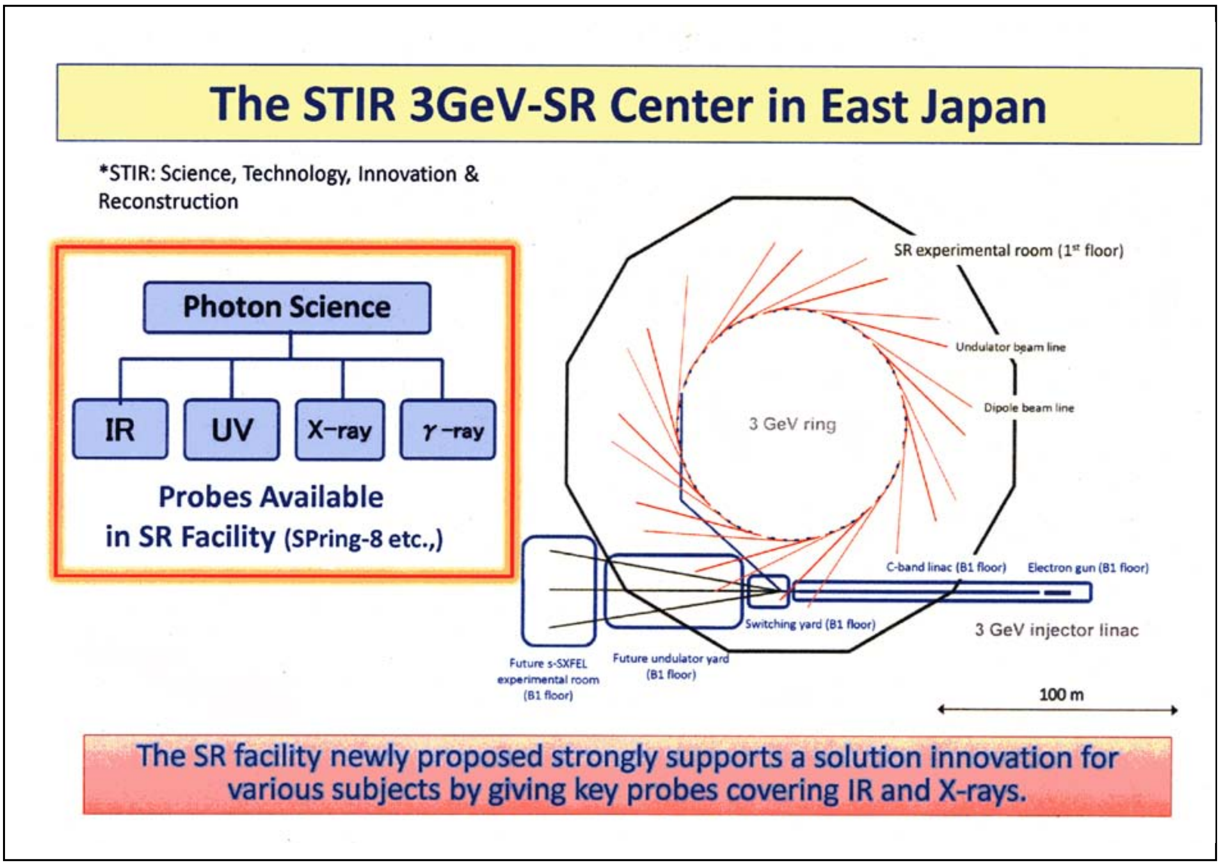
Futuristic medium size (3-GeV) synchrotron radiation facility with high brilliance in East Japan

December 2011

East Japan (Tohoku) synchrotron radiation facility committee (tentative name)

A new plan for a futuristic medium size (3-Gev) synchrotron radiation facility with high brilliance is proposed for carrying us over the East Japan great earthquake and tsunami disasters that happened on 11th March 2011 by providing an excellent advanced tool widely applicable to various disciplines and for samples in a variety of states.



"Proposal for energy-saving innovation support type synchrotron radiation facilities"

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December 2011

East Japan (Tohoku) synchrotron radiation facilities committee (tentative name)

A new plan for a futuristic medium size (3-Gev) synchrotron radiation facility with high brilliance is proposed for carrying us over the East Japan great earthquake and tsunami disasters that happened on 11th March 2011 by providing an excellent advanced tool widely applicable to various disciplines and for samples in a variety of states. The energy-saving innovation support type synchrotron radiation facility presently proposed enable us to strongly promote innovative development of science and technology in the area of East Japan (particularly north eastern Japan, Tohoku) and its surroundings. This is a light source which mainly covers the broad spectral region from X-rays to the vacuum infrared rays. It would be placed in the Science, Technology, Innovation and Reconstruction (STIR) center of East Japan. This futuristic medium size (3-Gev) synchrotron radiation facility and the SPring-8 facility located in western Japan would be complimentary. Such a dual system for Japan in two geographically different locations is considered very important for risk management from both the basic scientific and applied engineering points of view. The new plan will also contribute to enhancing the status of synchrotron radiation research and application in our country, which is in the top world class at the present time.

Introduction

The East Japan great earthquake of 11th March 2011 produced tremendous damage in Tohoku (Northern East) and Northern-Kanto (eastern half of Japan including Tokyo) districts. This disaster unexpectedly revealed that these districts serve as the supply base of valuable high-tech products and many advanced materials not only for Japan but also for the whole world. In other words, these districts have been well-recognized as global COE where there are many excellent factories for supplying high-tech materials such as car components and many institutions for advanced materials science research.

A large number of researchers in East Japan frequently use synchrotron radiation facility, either at the Photon Factory (PF) of High Energy Accelerator

Research Organization at Tsukuba, Ibaraki prefecture in the eastern half of Japan including Tokyo, or the high-intensity synchrotron radiation facility SPring-8 in Nishi-Harima, Hyogo-prefecture in the western part of Japan.

Public is aware that valuable high-tech products and many advanced materials are important for the survival of industries in our country, staying ahead of competition form newly emerging countries, such as BRICS (Brazil, Russia, India and China). In recent years, one of the essential requirements to stay ahead is the ability to design and manufacture valuable high-tech products and advanced materials, leading the world by exact grasp and fine control on the basis of knowledge about the behavior of substances at the atomic level. In other words, in order to keep the leading position of our country as a scientific- and technology-intensive nation in the world, it is indispensable from the nationwide perspective to fully consolidate the infrastructures for solving and controlling the materials behavior at the atomic level as a function of reaction time and then to continuously innovate advantages in fields of the valuable high-tech products and advanced materials.

For this purpose, the synchrotron radiation facilities producing X-rays with short wavelength and high permeability are considered among the best tools. There have recently been growing demands from many technological institutions to use the synchrotron radiation facilities. Applied engineering use is more than 20 % of all work carried out in Spring-8 facilities. In response to such increasing demands, several companies have made investments in installation of their own beam lines. Thus, there is a strong requirement in Japan for a new medium size (3 Gev) synchrotron radiation facility with high brilliance. The demand from the technological institutions and scholars working in basic science has exceeded supply by a wide margin.

The area of East Japan works well as the supply base of valuable high-tech products and many advanced materials, not only for our country but also for the whole world. However, since East Japan is located at relatively long distance from SPring-8 at Harima, some technological institutions in the east find it difficult to use the synchrotron radiation facilities with high brilliance. In near eastern Japan, the synchrotron radiation facilities / Photon Factory: PF(2.5 GeV) and PF-AR(6.5 GeV) are available at the High Energy Accelerator Research Organization (so-called PF/KEK) in Tsukuba. However, 30 years have passed since the facilities of PF(2.5GeV) was completed and operated under the inter-university research collaboration program including education in the relevant fields.

Taken from “Synchrotron Radiation unlocks the secrets of marvelous nano-world” by Japanese Society for Synchrotron Radiation Research, (2011)

Organization, Location	Beam energy	Circumference
Photon Factory, PF (High Energy Accelerator Res. Organization KEKTsukuba, Ibaraki	(PF, 2.5GeV) (PF-AR, 6.5GeV)	187m(PF) 377m(PF-AR)
Institute of Molecular Science Okazaki, Aichi	(750MeV)	53.2m
Chubu SR Center (Under construction) Nagoya, Aichi	(1.2GeV)	72m
Ritsumeikan Univ. SR Center (AURORA) Kusatsu, Shiga	(575MeV)	3.14m
RIKEN Harima Institute (SPring-8) Harima, Hyogo	(8GeV)	1436m
RIKEN Harima Institute (SACLA) Harima, Hyogo	(8GeV)	700m(linac)
Lab. of Advanced Sci. and Tech. for Industry, Univ. of Hyogo(New SUBARU) Akoo, Hyogo	(1.0GeV)	118m
Hiroshima Synchrotron Radiation Center, Hiroshima Univ., (HiSOR) Higashi-hiroshima, Hiroshima	(700MeV)	21.95m
Kyushu SLD Center (SAGA-LS) Tosu, Saga	(1.4GeV)	75.6m

Considering all these points together, it is very important to alleviate the serious inconvenience as quickly as possible by providing new top-level application-orientated synchrotron radiation facility to various technological institutions in East Japan. The facility is expected not only to definitely innovative technology promotion in East Japan, but also strengthen / develop industries for producing valuable high-tech products and advanced materials in the whole of Japan. Thus, we propose the new center in East Japan, where the energy-saving innovation support type synchrotron radiation facilities are installed (hereafter referred to as **STIR 3GeV-SR Center of East Japan**). This will make the Japanese economy better. Of course futuristic medium size (3 Gev) synchrotron radiation facilities with high brilliance also contribute to growing basic science and technology in various fields such as physics, chemistry, biology, life and environmental science.

Synchrotron radiation facilities

Modern trends in science and technology of synchrotron radiation in the world may be summarized as follows;

1. X-rays free electron laser (so-called linear accelerator source) aiming at the achievable resolution limit from the wavelength of the probe X-rays
2. Ring type photon source which can be used many persons simultaneously.

Here, we should rather focus on the ring type photon source. In this category, one of the typical facilities is the large-sized super-high-intensity light source of SPring-8, where many advanced technologies developed in our country have been assembled. A ring type photon source similar to Spring-8 is considered quite useful and valuable in Japan. However, such plan may not be socially accepted, because of its heavy construction costs as well as a long construction time.

For this reason, we propose futuristic medium size (3-Gev) synchrotron radiation facility with high brilliance where both construction and operating costs are reduced by combining the best technologies already developed at the present time. The concepts of “green and full sustainability” are taken into account in the machine design, construction and operation. New developments for the present ring plan are limited to a few necessary points only and this makes the cost of 3-Gev synchrotron radiation facilities minimum and also time for construction is reduced to two or three years from start. In other words, a ring photon source with high brilliance which corresponds to the 60 to 70 percent of SPring-8's performance can be installed at about (1/5)th cost, when combining appropriately the best knowledge, technologies and know-how from high-intensity synchrotron radiation facilities all over the world. In addition to good reduction in construction costs, remarkable reduction in energy consumption and operating costs is feasible by introducing the latest technologies. For example, the operating expenses are predicted to be about 20 percent of the large-sized synchrotron radiation facility currently under operation. This is one of the most important and characteristic features of the plan presently proposed.

Construction and management systems

Critical examinations for the construction system are required. The medium size (3-Gev) synchrotron radiation facilities of the ring-type photon source presently planned combine the best technologies already developed and established in Japan and only a few new developments. In eastern Japan, there are some specialists, whose knowledge and experience in science and technology of the accelerator and related research and development are well-recognized, so that we do not find any significant difficulty for construction when joining these specialists in the effort. Close collaboration with specialists involved in the Spring-8 and High Energy Accelerator Research Organization would be maintained. Moreover, depending on the conditions, an alternative way may be possible. For example, some private companies form a special group association which is responsible for the facility construction may be helpful.

The Japan Synchrotron Radiation Research Institute (JASRI) is known to support operations and users of Spring-8 at Harima. It is thought to be a model of the management system for the present 3-GeV synchrotron radiation facilities. It may be noted that Intelligent Cosmos Research (ICR) Institute at Sendai supports and promotes innovative developments of many organizations in six prefectures located in North-East Japan plus Niigata prefecture, so that one way may be to provide a role for ICR Institute in the management of the new facility.

Construction schedule

As shown in the following table, it takes less than three years to construct the present 3-GeV synchrotron radiation facility from start of the plan and its public use will be available in the 4th year. For example, if X = 2013, we can estimate with sufficient reliability that construction will be ended in 2015 and the public use will start from the 2016 fiscal year.

Year X	Year X + 1 year	Year X + 2 years	Year X + 3 years
Design study	Building Construction Accelerator components construction	Accelerator assembly Beam line construction	Accelerator control Public use will start

Future extensibility

As is well-known, many interesting and valuable results produced by the advanced photon source of Spring-8 or Photon Factory in the High Energy Accelerator Research Organization clearly indicate that the synchrotron radiation makes a great contribution to various subjects by providing answers for unsolved problems when using the conventional apparatus alone. In other words, the present 3-GeV synchrotron radiation facilities with high brilliance is quite likely to keep the top world position for the next 20 years or so, although some continuous modification and improvement would be required to maintain the goal. It is not too much to say that the synchrotron radiation facilities producing X-rays with short wavelength and high permeability are considered one of the best tools for many subjects from both basic science and applied engineering points of view. This is particularly true in “designing and manufacturing the valuable high-tech products and many advanced materials”, because it is possible only when attaining exact grasp and fine control on the basis of knowledge about the behavior of substances at the atomic level.

Although there can be several plans for extension of the proposed 3-GeV synchrotron radiation facility, one is to combine a ring type photon source with X ray free electron laser (called SACLA), as exemplified by Spring-8 case such extension makes the use of X ray free electron laser in the soft X-ray region possible. This may work as a complement to the SACLA of Spring-8.

The present plan in East Japan is also thought to be quite essential from a viewpoint of risk distribution, a lesson that we definitely learned from the huge disaster caused by earthquake and tsunami that happened on 11th March 2011. Because another huge earthquake is predicted with sufficiently high probability in both western and southern parts of the Japanese main island in the near future, distributed facilities may be provide risk reduction for the country as a whole.

Notes: SACLA: Spring-8 Angstrom Compact Free Electron Laser

Conclusion

New medium size (3-Gev) synchrotron radiation facilities with high brilliance have been proposed for creative reconstruction of science and technology in north eastern Japan (so-called Tohoku area) where great earthquake disasters happened on 11th March 2011.

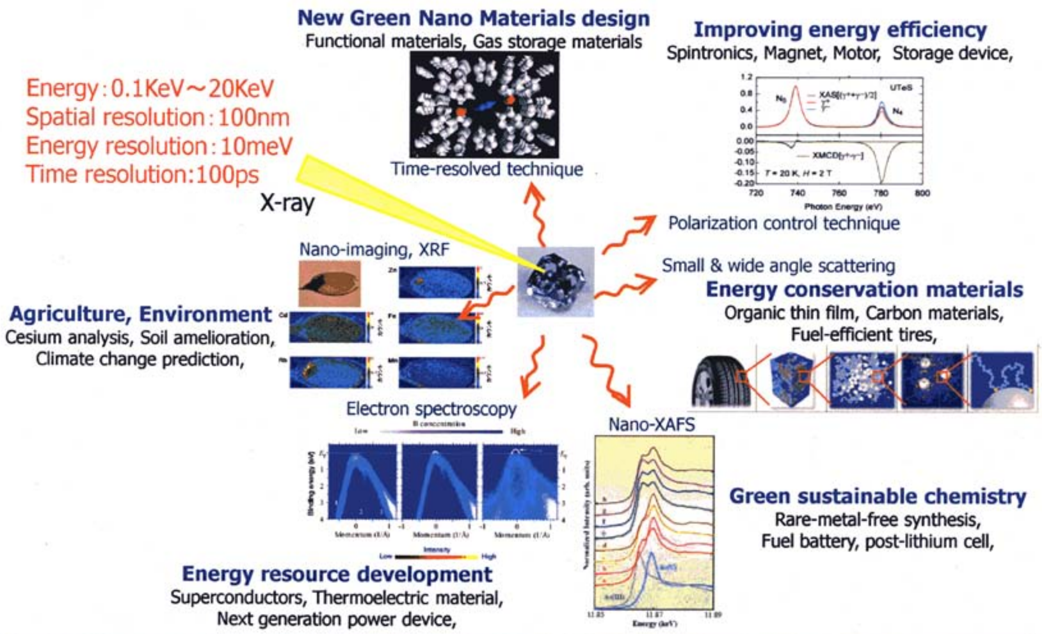
This energy-saving innovation support type synchrotron radiation facility is considered quite useful for both direct and indirect recovery from disasters in north eastern area. In addition, this facility would certainly enable us to support innovative solutions in a variety of areas by providing key probes covering IR and X-rays. Thus the leading position of our country as a scientific- and technology-intensive nation in the world is maintained. Prosperity of Japan will depend cutting edge technology well ahead of Brick countries. For this purpose, we sincerely request the strong support and collaboration from many people working in academia, industries and governmental organizations not only in north eastern area but also in other areas of Japan.

Characteristic Features of the present plan

1) Performances as a photon source of the energy-saving innovation support type synchrotron radiation facility (3-GeV) presently proposed are comparable with those of SPring-8 and KEK/PF. However, its construction costs are about 20% of SPring-8 and the construction period is about three years and the public use will be possible in the 4th year.
2) Center of Excellence at the global standard can be set for supporting strongly innovation in science and technology in north eastern Japan (so-called Tohoku region).
3) It is certainly possible to keep a leading position of our country as the technology-intensive nation in the world by realizing true creative reconstruction from great earthquake disasters in north eastern Japan and its circumferential areas, because these districts are found to serve as the supply base of valuable high-tech products and many advanced materials not only for Japan but also for the whole world.

Green & Life innovation on the basis of the light-element strategy;

Solutions from the STIR-SR 3GeV center



The innovations towards restoration and creation of sustainable society.

Design Concept:

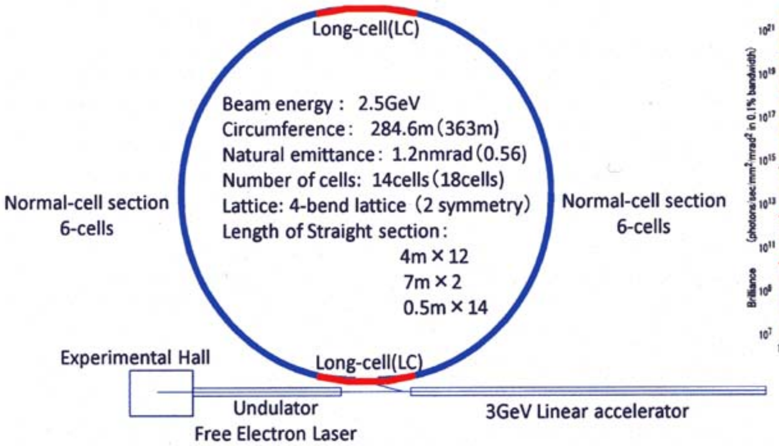
The STIR 3GeV-SR Center in East Japan

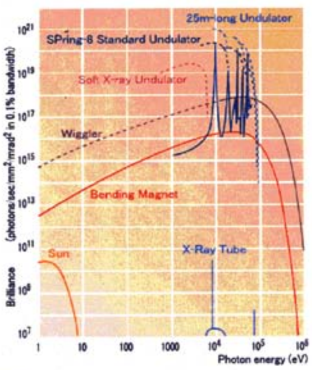
*STIR: Science, Technology, Innovation & Reconstruction

Energy saving design

Power consumption ≈ Expected photovoltaic generation at the STIR center

1.74 MW (SPring-8: 26MW) **1.57MW**





As a solution innovation center for innovative Photon Science, which assembles key probes, IR, X-ray, γ-ray, etc.

Accumulation and utilization of the latest quantum beam technologies;

State-of-the art light source

✓ Energy region indispensable to analyze light-elements (C, N, O Si, P, and S) is covered.
→ Energy range: 0.1～15 keV

✓ Low emittance for handling a nano-beam and fully controlling the polarization by insertion devices.
→ Emittance: 3～5 nmrad

✓ High brilliance for observing a nano-scale structure and function of materials.
→ Brilliance: 10^{20}–10^{21}photons/s/mm^2/mrad^2/0.1%B.W.

✓ Short pulse X-ray beam for real time search of a chemical reaction and phase transition of materials.
→ Pulse width: 100 ps

✓ Highly stable light source for maximizing the performance of nano-focusing system and high resolution X-ray monochromator.
→ Top-up operation

✓ Economical ring design for minimizing the cost of materials development.
→ Energy saving operation to reduce the operation cost

By the comprehensive technologies of Japanese photon science, the STIR-SR 3GeV center can be constructed by a lower cost (～20B¥) and shorter period (～3 years).

Innovative photon science leads green& life innovation

Research Field	Examples of Research object	Research techniques: Diffraction・Scattering	Spectroscopy	Imaging
For the utilization of recyclable energy source				
Alternative energy source	Organic solar cell, Silicon solar cell, Hydrogen storage alloys	XRD	XPS, NEXAFS	3D-ESCA Topography
Biochemical engineering	Biomass-based polymer, Biofuel, Artificial photosynthesis	SAXS, WAXS	NEXAFS Quick-XAFS	Nano-imaging
For improving the energy efficiency				
Energy-saving home appliance	Organic semiconductor, LED, Magnet, Solid oxide fuel cell	XRD SAXS, WAXS	NEXAFS,MCD XPS	Nano-imaging
Energy-saving home and building material	Energy conservation materials, Carbon fiber, Carbonaceous composite	XRD SAXS, WAXS	NEXAFS XPS	Nano-imaging Topography
Energy-saving electronics technology	SiC device, GaN device, Diamond device	XRD	NEXAFS, MCD XPS	3D-ESCA Topography
For cyclic usage of domestic resources				
Novel material developments using ubiquitous elements	Organic catalyst, post-lithium cell Porous materials, Zeolite	XRD SAXS, WAXS	NEXAFS, Quick-XAFS	Nano-imaging
Recycle technology of rare earth metals	Metal Biotechnology, Slag reutilization		XAFS	Element imaging
For safety and security of social environment				
Countermeasure for toxic Substances	Analysis of hazardous elements (asbestos, arsenic, cesium, aerosol), Polymer cement	XRD SAXS, WAXS	XRF, NEXAFS	Element imaging
Monitoring of vegetation and ecosystem change	Soil analysis, Water quality analysis	XRD	NEXAFS	Nano-imaging
Precise prediction of climate change	Air analysis, aerosol, Yellow sand	XRD	NEXAFS	Nano-imaging

East Japan (Tohoku) synchrotron radiation facility committee (tentative name)

[In the order of the Japanese alphabet]

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IMRAM: *Institute of Multidisciplinary Research for Advanced Materials*

RCEPS: *Research Center for Electron Photon Science*

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