RIKEN SPring-8 Center

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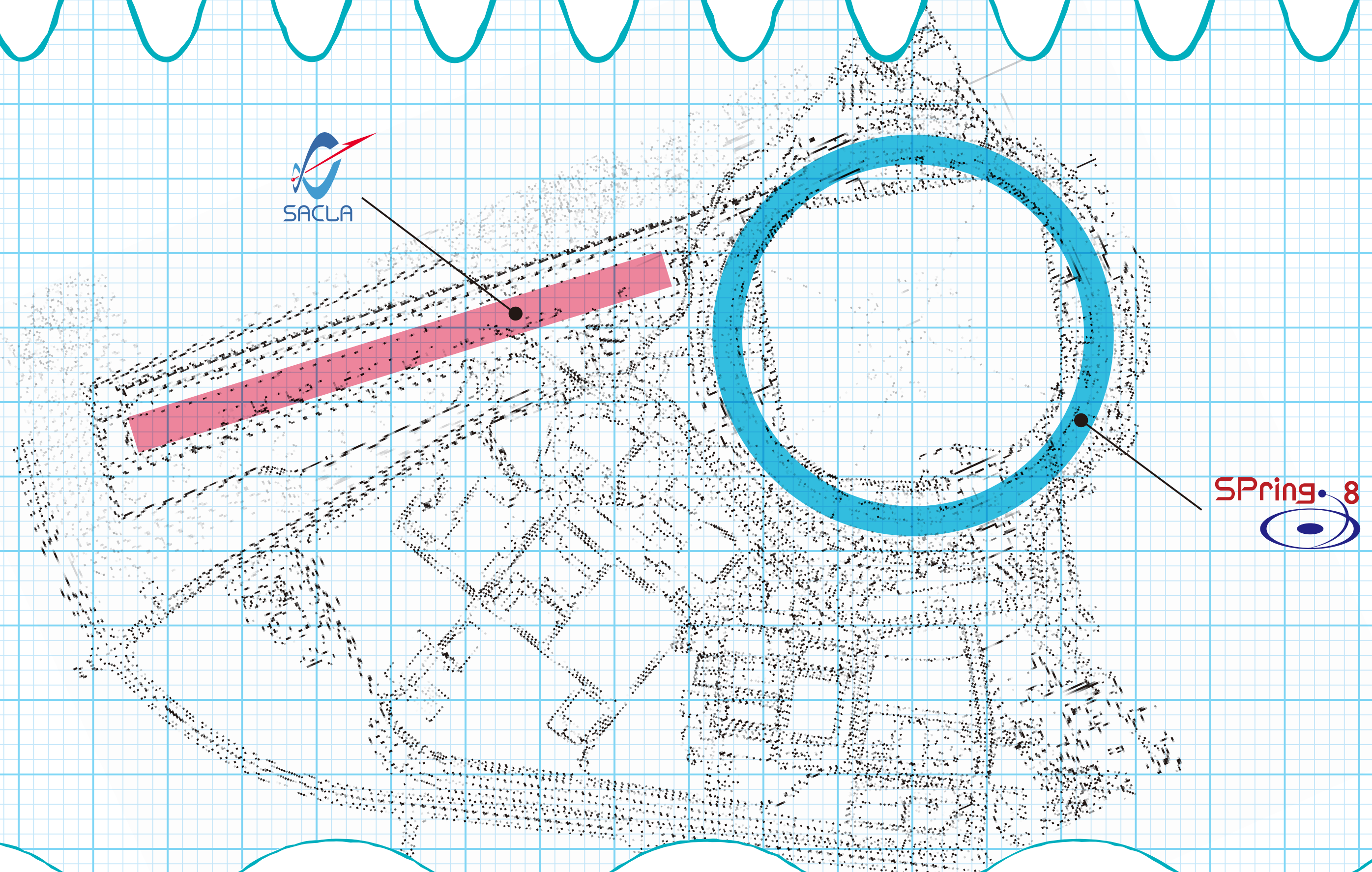
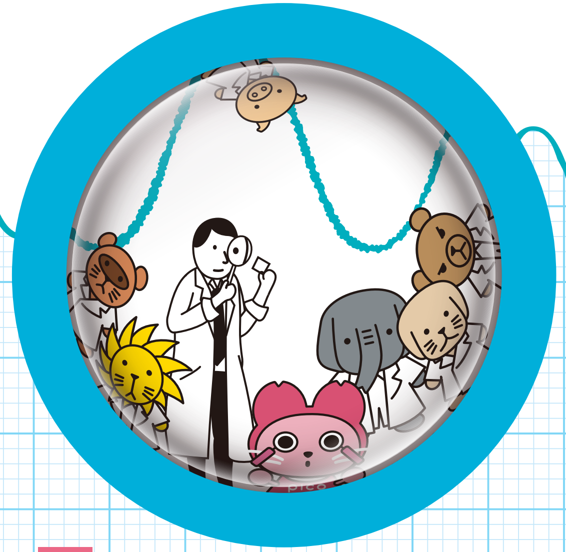


2019/4/1(No.001)

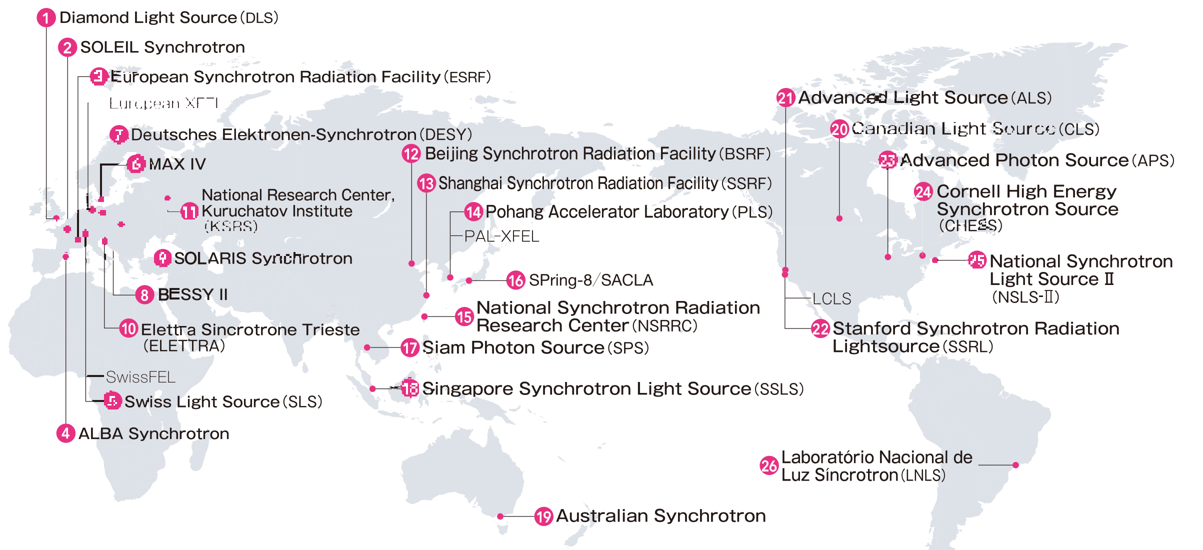
Why Do We Need Synchrotron Radiation Facilities?



SPring-8 SACLA

RIKEN SPring-8 Center
Director
Tetsuya Ishikawa

We use light, when we observe something. Long distance stars are observed with telescopes, while the tiny objects with microscopes, both using visible light.The light for observing much smaller "nano-world" consists of X-rays. Since their discovery, we have searched for the more intense X-ray sources for 120 years. It turned out the synchrotron radiation from the electrons in accelerators became intense X-rays when the electron energy is high. This synchrotron radiation(SR) has been gradually utilized since 1960's. While the nano-science and technology prosper in 1990s, utilizing the information of nano-scale structure and function of a substance and controlling it, SR became an indispensable probe to the nano-world.SPring-8 had developed many new technologies which tow the SR science in the world. Synthesizing some of them has led to a completely new X-ray free-electron laser, SACLA.Many SR facilities around the world are using the technology that SPring-8 has developed.SPring-8 and SACLA, illuminating the nano world, are now beyond the mere light source for observation, but have given the "solution" which clarifies the cause of the novel functions which nano-world has created.



16 SPring-8

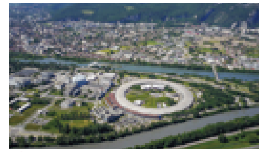
Start of Operations 1997
Circumference 1,436m
Energy 8GeV
Beamlines 62

Synchrotron radiation (SR) facilities generate intensive X-rays resulting from high-energy electrons changing their orbit. The X-rays are utilized to observe the atomic/molecular world. Among the many SR facilities in Japan and around the world, SPring-8 and SACLA provide the highest levels of capabilities.

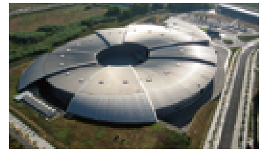
Synchrotron Facilities in the World

1 DLS (Diamond Light Source)
Start of Operations 2007
Circumference 562m
Energy 3GeV
Beamlines 33

2 SOLEIL Synchrotron
Start of Operations 2006
Circumference 354m
Energy 2.75GeV
Beamlines 29



3 ESRF (European Synchrotron Radiation Facility)
Start of Operations 1994
Circumference 844m
Energy 6GeV
Beamlines 44



4 ALBA Synchrotron Light Source
Start of Operations 2012
Circumference 269m
Energy 3GeV
Beamlines 8 (12 planned)

5 SLS (Swiss Light Source)
Start of Operations 2001
Circumference 288m
Energy 2.4GeV
Beamlines 17

6 MAX IV Facility
Start of Operations 2016
Circumference 96m / 528m
Energy 1.5GeV / 3GeV
Beamlines 17

7 DESY (Deutsches Elektronen-Synchrotron)
Start of Operations 2010
Circumference 2.3km
Energy 6GeV
Beamlines 17(25 planned)

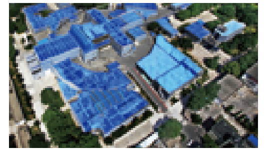
8 BESSY II (Berlin Electron Storage Ring Society for Synchrotron Radiation II)
Start of Operations 1998
Circumference 240m
Energy 1.72GeV
Beamlines 46

9 SOLARIS Synchrotron
Start of Operations 2016
Circumference 96m
Energy 1.5GeV
Beamlines 14 (planned)

10 ELETTRA (Elettra Sincrotrone Trieste)
Start of Operations 1994
Circumference 260m
Energy 2.0-2.4GeV
Beamlines 28

11 KSRS (Kuruchatov Synchrotron Radiation Source)
Start of Operations 1999
Circumference 124m
Energy 2.5GeV
Beamlines 18 (24 planned)

12 SSRF (Shanghai Synchrotron Radiation Facility)
Start of Operations 2009
Circumference 432m
Energy 3.5GeV
Beamlines 15 (36 planned)



13 BSRF (Beijing Synchrotron Radiation Facility)
Start of operations 1991
Circumference 240m
Energy 2.5GeV
Beamlines 14

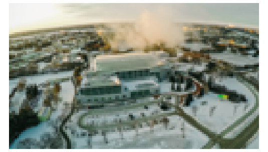
14 PLS (Pohang Light Source)
Start of Operations 2012 (PLS-II)
Circumference 282m
Energy 3GeV
Beamlines 34

15 NSRRC (National Synchrotron Radiation Research Center)
Start of Operations 2016 (TPS)
Circumference 518m
Energy 3GeV
Beamlines 7 (40 planned)

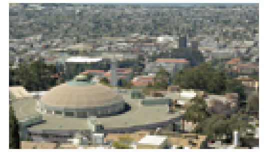
17 SPS (Siam Photon Source)
Start of Operations 1996
Circumference 81m
Energy 1.2GeV
Beamlines 10

18 SSLS (Singapore Synchrotron Light Source)
Start of Operations 2000
Circumference 10.8m
Energy 0.7GeV
Beamlines 7

19 AS (Australian Synchrotron)
Start of Operations 2007
Circumference 216m
Energy 3GeV
Beamlines 10

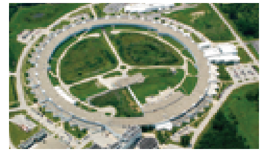


20 CLS (Canadian Light Source)
Start of Operations 2004
Circumference 171m
Energy 2.9GeV
Beamlines 16



21 ALS (Advanced Light Source)
Start of Operations 1993
Circumference 197m
Energy 1.9GeV
Beamlines 40

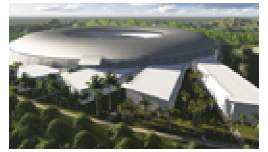
22 SSRL (Stanford Synchrotron Radiation Lightsource)
Start of Operations 1972
Circumference 234m
Energy 3GeV
Beamlines 32



23 APS (Advanced Photon Source)
Start of Operations 1996
Circumference 1104m
Energy 7GeV
Beamlines 68

24 CHESS (Cornell High Energy Synchrotron Source)
Start of Operations 1980
Circumference 768m
Energy 5.3GeV
Beamlines 11

25 NSLS-II (National Synchrotron Light Source II)
Start of Operations 2015
Circumference 792m
Energy 3GeV
Beamlines 22 (60 planned)



26 LNLS (Laboratório Nacional de Luz Síncrotron)
Start of Operations 1997 (UVX)/ 2020 (Sirius)
Circumference 93m/ 518.4m
Energy 1.37GeV/ 3GeV
Beamlines 20/ 40

Synchrotron Facilities in Japan

1 SAGA-LS (SAGA Light Source)
Start of Operations 2006
Circumference 75.6m
Energy 1.4GeV
Beamlines 11

2 HiSOR (Hiroshima Synchrotron Radiation Center, Hiroshima University)
Start of Operations 1997
Circumference 22m
Energy 0.7GeV
Beamlines 15

3 NewSUBARU (University of Hyogo, New SUBARU Synchrotron Radiation Facility)
Start of Operations 2000
Circumference 118m
Energy 1.5GeV
Beamlines 9

4 RitsSR (Ritsumeikan Univercity Synchrotron Radiation Center)
Start of Operations 1996
Circumference 3.14m
Energy 0.575GeV
Beamlines 13

5 Aichi SR (Aichi Synchrotron Radiation Center)
Start of Operations 2013
Circumference 72m
Energy 1.2GeV
Beamlines 11

6 UVSOR-III (UVSOR Synchrotron Facility)
Start of Operations 1984
Circumference 53m
Energy 0.75GeV
Beamlines 14

7 PF/PF-AR (Photon Factory)/ (Photon Factory Adcanced Ring)
Start of Operations 1983/1987
Circumference 187m/377m
Energy 2.5GeV/6.5GeV
Beamlines 22/8

8 SLiT-J (Synchrotron Lifht in Tohoku, Japan)
Start of Operations 2021(planned)
Circumference 354m
Energy 3GeV
Beamlines 26

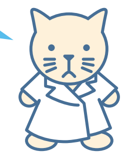
Q1 What are X-rays?

A1

X-rays are a type of electromagnetic wave discovered by Dr. Wilhelm Conrad Röntgen.

In 1895, Röntgen discovered a type of light able to penetrate materials. The X-rays were named after the 'X' used in mathematics to designate an unknown variable. The first X-ray image was the hand of his wife. Now X-rays are widely used in hospitals.

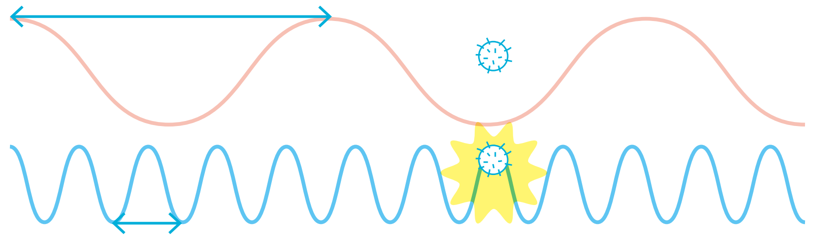
Light is a form of waves!



Q2 How can X-rays portray small objects?

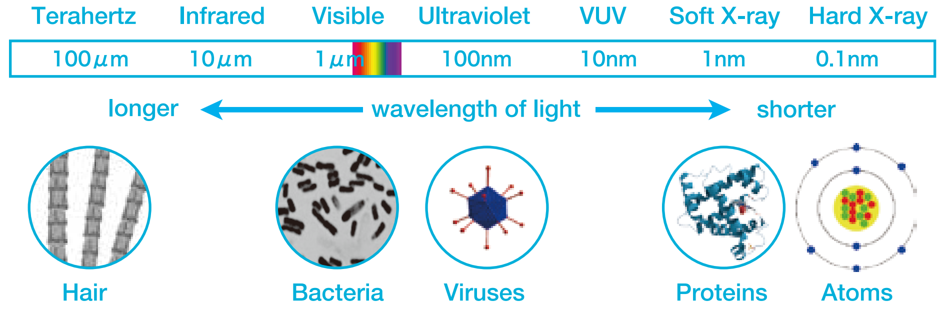
A2

Because X-rays have a very short wavelength.



Although light with a longer wavelength cannot image small objects, light with a shorter wavelength can.

We are able to see objects with light.
Shorter wavelength light allows us to see very small objects.



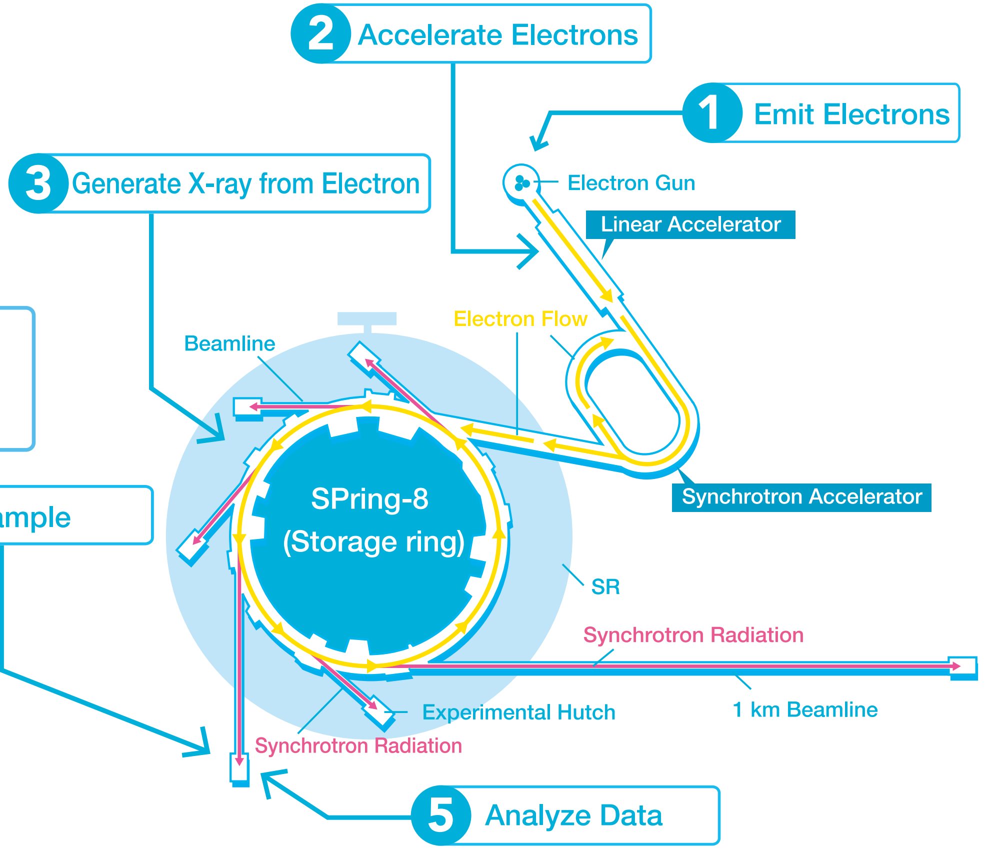
Q3 What can SPring-8 do?

A3

SPring-8 can image small objects that have never been observed before by using very strong X-rays from a large accelerator.

Since it began operations in 1997, SPring-8 has been the world largest energy storage ring for synchrotron radiation. The circumference of the ring is 1436m.

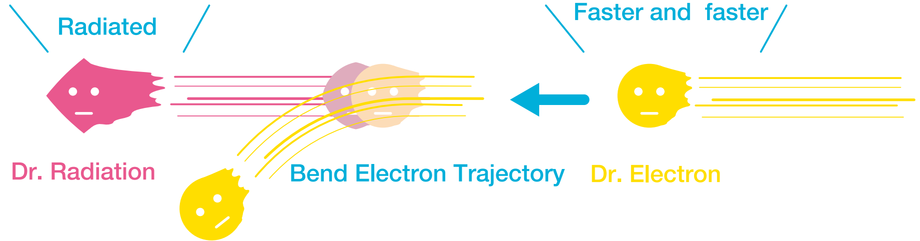
Observing small objects requires such a large facility!



Q4 How to generate strong X-rays?

A4

Strong X-rays are generated by bending electron beams moving at nearly the speed of light.
To create stronger X-rays, periodic arrays of magnets called undulators multiply bend electron beams.



Q5
A5

What is the most important technology invented at SPring-8?

Lead the World!

Two inventions at SPring-8 are particularly noteworthy.

In-vacuum Undulator
Stronger X-rays are generated by arranging magnets close together.

Osaka Mirror
A focusing mirror with extremely high precision achieves a high quality of focusing due to its small surface error of a nano-order.

Inside of SPring-8

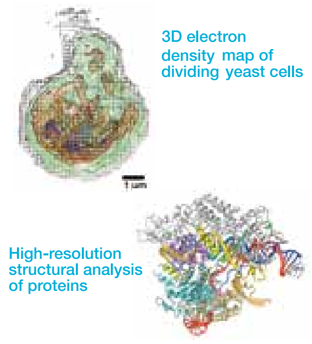
Q6
A6

What kind of research conducted at SPring-8?

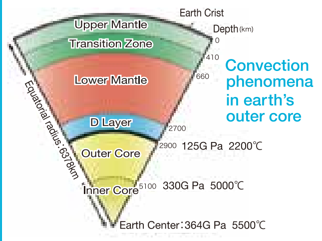
Results of our research improve our daily life!

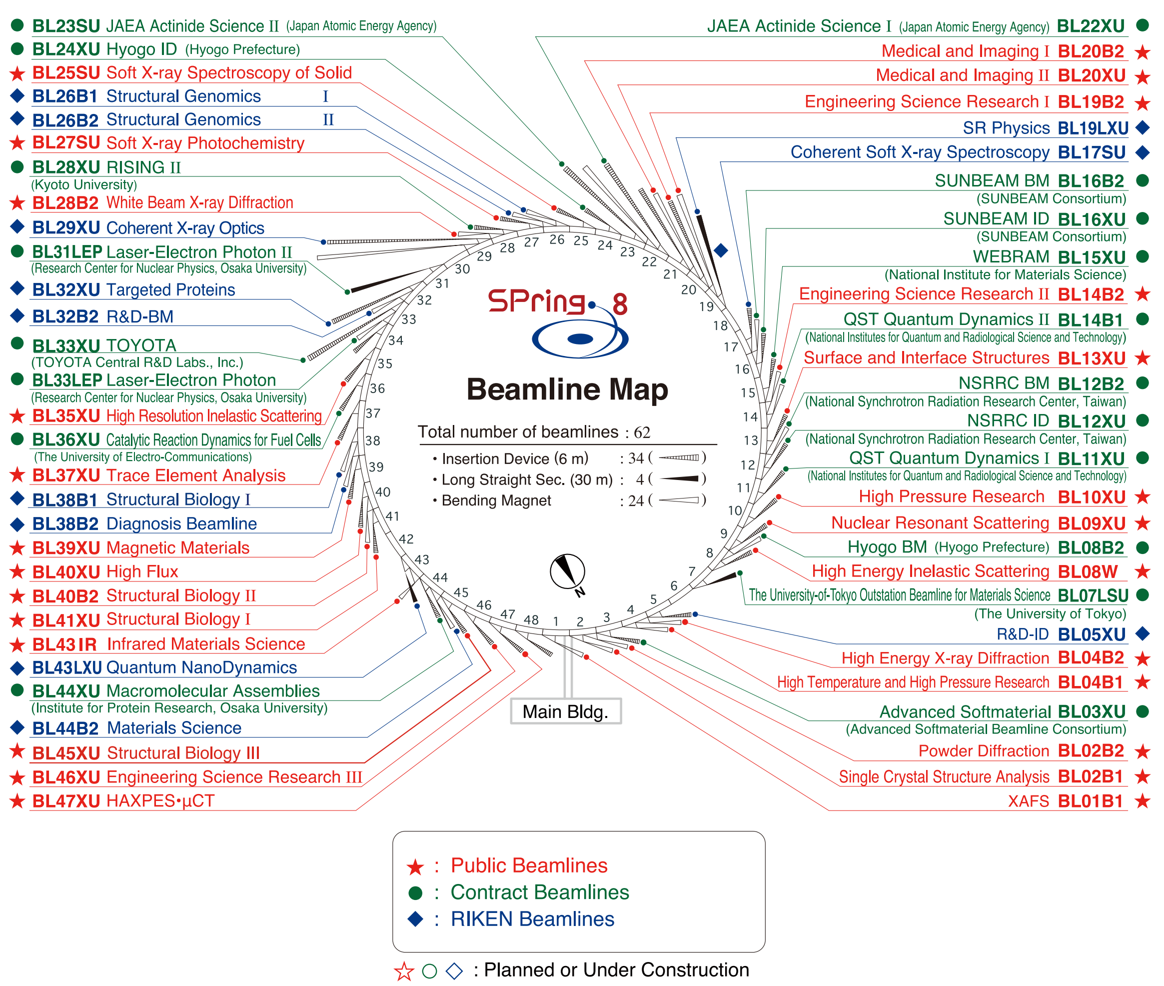
SPring-8 has 57 beamlines serving numerous research fields, ranging from advanced science to everyday life.

Medicine and Biology



Environmental and Geo-science





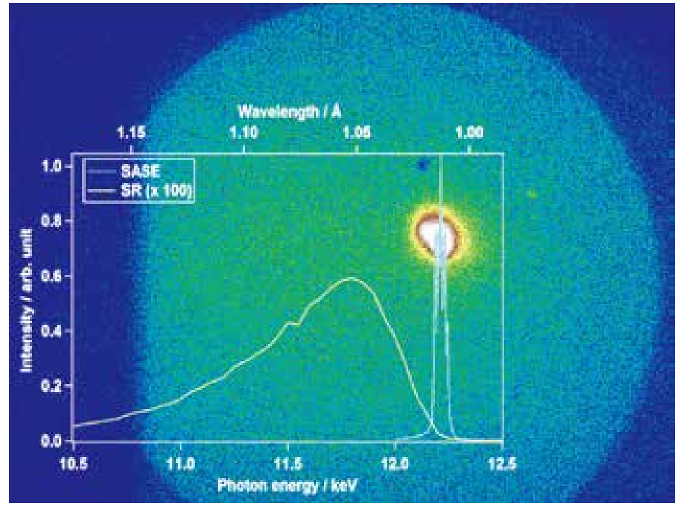
Archeology and Forensic Science

Industry

Q7
A7

What is SACLA?

SACLA is an X-ray free electron laser facility that enables us to visualize ultrafast phenomena such as the motion of atoms and molecules during their chemical reaction

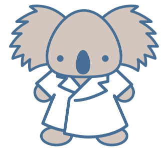


SACLA lased on June 7, 2001
at the world's shortest wavelength of 1 angstrom.

Q8
A8

How is SACLA different from other XFEL facilities?

SACLA, at one fifth the size of European and American facilities, can provide the comparable performance.



Compare!

European XFEL	3.4 km
LCLS	4 km
SACLA	700 m

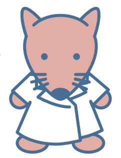
Super short!

Q9
A9

How was SACLA built?

SACLA was built by leveraging the Japanese technology born and nurtured at SPring-8.

SACLA is the offspring of Japanese technology!

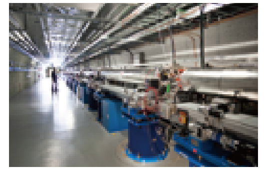


SACLA Hyogo JAPAN

SPring-8 Angstrom Compact Free Electron Laser

Start of Operations 2012 Length 700m Energy 8GeV Beamlines 5

XFEL Facilities in the World



LCLS
(Linac Coherent Light Source)

Start of Operations 2009 Energy 15GeV
Length 4km Beamlines 1

European XFEL

Start of Operations 2017 Energy 17.5GeV
Length 3.4km Beamlines 3

SwissFEL

Start of Operations 2017 Energy 5.8GeV
Length 713m Beamlines 2

PAL-XFEL
(Pohang Accelerator Laboratory-XFEL)

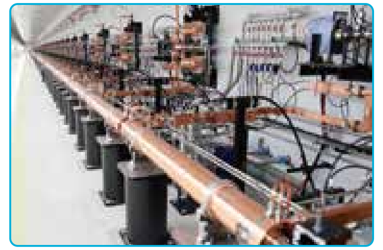
Start of Operations 2017 Energy 10GeV
Length 1.1km Beamlines 2

Q10 How do you make the X-ray laser at SACLA?

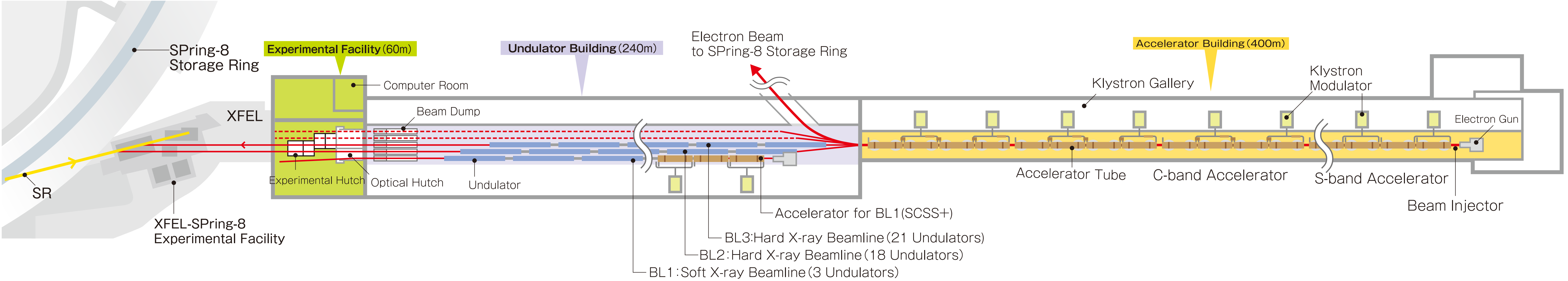
A10

Electrons are accelerated with linearly aligned C-band accelerators and transported to the long in-vaccume undulator, in which the X-ray laser is generated.

C-band Accelerator



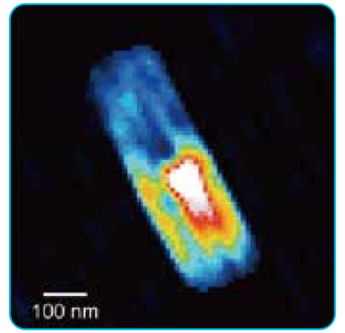
In-vacuum Undulator



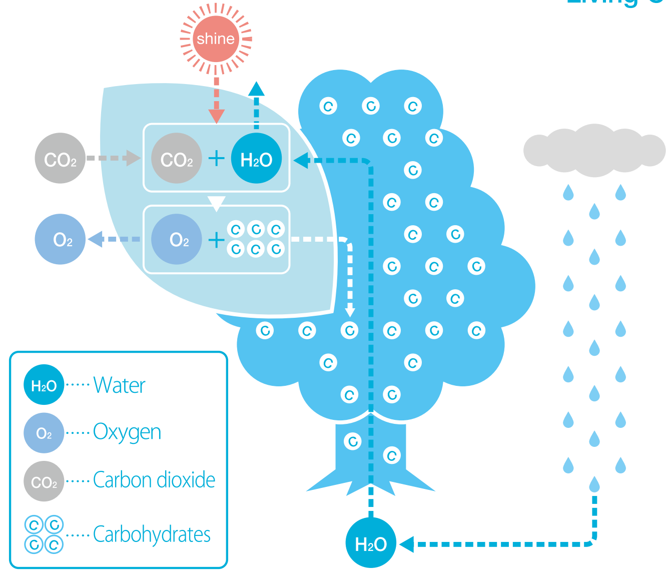
Q11 How can SACLA improve our lives?

A11

SACLA has revealed the mechanisms of photosynthesis in plants. This can potentially lead to artificial photosynthesis, which would help us generate environmentally friendly energy. SACLA has visualized living biological cells, which may contribute to advances in medical research.



Living Cell Image



Photosynthesis is a familiar phenomenon, but its detailed mechanism have been unknown. SACLA has revealed a part of the mystery.