Today's *take-away* is ・・・・・・▪

"Compact SASE Source"

- If the SASE XFEL is really wonderful light source,
  it is not enough to have only a few sources around the world!

- Lower electron energy may be feasible,
  if we could use the short-period in-vacuum undulator
  instead of the conventional out-of-vacuum undulator.

- In addition,
  if we use a higher energy gradient accelerator tube,
  the LINAC length may be further reduced.

- RIKEN XFEL with 8 GeV LINAC is the first step
  for the 'COMPACT SASE SOURCE',
  but ,
  our dream is to construct an XFEL with < 1 GeV LINAC.

Nobel Symposium on Free Electron Laser Research,
Sigtunahöjden, June 14-18,2015

Progresses in XFEL Science via SACLA

Outlook of Compact SASE Source

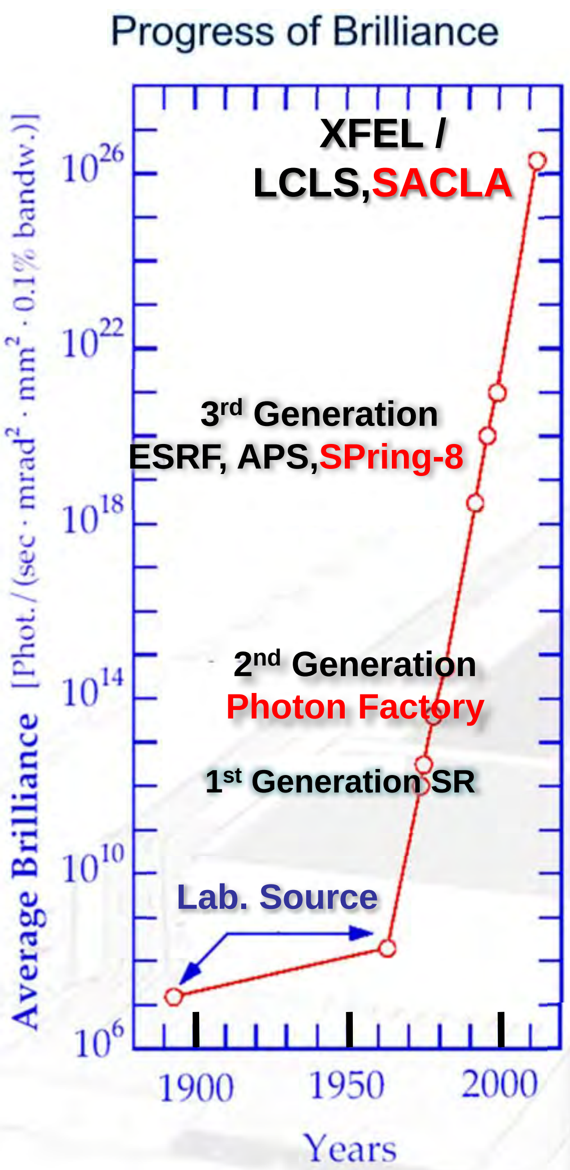
Executive Advisor to the President: SLiT-J Project
Tohoku University
Materials Visualization Photon Science Group
RIKEN SPring-8 Center

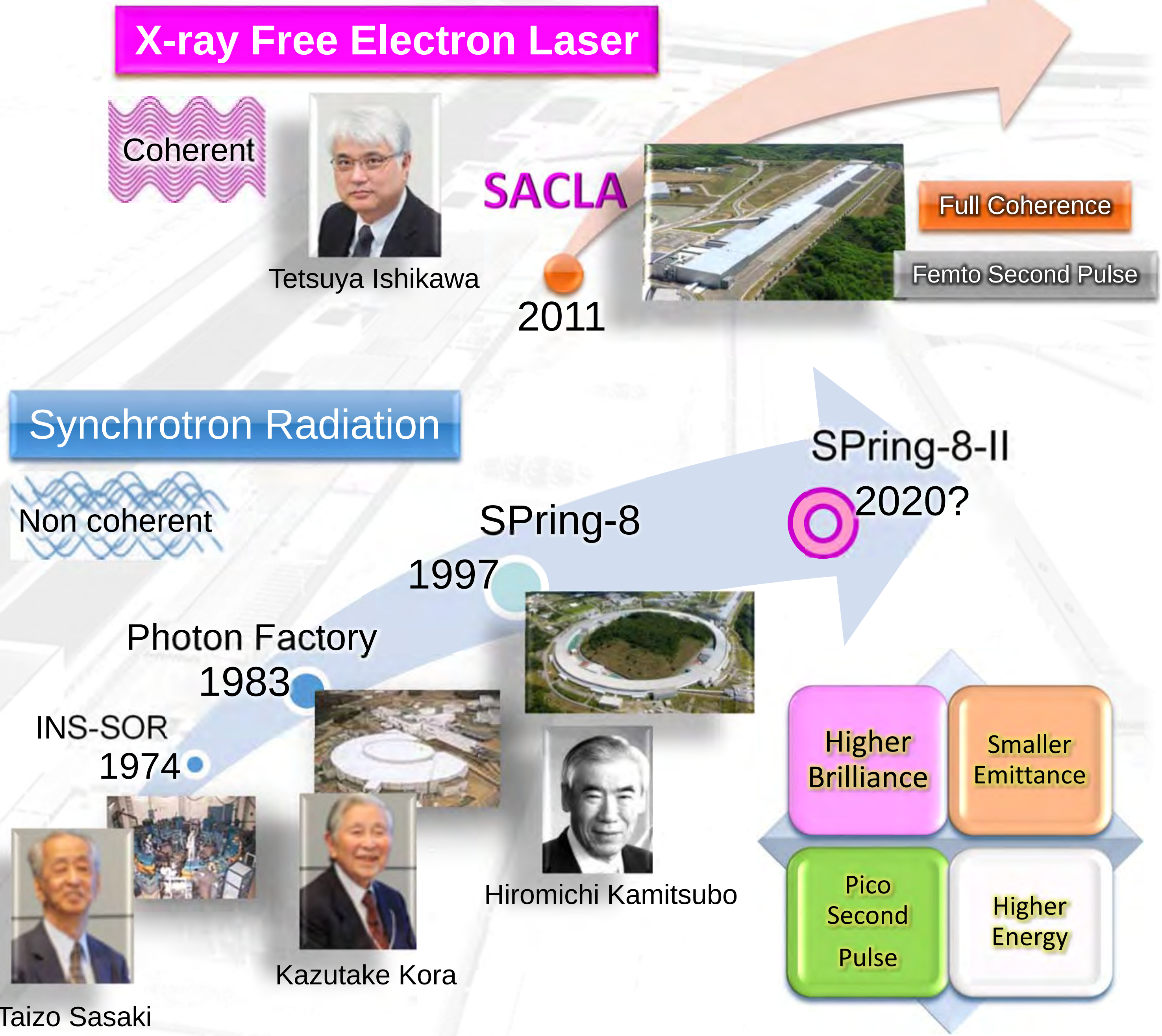
Masaki TAKATA*

* Institute of Multidisciplinary Research for Advanced Materials, Tohoku Univ. (IMRAM)
Laboratory of Synchrotron Radiation Soft X-ray Microscopy

0. The History of Synchrotron Radiation S&T in Japan

With Project Icons





Outline

1) Breakthrough Technologies toward SACLA

Invention of In-vacuum Undulator,
Founding of Coherent X-ray Application
Long Undulator Technology
innovation of C-band Accelerator

2) SCSS: Integrated Test Facility

Key Challenges
Low Emittance Thermionic Electron Gun: CeB6
Velocity Bunching: Bunch Compression

3) SACLA Challenges (constructions)

5 parallel beam lines arrangement,
XFEL/SPring-8 Experimental Facility
XSBT(Beam Transport Line) : from XFEL/SPring-8(SACLA) Linac to SPring-8 Storage Ring

4) Technical Developments in SACLA Commissioning

Electron Beam Orbit / Magnetic Field Alignment via Coincidence Spectrometry using Undulator Light
Energy Tuning by Undulator Gap Control
Tapering of Undulator Magnetic Filed
Two-color XFEL Operation
MPCCD Detectors

5) General Applications of SACLA

Ultrafast diffraction, spectroscopy, Imaging······· etc.

6) New range of the state-of-art in SACLA

Quantum X-ray Optics at SACLA

7) Build-up of Experimental Facilities

Second XFEL Beam Line Construction
SCSS Test Facility Implantation
Promotion of High Power Laser Facility

8) Future Perspective

SPring-8/SACLA complementary application, ImPACT Project, Catalyst in functioning,
Science of deterioration, degradation, and/or break
Ring-type XFEL: CW X-ray laser

1) Breakthrough Technologies toward SACLA

Invention of In-vacuum Undulator

Founding of Coherent X-ray Applications

Long Undulator Technology

Innovation of C-band Accelerator

Hideo Kitamura

Tetsuya Ishikawa

Tsumoru Shintake

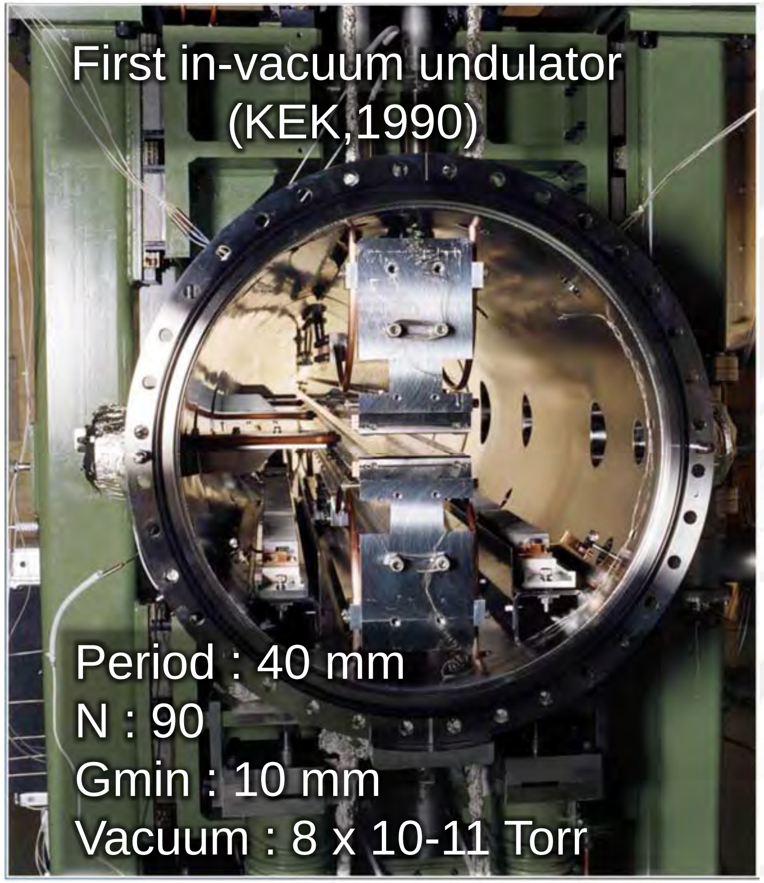
Invention of In-vacuum Undulator

Key developments:

(1) Heat treatment: Degassing process on PMs

(2) Surface treatment: Ni wet-plating (100 micron)

(3) High Power PM: NdFeB ->Intrinsic Coercive Force(iHc) > 2 MA/m



Dating back engineering innovation

1997 Standardization as Insertion Device;
In-vacuum Undulator with 32 mm period — SPring-8

1990 Prototype Practical Model — PF-KEK

1987 Workable Model with metal plates PM anchor — BESSY
-- intrinsic gap loss of 4 mm

1983 Test Model with flexible vacuum chamber — LBNL
-- vacuum problem

1983 Primitive Model — NSLS- BNL
-- vacuum problem

Founding of Coherent X-ray Applications

Crazy challenge met great ideas: 1 km Beamline at SPring-8

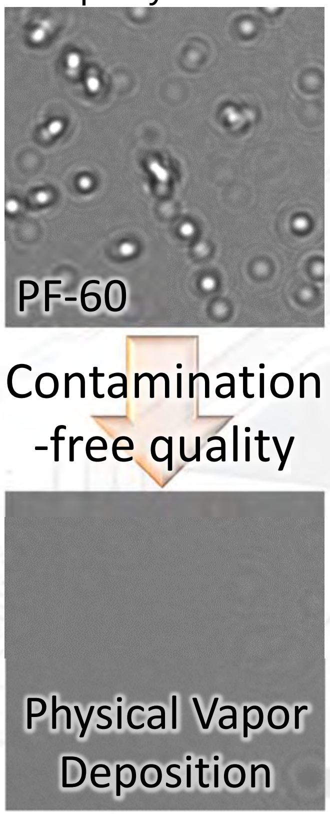
T. Ishikawa

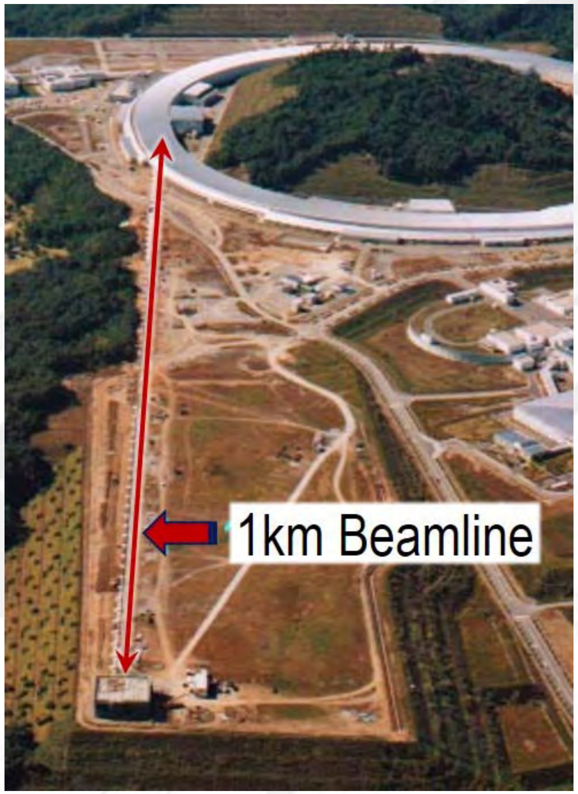
Provided an insight into XFEL Science

Finding problems in optical elements under coherent x-ray illumination
-> High-quality, speckle-free optics to be optimized to XFEL applications

Be window

impurity control





Mirror

flatness control
in atomic level

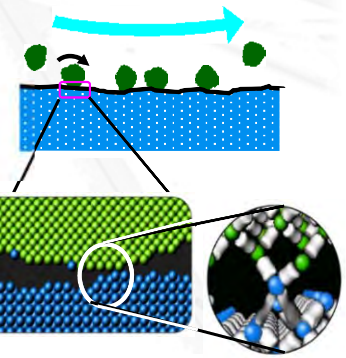
Conventional polishing

speckle-free quality

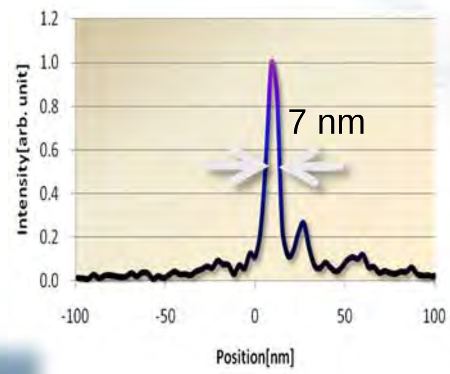
EEM polishing

K. Yamauchi

Elastic Emission
Machining



Atomic scale polishing



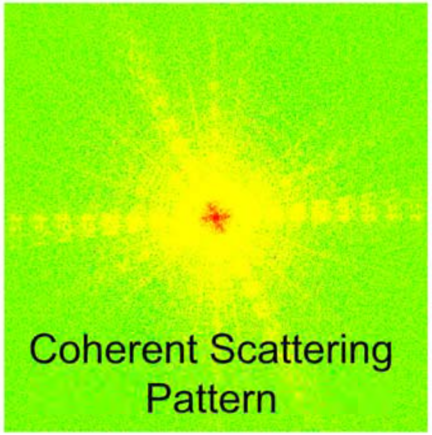
K. Yamauchi et al.
Nature Phys. 2009

The Beginning of Coherent Hard X-ray Imaging via 1km Beamline, BL29XU

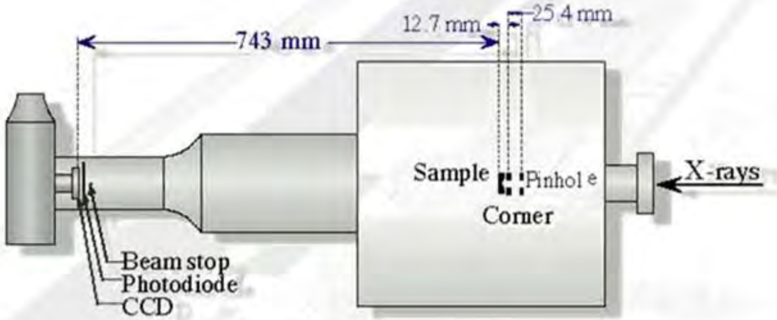

J. Miao (UCLA)

High Resolution 3D X-Ray Diffraction Microscopy
J. Miao & T. Ishikawa et al.,
Physical Review Letters, 89, (2002), 088303

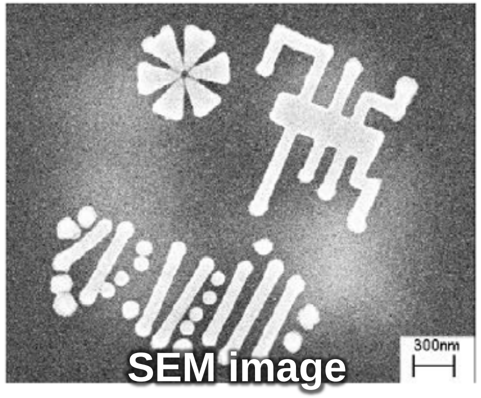

T.Ishikawa (RIKEN)


Coherent Scattering Pattern

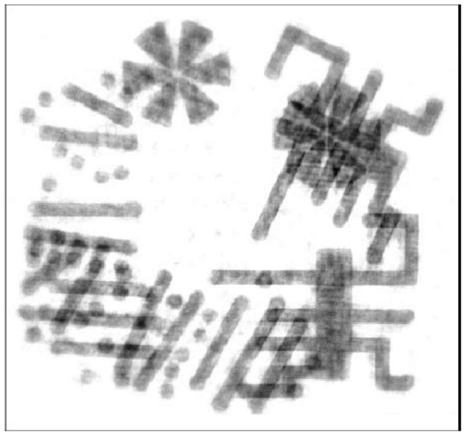
Coherent X-ray Diffraction Camera
SPring-8 BL29XU



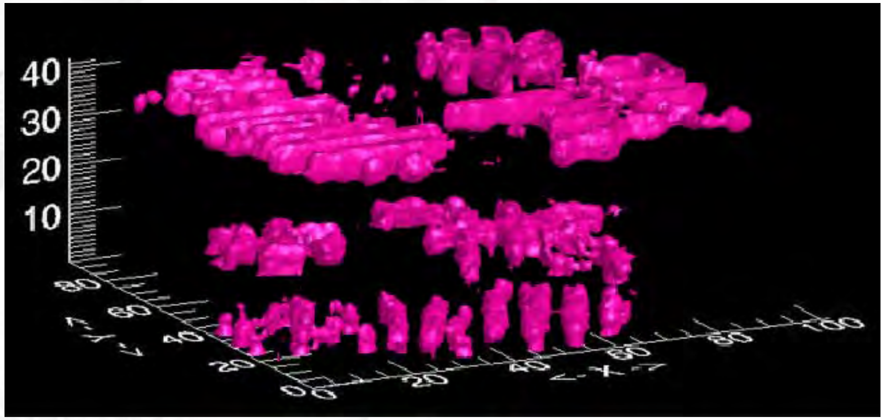
Two Layer Ni Pattern on SiN



SEM image



2D Reconstructed Image
(<10 nm resolution)



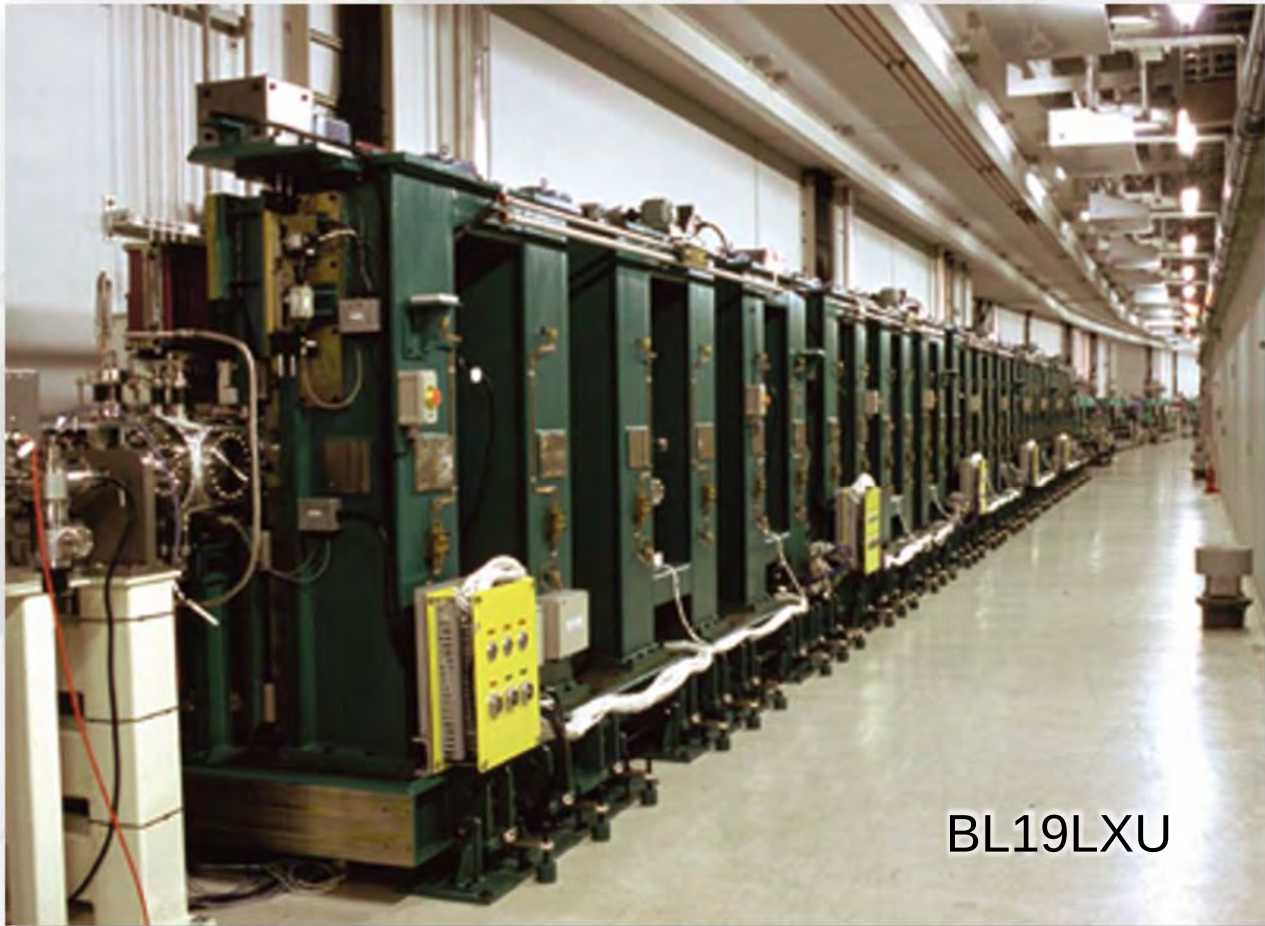
3D Reconstructed Image (~50 nm resolution)

Long Undulator Technology

25-m In-vacuum Undulator: since 2001 at SPring-8

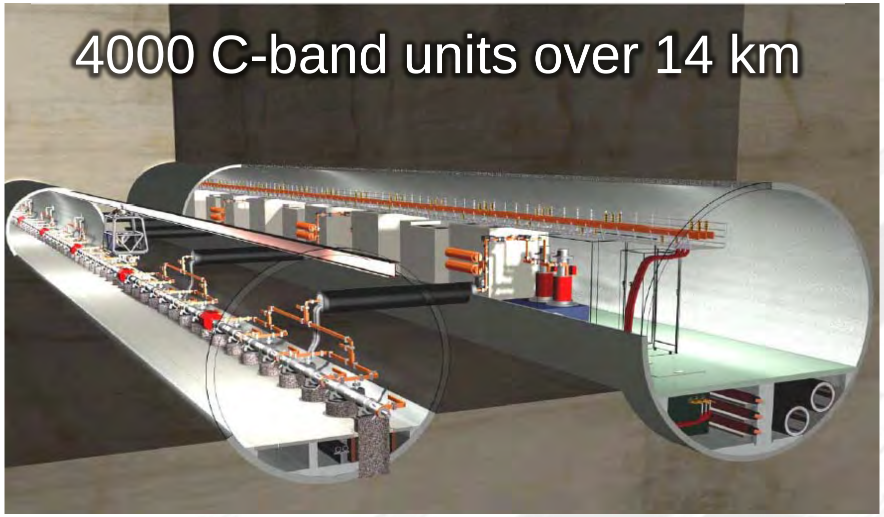
H.Kitamura
(RIKEN)

T.Hara
(RIKEN)

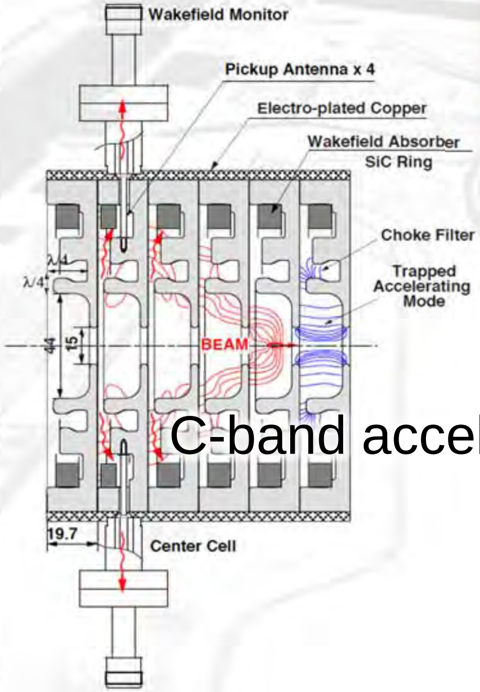


Innovation of C-band Accelerator

Technology Transfer from Linear Collider Project




T.Shintake

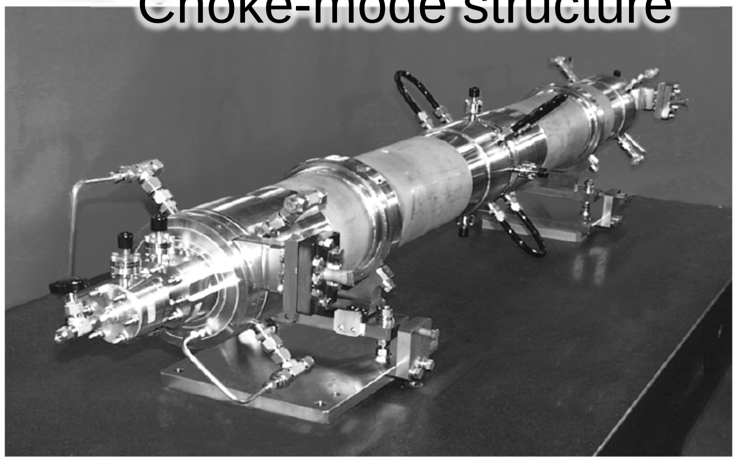


C-band accelerator

Key Components Development
KEK (1996~2000)

- Klystron
- Waveguide components
- RF pulse compressor
- Accelerating structure

Choke-mode structure



2) SCSS: Integrated Test Facility

SPring-8 **C**ompact **S**ASE **S**ource

Key Challenges

Low Emittance Thermionic Electron Gun

Velocity Bunching: Bunch Compression

To Achieve Compact Concept of SACLA

Compact Concept of SACLA

Key technologies achieving compact XFEL source

Lower Beam Energy Available

Primary Contribution in Compactness

+

Efficient Acceleration

Secondary Contribution in Compactness

Higher Brightness
(Smaller Normalized Beam Emittance)

Must-have Component for Compactness

Short-Period In-vacuum Undulator

C-band High Gradient Acceleration System

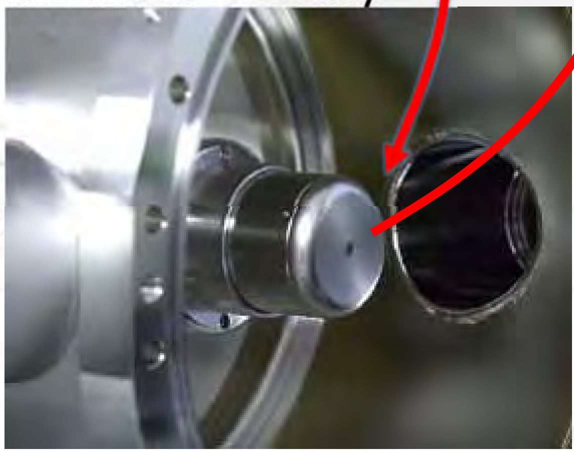
Thermionic Gun, Low Emittance Injector

Low Emittance Thermionic Electron Gun:CeB_6

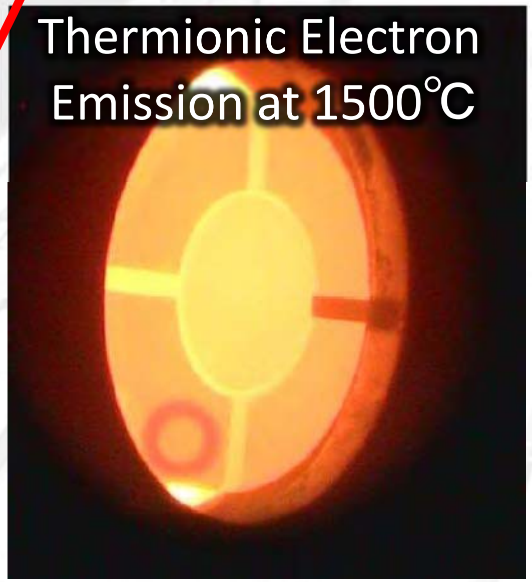
for a stable and clean beam

-500 kV high voltage

Cathode assembly



- A few Ampere beam
- Atomic level flat surface;
  uniform emission density, ensures no emittance break associated with rough surface,



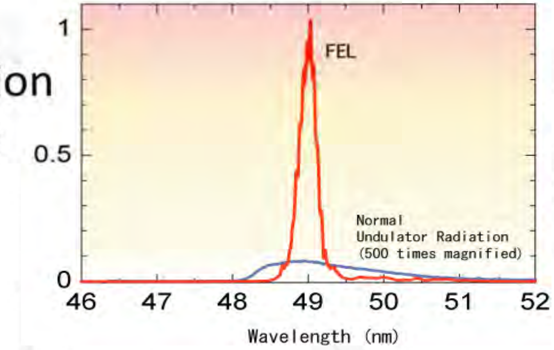
- No residual gases
- Constant evaporation flow;
  continuous cathode activation
- Self-cleaning process;
  quick recovery from contamination

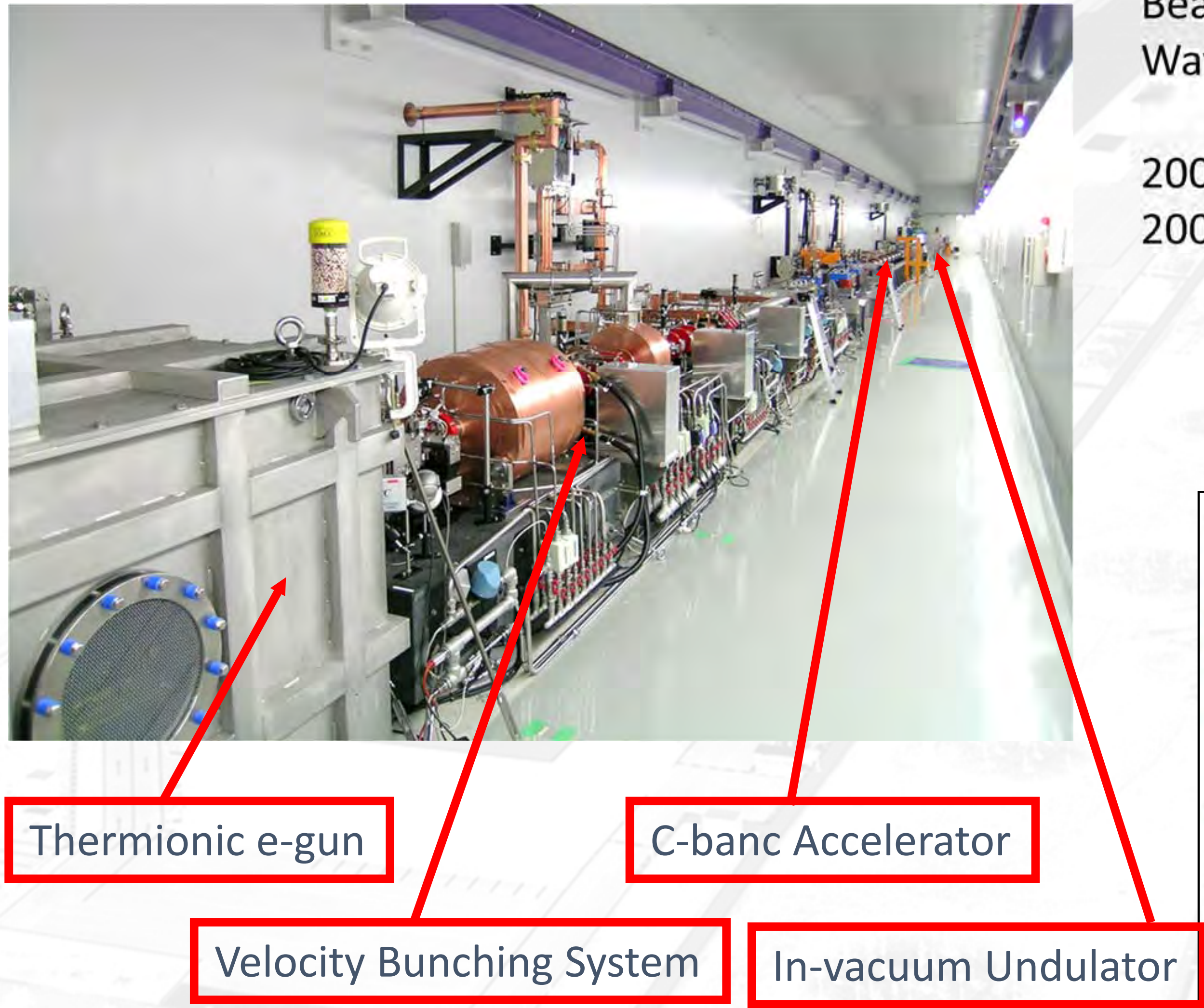
SCSS: Integrated Test Facility

A Proof-of-principle Experiment toward SACLA

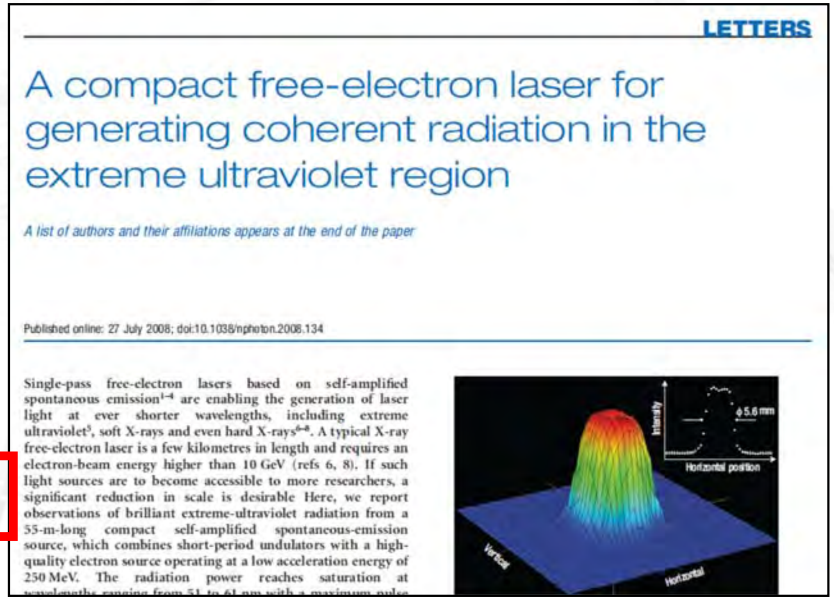
Total length: 60 m（1/12 of SACLA）
Beam energy 250 MeV
Wavelength: 50～60 nm

2005: Construction
2006: First lasing





Nature Photonics 2008



LETTERS

A compact free-electron laser for generating coherent radiation in the extreme ultraviolet region

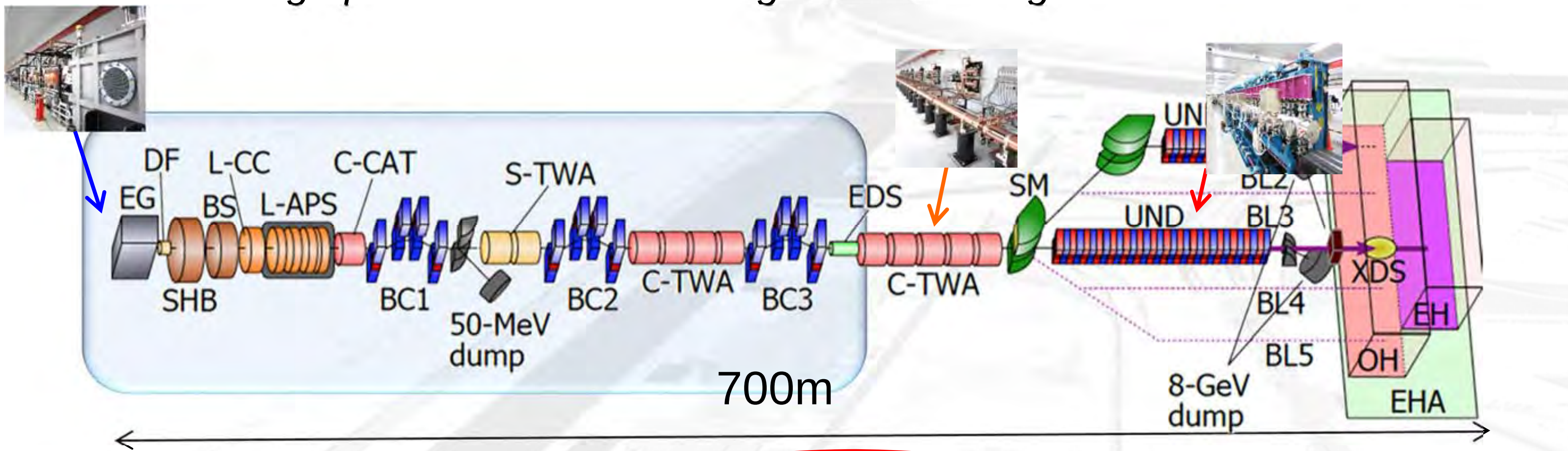
A list of authors and their affiliations appears at the end of the paper

Published online: 27 July 2008; doi:10.1038/nphoton.2008.134

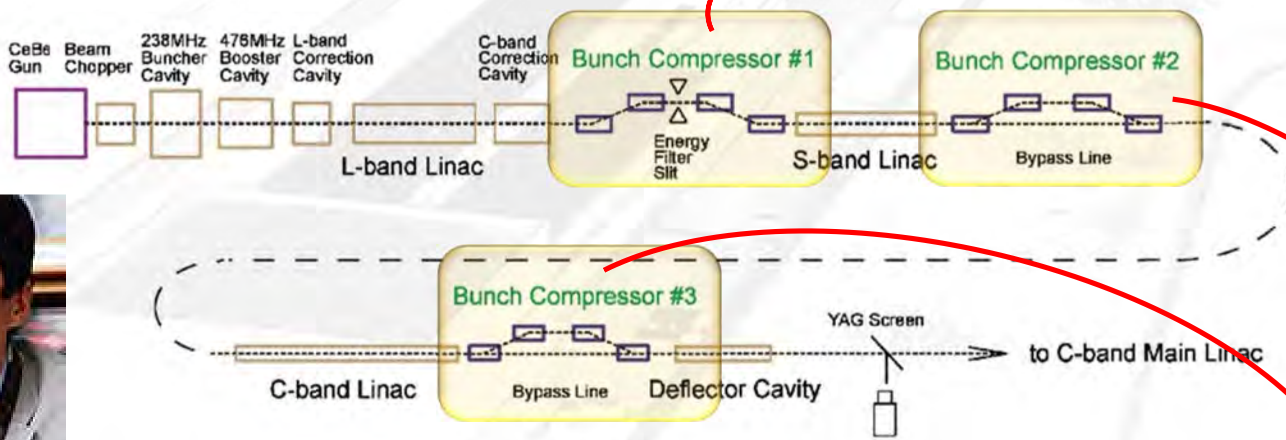
Single-pass free-electron lasers based on self-amplified spontaneous emission[1–4] are enabling the generation of laser light at ever shorter wavelengths, including extreme ultraviolet[5], soft X-rays and even hard X-rays[6–8]. A typical X-ray free-electron laser is a few kilometres in length and requires an electron-beam energy higher than 10 GeV (refs 6, 8). If such light sources are to become accessible to more researchers, a significant reduction in scale is desirable Here, we report observations of brilliant extreme-ultraviolet radiation from a 55-m-long compact self-amplified spontaneous-emission source, which combines short-period undulators with a high-quality electron source operating at a low acceleration energy of 250 MeV. The radiation power reaches saturation at

Velocity Bunching: Bunch Compression for SACLA

For High peak current toward high SASE-FEL gain



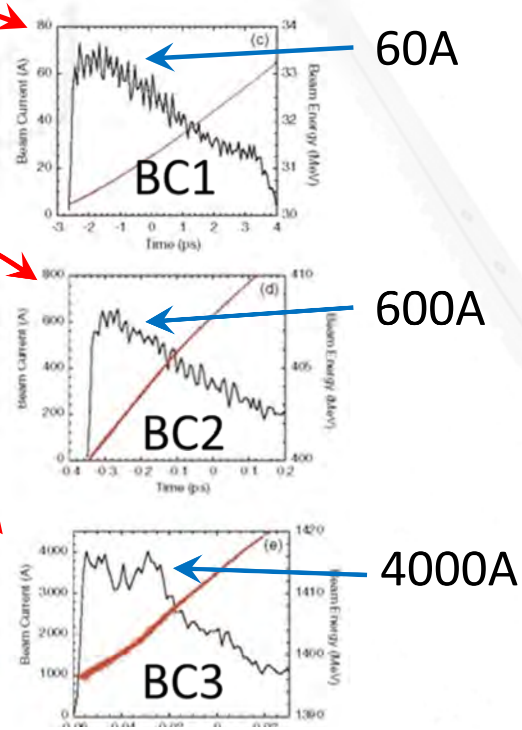
velocity bunching in injector and magnetic chicane buncher



H.Tanaka (RIKEN)

Multi-stage bunch compression system at SACLA

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 12, 080706 (2009)



Longitudinal bunch profile

3) SACLA Challenges

Constructions

5 parallel beam lines arrangement

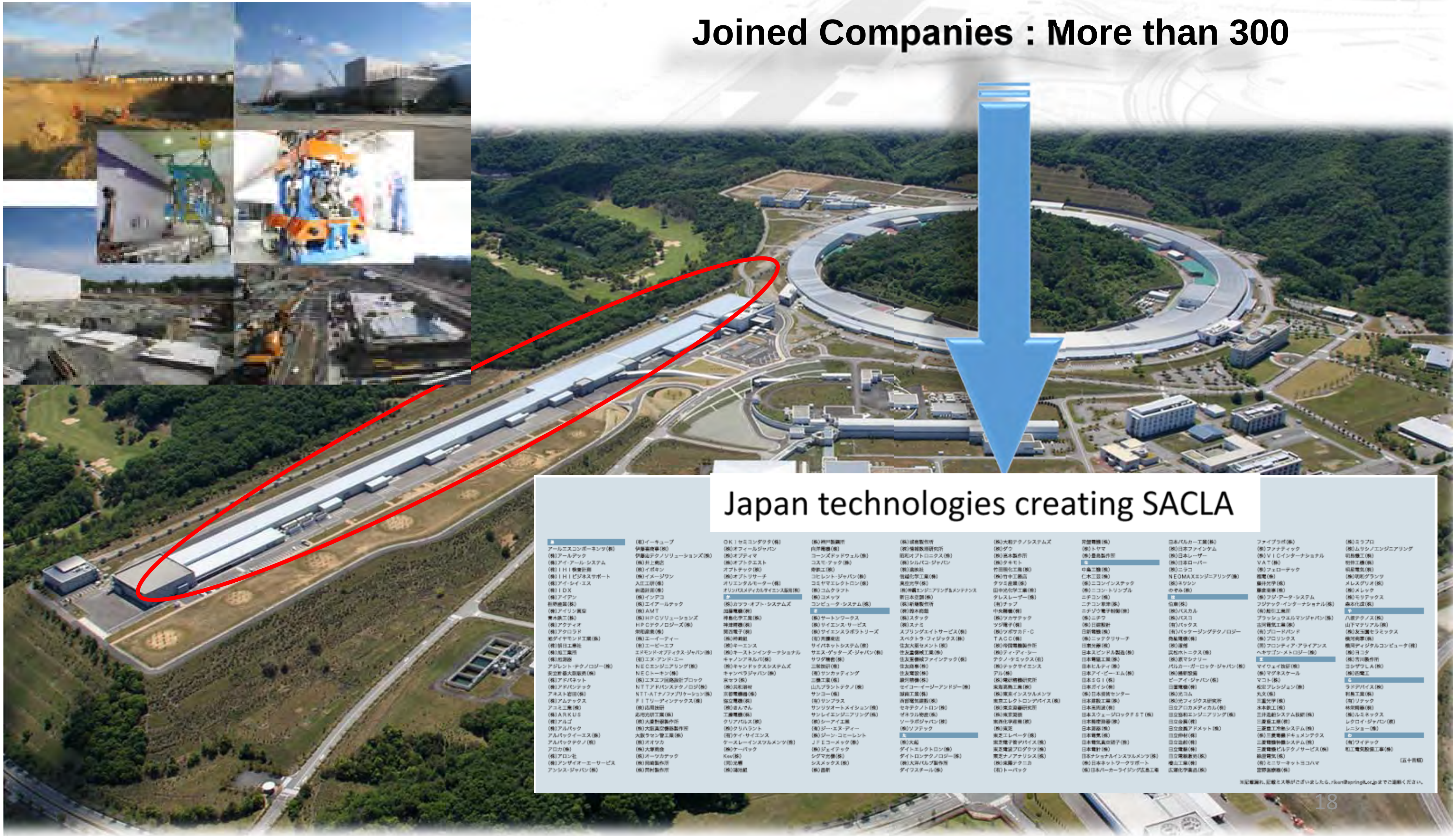
XFEL/SPring-8 Experimental Facility

XSBT(Beam Transport Line) :
from XFEL/SPring-8(SACLA) Linac to SPring-8 Storage Ring

SACLA Construction

FY 2006 ~ 2010
Key Technologies of National Importance

Joined Companies : More than 300



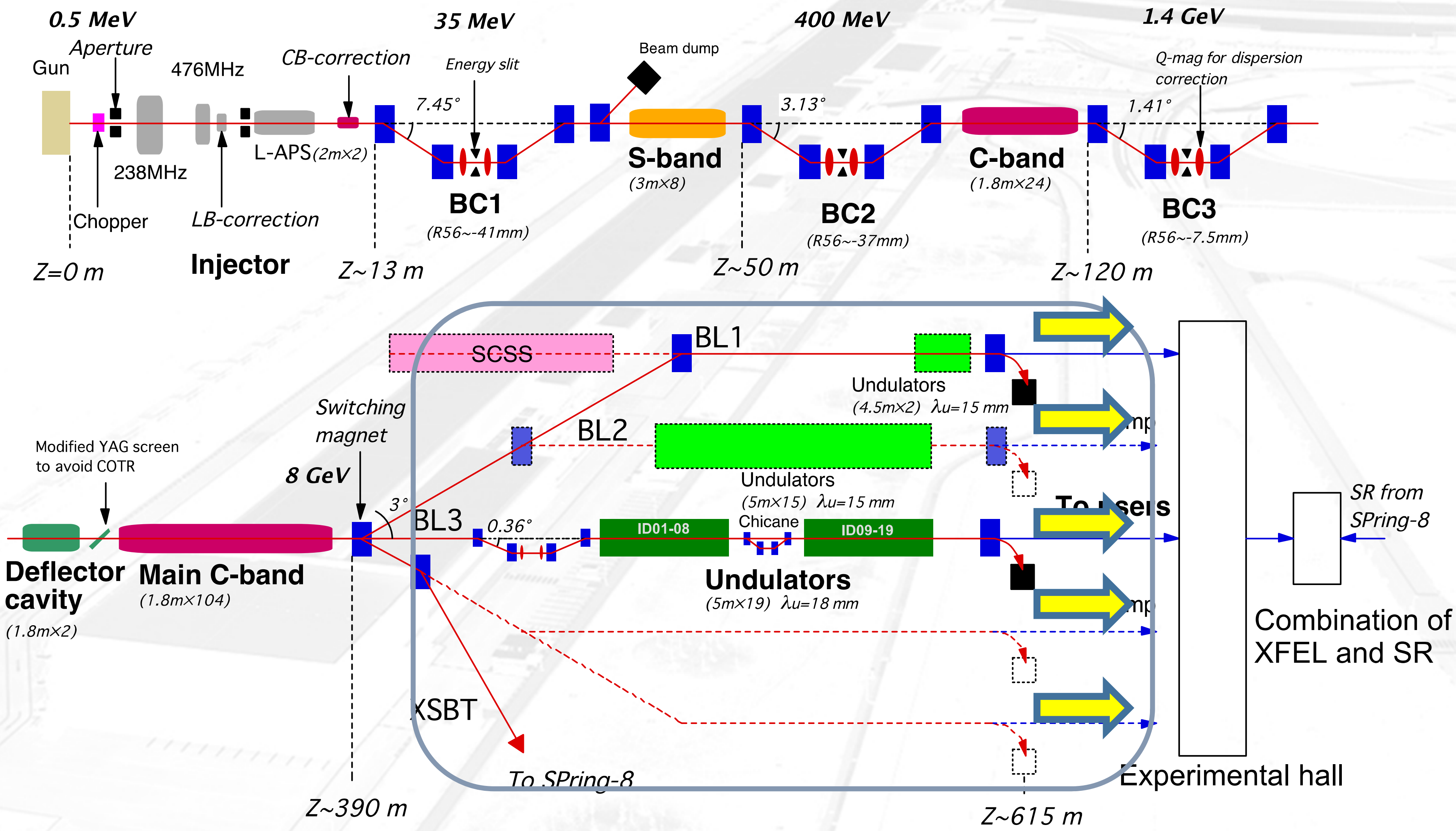
How compact SACLA is!

Scale & Budget

2011～ SACLA (Japan)

Length 700 m. 8 GeV, 0.06 nm, 388 M$ (1$=1oo JPY)

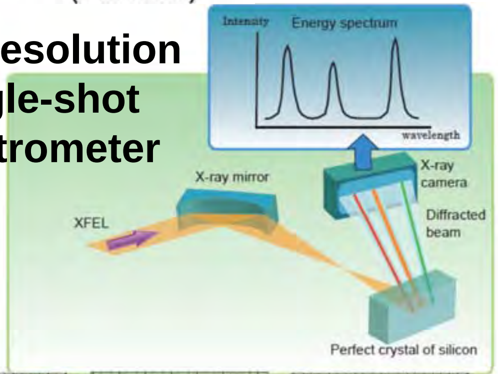
5 Parallel Beamlines Arrangement

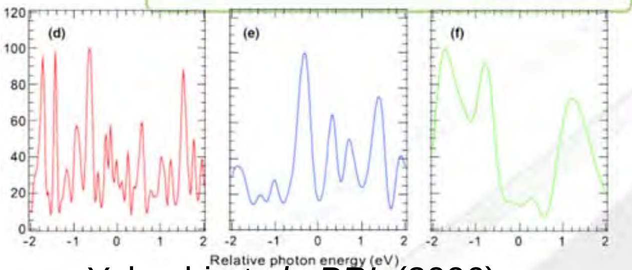


State-of-the-art X-ray Optic & Beamlines for Developing XFEL Sciences

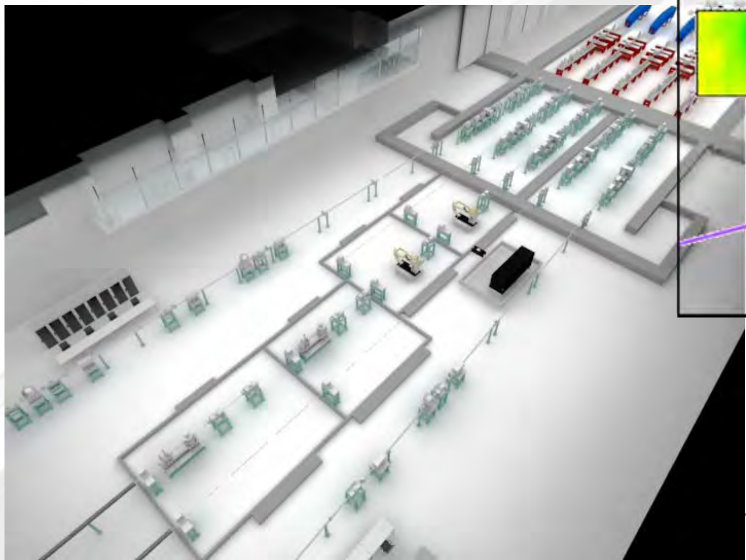
Makina Yabashi
(RIKEN)

High-resolution single-shot spectrometer

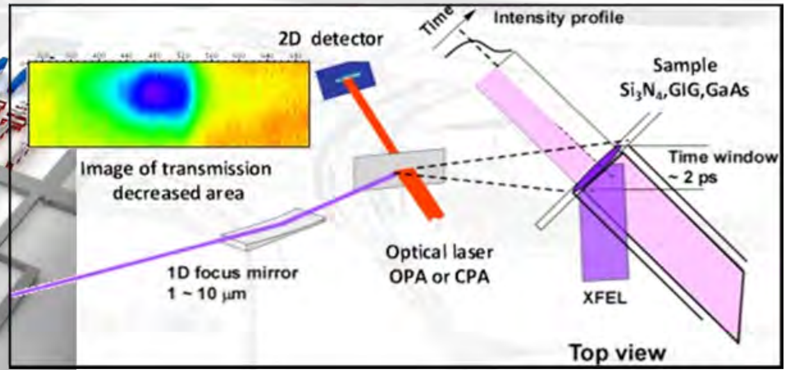




Yabashi *et al.*, *PRL* (2006);
Inubushi *et al.*, *PRL* (2012)

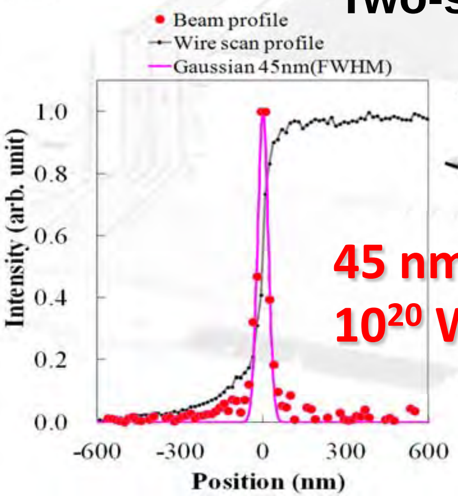


Femtosecond arrival-timing diagnostics

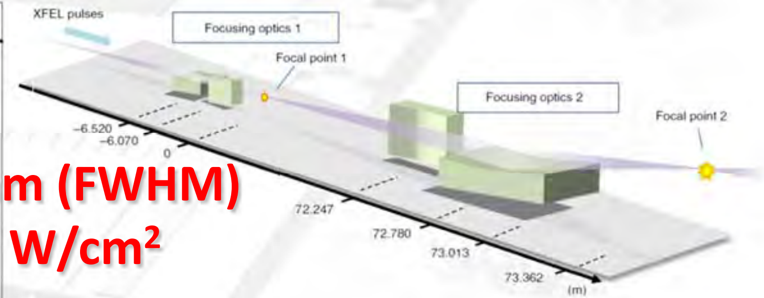


Sato *et al.*, APEX (2015)

Two-stage focusing

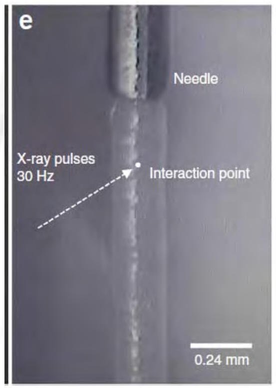


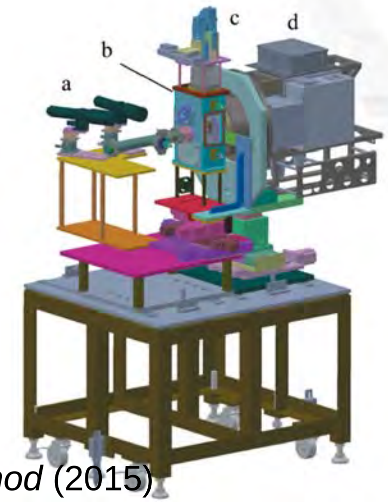
45 nm (FWHM)
10^{20} W/cm^2



Mimura *et al.*, *Nat. Com.* (2014)
Yumoto *et al.*, *Nat. Photon* (2012)

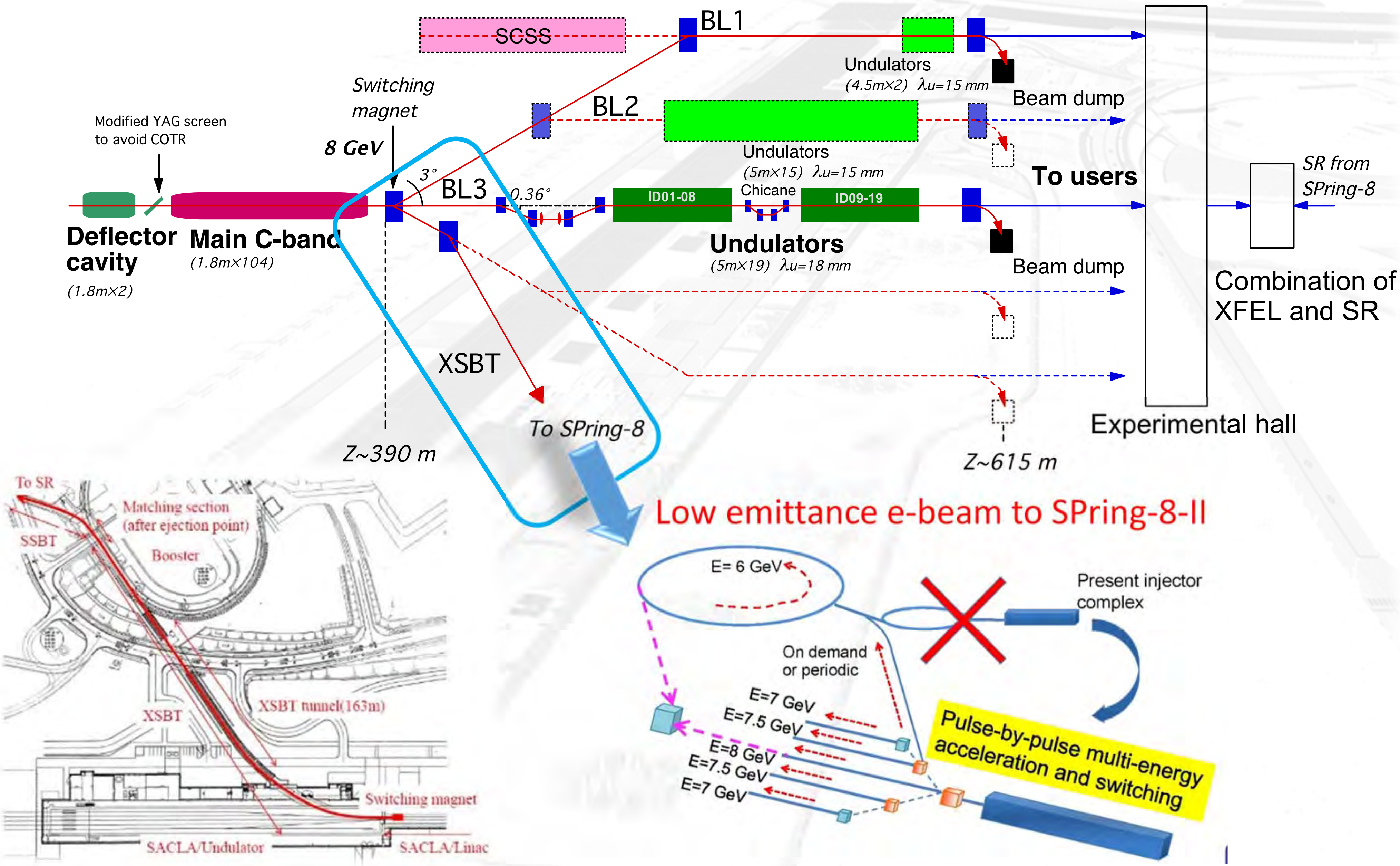
Experimental Instrumentation



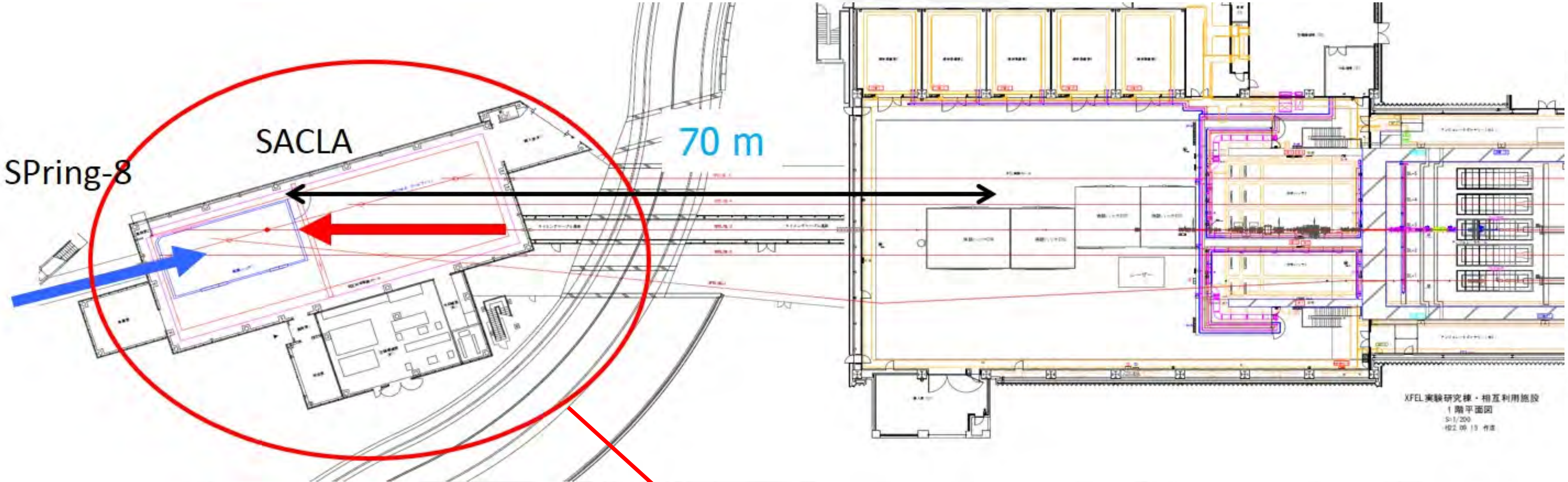


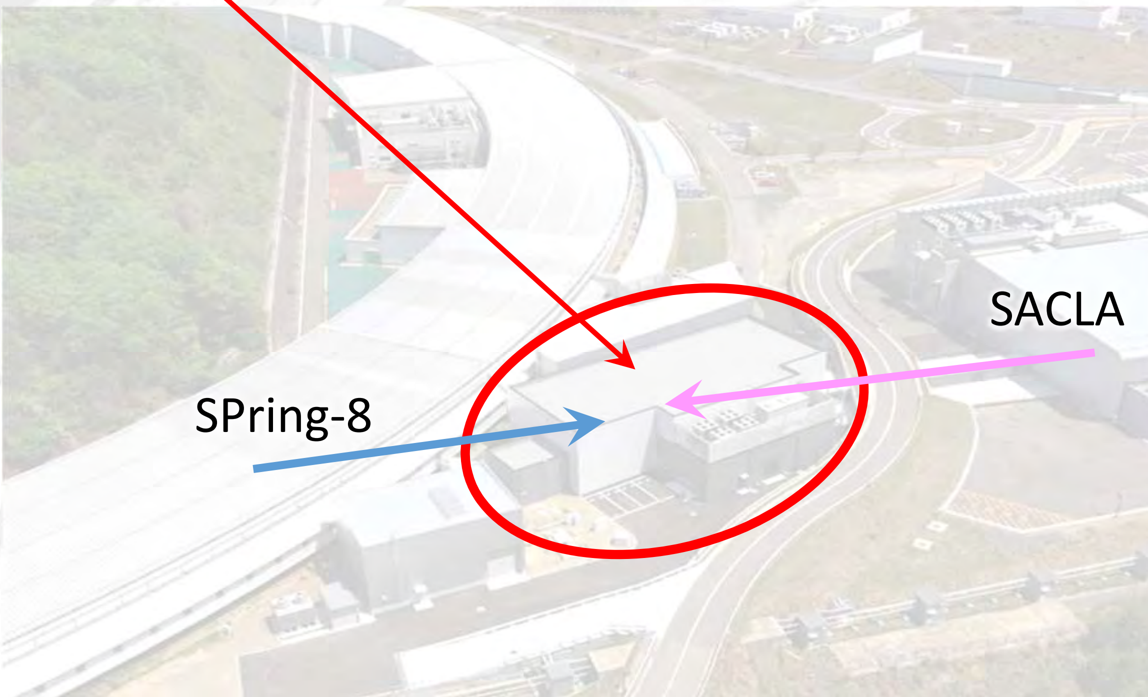
Tono *et al.*, *JSR* (2015)
Sugahara *et al.*, *Nat. Method* (2015)

XSBT (Beam Transport Line): from SACLA Linac to SPring-8 Storage Ring



SACLA-SPring-8 Experimental Facility





4) Technical Developments in SACLA Commissioning

Electron Beam Trajectory/Magnetic Field Adjustment
via X-ray based alignment

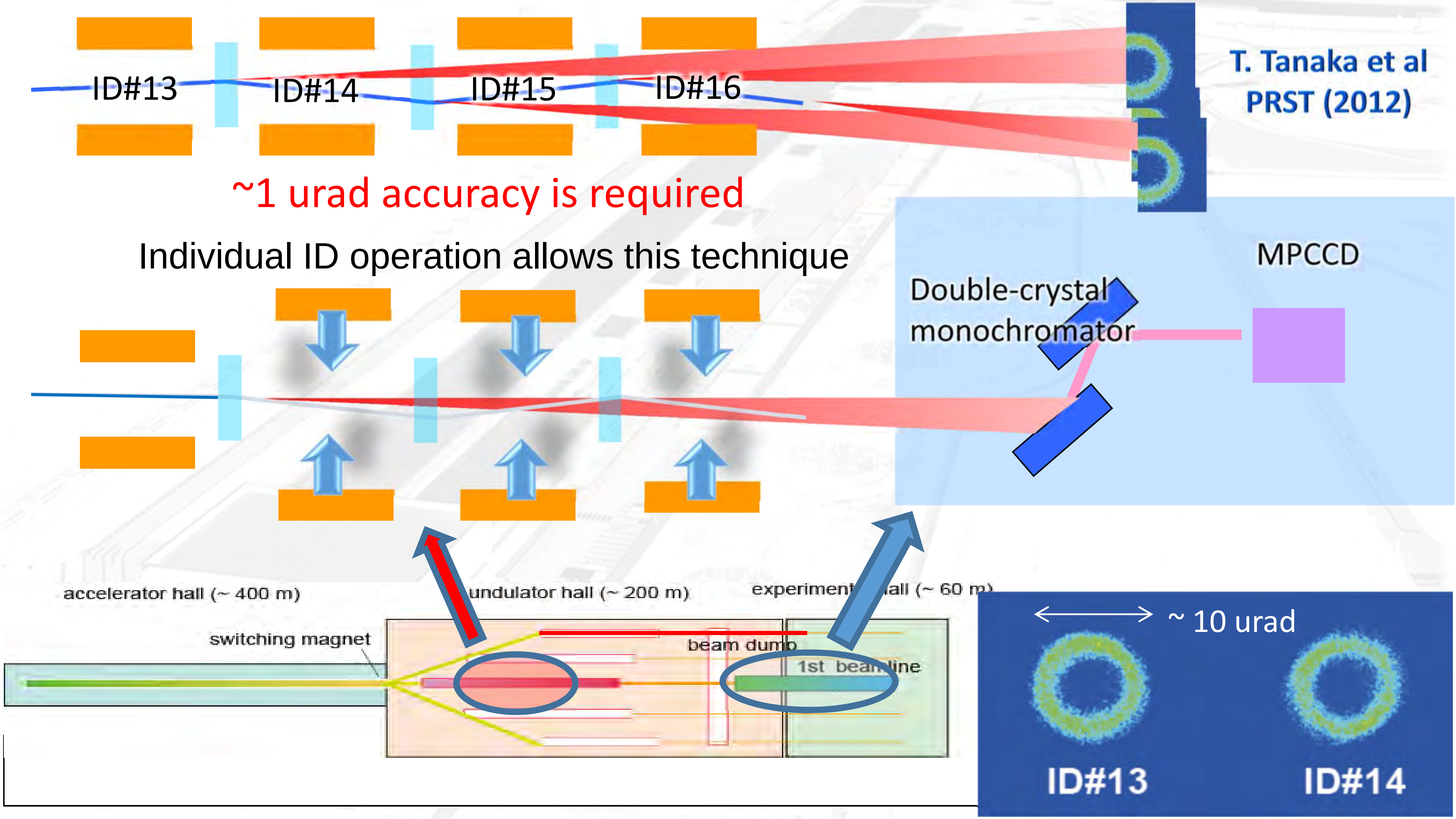
Wavelength Tuning by Undulator Gap Control
- Tapering of Undulator Magnetic Filed
- Two-color XFEL Operation

MPCCD Detectors

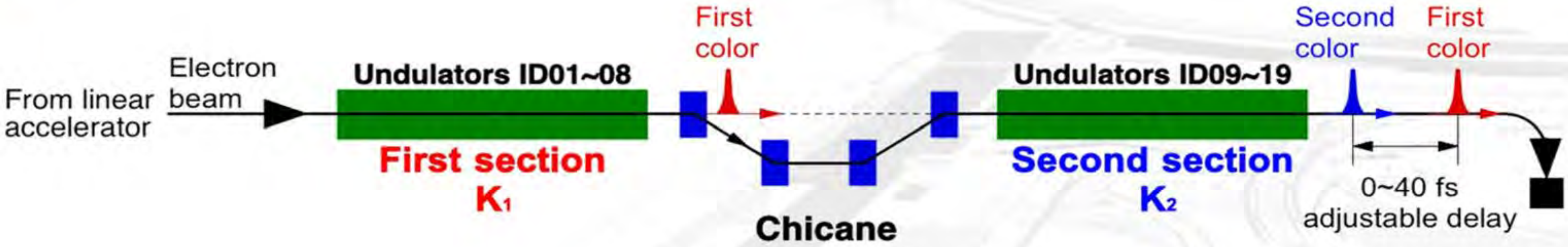
X-ray Based Alignment

A requisite technique for prompt alignment for lasing

T. Tanaka



Two-color XFEL operation in SACLA



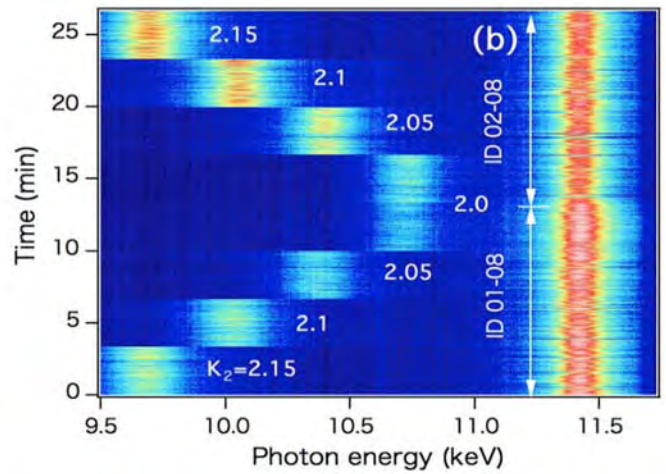
- **Double Section Arrangement;**
  8+10 scheme under two K-values operation
- **Variable Gap Undulators**;
  Large wavelength separation (~30 %)
- **Chicane in between Sections**;
  Time delay(0~40 fs) control with a sub-femtosecond resolution
- **User Operational Mode:**
  Two-color FEL is open to the user experiments.

ARTICLE

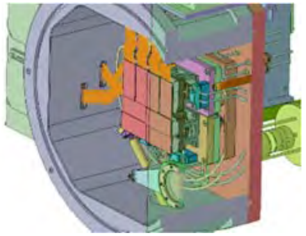
Received 8 Sep 2013 | Accepted 12 Nov 2013 | Published 4 Dec 2013 DOI: 10.1038/ncomms3919

Two-colour hard X-ray free-electron laser with wide tunability

Toru Hara[1], Yuichi Inubushi[1], Tetsuo Katayama[2], Takahiro Sato[1,†], Hitoshi Tanaka[1], Takashi Tanaka[1], Tadashi Togashi[2], Kazuaki Togawa[1], Kensuke Tono[2], Makina Yabashi[1] & Tetsuya Ishikawa[1]



Hara *et al.*
Nature Commun 2014



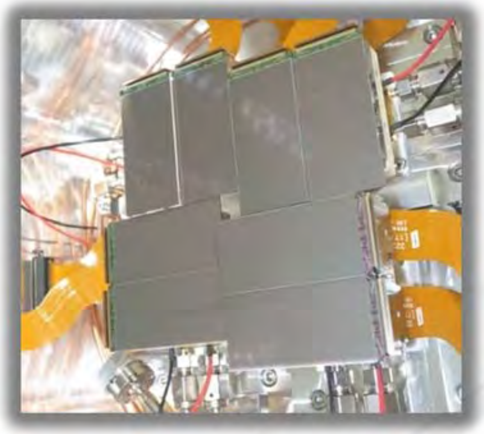
MPCCD Detectors

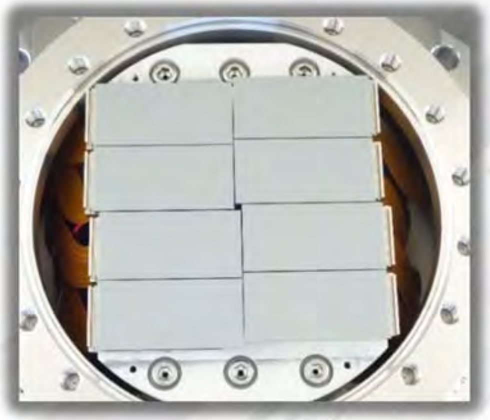
(Multi-Port Charge Coupled Device)

T. Hatsui

MPCCD Detector Family

T. Kameshima et al., Rev. Sci. Instrum. **85**, 033110 (2014).





- **Bread-and-butter apparatus for data acquisition at SACLA**

  Covering over 75 % of user experiments

- **Higher radiation hardness**

  x1000 higher radiation hardness assurance compare to inter-planetary satellite missions

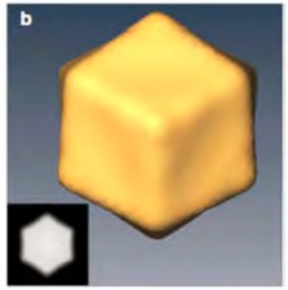
- **Top performance in dynamic range and pixel counts**

  the best X-ray imaging detector for XFEL Science

  great contributions to significant progress in

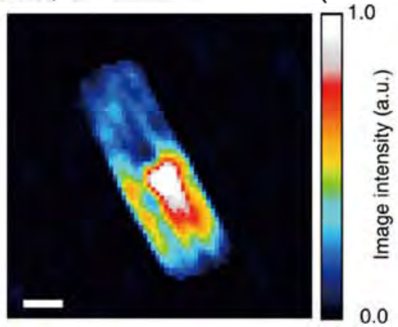
3D Imaging of Nano-materials

Rui Xu et.al., Nat. Com., 5, 4061 (2014)



Live Cell in Micro-liquid Enclosure

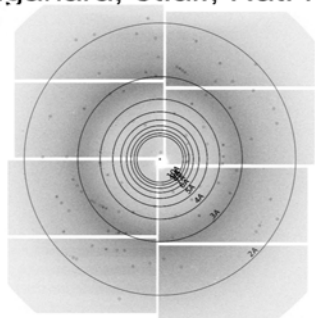
T. Kimura et.al., Nat. Com. 5, Art. Num. 3052 (2014)

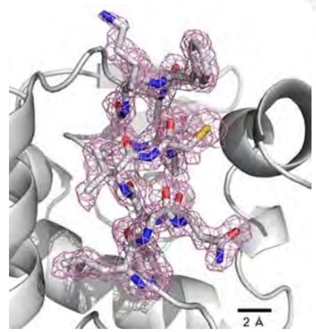


Serial Femtosecond Crystallography

C. Song, et.al., J. Appl. Cryst. (2014). 47, 188–197.

M. Sugahara, et.al., Nat. Methods, 12, 61 (2015).





5) General Applications of SACLA

Diffraction,

Spectroscopy,

Coherent Diffraction Imaging,

Damage-free structural analysis

Getting closer to the truth of Photosynthesis
via XFEL diffractometer-based crystallography

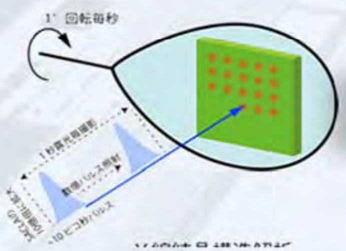
Prof. Shen
(Okayama U)

Dr. Ago
(RIKEN)

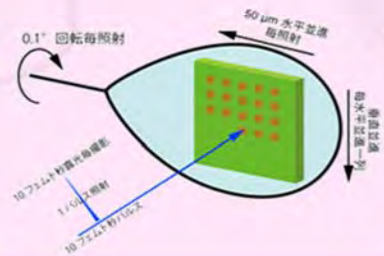
Hirata, Ago *et al*,
Nat. Methods (2014)

Single-shot femtosecond XFEL pulse allowed
Damage-free Structure Analysis of PS-II (S1)

SR
- Sec long Exposure
- Radiation damages to proteins.



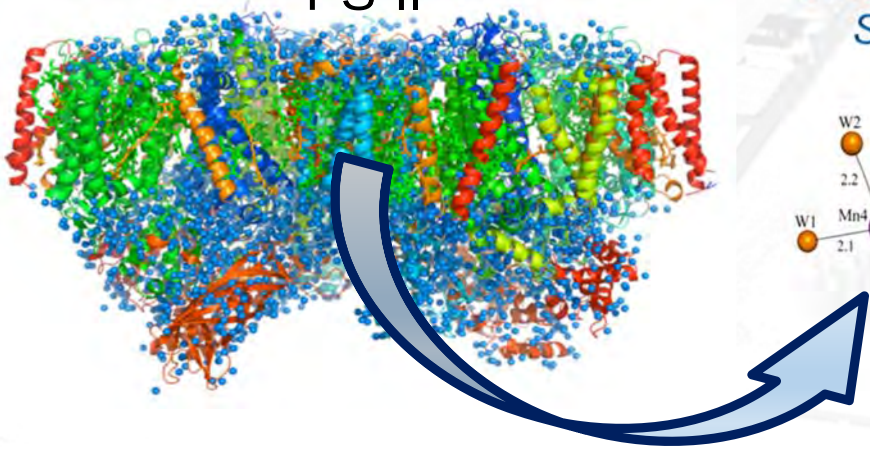
SACLA
- 10 Femto sec. Exposure
- Measurement before being damaged

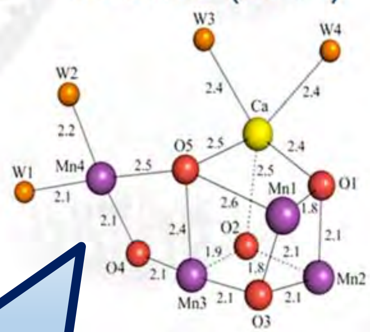


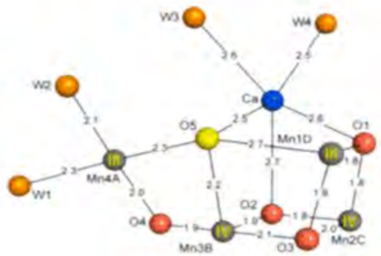
Umena, Shen, *et al.*
Science (2011)

Suga, Shen *et al.*,
Nature (2014)

PS-II





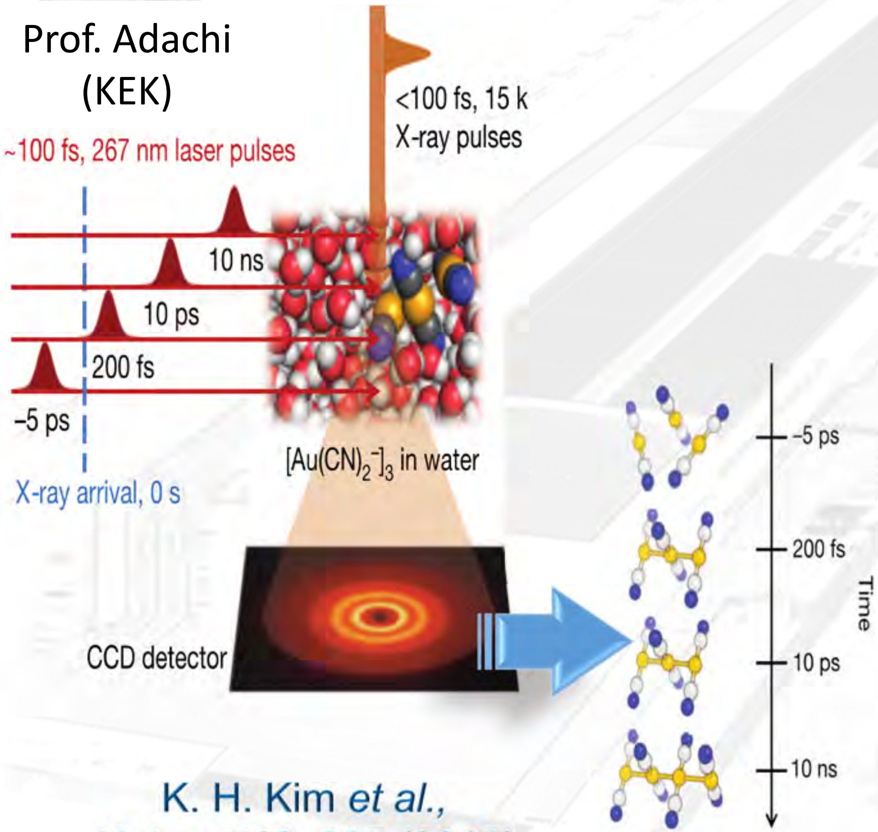


Ultrafast Chemistry

Ultrafast wide-angle scattering (WAXS):

Molecular movie
for bond-making processes
in Au complex

Prof. Adachi
(KEK)



K. H. Kim *et al.*,
Nature **518**, 385 (2015)

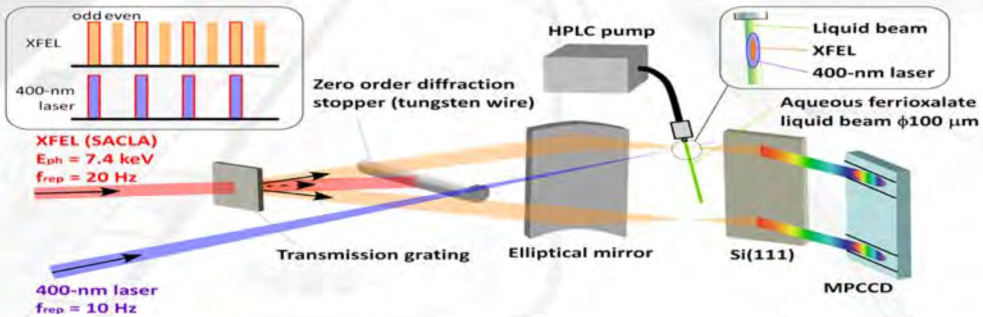
Novel femtosecond X-ray absorption spectroscopy (XAS):

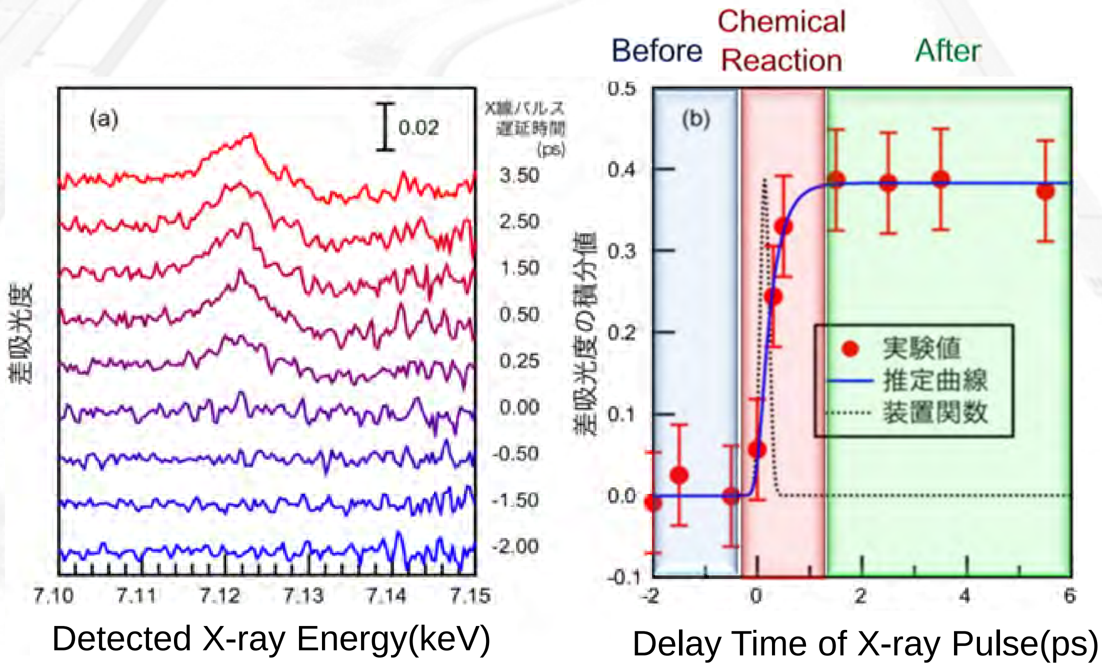
Combining dispersive spectrometer
with grating beam splitter

T. Katayama *et al.*, *APL.* **103**, 131105 (2013)
Y. Obara *et al.*, *Opt. Exp.* **22**, 1105 (2014)

Dr. Katayama

Prof. Suzuki



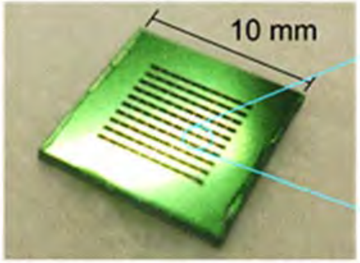


XFEL CDI has made Live Cell Imaging

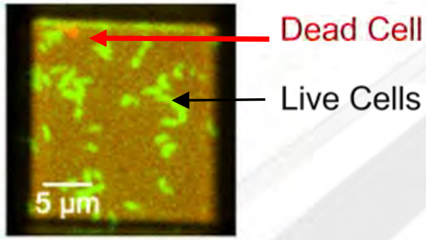
Successful Visualization of Natural Living Cells,
encapsulated in MicroLiquid Enclosure Array,
immediately before damage by radiation,
using femtosecond X-rays pulse duration

Y.Nishino
(Hokkaido Univ.)

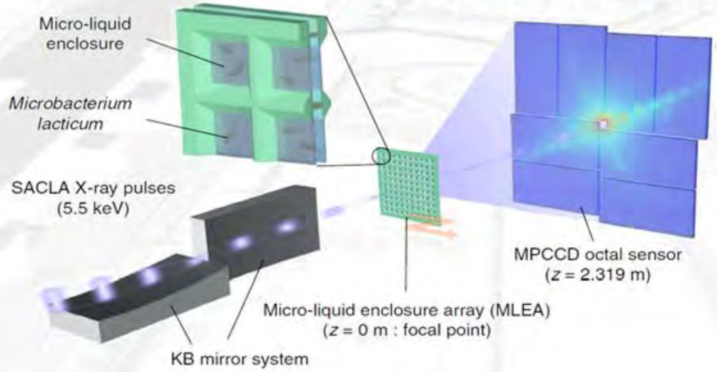
Kimura, Nishino et al, Nat. Commun. (2014)



Microliquid enclosure array
(MLEA)



Immediately after
cells are enclosed in MLEA



37 nm Resolution achieved by Single Shot XFEL Exposure

CXD pattern from a living cell
exposed to single XFEL pulse

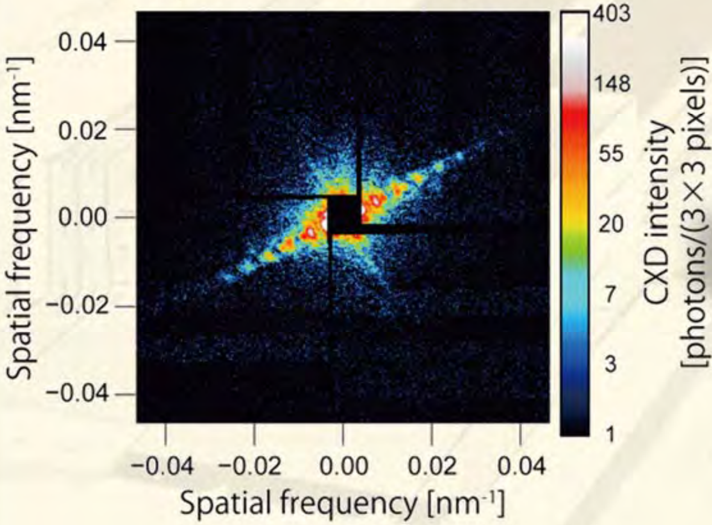
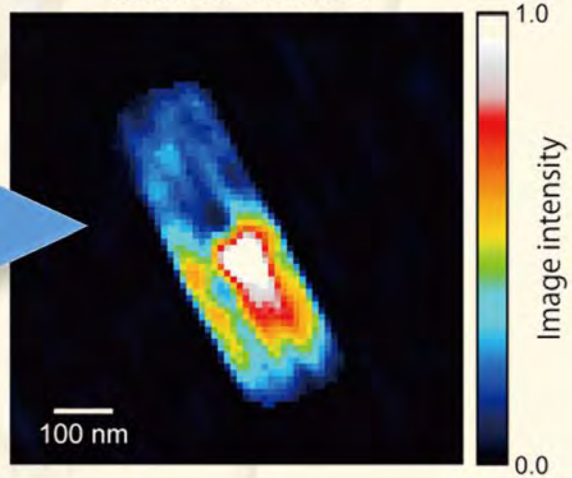
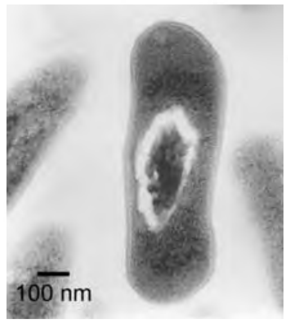


Image of a living *M. lacticum* cell
observed with XFEL



High-contrast image of internal
nanostructures of living cell

TEM image
Stained Section of
M. lacticum cell

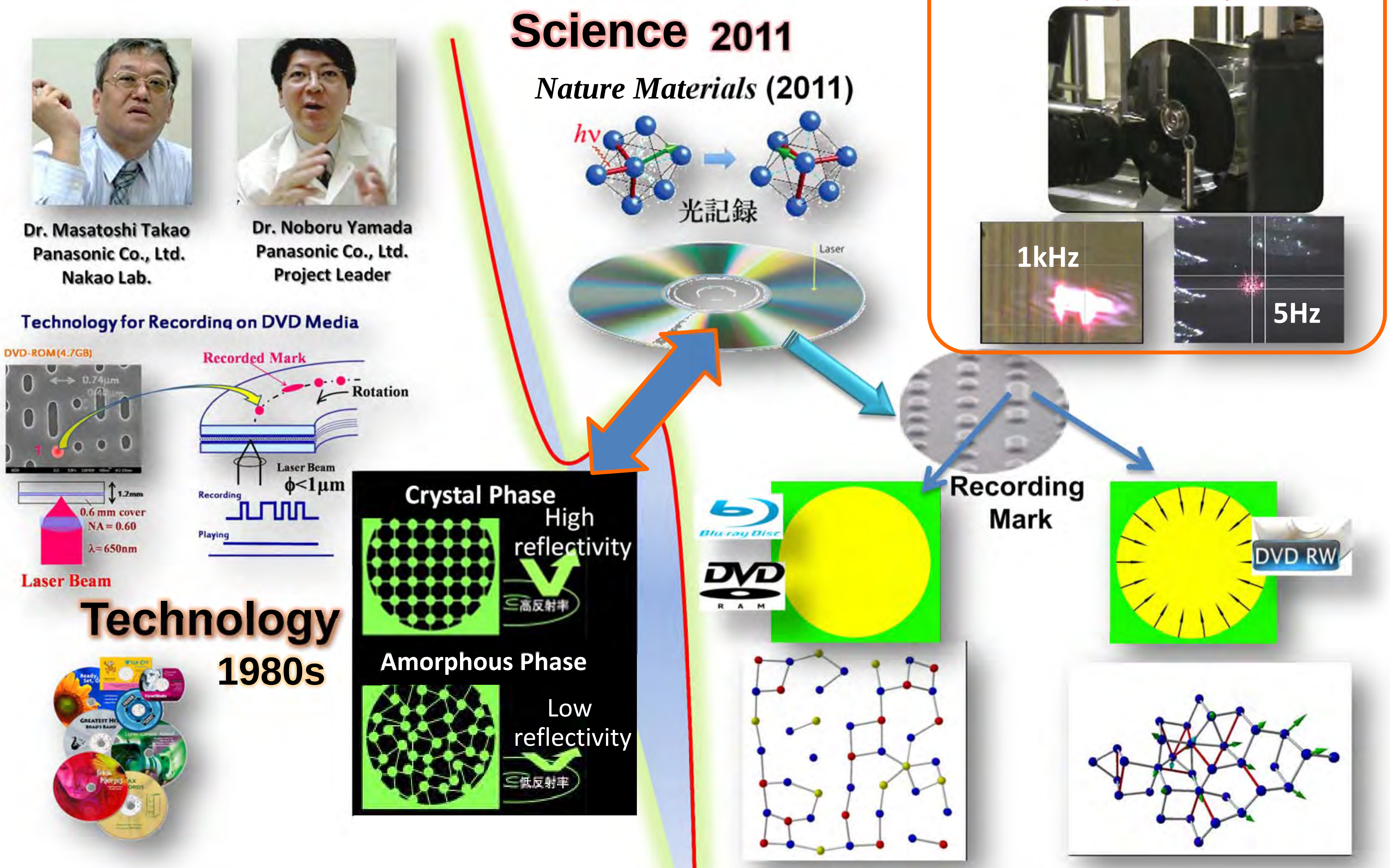


RIKEN

SPring-8

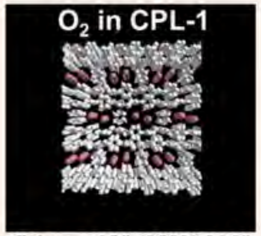
Crystal-Amorphous Phase Change for Optical Recording of DVD/RAM System

Takata CREST Project
X-ray Pinpoint Structural Measurement
(40ps./100nm)

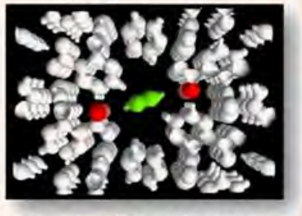


Challenge: Visualization of nanoporous dynamics by SACLA

S.Kitagawa
(Kyoto Univ.)

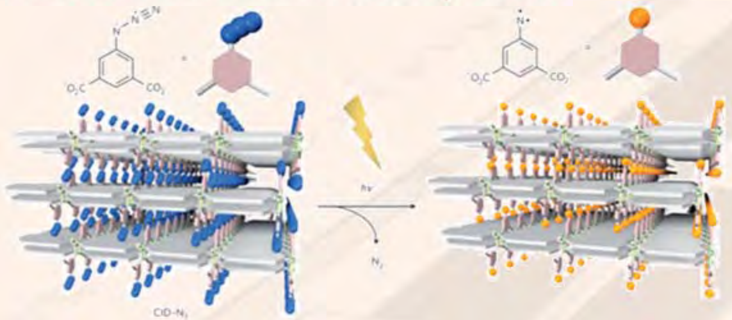


Science **298** (2002) 2358



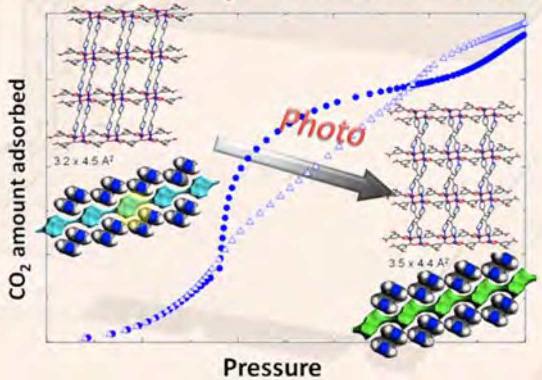
Nature **436** (2005) 238

Photoactivation of nanoporous

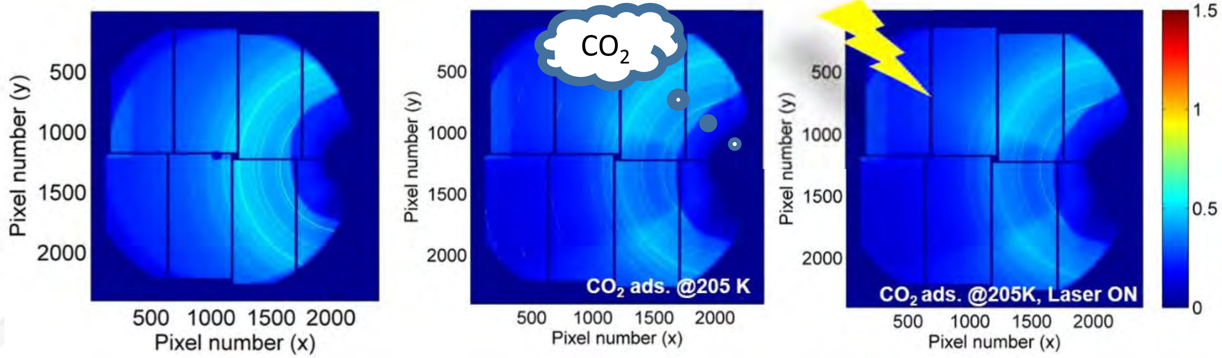


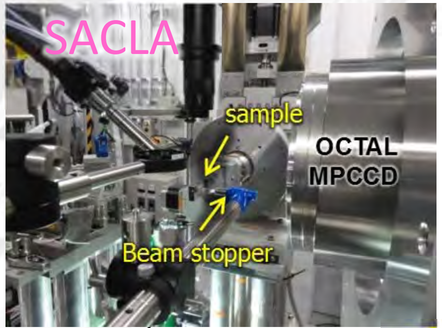
R. Matsuda *et al*., Nature Mater. 9 (2010) 661.

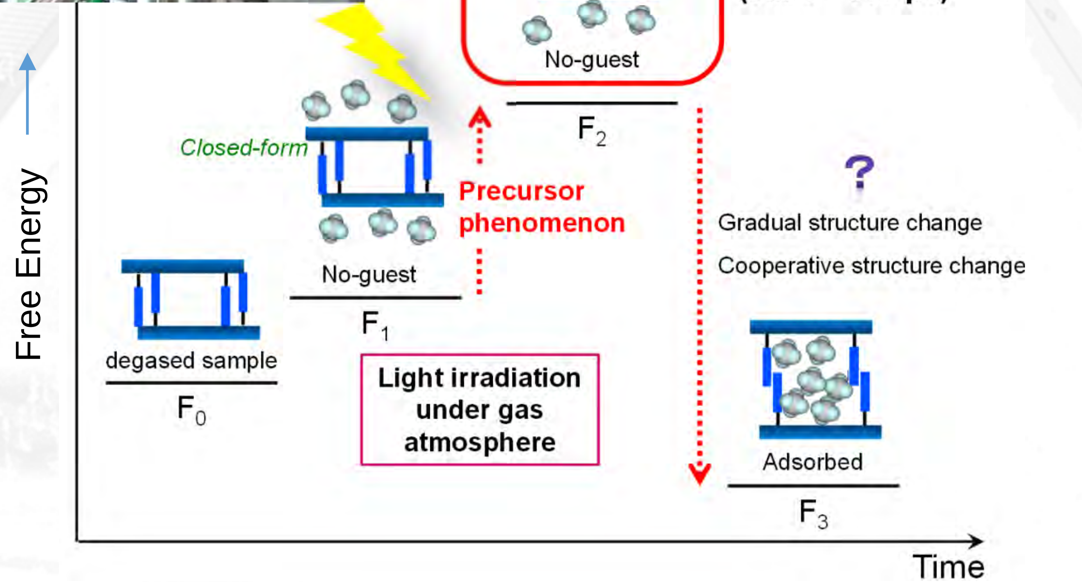
Photo-induced pore structure change



R. Matsuda *et al*., Chem. Commun. 9 (2010) 661.







6) New range of the state-of-art in SACLA

Quantum X-ray Optics at SACLA

Two Photon Absorption

Second Harmonic Generation

Saturable Absorption

Photon-Photon Scattering

Ultrahigh intensity

Quantum X-ray Optics

SACLA

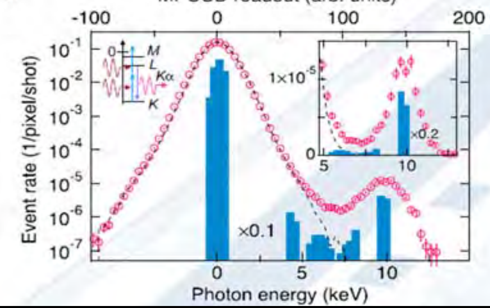
Two photon absorption

nature photonics LETTERS

PUBLISHED ONLINE: 16 FEBRUARY 2014 | DOI: 10.1038/NPHOTON.2014.10

X-ray two-photon absorption competing against single and sequential multiphoton processes

Kenji Tamasaku[1]*, Eiji Shigemasa[2], Yuichi Inubushi[1], Tetsuo Katayama[3], Kei Sawada[1], Hirokatsu Yumoto[3], Haruhiko Ohashi[3], Hidekazu Mimura[4], Makina Yabashi[1], Kazuto Yamauchi[5,6] and Tetsuya Ishikawa[1]



K.Tamasaku *et al.*, *Nature Photonics*, **8** 313 (2014)

Second harmonic generation

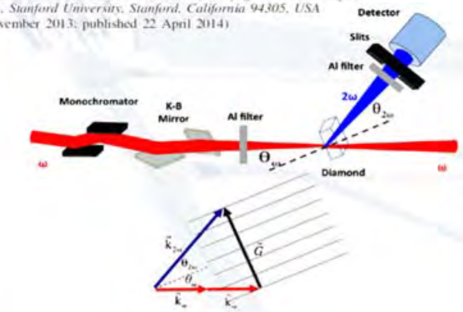
PRL **112**, 163901 (2014) PHYSICAL REVIEW LETTERS 25 APRIL 2014

X-Ray Second Harmonic Generation

S. Shwartz,[1,2,*] M. Fuchs,[3,4] J. B. Hastings,[5] Y. Inubushi,[6] T. Ishikawa,[6] T. Katayama,[7] D. A. Reis,[3,8] T. Sato,[6] K. Tono,[7] M. Yabashi,[6] S. Yudovich,[1] and S. E. Harris[2]

[1]Physics Department and Institute of Nanotechnology, Bar Ilan University, Ramat Gan 52900, Israel
[2]Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305, USA
[3]PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
[4]Department of Physics and Astronomy, University of Nebraska, Lincoln, Nebraska 68588, USA
[5]The Linac Coherent Light Source, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
[6]RIKEN SPring-8 Center, Kouto 1-1-1 Sayo, Hyogo 679-5148, Japan
[7]Japan Synchrotron Radiation Research Institute, JASRI, Kouto 1-1-1 Sayo, Hyogo 679-5148, Japan
[8]Department of Applied Physics, Stanford University, Stanford, California 94305, USA

(Received 1 November 2013; published 22 April 2014)



S. Shwartz *et al.*, *PRL* **112** 163901 (2014)

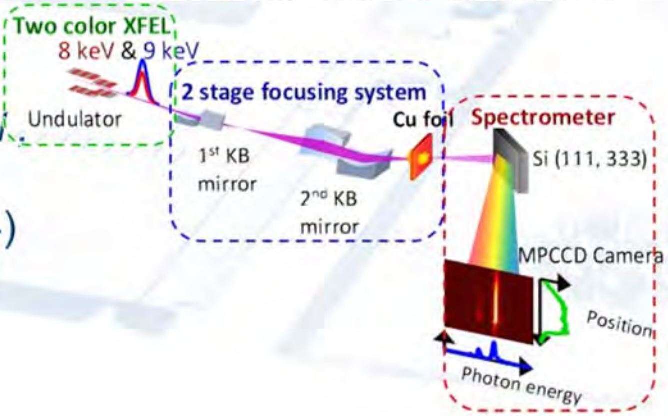
Saturable absorption

nature COMMUNICATIONS

ARTICLE

Saturable absorption of intense hard X-rays in iron

Hitoki Yoneda, Yuichi Inubushi, Makina Yabashi, Tetsuo Katayama, Tetsuya Ishikawa, Haruhiko Ohashi, Hirokatsu Yumoto, Kazuto Yamauchi, Hidekazu Mimura & Hikaru Kitamura



H.Yoneda *et al.*, *Nature Com.* **10**.1038 (2014) ncomms6080

Photon-photon scattering

ELSEVIER

Contents lists available at ScienceDirect

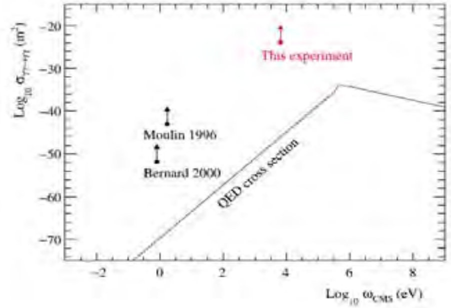
Physics Letters B

www.elsevier.com/locate/physletb

Search for photon–photon elastic scattering in the X-ray region

T. Inada[a,*], T. Yamaji[a,*], S. Adachi[a], T. Namba[b], S. Asai[a], T. Kobayashi[b], K. Tamasaku[c], Y. Tanaka[c], Y. Inubushi[c], K. Sawada[c], M. Yabashi[c], T. Ishikawa[c]

[a] Department of Physics, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan
[b] International Center for Elementary Particle Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan
[c] RIKEN SPring-8 Center, 1-1-1 Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5148, Japan



Shoji Asai (U Tokyo)

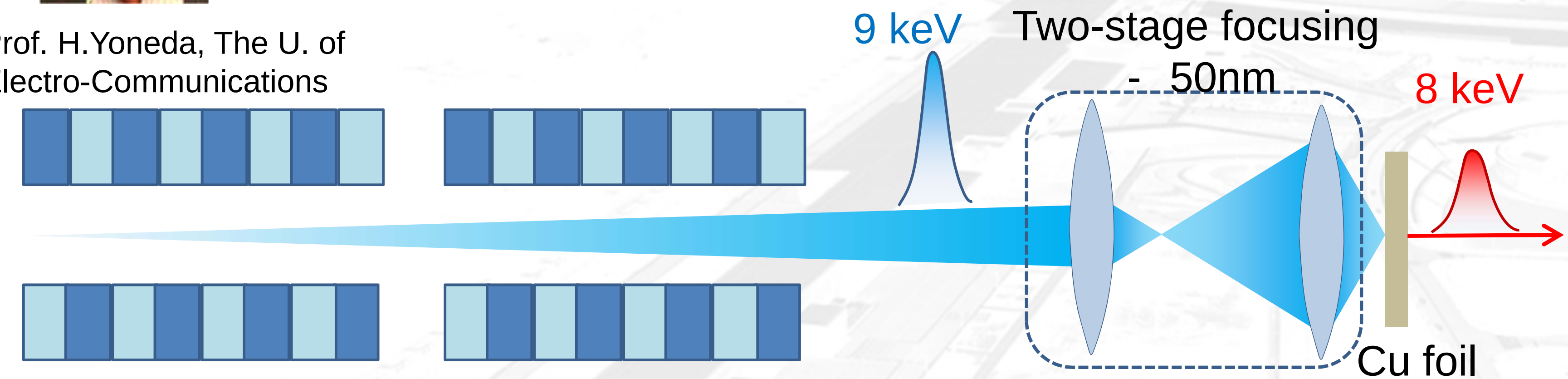
Inada *et al.*, *Phys Lett.* B **732**, 356-359 (2014)

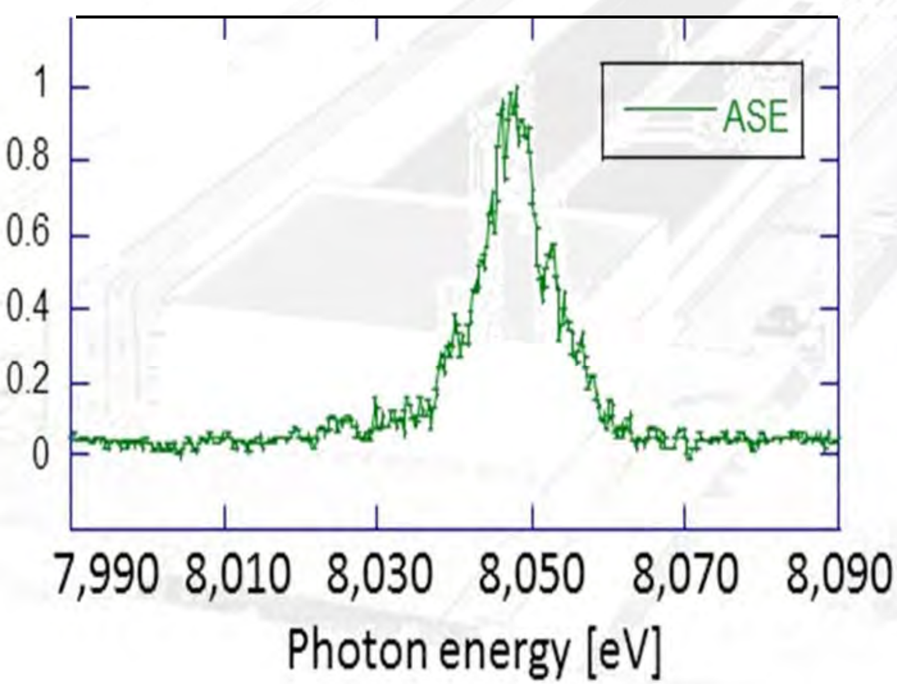
Amplified Spontaneous Emission (ASE)

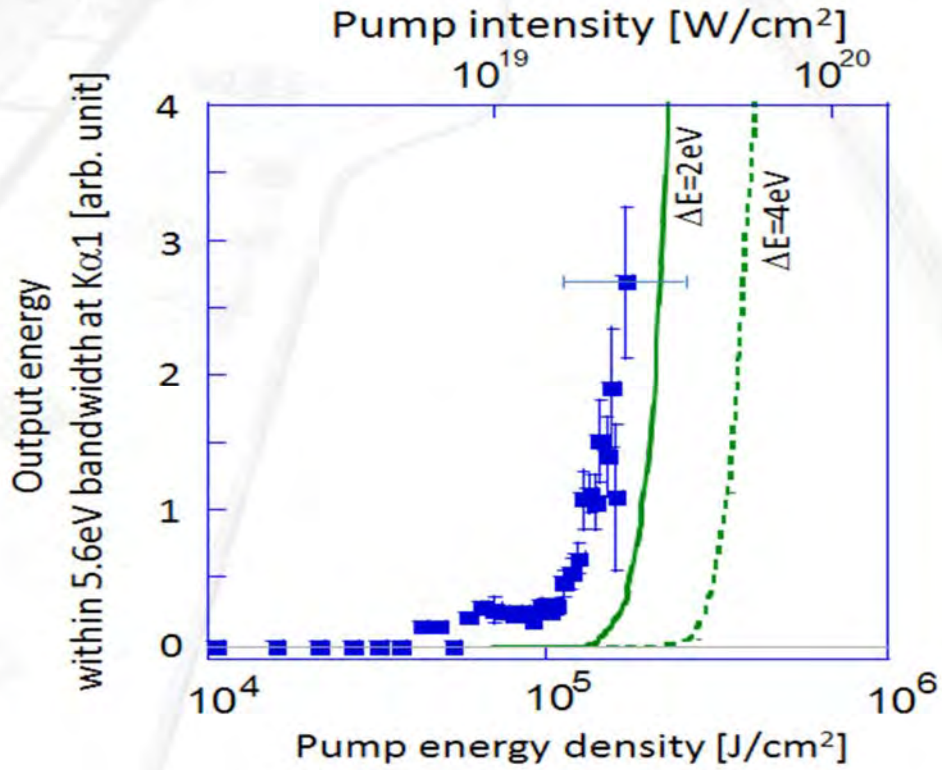
Achievement of Hard X-ray Cu-Kα Atomic Laser

H. Yoneda, Y. Inubushi *et al.*, *Under Review*

Prof. H.Yoneda, The U. of Electro-Communications







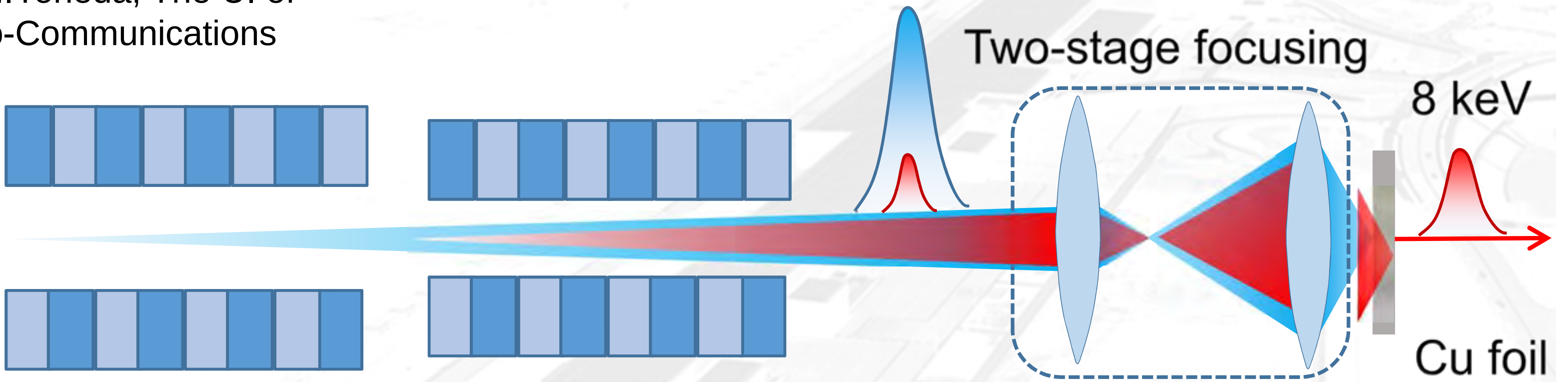
Seeding

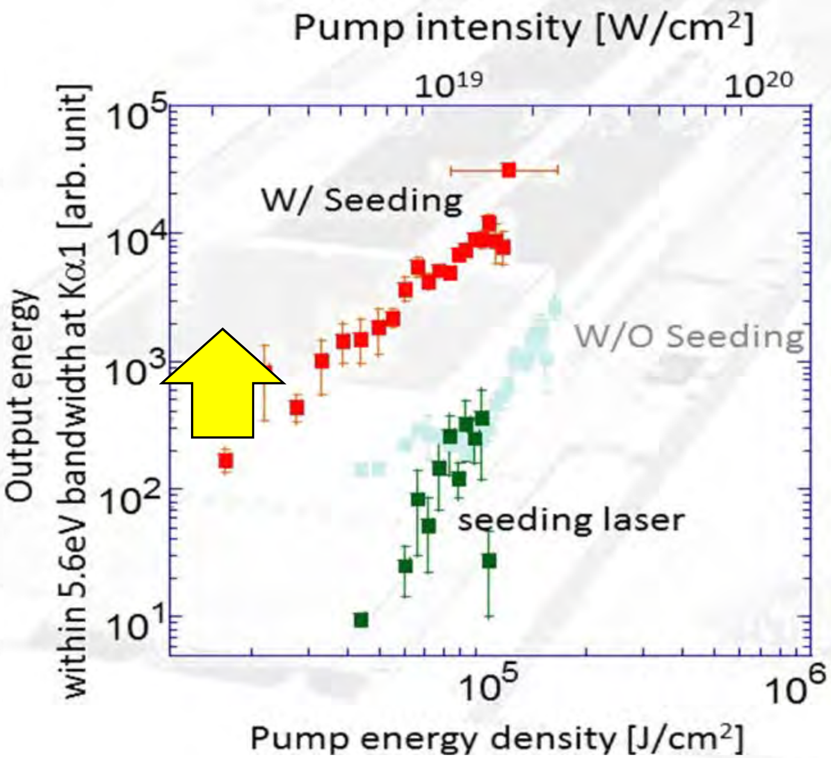
Achievement of Hard X-ray Cu-Kα Atomic Laser

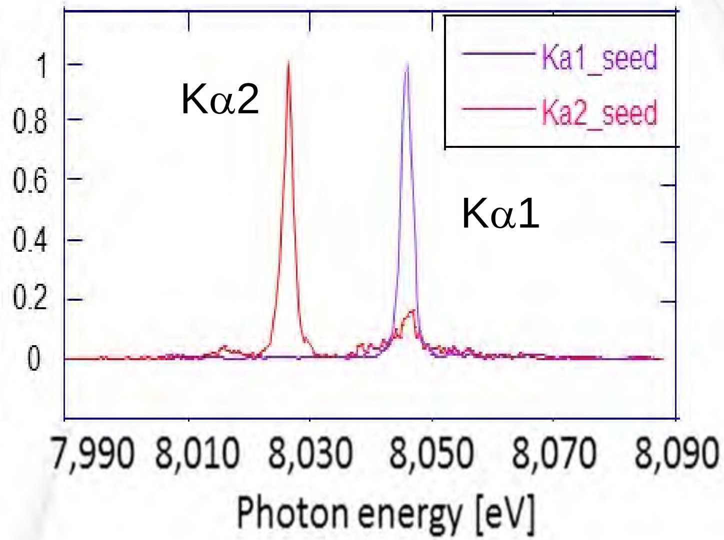
H. Yoneda, Y. Inubushi *et al.*, *Under Review*

9 keV (pump) & 8 keV (seed)

Prof. H.Yoneda, The U. of Electro-Communications







Investigation of “Vacuum” with XFEL

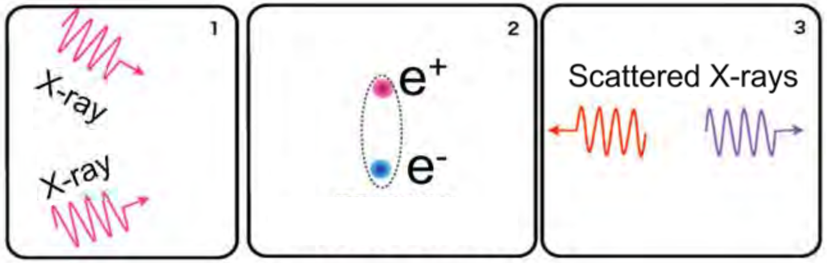
Investigation of “Vacuum” through photon-photon scattering

T. Inada *et al.*, *Phys. Lett.* B **732**, 356 (2014)

Prof. Shoji Asai
(U Tokyo)

Predicted in 1936

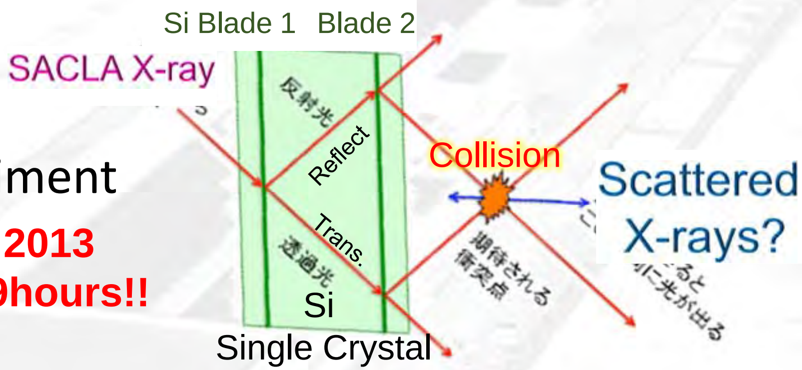
Proving after 80 years



extremely-short time
< 10^{-21}sec

XFEL
Collision Experiment

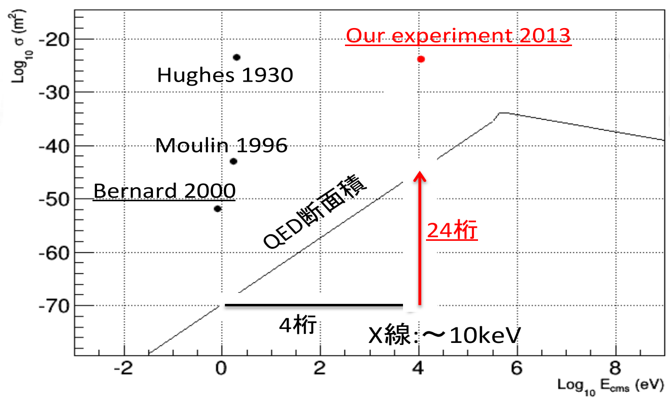
23rd-24th July 2013
650,000 times, 9hours!!



One in a Million

Prediction with QED:
Cross section increases as 6th power of the photon energy:
VIS-> X-rays: 10^{24} increase

May find a novel scheme beyond modern physics



7)Build-up of Experimental Facilities

Second XFEL Beam Line Construction

SCSS Test Facility Implantation

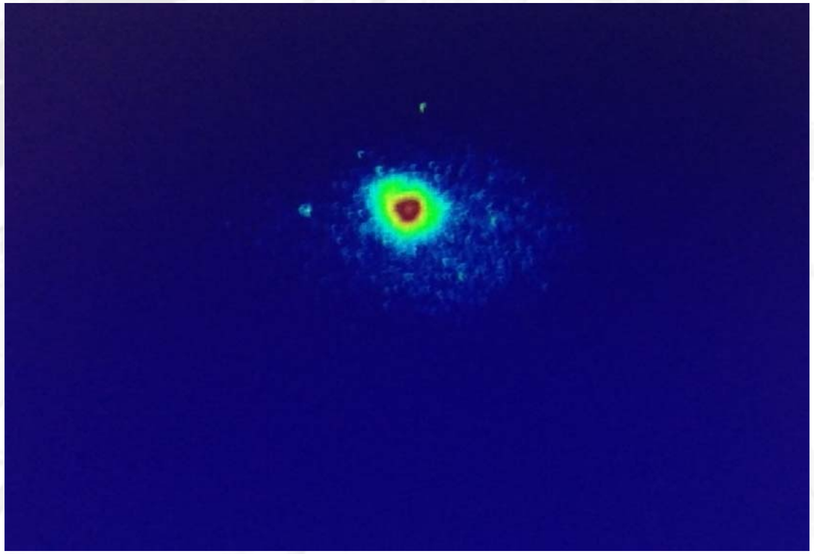
Promotion of High Power Laser Facility

New beamline: BL2

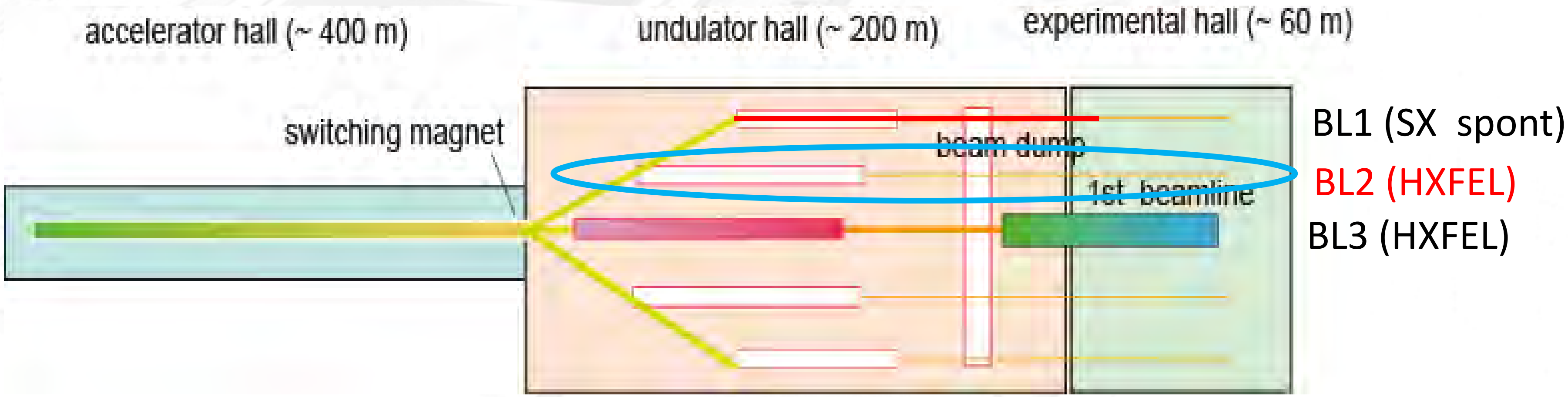
To meet the big demands for increasing diversity of XFEL science

Construction of 2nd hard X-ray FEL beamline

Undulators installed in summer 2014



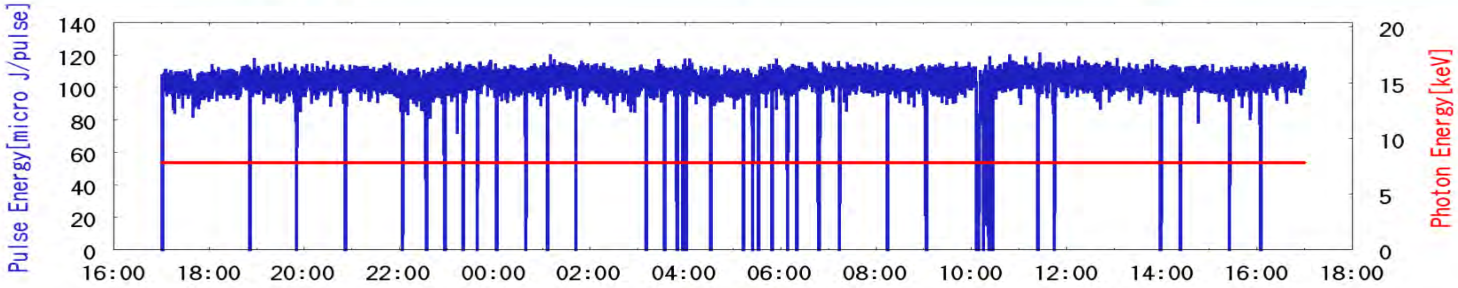
First lasing on Oct 20th, 2014

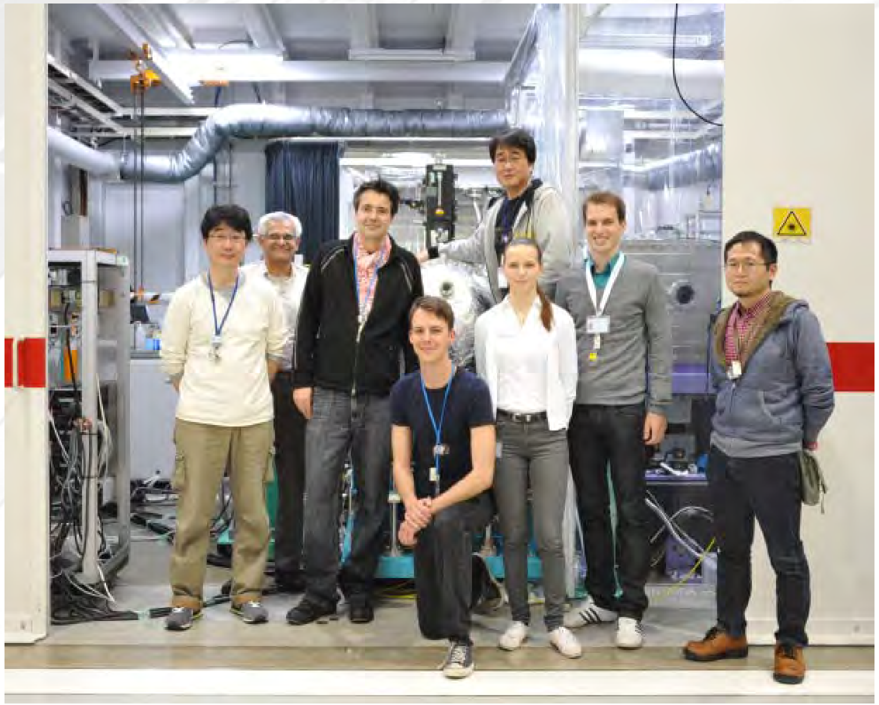


First user operation started on April, 2015

2015/4/19	SACLA Operation Status	17:00:10

Operation Mode	
BL2 User Operation	
Hutch in Use	
BL2 EH3,4b	
Pulse Energy	Photon Energy / Wavelength
110.1 micro J/pulse	7.8 keV / 0.158 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	11.3 %



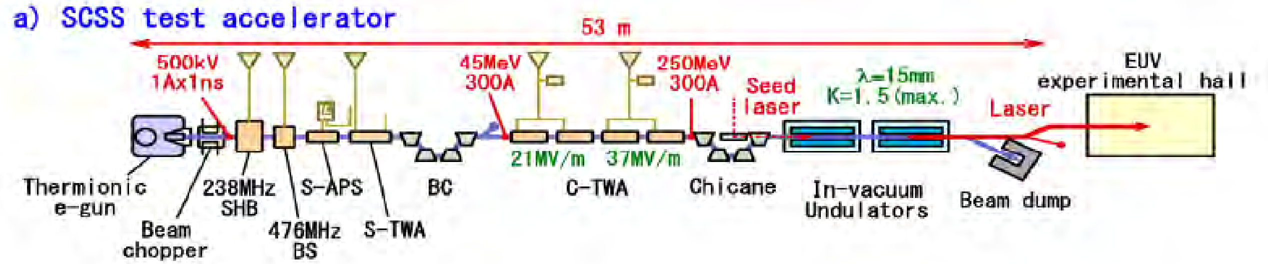


SCSS Test accelerator Implantation

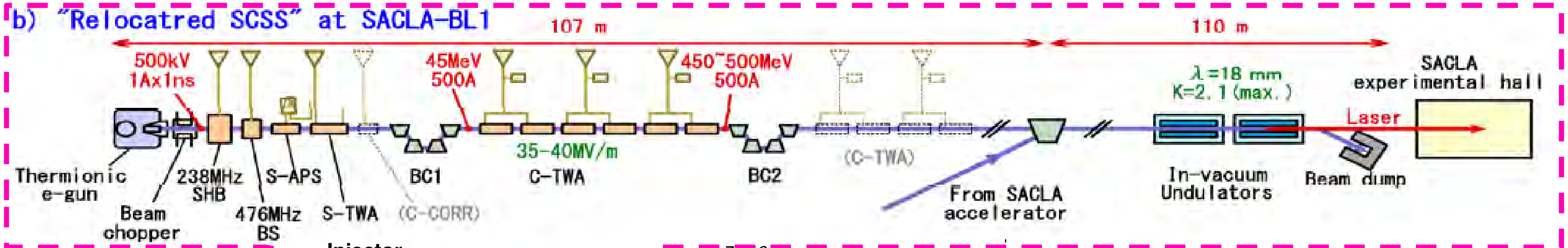
SCSS test facility was upgraded (from 250MeV to 450 MeV)

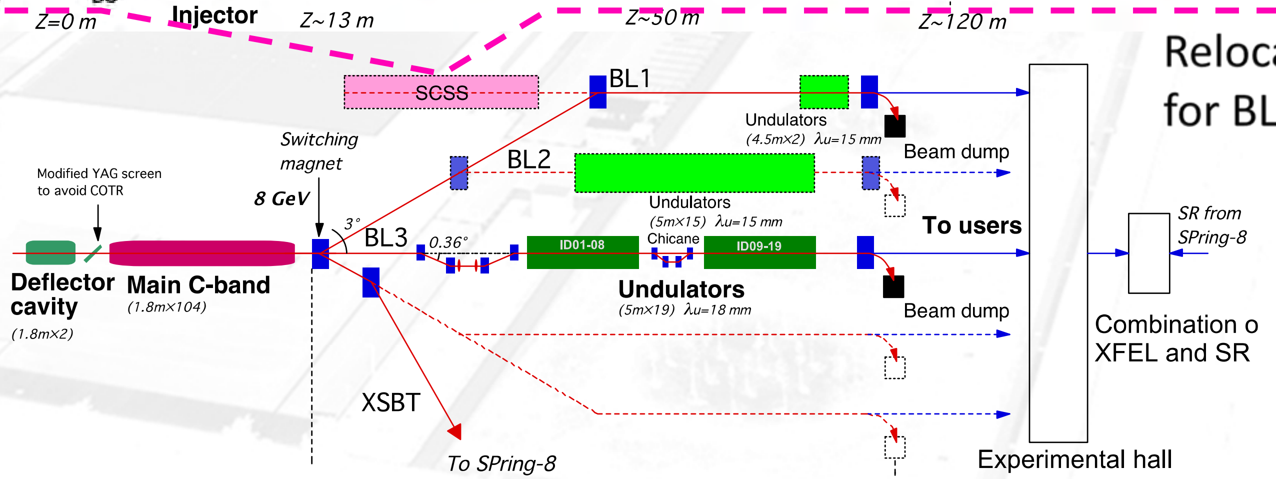
and being relocated in the SACLA undulator hall

as an electron beam driver dedicated to BL1, EUV to SX SASE beamline.



Original SCSS test accelerator





Relocated new electron driver for BL1

RIKEN Osaka U.

High Energy Density Science

High Power Laser Systems at SACLA
HERMES Project

Prof. R. Kodama
(Osaka Univ.)

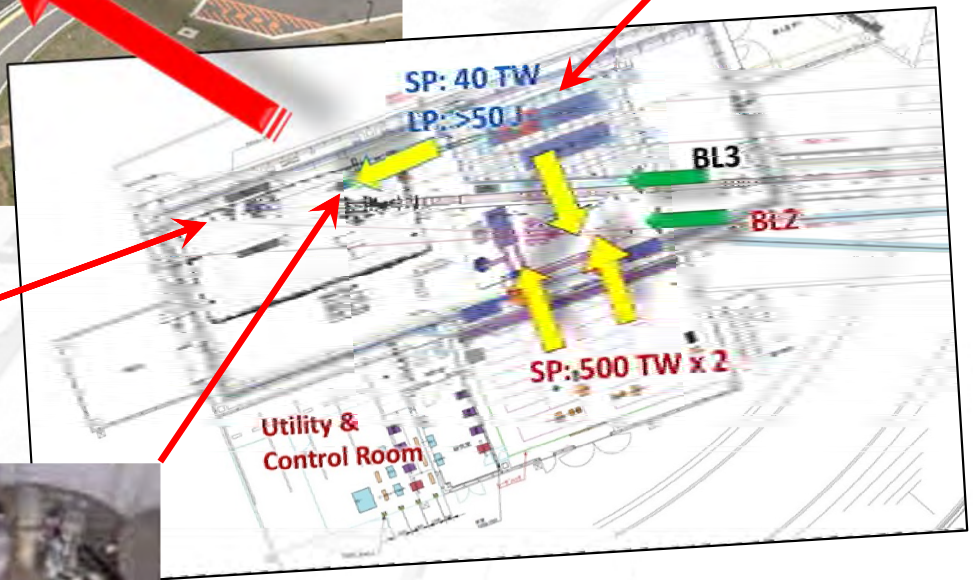
High Energy density Revolutions
of Matter in Extreme States

Prof. K. A. Tanaka
(Osaka Univ.)

SACLA

Science under 10 million atm. pressure

40TW Laser System
(Pulsar)



Experimental Chamber

Pulse compressor

8)Future Perspective

SPring-8/SACLA complementary application

ImPACT Project

Catalyst in functioning

Science of deterioration, degradation, and/or break

Ring-type XFEL: CW X-ray laser

SACLA & SPring-8

SACLA

- High peak brilliance with fs pulses
- High peak intensity
  - Samples are destroyed after shot
  - Every shot is "new" experiment with fresh sample
- Suitable for single-shot, high resolution observation of small, complex samples

New regime of X-ray science

SPring-8

- High average brilliance with high rep rate
- Deliver x-rays to several tens beamlines
- Moderate peak intensity
  - Sample will not be damaged in single shot
  - Suitable for extracting information with correlation techniques

SACLA & SPring-8

New regime of X-ray science

Large potential for
diffraction-limited source, enhance brilliance
and
attracting new science

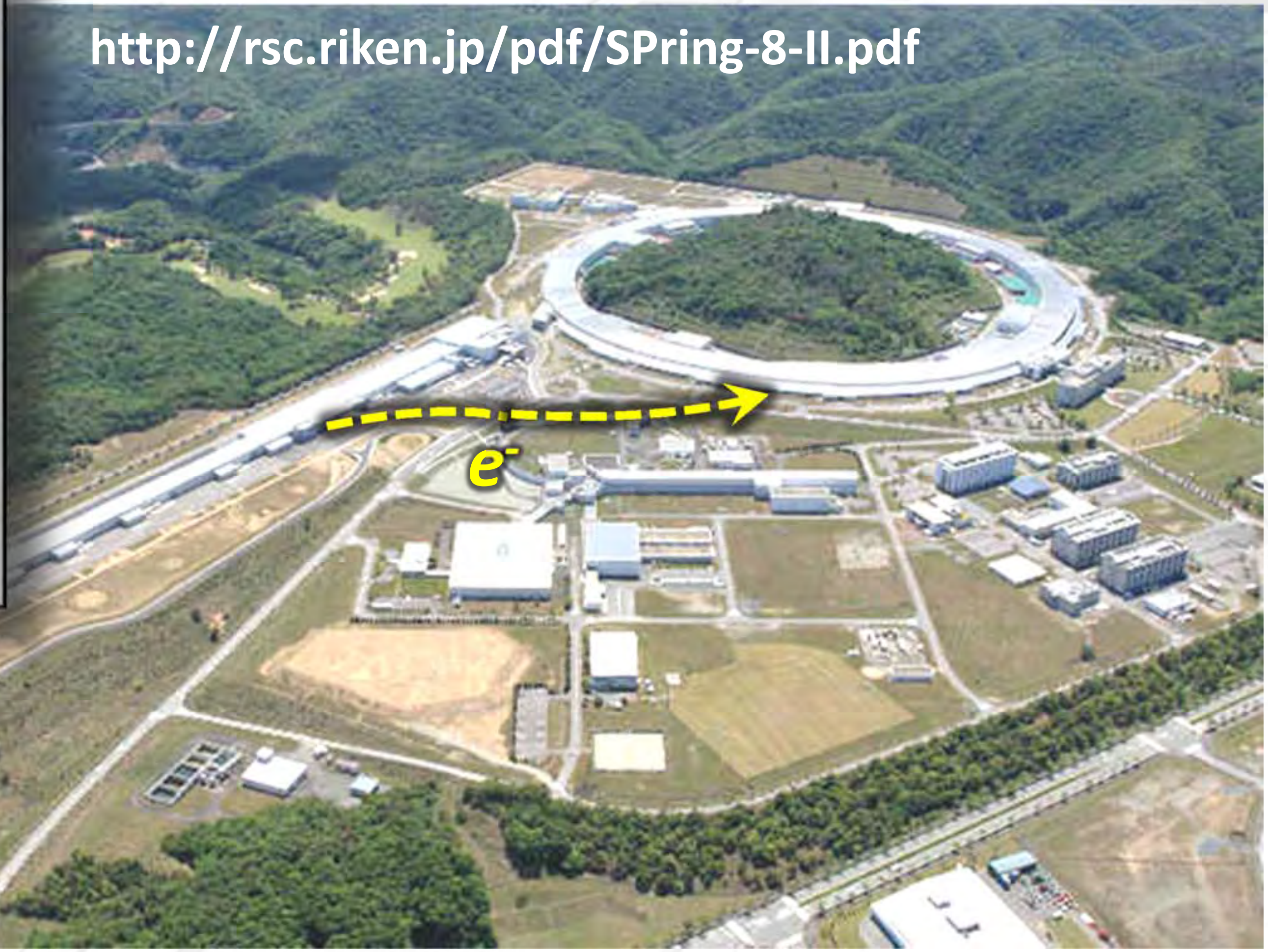
SPring-8 II CDR published


SPring-8-II

Conceptual Design Report

RIKEN SPring-8 Center

November, 2014

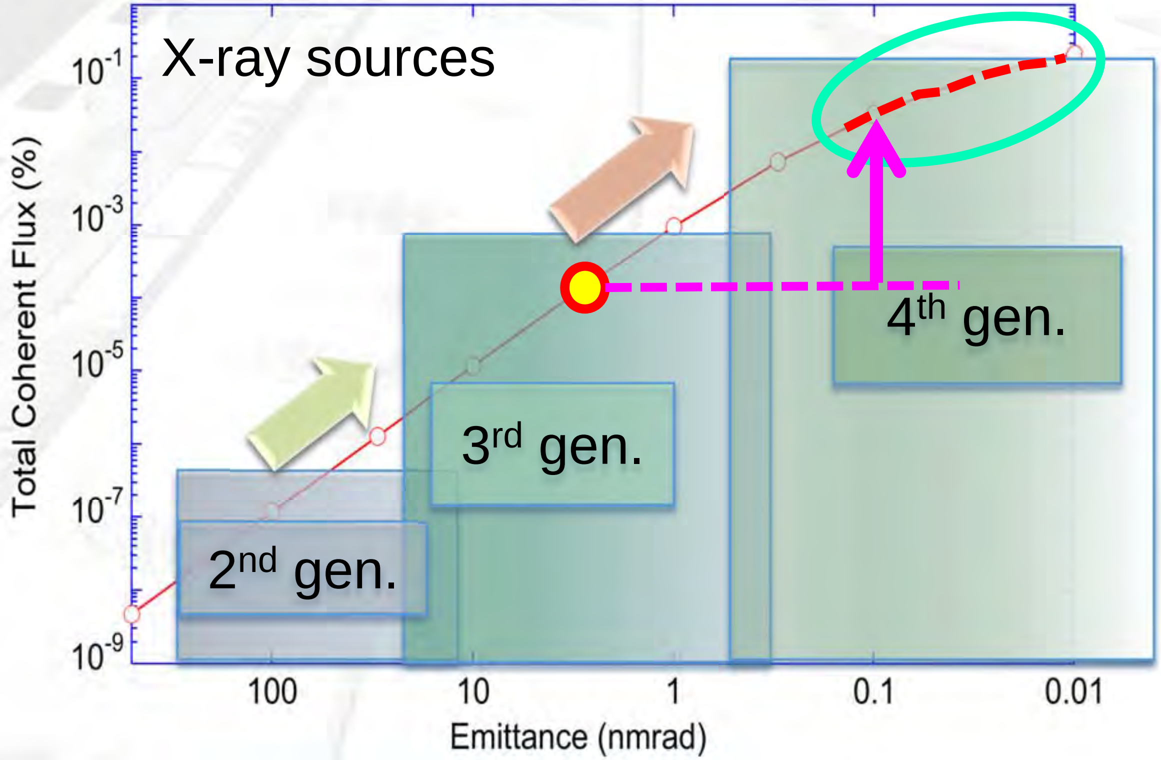


Target

- Diffraction-limited SR for enabling cutting-edge researches with brilliant x-rays
- Energy-saving facility
- Key step towards development on future CW XFEL source

Target Performance

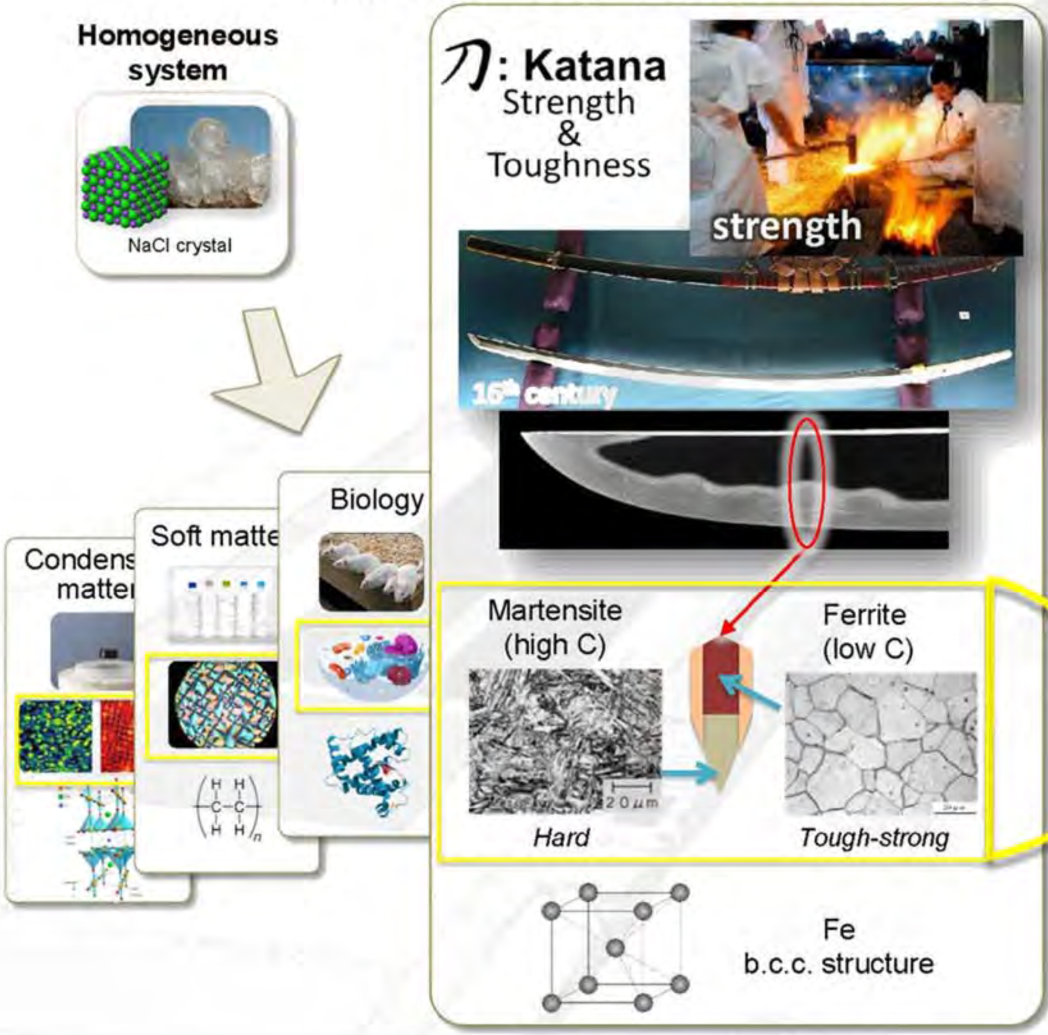
- Practical electron beam emittance in the storage ring less than 100 pm.rad
- Stored beam current of 100 mA
- Stability enabling a off-axis top-up injection
- Beam lifetime around 10 hr with 100 mA



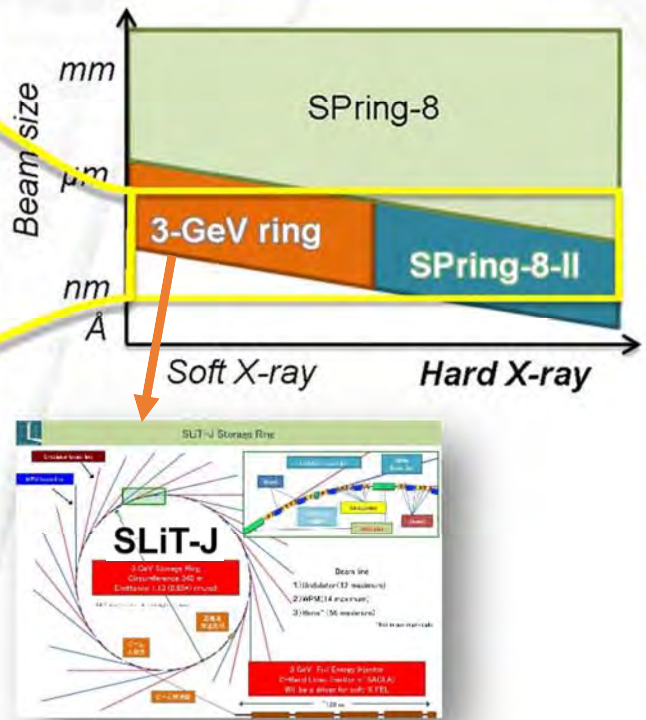
SPring-8 Upgrade : Scientific Motivation

For many phenomena, we know ***how*** they happen,
but not ***why*** they happen.

Inhomogeneous / Hierarchic / Composite - system



Nano-Scopy:
- Nano-Diffraction
- Nano-Spectroscopy
- Nano-Imaging



ImPACT Project

Council for Science, Technology and Innovation

ImPACT Program (2014～; 3-5years, 30-50M€/Program)

Impulsing Paradigm Change through Disruptive Technologies

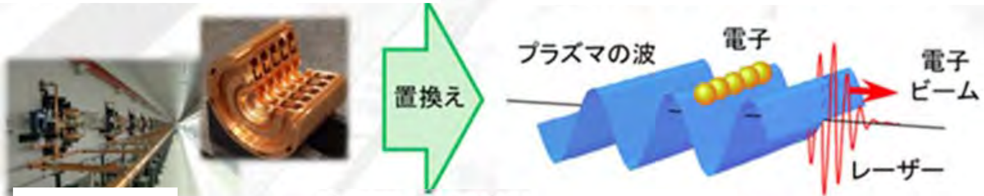
"a new system that, if realized, will create disruptive innovation that brings about change in society"

Yuji Sano
(Program Manager)

- Develop synergy between XFEL and high-power lasers
- To construct very compact XFEL based on laser wakefield technologies

electromagnetic acceleration

plasma wakefield acceleration



Accelerated gradient 50 MV/m

Game-changing Technology

Accelerated gradient 100 GV/m

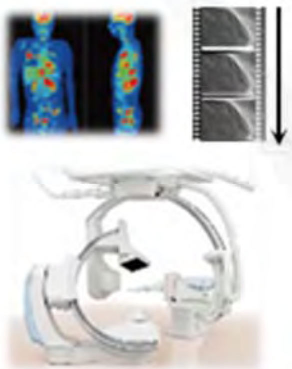
Ultracompact XFEL R&D Base

LAPLACIAN
Laser Acceleration Platform as a Coordinated Innovative Anchor

Laser **A**cceleration **PLA**tform as a **C**oordinated **I**nnovative **AN**chor

SACLA **truck-mounted FEL**

Smart Engineering



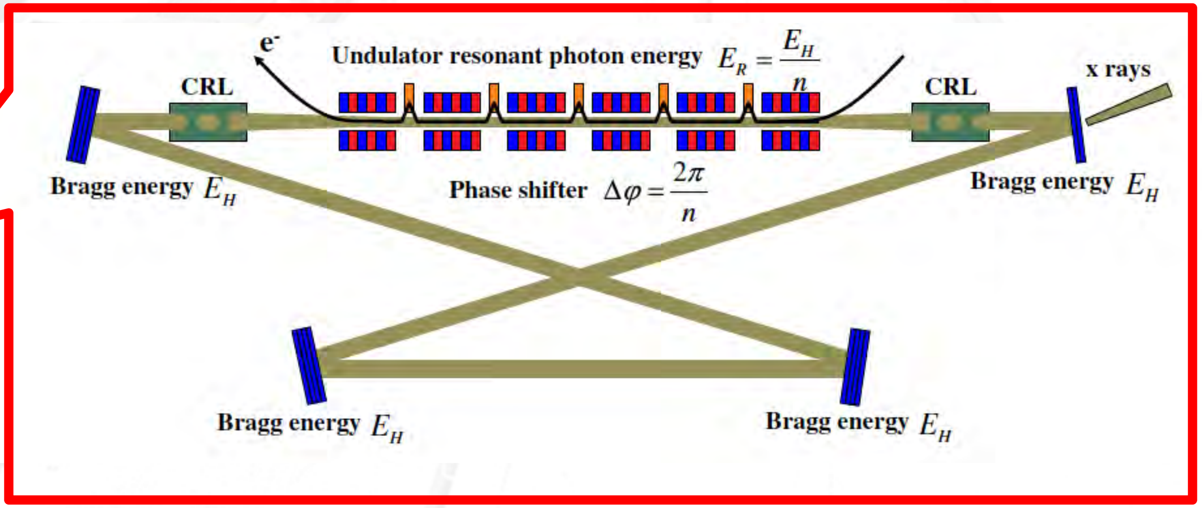
Smart therapy

Ring-type XFEL: CW X-ray laser

Presently the scheme is still unclear,
but in the future some innovative scheme will come up.

One candidate will be a XFELO,
a low gain oscillator configuration
with a high-reflectivity high-resolution X-ray crystal cavity.

SR with
Long Straight Sections

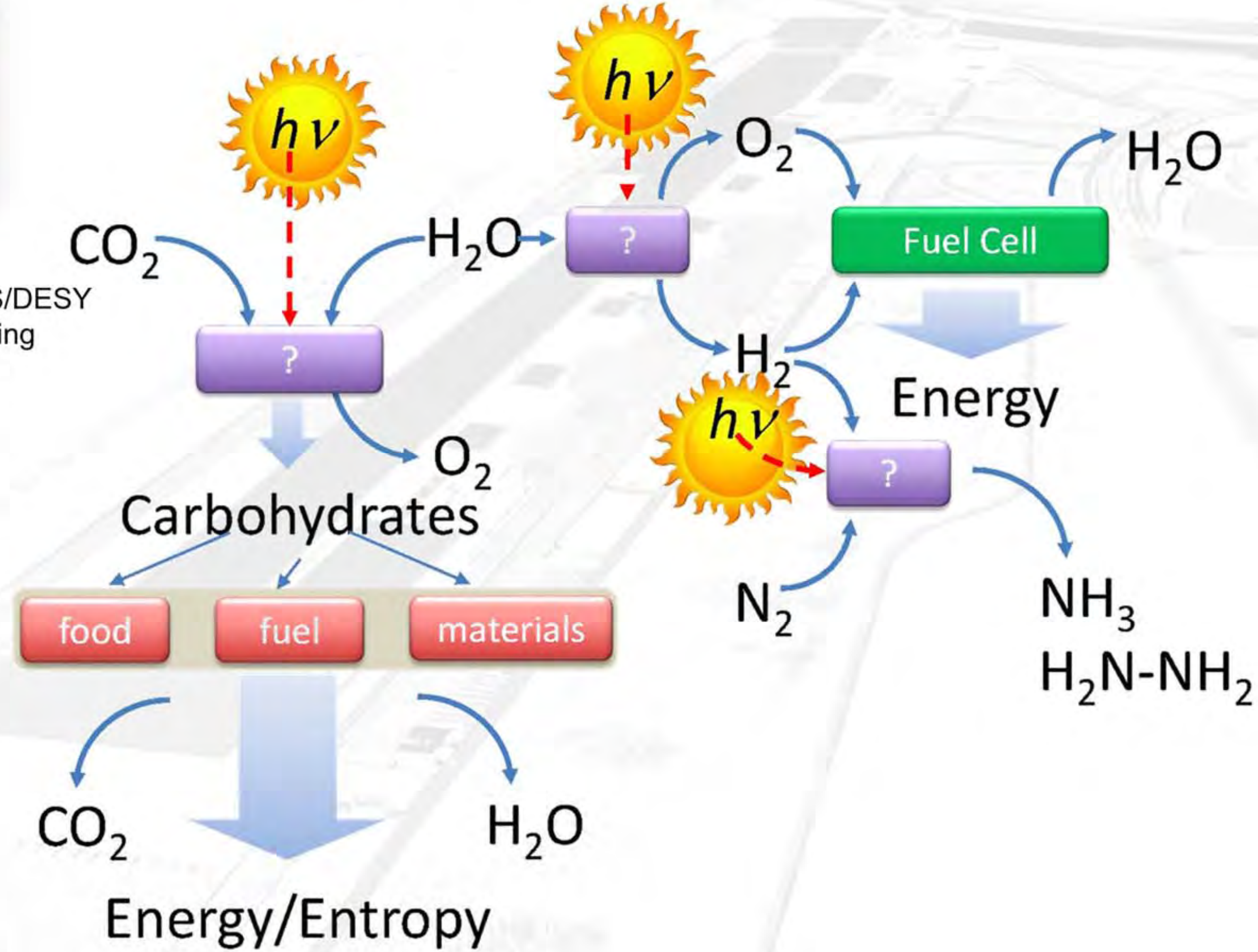


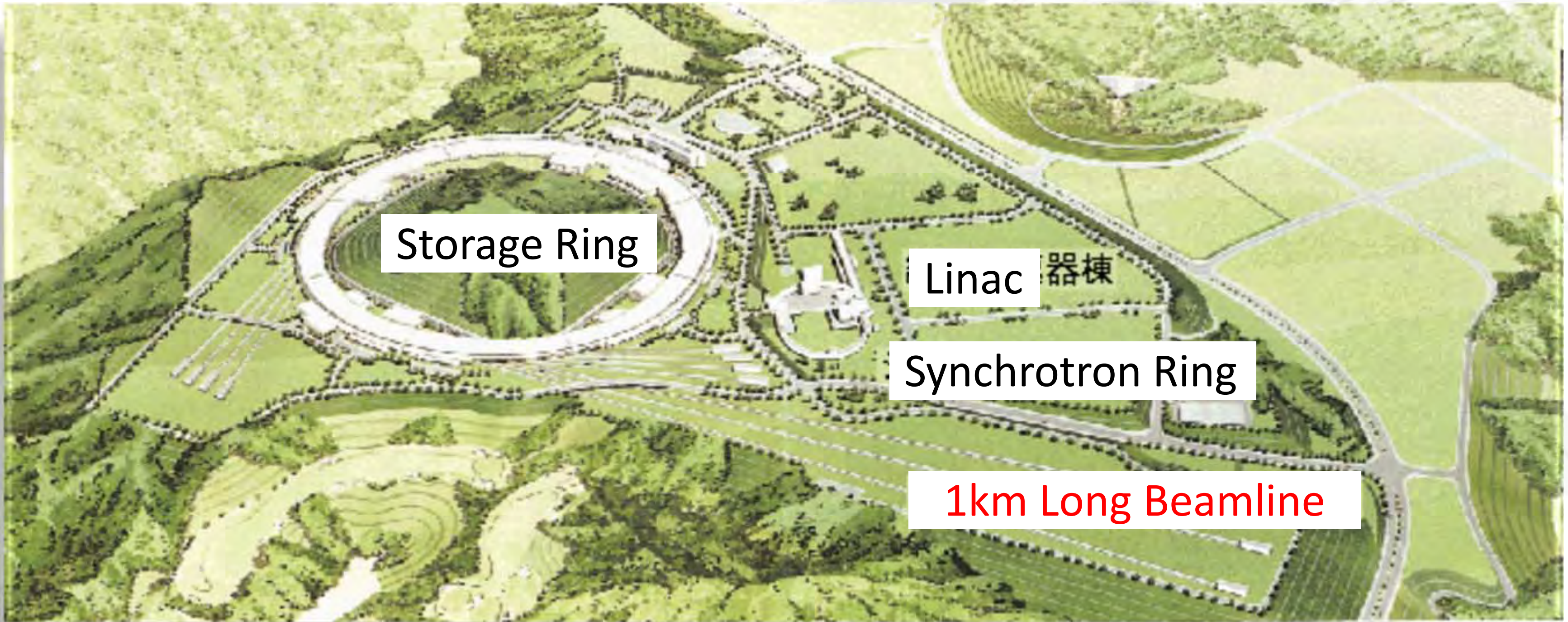
We'd like to contribute to a recyclable society

-One of the Potential Goals-

T. Ishikawa

SPring-8/ESRF/APS/DESY
Three-way Meeting
Feb. 2015





Rendering of SPring-8(1995)

Thank you for your attention