An International Evaluation of The SLiT-J Project

Tohoku University July, 2016

Report of the SLiT-J International Review Committee

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I. Comment on the general scientific/technical merits of the design for the proposed facility as well as the proposed budget and time-frame for completing the project.

The conceptual design of the SLiT-J facility that was presented fulfills the needs for a world class medium energy storage ring. Powerful x-rays with high brightness are increasingly becoming available from storage ring sources because of recent technical advances in modeling, design, and construction of such sources, with the specific enabling technology of "multibend achromat" magnets for storage rings. Globally, it has been relatively recently recognized that new sources based on this technology will revolutionize the ability to examine materials and devices - with nanometer resolution, chemical specificity, and dynamic time resolution - that will provide unprecedented analytical capability to industry and academic researchers. It meets the needs for the unique vision for industrial use of synchrotron radiation as a partnership with academia.

A primary focus of SLiT-J is the industry-academia partnership which is unique worldwide. To meet the exacting demands of industry for availability a storage ring design needs to be robust to insure reliable operation. The SLiT-J design is indeed robust, meeting the demanding needs of industry for reliable operation.

There are compelling reasons to build a new synchrotron x-ray light source in Japan for science and technology, now. These reasons include emerging needs:

- to look deep inside functional materials, to understand and increase the capabilities of modern devices;
- to have higher spatial imaging resolution down to the nanoscale, where material properties and catalytic, bio-chemical, and photo-chemical reactions are determined;
- to have wavelength precision for chemical resolution, in order to identify the relevant atomic and molecular constituents of inherently heterogeneous materials as they function;
- to have the bright beams that can be used to probe *in-situ* and *in-operando* devices, under real-world conditions of temperature and pressure, using gas, liquid, and solid interfaces and also under electric and magnetic fields and for chemical reactions at ambient pressure.

The design approach and performance addresses these questions for the Japanese scientific community specifically in the soft x-ray spectral range with specifications beyond any existing synchrotron source in Japan.
The proposal for the SLiT-J facility has been developed with advanced technical capabilities in mind, and very importantly, with operational modes envisioned that will

make it particularly enabling to industry through university partners. For example, the new concept of using the TM_{020} mode for the RF frees an additional straight section for an undulator source.

The scope, described above, providing a 16 cell double-double bend achromatic lattice with 14 long straight sections and 16 short straight sections for undulator sources has the capacity to meet the present and expected future needs of the Japanese community in this spectral region for the next twenty plus years.

The proposed schedule for completion, 3 years, is perhaps optimistic but is fully consistent with the needs of industry. Only after a technical design report is available can the plan be fully evaluated.

The proposed three year construction schedule and this scope are the basis for the budget estimate which takes advantage of recent budget estimates from SPring-8 for their development of a near diffraction limited storage ring concept. The budget is also consistent with the costing of the recently completed NSLS-II 3 GeV storage ring in the United States. The costs are further verified against a similar comparison with the Japanese free electron laser, SACLA, and the US free electron laser LCLS.

II. Comment on the potential benefits of having a 3GeV synchrotron light source of the SLiT-J kind in Japan, including the impact on the industrial and public sector

An important fundamental design feature of a synchrotron light source is selection of the electron beam energy of the storage ring. Globally, the range of modern rings is moving to a range of 2 GeV to 6 GeV. The photon energies from such sources are optimized from softer to harder x-rays, with peak performance depending on the square of the electron energy. With the selection of 3 GeV, SLiT-J will have optimal performance in the intermediate, or so-called “tender x-ray regime,” extending mainly in the region between very soft x-rays and very hard x-rays (with the latter exemplified by the performance of the SPring-8 synchrotron, which is changing to 6 GeV energy). This spectral range covers the K edges of the light element, the 'top ten' abundant elements, including for example Li as well as C, N, and O. Further the 3d, 4d and 4f metals have important edges in this energy range.

SLiT –J will thus be a globally-competitive source, especially for soft x-ray applications, that broadly serves users, and complements both the performance of SPring-8 and the larger network of existing synchrotron sources in Japan that have complementary capabilities. It will provide particular opportunities in the exploration of materials and systems where lighter elements play a key role, from healthcare and agriculture, to organic functional materials and batteries.

The “phase space” of design parameters for a synchrotron, which all come together in a final design, is large, and optimization is a complex procedure that must take into account the interdependence of technical parameters, together with cost, schedule, and other practical considerations. SLiT-J has been designed with heavy emphasis on serving user needs, utilizing the anticipated techniques of spectroscopy (absorption, photoemission, and resonant emission), scattering, and diffraction, combined with nanoscale microscopy and imaging.

Key novel properties of SLiT-J include increased beam brightness allowing smaller focused spots for probing samples and higher coherent flux for enabling novel imaging capabilities that extend to the fundamental limit of the wavelength of the x-rays, that is *'single nanometer spatial resolution'* . The potential is there to allow researchers to make real-time movies of dynamic processes. For example, the time it takes to do an experiment, or the number of experiments you can do in a finite time, or the time resolution of the movie you can make when watching a chemical process, all depend on the number of photons delivered to an experiment; some more advanced techniques such as photon correlation spectroscopy, depend on the square of the number of photons. In either case, advanced science and modern technologies will require the highest brightness and/or coherent beams.

III. Comment on the estimated running costs and the timeliness for construction of the facility.

There is worldwide experience that relates running costs to construction costs for facilities of this type and complexity, typically 10-15 % of the construction. Thus the proposed running costs are consistent with this and seem reasonable at this stage of the development of the proposed facility.

The project concept focuses on minimizing the running costs. For example, the choice of a LINAC as an injector, although higher in initial costs, will reduce operating expenses for the electrical consumption and is predicted to have a 5 year time for return on investment.

One cannot overemphasize the timeliness of the project. The SLiT-J performance in the tender x-Ray regime is unmatched in Japan and is at the level of the most modern 3 GeV storage rings worldwide. The soft x-ray spectral range is crucial for addressing problems directly affecting society through both basic research underlying technology and the developments of industry in partnership with academia. Any delay in the start of construction will only mean delay in delivery of the tools for industrial development taking full advantage of the unique partnership model which forms the basis of SLiT-J.

IV. Evaluate, from an international viewpoint, the scientific and technological value of the project for development of interdisciplinary research and industry-academia collaboration.

The approach of cooperation between industry and academia demonstrated at SPring-8 with the consortium for polymer science has yielded dramatic successes and is unique worldwide. The unique approach creates a basis for the cooperation amongst industries on common problems, as well as the opportunity to work independently as the R&D comes closer to market potential. The SLiT-J project brings this approach to a new level and will establish a new paradigm for effective engagement of synchrotron facilities in general with industry. The proposed facility will have a broad range of these consortia and also will have the facility construction funded jointly by government and industry.

The combination of 'automated' experimental hutches and innovation bench hutches on each beam line will provide the complete range of access needs of individual scientists and engineers, industrial-academic partnerships, as well as enabling unique R&D opportunities for future developments.

V. General Observations

Critical to the success of SLiT-J will be ease of user access from the Tokyo Bay Area and major international airports. Travel times door to door of less than 3 hours will permit one day access for experiment. Also important is the location of SLiT-J in close proximity to a world class university that will significantly enhance the entrepreneurial development that is a basis of the industry-academic partnerships, as well as the overall intellectual environment. The concept for the development of a platform for the synchrotron radiation facilities distributed across Japan has the potential to maximize the productivity of the sources and access for users.

The approach to the realization of SLiT-J as a partnership in use and funding between industry and government is both innovative and may point the way to developing other large facilities.

Not only does the LINAC reduce operating costs but it has the potential in the future to serve as a driver for a low repetition rate soft x-ray free electron laser.

Early and significant engagement of industry in planning for SLiT-J beam lines and operations will insure responsiveness to emerging user needs. Particular attention to space needs is important to make the 'innovation bench concept' a success. Explicitly informing companies of opportunities enabled by SLiT-J that they cannot now do at existing synchrotron facilities (including technical capabilities, skilled beamline scientists, and beamline access modes) will be important to secure their commitments.

It is important to have large enough space around beamlines to accommodate multiple, large endstations that are of interest to industry, for the highest resolution instruments, for expediting changes in users, and for materials preparation on site.

As the proposed SLiT-J facility moves from concept to detailed technical design, we encourage further exploration of alternative technologies – For example for insertion devices (CPMUs, superconducting undulators) as well as the state-of-the-art in x-ray optics, an area Japan is world leading in.

SLiT-J, with state-of-the-art detectors will generate large volumes of data. Encouragement is given to plan to meet the increasing challenges both of ‘big data’ and real-time analysis for increasingly large or complex data sets.

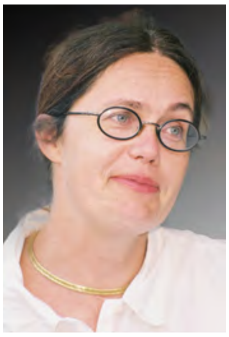
The open competition for end station concepts is supported. In the solicitation for the open competition for end station concepts to circulate a clear statement of the selection criteria To be successful it will be important that a significant proportion of the potential user community participates in this open competition, perhaps through active encouragement of key companies or sectors, ensuring that the full range of potential beamlines is represented. In addition it would be helpful to have curves of (1) total flux per BW (band width) and (2) coherent flux per BW, as function of photon energy.

As has been pointed out, no one technique can address all aspects of a specific problem. While SLiT-J in its basic concept makes available multiple x-ray techniques through the concept of the innovation bench, it would be good to coordinate the SLiT-J proposal to make available of local related technical capabilities (e.g., electron microscopies, materials preparation and characterization capabilities, lasers, computational capabilities, etc.).

Availability and reliability of the facility are critical to industrial utilization. The proposed 6000 hours of reliable operation without significant and extended shutdowns is a very desirable goal.

In the solicitation for the open competition for end station concepts to circulate a clear statement of the selection criteria.

International Review Committee



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IMRAM: Institute of Multidisciplinary Research for Advanced Materials
ELPH: Research Center for Electron Photon Science

INTERNATIONAL REVIEW MEETING

21st-23rd June 2016

PROGRAM

JUNE 21st (TUE)

18:00 – 20:00 **Welcome Reception**

Attendees: International Review Committee Members
Sadayoshi Ito
Hideo Shindo
Atsushi Muramatsu
Hiroyuki Hama
Masaki Takata

JUNE 22nd (WED)

Attendees: International Review Committee Members
Masaki Takata
Hiroyuki Hama
Hideo Shindo

9:00 –18:00 **International Review of SLiT-J Project**

9:00 - 9:15 *"Introduction"* Masaki Takata

9:15 - 10:15 *"Expected performance of SLiT-J, - at a glance –"* Hiroyuki Hama

10:15 - 10:30 *Coffee Break*

10:30 - 11:30 *"SLiT-J Strategic Plan - Vision, Strategy and Approach -"* Masaki Takata

11:30 - 12:30 *Discussion with presenters*

12:30 - 13:30 *Lunch Meeting*

14:00 - 16:00 *Closed Discussion with the presenters*

16:00 - 18:00 *Closed Discussion for Review Report*

19:00 - 21:00 **Dinner Session**

Attendees: International Review Committee Members
Susumu Satomi
Sadayoshi Ito
Hideo Shindo
Atsushi Muramatsu
Hiroyuki Hama
Masaki Takata

JUNE 23rd (THU)

9:00 - 12:00 *Closed Discussion (Review Committee Members only)*

Persons in Charge: Hideo Shindo
Atsushi Muramatsu
Hiroyuki Hama
Masaki Takata

12:00 - 13:00 *Report from the Chair of International Review Committee*
Jerome Hastings

Attendees: International Review Committee Members
Susumu Satomi
Sadayoshi Ito
Hideo Shindo
Atsushi Muramatsu
Hiroyuki Hama
Masaki Takata

13:10 - 14:00 *Lunch Meeting*

Attendees: International Review Committee Members
Atsushi Muramatsu
Sadayoshi Ito
Hideo Shindo
Hiroyuki Hama
Masaki Takata

14:00 **Adjourn**

Meeting Scene