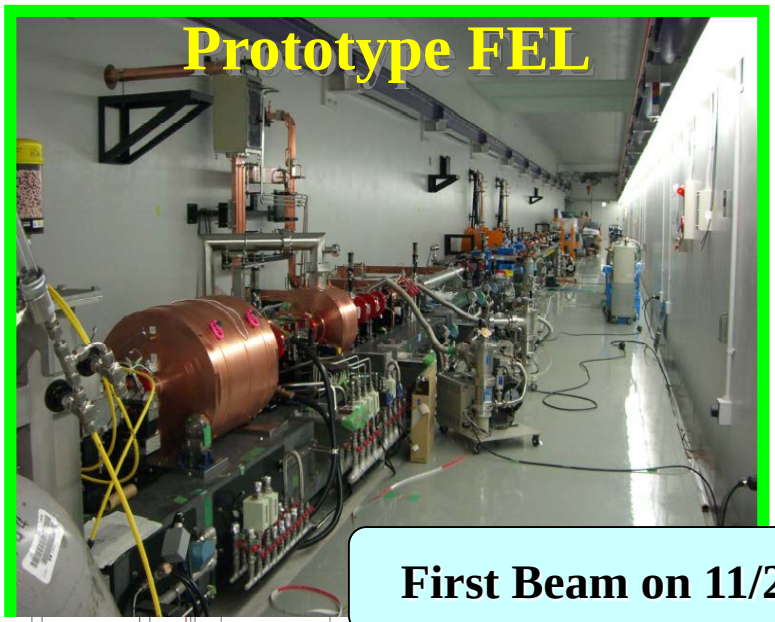
⟶ SPring-8 In-Vacuum Undulator

High gradient linear accelerator reduces the total length required for a given electron beam energy E.

⟶ KEK C-Band Linac

Prototype Construction

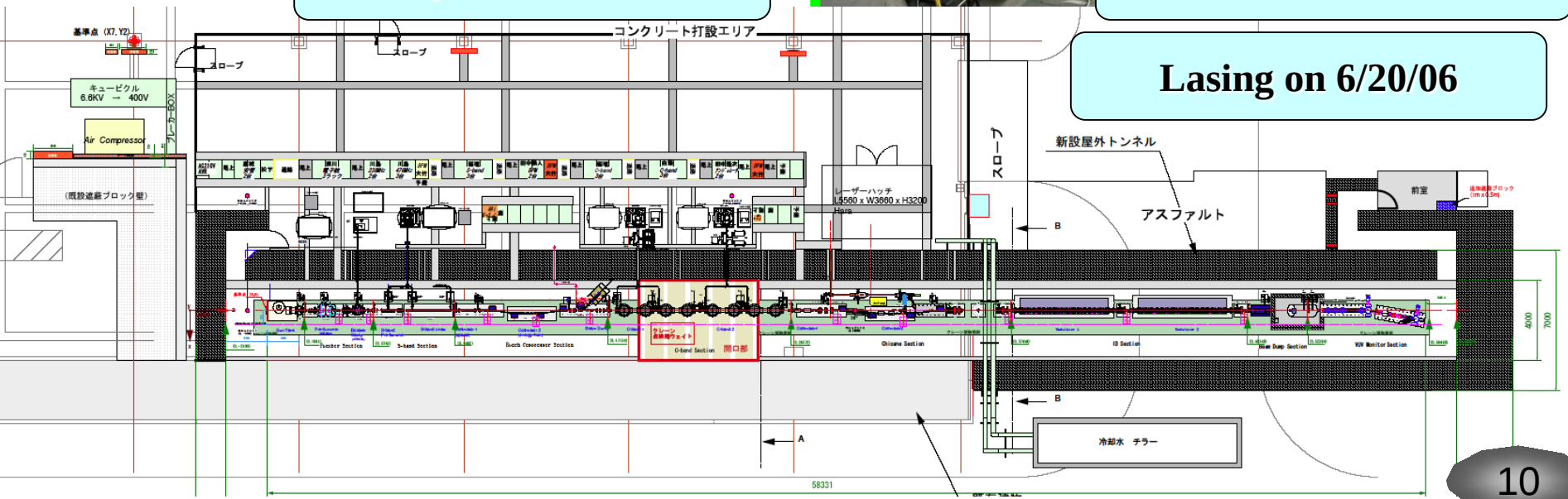
250 MeV Prototype, Total Length: 60 m, Target Wavelength: 60 nm



Completed on 8/31/05

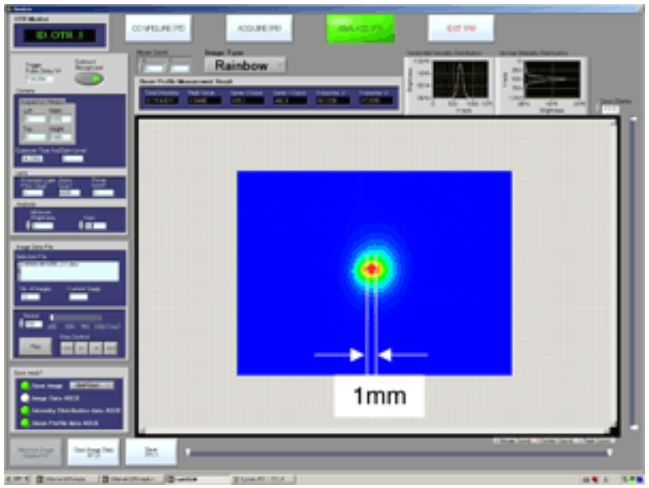
First Beam on 11/25/05

Lasing on 6/20/06

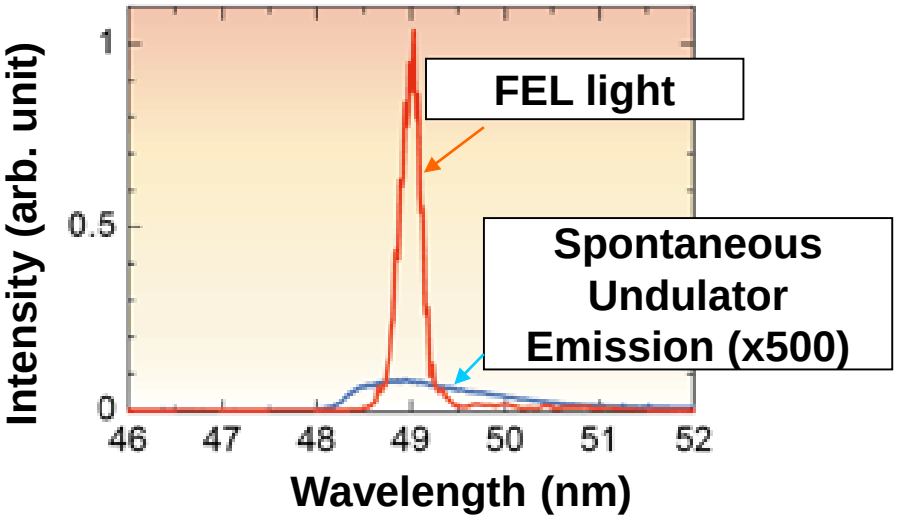


First Lasing at 49 nm (June 20, 2006)

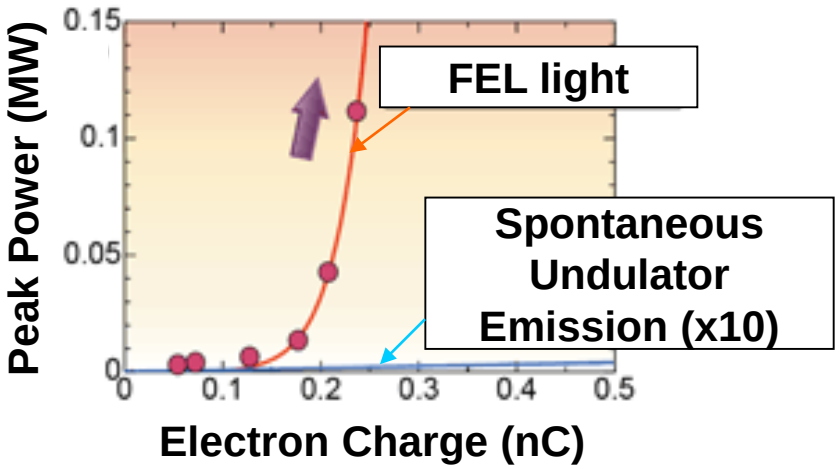
Electron Beam Profile



Spectrum



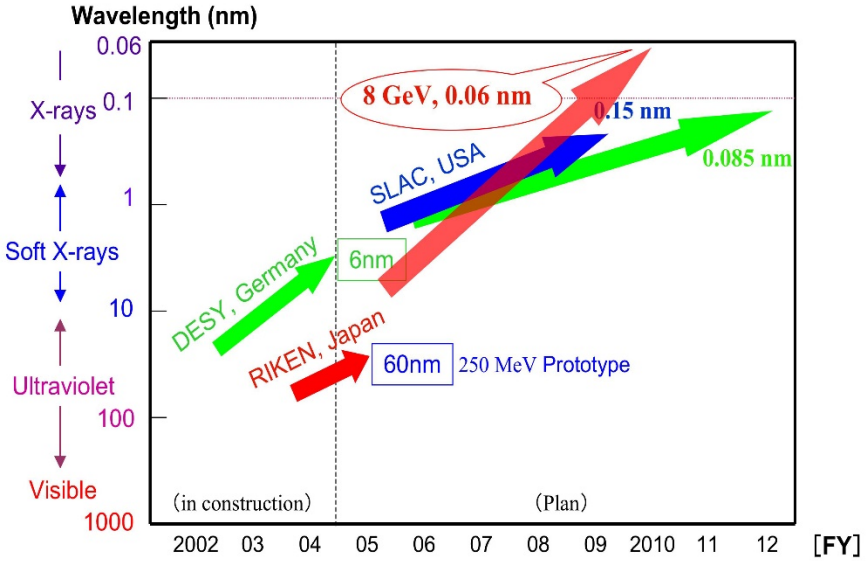
Charge Dependence



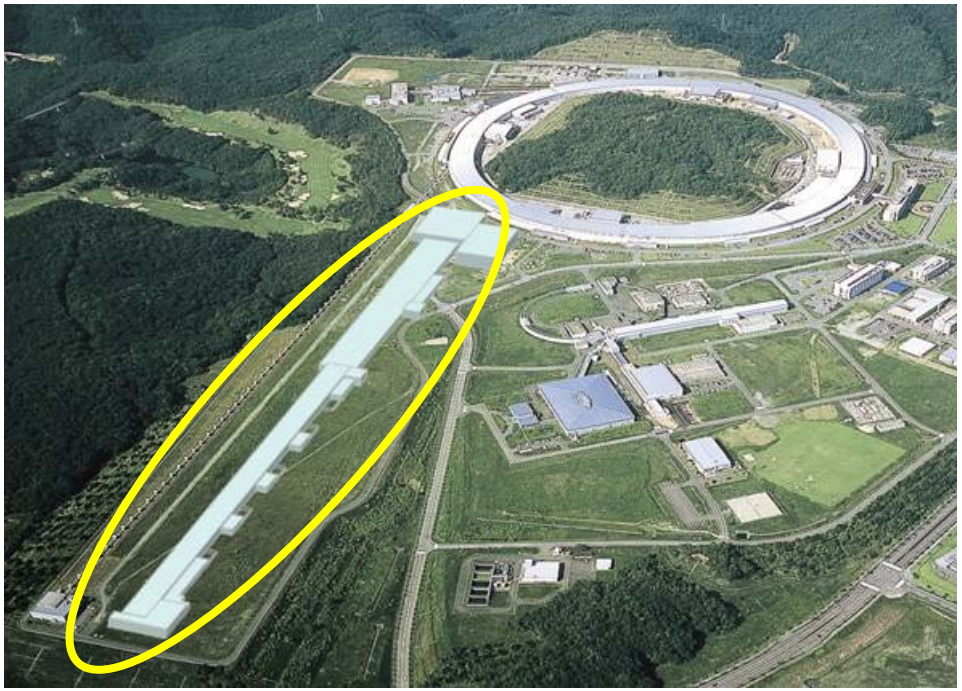
E = 250 MeV
Charge/Pulse ≤ 0.25 nC
Emittance ≤ 2π mm·mrad
Pulse Length ≤ 2 ps
Wavelength = 49 nm
Max. Power = 110 MW

8GeV XFEL Approved!

Milestones



Image



1st Phase Construction (2006-2010)

Accelerator Shield, Linear Accelerator Experimental Hall, Office Bldg, XFEL Beam Line 1, Wide Range FEL Beam Line 1

Budget (2006-2010)

Construction	290 M US$
R&D	20 M US$

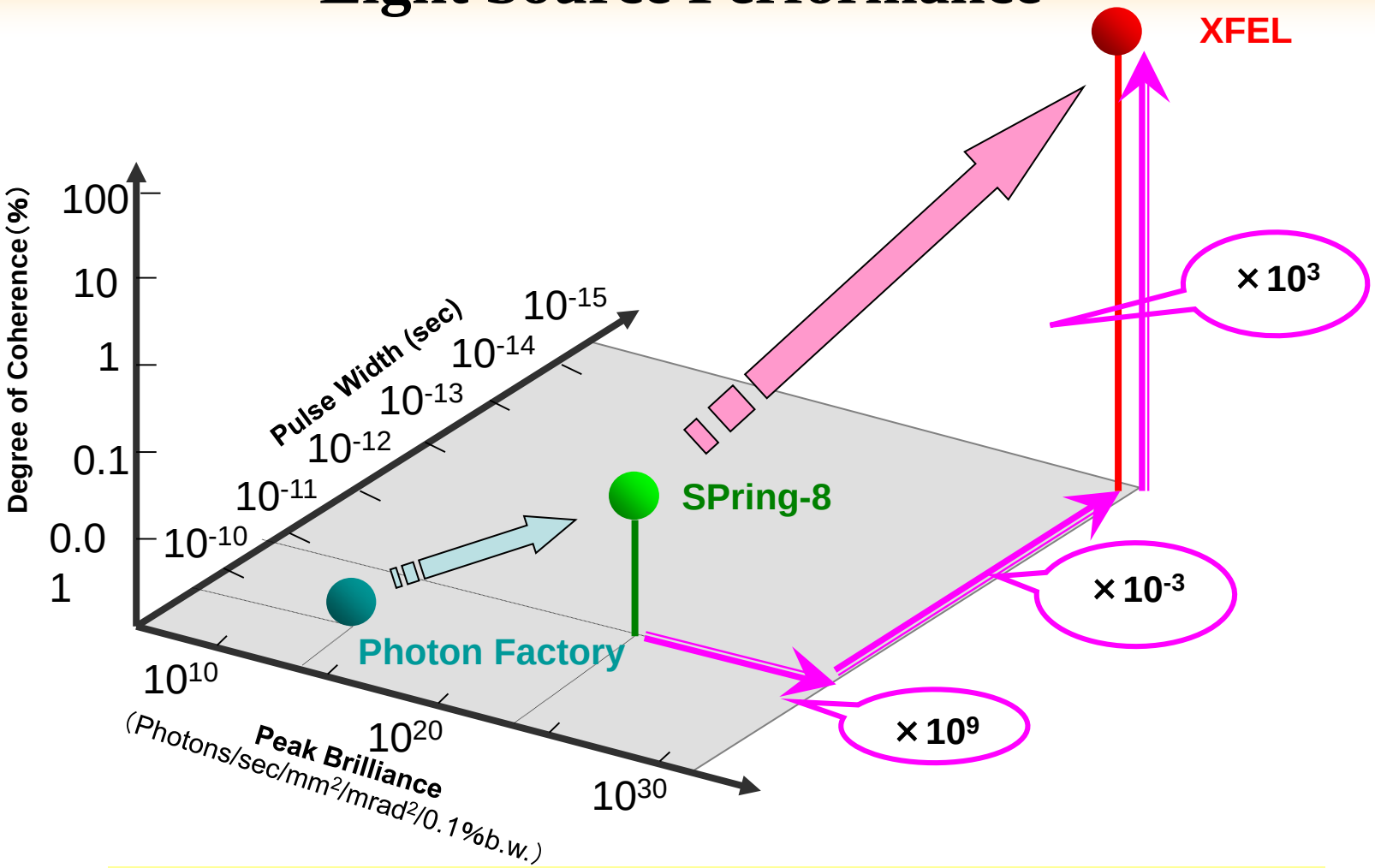
World-Wide Open Facility

The same proposal-review process as SPring-8

2nd Phase Construction

5 XFEL Beam Lines, 5 Ultrashort Pulsed Spontaneous X-Ray Beam Lines

Light Source Performance



3 Remarkable Features of XFEL producing λ<0.1 nm X-Rays

- ◎ High Peak Brilliance
- ◎ Narrow Pulse Width
- ◎ High Degree of Coherence

RIKEN

Envisaged, Unprecedented Applications

Limitation of the current technology

Modest Brilliance Modest Time Resolution Non-Coherent Source

XFEL

High Brilliance fs Time Resolution Full Lateral Coherence

Atomic Resolution Imaging

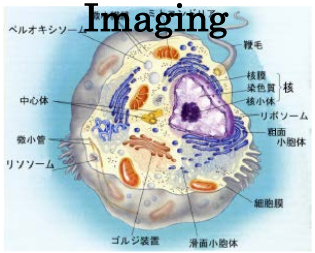
Ultrafast (fs) Imaging

Life Science

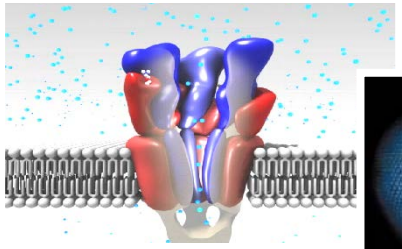
High Field Science

Nano Science/Technology

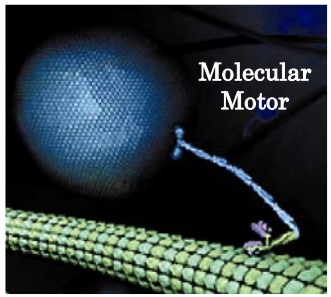
Atomic Resolution Cell Imaging

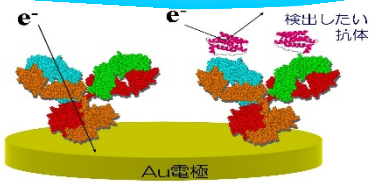


Single Molecular Analysis



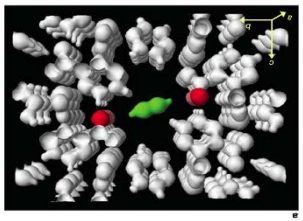
Dynamics of Bio-nano Machine



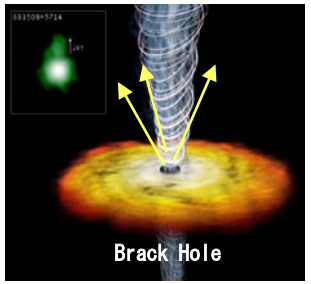


Observation/Control of Electronic State

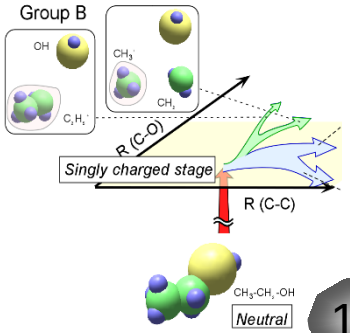
Nano Dynamics



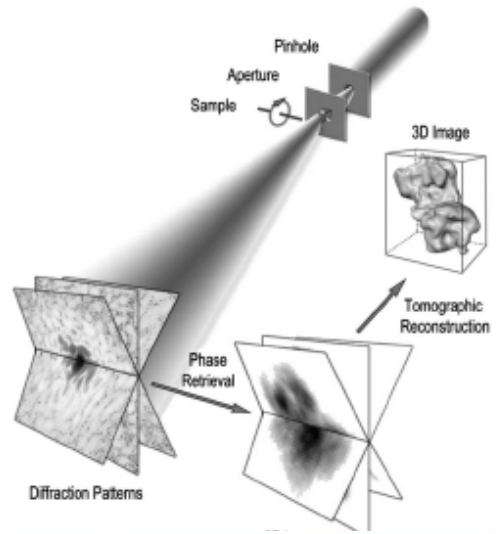
Astoronomy

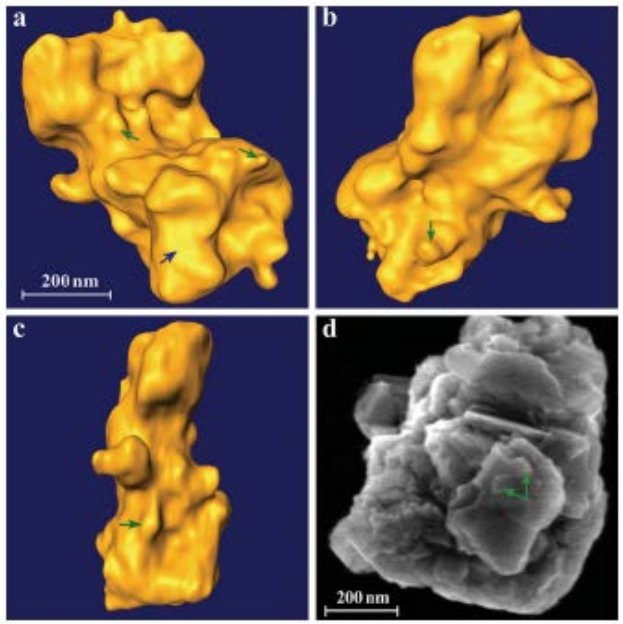


High Field Chemistry

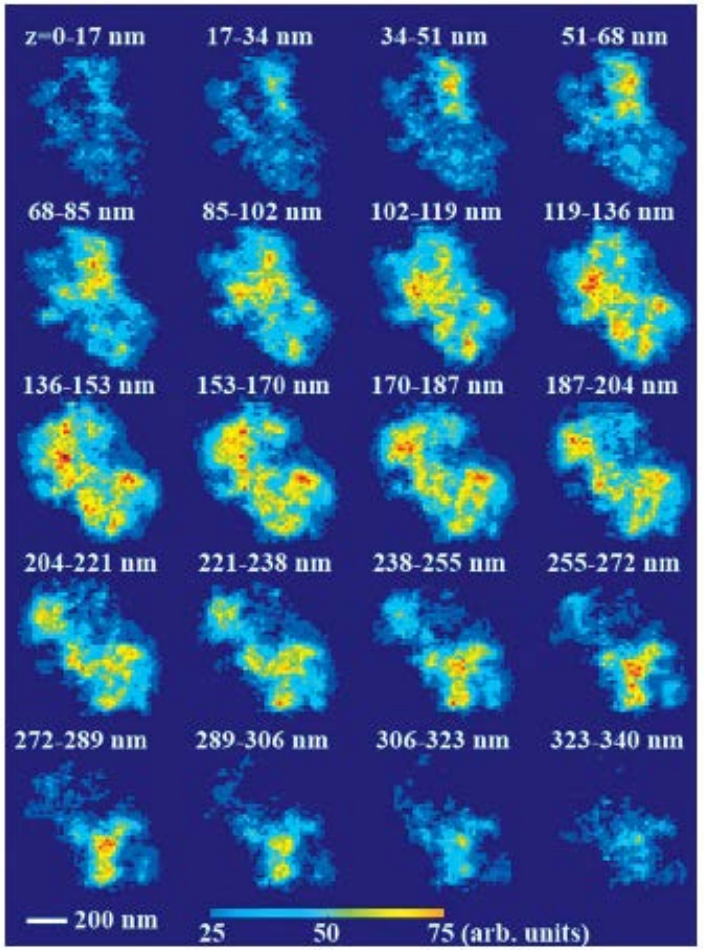


Coherent Scattering Imaging (SPring-8)



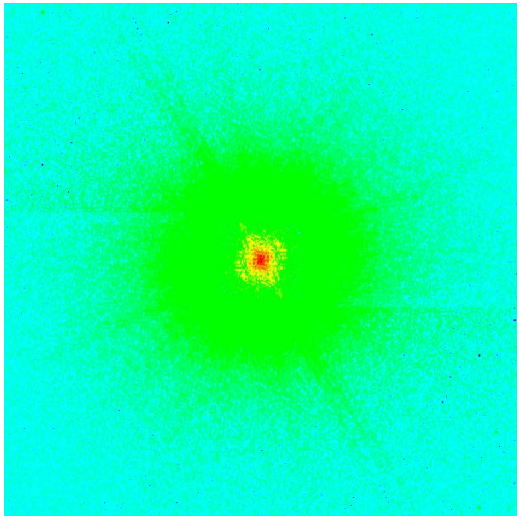


3D Rendering of GaN Nano-Dot
Miao et al, PRL (2006)

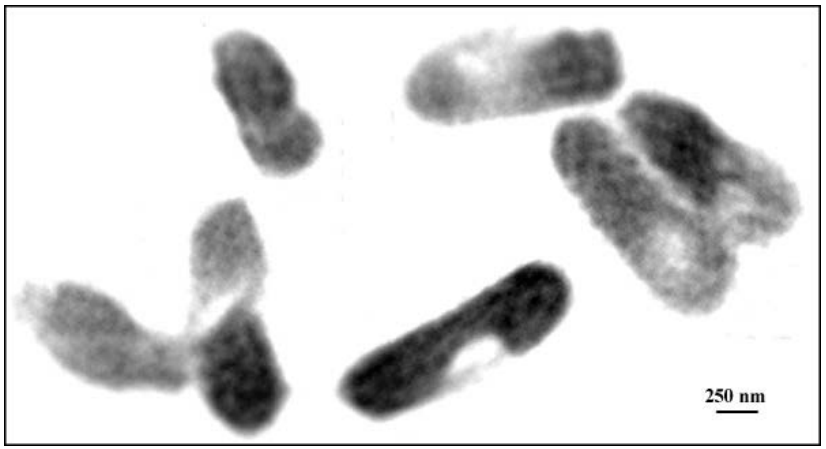


Application to Biological Samples (SPring-8)

Escherichia Coli Bacteria

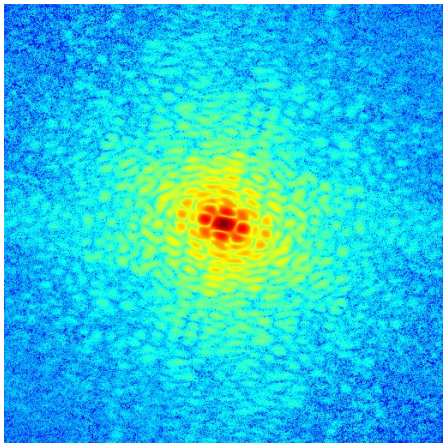


Coherent Scattering Pattern

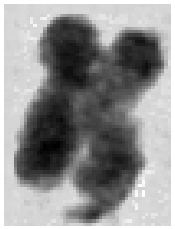


Reconstructed Image

Human Chromosome

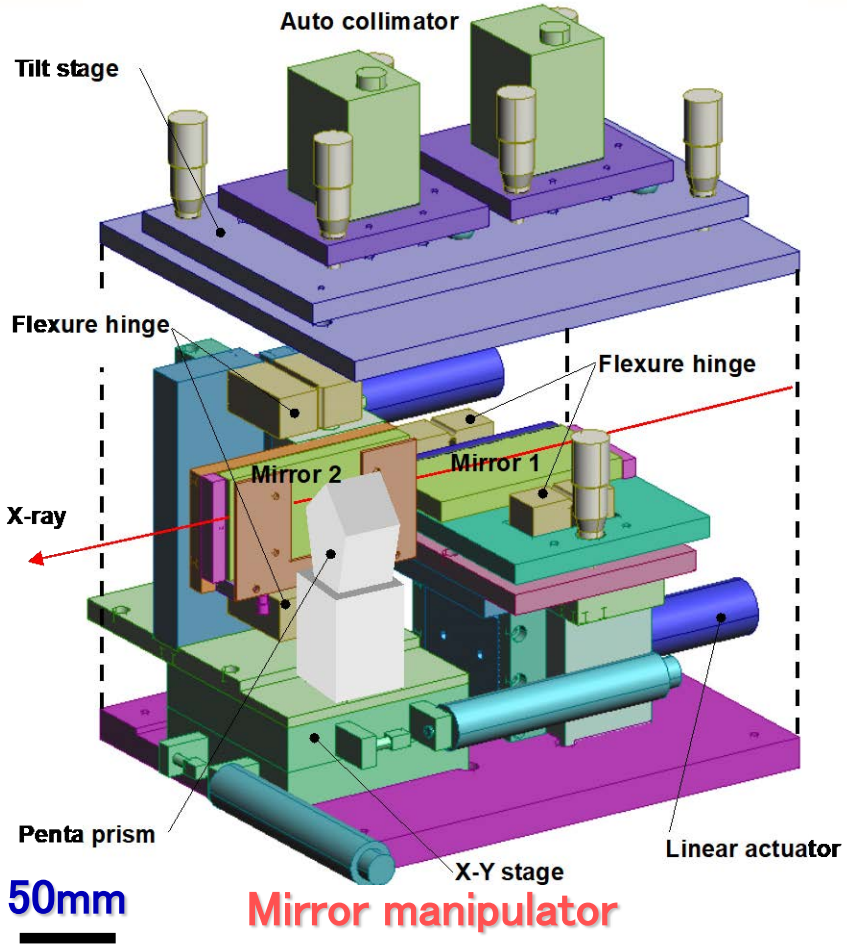


Coherent Scattering Pattern

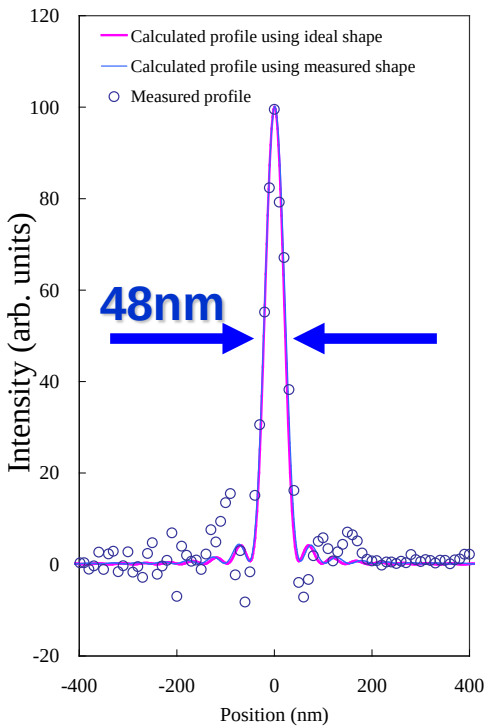


Reconstructed Image

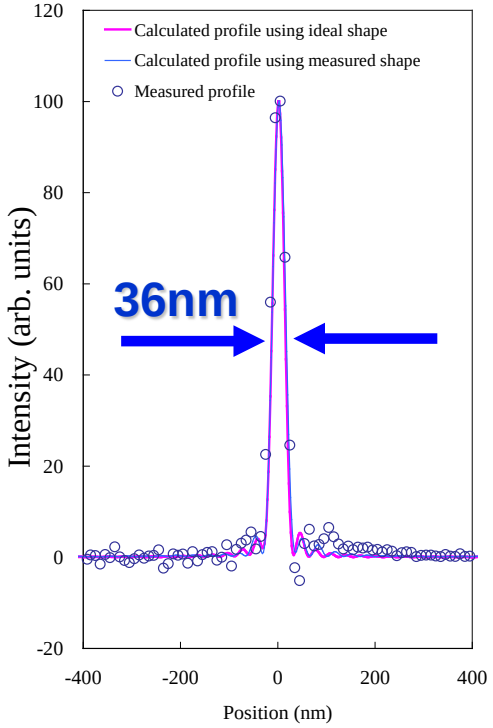
Nano-Focusing at SPring-8



Mirror manipulator



Vertical focusing



Horizontal focusing

X-ray energy: 15keV

- At the 1-km-long beamline (BL29XUL) of SPring-8, the focal size in FWHM was achieved to be **48nm x 36nm (V x H)** by this manipulator.
- Measured and simulated profiles are almost the same. ⇒The mirrors alignments were carried out with the required accuracies to realize the diffraction-limited focusing. .

Summary & Outlook

- Japan has launched a project to construct an X-ray Free Electron Laser (XFEL) as one of the National Key Technologies.
- SPring-8 was selected as the site of the XFEL.
- The project period is from 2006 to 2010.
- The facility will be open for the world-wide users.
- We believe the coherent X-rays from the XFEL will expand the frontier of sciences of the photons, with the photons and for the photons.

Join us to explore new science!

RIKEN

Happy birthday !