Synchrotron Radiation

Contribution to Advanced Research

What is Synchrotron Radiation?

Synchrotron radiation (SR) is emitted from an electron traveling at almost the speed of light when its path is bent by a magnetic field. As it was first observed in a synchrotron in 1947, it was named "synchrotron radiation".

General Features of Synchrotron Radiation

- Ultra-bright
- Highly directional
- Spectrally continuos(BM/W) or quasi-monochromatic (U)
- Linearly or circularly polarized
- Pulsed with controlled intervals
- Temporally and spatially stable

BM: Bending Magnet
W : Wiggler
U : Undulator

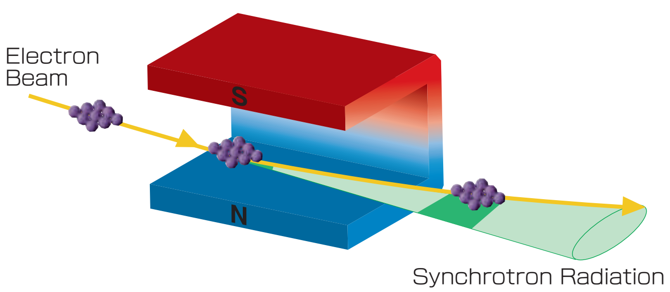
Generation of Synchrotron Radiation

Synchrotron radiation is emitted at a bending magnet or at an insertion device. The insertion device is comprised of rows of magnets with alternating polarity and is installed in a straight section of the electron orbit. Corresponding to the weak and strong magnetic field, there are two types of insertion devices: an undulator and a wiggler.

Bending Magnet ● Stored electrons run on a circular orbit and emit synchrotron radiation with a continuous spectrum when they encounter the bending magnet.

Undulator ● The electron beam undulates with a small deviation angle. As a result, ultra-bright and quasi-monochromatic light is obtained by the interference effect.

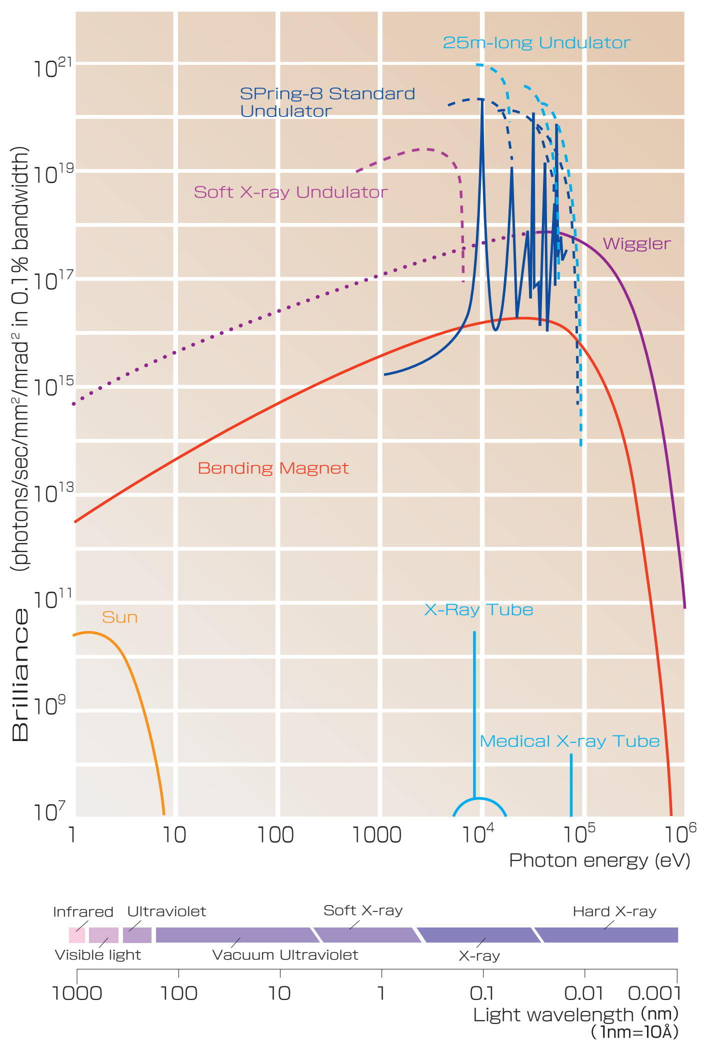
Wiggler ● The electron beam wiggles with a large deviation angle. As a result, bright and spectrally continuous light with short wavelengths is obtained.

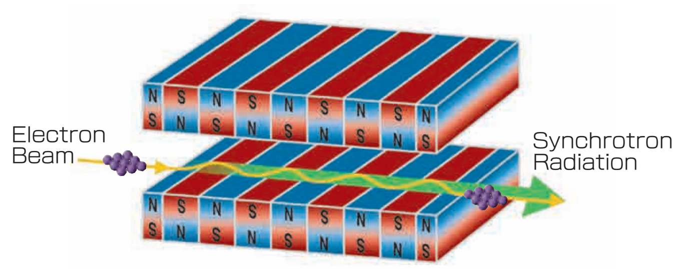


▲Synchrotron radiation produced at a bending magnet

Synchrotron Radiation Spectrum of SPring-8

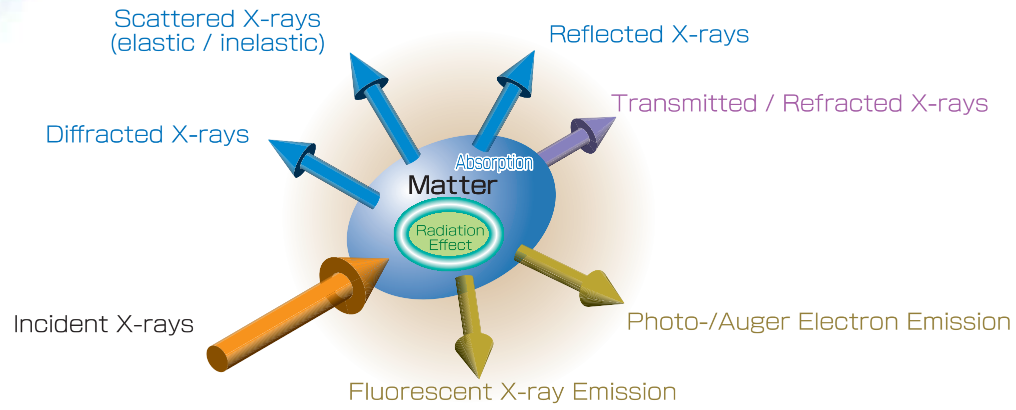
SPring-8 produces light that is about one billion times more brilliant than conventional X-ray sources.





▲Synchrotron radiation produced at an undulator

Interaction of X-rays with Matter



Utilization of the Features of the SR Beam

1) With the use of the microbeam, diffractometry of very small samples and microscopy with high spatial resolution are carried out.
2) Time-resolved experiments are conducted on various time scales using the pulsed beam.
3) Energy tunability of the beam is effectively applied, for example, to crystal structure analysis using anomalous dispersion.
4) By making use of the highly collimated beam, various types of imaging techniques with high spatial resolution are developed.
5) The linearly / circularly polarized beam is used especially for studies on the magnetic properties of materials.
6) The availability of the high energy X-ray beam enables high-Q experiments, Compton scattering, excitation of high-Z atoms and nuclear excitation of isotopes.
7) With the use of the highly coherent beam, X-ray phase optics and X-ray interferometry are studied.

Application of SR to Various Scientific and Technological Fields

Synchrotron radiation is very useful for various fields in both basic and applied research. Synchrotron radiation available in SPring-8 is applied to the following advanced research fields.

Life Science	: Atomic structure analysis of protein macromolecules and elucidation of biological functions. Mechanism of time-dependent biological reactions. Dynamics of muscle contraction.
Materials Science	: Precise electron distribution in novel inorganic crystals. Structural phase transition at high pressure / high or low temperature. Atomic and electronic structure of advanced materials of high Tc superconductors, highly correlated electron systems and magnetic substances. Local atomic structure of amorphous solids, liquids and melts.
Chemical Science	: Dynamic behaviors of catalytic reactions. X-ray photochemical process at surface. Atomic and molecular spectroscopy. Analysis of ultra-trace elements and their chemical states. Archeological studies.
Earth and Planetary Science	: *In situ* X-ray observation of phase transformation of earth materials at high pressure and high temperature. Mechanism of earthquakes. Structure of meteorites and interplanetary dusts.
Environmental Science	: Analysis of toxic heavy atoms contained in bio-materials. Development of novel catalysts for purifying pollutants in exhaust gases. Development of high quality batteries and hydrogen storage alloys.
Industrial Application	: Characterization of microelectronic devices and nanometer-scale quantum devices. Analysis of chemical composition and chemical state of trace elements. X-ray imaging of materials. Residual stress analysis of industrial products. Pharmaceutical drug design.
Medical Application	: Application of high spatial resolution imaging techniques to live animals and pathological samples.
Nuclear Physics	: Quark nuclear physics by GeV photons, astronuclear process and photo nuclear reactions by MeV photons.