A new plan for the Tohoku synchrotron radiation facility:

Synchrotron Light in Tohoku, Japan (SLiT-J): white paper II

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Tohoku synchrotron radiation facility committee (tentative name)
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Based on the contents of the white paper issued on May 7, 2012 and in consonance with the latest trends concerning synchrotron radiation facilities in Japan and the world over, this white paper (II) discusses four aspects of the new plan for a futuristic medium size (3-GeV) synchrotron radiation facility with high brilliance in the north eastern provinces (Tohoku) of Japan, hereafter referred to as "Tohoku synchrotron radiation facility": 1) social demand, 2) scientific and technological validity and usefulness, 3) management of construction and operation of the facility and 4) regional promotion/reconstruction in Tohoku district and its synergetic effects on the Japanese society.

First, some thoughts on the site for construction. The so-called "nano-meter sized beam application" developed by researchers in Japan is considered to be one of the main uses of the proposed advanced synchrotron radiation facility. Thus, the construction-site of Tohoku synchrotron radiation facility should be chosen to minimize vibration, an essential requirement for "nano-meter sized beam application". The Great East Japan Earthquake has revealed strong solid rock formations as well as the weak ones in the north eastern region. Using this information and considering proximity to power supply, connectivity and easy accessibility for traffic, a final decision on the construction-site will be made. The currently available transportation networks such as bullet-train (Shinkansen) and major highways, access to airport, presence of a wide range of manufacturing industries and the issue of risk reduction all seem to point to the Tohoku region as the suitable area for location of the new synchrotron radiation facility.

1) Social Demand

Status of Japan in the world and the strength of Japanese economy and society in the 21st century depend to a large extent on innovation in science, technology and industry. Many cutting-edge technologies are crucially dependent on the development of new multifunctional materials. Development of new critical materials for advanced applications requires information on structure-property relationships at different length scales, most essentially at microscopic level. Required is information on the possible origin, mechanism including reaction intermediates of nano-materials at atomic level. There has been a vast amount of research on new materials as well as better understanding of the physical and chemical properties of these materials, which are known to depend heavily on their structural characterization. For these purposes, various methods have been applied to determine the arrangement of atoms and molecules of subject substances under various conditions, but the accuracy of these results does not appear to be sufficient to allow definite interpretation of the data in some cases. The use of advanced methods, such as magnetic circular dichroism spectroscopy and time-resolved XAFS will bring about significant breakthroughs in difficult areas by permitting the accurate evaluation of the atomic (or molecular) arrangements including the environmental structure around a specific element or the dynamical structure analysis of reaction intermediates in multi-component systems, particularly when coupled with a high intensity white X-ray source such as the synchrotron radiation. This is also true for structural analysis of bio-molecules, proteins and human chromosomes.

The usefulness of "synchrotron radiation facility" has been globally recognized. An advanced light source with extremely high brilliance is very useful for providing appropriate solutions to different problems in wide range of fields; materials physics/chemistry, materials engineering, life and agricultural science, environmental science, innovative drug development, as well as conservation of historic and artistic works and scientific criminal investigation. For these reasons, a number of "synchrotron radiation facilities" were set up quickly around the world. More than 30 facilities with high brilliance are now available and 4 facilities are under construction. In Japan, Photon Factory (2.5 GeV), a second-generation light source, was constructed at KEK/Tsukuba in 1982, High Energy Accelerator Research Organization. In 1997, SPring-8 (8 GeV), a third-generation light source, started to offer researchers opportunities for shared-use of one-of the world’s most powerful synchrotron radiation source at Riken/Harima. In 2011, the Spring-8 Angstrom Compact free electron LAser (SACLA) started the use of X-ray free electron laser (XFEL) in Riken/Harima, although it is a "linear-type light source" and mainly used for pioneering work in optical science. These facilities challenged us to produce many new technological developments in accelerator engineering and also make possible a wide range of unique experiments. As the result, a user community (SPRUC) of about 14,000 members has been formed at SPring-8. Compared to a total of about 2000 persons who joined together to from the Japanese Society for Synchrotron Radiation Research in 1988, the recent increase in the size of the synchrotron user community is remarkable. Considering many potential users of synchrotron radiation facilities in industries, this growth rate is likely to continue for the next 20 to 30 years.

Many core subjects of research and development carried out by various institutions located in the Tohoku district are related to key technologies. Fundamental understanding of crucial issues is extremely important for the survival of industries in our country, staying ahead of competition from newly emerging countries. It is important from the view point of technological strategy of our country. Since many researchers in universities and public research institutions of the Tohoku region are recognized as international leaders in their respective fields, they can provide leadership and contribute significantly to reconstruction and innovation of science and technology. This is particularly true when considering the recovery from the last Great East Japan Earthquake and Tsunami disaster which occurred on 11th March 2011. In addition, such issues include an emergency subject–decontamination of the environment around the Fukushima Daiichi Nuclear Power Plant. Exact and precise information on radioactive contamination is required. For very small samples, it is difficult to determine contamination using conventional detectors. It is to be kept in mind that there are still about 240,000 disaster evacuees in the large area of Fukushima prefectures, a shattering reality.

Tohoku district, which is known to be a national leading area for agriculture, forestry and fisheries, also requires change by accelerating innovative developments, not only for the engineering products but also for agricultural products and plants. For this purpose, some challenging research projects should be done by using advanced methods coupled with a fundamental scientific base. For example, "development of a new diagnostic method for agricultural products/plants using a very dilute element as an indicator", "development of quantitative description of food texture and its application for further upgrading agricultural/plant products" and "development of vegetable oil for lowering cholesterol" are important challenges. Such demanding projects and their results will certainly contribute to strengthening the Tohoku district by giving possible solutions for several global economic conditions such as TPP (Trans Pacific Partnership) and price competition of agricultural products/plants and fisheries products.

In order to keep the leading position of our country in the world as a science- and technology-intensive nation, it is indispensable from a 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 valuable high-tech products and advanced materials. For this purpose, the ring-type synchrotron radiation facility producing X-rays with high brilliance is well recognized as one of the best tools. There have recently been growing demands from many technological institutions to use the synchrotron radiation facilities.

When a futuristic medium size (3-GeV) ring-type synchrotron radiation facility with high brilliance is constructed in the Tohoku region, a wide range of research subjects can be definitely covered by using various advanced tools for analyzing samples in a variety of states. It can also be anticipated that there will be an economic impact from a rise in local production and local consumption. The proposed facility also contributes to disaster risk diversification of the research infrastructure in our country, which is a lesson learned from the great earthquake of 11 March 2011. Fundamental and important research infrastructures should be disbursed in both east and west regions of our country.

2) Scientific and Technical Validity and Usefulness

As mentioned above, Photon Factory (2.5 GeV) at KEK/Tsukuba and SPring-8 (8 GeV) at Riken/Harima have been the driving force behind science and the related technology in the synchrotron radiation source worldwide, in parallel with leading materials science and life science in Japan. Nevertheless, a new synchrotron radiation facility with high brilliance is strongly required for better understanding of complicated subjects and materials using further advanced methods with high-intensity nano-meter sized beam. The need for the proposed facility is also based on two main reasons: (1) The present emittance-performance of PF does not produce high flux soft X-rays, (2) SPring-8 originally designed for a higher energy ring covers the soft X-ray region with insufficient flux density. Thus, our experimental capability in the soft X-ray region (1-10 keV, particularly the energy less than 5 keV) of synchrotron radiation source falls far behind those in other industrially advanced countries. The nano-meter sized beam application in the soft X-ray region is known to be indispensable for innovation or promotion of research related to light elements, such as carbon and oxygen. It appears that some Japanese companies are trying to do their research/development projects at foreign synchrotron radiation facilities indicating that our competence in this area may be falling behind international standards. Extensive discussion about construction and utilization of "a medium size (3-GeV) synchrotron radiation facility with high brilliance” has not been held in our country for almost 15 years. The present new plan for the Tohoku synchrotron radiation facility certainly offers a means to sidestep such limitations in one stroke.

It is well known that many medium size (3-GeV) synchrotron radiation facilities, especially the ring-type light source, were set up in the 2000s throughout the world. They include SLS of Switzerland, SOLEIL of France, DIAMOND of UK, AS (referred to also as VICTORIA) of Australia, SSRF of Shanghai, China, and ALBA of Spain, most of which are now functional. Furthermore, medium size ring-type synchrotron radiation sources with high brilliance, such as TPS of Taiwan, NSLS-II of USA and MAX-IV of Sweden have been planned one after the other and construction has commenced. Such international activities clearly indicate the importance and the necessity of "medium size (3-GeV) synchrotron radiation facility” as an advanced fundamental tool. Only such facility can provide the nano-meter sized beam with high brilliance, so that innovation in a wide range of areas such as biotechnology, materials, electronics, energy and security/safety can take place. The synchrotron radiation facility is no longer regarded as a tool only for scientific use.

The "ring-type light source" proposed in this plan can find solutions to challenging problems of research and development for various purposes by supplying opportunities to address many fundamental and essential requirements at once. Such "diversity and simultaneity” of utilization and application of synchrotron radiation facility is considered an essential feature of the advanced light source presently proposed. The ring-type advanced light source is certainly suitable for recovery from the earthquake disaster in the Tohoku region, as well as for supporting innovation in various industries in the whole of Japan within a reasonable time.

The present proposal for "ring-type synchrotron radiation facility" in north eastern Japan (Tohoku) may be viewed in the light of the fact that even SPring-8 will give up its position of highest brilliance in Asia to TPS of Taiwan when the new light source is completed in 2014. Of course, there is a possibility of recovery in part from such a situation by upgrading SPring-8 or following the ERL plan of Photon Factory at Tuskuba, from a relatively long term perspective. However, at least in the next 5 to 10 years, our country is likely to play second fiddle to the ring-type synchrotron radiation facilities in the world. For this reason, there is urgent need to promote the present plan as soon as possible. It is particularly true from the viewpoint of international competition in science and technology of the ring-type synchrotron radiation facility.

From a technological viewpoint, the present plan will certainly catch up with the light source performance of the medium size ring-type synchrotron radiation facilities available in the world, within a short construction period of about two years by effectively using the latest technologies such as C band accelerator and a vacuum sealing undulator originally developed by SPring-8/SACLA. The usefulness and validity of such original technologies developed in our country have been fully confirmed by the recent excellent results of SPring-8 and SACLA in relation to accelerator science and X-ray optics, and their application to new research subjects in various fields.

3) Management for Construction and Operation of the new Facility (SLiT-J)

The construction of this facility is expected to cost about 30 billion yen. This includes the cost of the main machine consisting of injection and storage ring and their buildings (23.5 billion yen), beam lines set-up initially (4 billion yen) and solar panel/battery system (2.5 billion yen). About 30 beam lines will be available and thus 30 or more research and development domains can be covered. Assuming 5000-hours of operation in a year, a total of 2000 to 3000 research projects can possibly be carried out and it is expected to contribute to research and development not only of Tohoku district, but also of the whole country. So this plan may be considered as a very efficient investment. Only the advanced synchrotron radiation facility herein proposed can provide the nano-meter sized beam with high brilliance, so that one can realize innovation in a wide range of areas, such as materials production technology, biotechnology, and energy and environmental technology. It is thought that the actual working group for construction should be formed by specialists from entire Japan, using human resources in north-eastern provinces of Japan.

The proposed facilities with low operation cost will be planned following a rigorous energy-saving design. For example, the solar panel/battery system included in the initial investment covers 80% of an electric power cost (about 500 million yen per year) during the period of life-time of solar panel (about 20-25 years). Nevertheless, it is thought that about 1 to

1.5 billion yen per year for operational expenses will be further needed for maintenance and subsequent upgradation. Although there are several ways of meeting the operational expenses after construction, the minimum expenditure should be continuously provided. Such resources will be ensured before starting construction of the proposed advanced light source. Since this plan basically supports science and technology in our country, such support is of strategic importance.

For the management system, various possibilities can be examined besides the public-use promoting method presently used. For example, the management can be entrusted to a technical research association composed of representatives from industrial, administrative and academic sectors. The investment responsibility, the results and intellectual property obtained are defined by legal contract. With respect to the governmental contribution, it is desirable that both Ministry of Education, Culture, Sports, Science and Technology and Ministry of Economy, Trade and Industry take part in the management to build a smart system for strongly supporting the cooperation between industrial side and the academic side, for example through the organizations such as NEDO (New Energy and Industrial Technology Development Organization) and JST (Japan Science and Technology Agency). Such involvement is based on the notion that the nation has properties and operational expenses, users take part in management and utilization, and the application of advanced synchrotron radiation facility to various industrial subjects result in solutions that will benefit the economy. This is one of the main targets of the present plan. Such arrangement is believed to be effective for promoting innovation in industries by making it possible to put forward new applications of advanced synchrotron radiation facility to various industrial subjects through good industry-university cooperation. This concept differs somewhat from the management system of PF and SPring-8, where the viewpoint of the academic side is preferentially taken into account.

For this purpose, the supporting system should be designed for non-academic personnel, in order to facilitate the use of this cutting-edge tool - synchrotron radiation - for various industrial applications. For example, the "synchrotron radiation user bank (tentative name)" can be organized with the help of professors and researchers of the seven National University Corporations, public research institutes and research centers located in the Tohoku district. The plan will catalyze cooperation between industry and academia. The joint use of the synchrotron radiation facility makes "close cooperation of basic science and industrial application" possible. It will also contribute to "the expansion and development of the synchrotron radiation community" nationwide. Professional persons also want to help and support non-specialists who wish to use synchrotron radiation for the first time in their own field. The plan will include a positive introduction as well as adaptation and synchronization of nano-meter sized beam applications of the proposed advanced light source to various subjects, starting from the time of construction.

The new synchrotron radiation facility (SLiT-J) should be as user-friendly and society-accountable as possible. Five beam lines, equivalent to about 20% of the total beam lines, will be reserved exclusively for various industrial subjects resulting in solutions that will benefit the economy of our country. In this restricted use for industrial applications, the beam charge for the dedicated lines is requested and the management will be by a private company. For academic research passing a fair peer review, the beam charge is not requested; the expenses for travel, consumables, etc., shall be paid by users. For users who desire immediate use, a "priority-use system" can be introduced with an appropriate charge. However, it is also important to keep the supporting system for assisting the users who have original ideas and attractive and innovative proposals, but have financial difficulty.

In conclusion, it is very important to make the advanced synchrotron radiation facility (SLiT-J) user-friendly and accountable to the user community by incorporating management know-how and best-practices being deployed in the different synchrotron radiation facilities currently operating around the world.

4) Regional Promotion/Reconstruction in Tohoku District and Synergistic Effects on the Japanese Society

The present plan is based on discussions on regional promotion and reconstruction by a number of academic staff of seven national universities in the north eastern provinces (Tohoku) of Japan. Influenced by the traditions of Professor Kotaro Honda of Tohoku Imperial University, who is remembered as the "founder of the strategic researches in materials engineering", and in response to the current and futuristic needs of the "manufacturing industry", especially those related to magnetic materials, green materials, etc., the creation a futuristic medium size (3-GeV) synchrotron radiation facility with high brilliance for research and development of industrial subjects evolved naturally as the central theme. It is worth mentioning that the usefulness of the use of such cutting-edge tool has been verified/demonstrated by the results from SPring-8/Harima and PF/Tsukuba.

As already stated, the north eastern (Tohoku) district is known to be a national leading area for agriculture, forestry and fisheries. For example, one-fourth of the agricultural production of rice, fruits, etc. in our country comes from the six prefectures of the Tohoku region. Thus, both regional and nation perspectives demand innovative developments, not only for the engineering products but also for agricultural and forest products and fisheries as well. For this purpose, some challenging research projects should be done using the futuristic medium size (3-GeV) synchrotron radiation facility with high brilliance coupled with fundamental scientific disciplines. Some typical examples of projects for consideration are "development of a new diagnostic method for agricultural products/plants using a certain dilute element as an indicator", "quantitative analysis for distribution of the very small amounts of metallic elements in genetically-modified corn, soybean with low phytin and its application for further upgradation of the products for health industry", and "development of vegetable oil for lowering cholesterol". Such challenging missions and their results will certainly strengthen Tohoku district by providing solutions for several global economic challenges such as TPP (Trans Pacific Partnership), price competition of agricultural products/plants and fisheries products.

Simultaneously, "much effort should be done for obtaining the exact environmental measure against radioactive contamination arising from the Fukushima Nuclear Power Plant catastrophe and development of new technology for an emergency subject–decontamination of the environment”. For such important purposes, the use of a medium size (3-GeV) synchrotron radiation facility with high brilliance is believed to be one of the better solutions to overcome the present difficulties by fully maintaining leadership in research and development of safe and secure avenues, leading to quick recovery of international credit. This corresponds to one of the campaign phrases of our plan; **"solutions for subject-problems in the Tohoku district enable us to provide some effective ways or means for solving subject-problems which will face our country in the future".**

One of the main aims of this plan covers the experimental condition for the soft X-ray region (1-10 keV, particularly the energy less than 5 keV) of synchrotron radiation with high brilliance. This is suitable for innovation or promotion of research related to light elements, such as carbon and oxygen. Since, SPring-8 originally designed for a higher energy ring covers the hard X-ray region with sufficiently high flux density, synergetic effect of the use of synchrotron radiation source is certainly obtained by covering any energy region with high brilliance using these two ring-type synchrotron radiation facilities in our country. This plan is also to strongly promote wide range of innovative ideas on the use of "high-intensity nano-meter sized beam" or "short pulse duration" to industrial applications. This is realized with the help of professors and researchers of seven National University Corporations and public research organizations, located in the north eastern provinces of Japan. A new "Tohoku STIR base" (STIR: Science, Technology, Innovation and Reconstruction) will be established that will create a stream of good cooperation between industry, government and university.

(Notes: STIR:Science, Technology, Innovation and Reconstruction)

As already mentioned, for keeping the leading position of our country in the world as a technology-intensive nation, it is indispensable from a nationwide perspective to fully consolidate the infrastructures for understanding and controlling materials behavior at the atomic level as a function of reaction time and then to continuously innovate and engineer valuable high-tech products and advanced materials. The advanced synchrotron radiation facility with high brilliance is well recognized as an excellent tool. Recently there has been a growing demand from many technological institutions to use the synchrotron radiation facilities. For this reason, the present plan can help and support such requirements in the whole country. This also efficiently contributes to the short-term plan for recovery from the Great East Japan Earthquake that took place on 11 March 2011.

The medium size (3-GeV) synchrotron radiation facility with high brilliance herein proposed certainly provides for high productivity in the future, even if the international energy-resources situation changes, because the new facilities with low operation cost will be planned by adopting an integrated energy-saving design using regionally produced electricity from a mega-solar photovoltaic generation system. The proposed plan is likely to become a model for STIR base organizations of the future.

The ripple effects of the plan are not limited to the Tohoku region. As already mentioned, 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 from other countries, such as South Korea, Taiwan 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 based on knowledge about the behavior of substances at the atomic level. Thus, the joint use of the synchrotron radiation facility makes "close cooperation of basic science and industrial application" possible. In addition, such synergistic effects are not limited to substances/materials, but has the potential of producing new innovation in a wide range of fields, such as life science, biotechnology, and environmental science and engineering. In other words, the ring-type synchrotron radiation facility with high brilliance proposed here can provide many opportunities and meet many needs concurrently. "Diversity and simultaneity of utilization" will be the main characteristics, providing solutions to research and development, so that the ripple effects can engulf the entire society.

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