High Energy Accelerator Research Organization (KEK)
Institute of Materials Structure Science (IMSS)
Photon Factory

Photon Factory Review - 2006

Report of the Review Committee

March 13-15, 2006

Introduction, Committee Process and Report Organization

A panel of scientists was charged by the Institute of Materials Structure Science (IMSS) of the Inter-University Research Institute Corporation High Energy Accelerator Research Organization at KEK with carrying out an external, independent review of the Photon Factory (PF). The Review Committee consisted of 10 members. The Committee was provided extensive written information, including a list of questions to be specifically considered and documents related to the operation and science program of PF, in advance of the review meeting that was held in Tsukuba, Japan at the Photon Factory on March 13-15, 2006. The Committee heard a series of technical and scientific presentations and was given a tour of the PF facility. Opportunities were provided to meet users, staff scientists and hear from a representative of the users' organization. Following questions and discussion, the Review Committee met in executive session and formulated its observations, conclusions and recommendations. The Review Committee reached unanimous agreement on the material presented in the closeout to the management of the IMSS and PF held on Wednesday morning, March 15.

This written report summarizes the findings and recommendations of the Review Committee. Included in the Executive Summary immediately below are the summary recommendations on the 6 specific questions. The report that follows the Executive Summary follows the same topical order and elaborates on the observations and recommendations made in the Executive Summary in Sections 1 through 6 with several general points discussed in Section 7. The Appendix contains *i)* a list of the members of the Review Committee; *ii)* the list of questions posed by the PF management for specific consideration by the Review Committee; and *iii)* the Agenda of the Review Committee meeting.

Executive Summary

Following are the observations, conclusions and recommendations of the Review Committee as unanimously agreed upon and presented at the closeout to the management of IMSS and PF on March 15, 2006.

1. The 2.5 GeV and 6.5 GeV Storage Rings

- Committee observes great success in the incremental upgrade program of the PF 2.5 GeV ring. This upgrade makes PF fully competitive with other intermediate energy 3rd generation light sources in the world in many research fields.
- The reliability, delivered user hours, number of users, and number of new projects per year of the PF 2.5 GeV ring are comparable to the best of its class in the world.
- Continuous upgrades of the PF accelerator are important and the next major element – the introduction of "top up" operation – is viewed as being very important for lower emittance operation and improved optics stability for PF beam lines.
- The exceptionally strong performance and success of the operation and upgrades results from a fully integrated light source (accelerator) division and this strength and close coupling should be maintained.

- PF has demonstrated excellent research utilizing a wide range of photon energies – from VUV to hard x-rays. There are excellent examples of technical developments, including the insertion device development program at PF.
- While the Committee acknowledges the quality of science done at the PF-AR, including structural biology and the international interest in new possibilities in time-resolved experiments, we urge the PF management to consider of the value of further expanding this investment ***relative to*** developing new ID beam lines on the 2.5 GeV ring, allocation of resources to the ERL prototype development and in the broader context of SR facilities in Japan.

2. Beam Lines on the 2.5 GeV Ring

- PF has ~59 beam lines, a number of which are high quality. The ring upgrade offers valuable straight section space for five more ID beam lines.
- There are too few scientists supporting too many beam lines. The number of beam lines needs to be reduced but against the background of a well-conceived strategic plan that focuses on a relatively small number of carefully selected areas of excellence.
- The Committee suggests that a reasonable number of beam lines for a facility of the scale and scope of the PF might be around 30-40 and there could be around 5-10 selected areas of excellence. The structural biology model has proven to be a very successful and exemplary approach.
- The Committee strongly encourages the new PF Director to move swiftly to develop a new strategic plan and begin its implementation in full consultation with the affected parties.

3. Users' Experimental Programs, Scientific Activities

- The Committee found that the overall quality of science presented was very high and comparable with the best in the world – examples included structural biology, materials science with soft x-rays, spectroscopy and scattering studies of strongly correlated materials, investigation of systems under extreme conditions, development of new imaging techniques.
- There is a wide variation in quality and productivity of the beam lines. A selected reduction in the number of beam lines will lead to an even higher level of excellence for general user proposals. The average productivity per beam line will be enhanced as well.
- The Committee would recommend, as a part of the strategic plan for evolving the beam lines, that a careful analysis be made of the scientific output and quality (for example, publications in high impact journals and citations).

4. Role of Photon Factory in Japanese SR Community

- PF has been a pioneer in SR radiation research in Japan. The PF fulfills a key role in providing facilities for inter-university access and has a vital role in training future scientists – this should be sustained. This aspect of PF activity underpins much of the SR program in Japan.

- The decision by the University of Tokyo to not build a new 3rd generation VUV/soft x-ray facility has given PF the opportunity and responsibility to take the lead in further developing this important research field in Japan – additional resources should be sought for this effort so as not to compromise the x-ray program or the R&D on the ERL. The Committee urges the PF to recognize this responsibility and fold it into its strategic plan, to further complement its outstanding hard x-ray portfolio.
- Given limited resources, for the PF to maintain international competitiveness, it should target strongly focused science partnership programs particularly with universities and industry in the region and concentrate its in-house effort accordingly.
- PF should aggressively seek to increase funding for the new developments, including an ERL and new ID beam lines on PF.
- A balanced strategic plan thus needs to be prepared and implemented that builds on the staff at PF and the world class groups in the region. Given the severe funding constraints, the relatively large investment in operations of the PF-AR should be critically reviewed and compared with other options (*e.g.* SPring-8). A resource re-allocation could be one strategy to make urgently needed human and financial resources available for the ERL prototype R&D and/or additional state-of-the-art ID beam lines on the 2.5 GeV ring.

5. Long Term Future Directions for PF

- The PF provided the Committee with a long term strategic plan to provide cutting-edge research capabilities for Japanese and worldwide science. The Committee recognizes that plan as very visionary and able to take full advantage of the outstanding talent at KEK and PF.
- With upgrades to PF, the Committee sees a productive 10-yr+ life for SR science. For future scientific opportunities, it is important to begin planning R&D now for a next generation light source at PF. The ERL, when recognized around 2015, will complement the x-ray storage ring and XFEL at SPring-8 and provide a full complement of VUV, soft x-ray and hard x-ray scientific opportunities for Japanese users with leading edge capabilities in brightness and time resolution.
- The ERL plan – with sufficient and successful R&D effort, followed by a prototype should lead to a very successful implementation of a hard x-ray ERL. The synergy with JAEA and accelerator developments at KEK offers a significant strategic advantage.
- The plan to convert the prototype into a VUV ERL user facility that complements the hard x-ray ERL is a good, cost effective, strategy that offers risk mitigation in the event that the hard x-ray ERL development experiences difficulties.

6. Role and Function of In-house Staff Scientists

- The scientific staff at the current level cannot at all be expected to provide adequate support for 69 beam lines and as well maintain strong scientific programs. The obvious option of increasing staff levels to an international standard of 2-4 per beam

line appears not to be feasible. Hence the Committee strongly supports prioritization and reduction of the number of operational beam lines.

- Such a reduction in the number of operational beam lines should lead to an increased scientific productivity of the staff, which is very desirable.
- The Committee feels that establishing staff research groups, including a critical mass of scientists, is a sound strategy. This approach, used very successfully for the structural biology initiative, should be extended to other fields. The integration of staff doing science and technology development within the same group has a great potential for payoff.
- These groups should be led by excellent scientists who are trusted with the necessary managerial responsibility. They should seek broad partnerships and engagement with regional universities and institutes.
- The Committee strongly endorses the need to standardize performance reviews, job expectations, and career planning for scientific staff at PF.

7. Other Conclusions and Comments

- The Committee strongly endorses the need for a regular and sustained high level scientific advisory committee with international representation to provide advice to PF and KEK management of performance and strategic planning.
- The Committee urges IMSS and PF to work closely with the user community, the JSSRR and other interested parties to develop photon science as one of the main activities on the KEK campus to have this area fully reflected in the strategic planning. There is a remarkable opportunity to take advantage of the unique expertise at KEK in accelerator science together with strength in regional universities and institutes to build a truly world class program.
- The Committee wishes to offer its support in near term decision making, strategic planning and in prioritization by the PF management.
- The Committee wishes to most enthusiastically thank the PF staff and users for their excellent support in advance of, and during, this Review Committee meeting.

1. The 2.5 GeV and the 6.5 GeV Storage Rings

The PF 2.5 GeV storage has been in operation since 1982 and since that time has served the scientific community in Japan as well as internationally in an exemplary manner. A main reason for success over such a long time has been a continuous improvement in the program with major upgrades. In 1987, the PF ring emittance was reduced from an original 400 nm-rad to 130 nm-rad, and in 1997 a rearrangement of the lattice led to a further reduction to 36 nm-rad with a capability of an even further decrease to 27 nm-rad. In 2005, the lattice was again extensively modified to accommodate additional straight sections, their number being increased from 7 to 13. This modification also provided for increasing the length of several specific straight sections. From the original PF ring hardware, basically only the bending magnets are still in use – everything else is new. With the top-up injection scheme, as planned for the next two years, the long lifetime of the

beam can partly be sacrificed for lower emittance, narrow undulator gaps, and for avoiding artificial beam lengthening. Further, heat load on the optical elements will be kept constant, which should enhance x-ray beam position stability to equal the best sources in the world. The activities of the ID group, who have developed various types of in-vacuum insertion devices including the small gap undulator (SGU), are remarkable. The PF 2.5 GeV ring is indeed a modern 3rd generation synchrotron radiation accelerator and is competitive in many aspects with other state-of-the-art third generation sources in its energy class in the world, especially serving a large base of x-ray users. The excellent record in operation as is evident from data presented on user time, failure rate (less than 2% of scheduled time), and beam stability demonstrates world class performance. However, construction of new beam lines and, equally important, decommissioning of old beam lines has not keep pace with the modernization of the ring.

The second ring operated for photon science research is the 6.5 GeV (PF-AR), originally built as an injector for the high energy TRISTAN collider. The PF-AR was used first in parasitic mode for synchrotron research beginning in 1986 and was later dedicated to this purpose in 1997. As the PF-AR was not originally designed to be a dedicated x-ray source, the performance lags quite far behind other modern high-energy light sources in several characteristics. Incremental improvements have helped, including the vacuum system upgrade in 2002. The emittance of this larger machine is nearly 300 nm-rad but it does offer the ability to operate in a single or two bunch mode with comparatively high currents of 60 mA and 70 mA, respectively. With its high particle energy and single bunch operation, the AR is used for harder x-ray experiments in protein crystallography, time resolved phenomena, medical research, and others. Even though the Review Committee acknowledges the quality of science produced at the PF-AR, it raises a question for PF management to consider about the longer term viability of the concept of operating two rings with insufficient manpower and a lack of adequate financial resources. In particular, the Review Committee feels that investment in the ERL R&D project and in the aggressive beam line developments for the 2.5 GeV ring are both vital for the future of the laboratory and should have high priority in the near future. In this light, the following points should be carefully weighed by PF management: 1) currently the PF-AR operation (including beam lines) costs about $5.7M per year; 2) it has been noted that short-gap undulator beam lines on the 2.5 GeV ring can be superior for protein crystallography by factors of 3 to 6 compared to other ID beam lines on the PF-AR and PF 2.5 GeV rings; 3) a superb hard x-ray high energy machine, SPring-8, serves the Japanese science community and has the capacity for accommodating more beam lines and users; and 4) for lower photon energies, Japan lacks a new state-of-the-art ring and this will likely continue for the years to come since the University of Tokyo withdrew its plans for a 3rd generation VUV/XUV facility.

In summary, the Review Committee recommends that the PF and IMSS management consider focusing resources, as much as possible, on the 2.5 GeV ring (in particular, the beam lines on this machine which can exceed the performance levels achievable on the PF-AR ring) and on the new ERL project. PF management should develop the 2.5 GeV ring in such a way that the PF will continue to strengthen the x-ray activities to maintain and enhance their world class performance while taking the opportunity to increase the activities in focused areas of the VUV/XUV area. With appropriate balance, the PF-AR can continue to provide unique capabilities for time-resolved experiments, for example, on

NW14A and NW2A, but this should not compromise optimum utilization of PF and R&D on the ERL project.

2. Beam Lines on the 2.5 GeV Ring

The Photon Factory has about ~59 beam lines, some of which are of very high technical quality and scientific capability. A recent upgrade to the PF 2.5 GeV ring (see above) has expanded the number and length of straight sections to permit the accommodation of five more insertion devices. The Committee applauds the PF on this very significant accomplishment and very expedient re-commissioning and return to routine operation of the PF 2.5 GeV ring.

The Review Committee was informed repeatedly that there are simply too few scientists supporting too many beam lines. Based on the Committee's own knowledge of the situation at other world class synchrotron facilities in Europe and in the USA, it fully agrees with this assessment. The ideal solution would be to hire more scientists. However, as this appears not to be an option given the budget, the only alternatives are to close some beam lines or to reallocate resources from some other source. While this is a painful process for all parties concerned, the Committee most strongly recommends that such action be taken. It should be done within the framework of a well-conceived and reviewed strategic plan. The strategic plan should focus on a relatively small number, say 5-10, areas of excellence. The structural biology program at PF offers a model for a successful approach.

The Review Committee learned that the beam lines have already been sorted into four categories: S, A, B, and C. The definitions are as follows: S = high level of support and significant capital investment; A = a fairly high level of support and proper capital investment; B = modest support and minimal investment; C = limited support and minimal investment. The Committee was also shown the publication history that revealed that some beam lines have generated rather few publications. These data provide valuable input on which beam lines to decommission. An optimum number of beam lines appears to be in the 30-40 range. The Review Committee re-emphasizes, however, that such choices should conform to an over-arching strategic plan and that input from the users be considered carefully in developing this plan. The choice of which beam lines to close should be closely coordinated with the development of new insertion device stations on the remaining unused straight sections on the PF 2.5 GeV ring. While some users and staff scientists might find decommissioning old equipment to be stressful, the Review Committee expects that staff focused on new capabilities of the insertion device beam lines will raise the level of excitement of the staff and lead to more competitive scientific projects.

The Committee notes that some of the less productive beam lines can still produce high quality research when compared with laboratory sources. If support for these beam lines can be obtained from groups of universities or research institutes over a given period, then there may be an opportunity to keep them in productive operation. This should not be done at the expense of the high priority beam lines as defined in the strategic plan.

The science and technical reports presented to the Review Committee make it very clear that many technical developments and experimental methods have been innovated by the

research groups at PF using a comprehensive approach of integrating beam line and instrument development with research applications. The Review Committee strongly feels that the PF can maintain this advantage in selected fields of methodology in synchrotron research if it appropriately prioritizes and focuses its resources and beam line scientists. It might be possible to augment the support provided by PF staff on the beam lines by introducing more broadly a user access system where strong user groups are given some priority on specified beam lines for a fixed term and in return, they would have a duty to support other users who come to use these beam lines.

With the abandonment of the proposal by the University of Tokyo to build a VUV/soft x-ray ring, the PF 2.5 GeV ring emerges as the flagship Japanese facility in this important scientific area. The Committee recommends the PF embrace this responsibility and incorporate it into its strategic plan as it is strongly complementary to the excellent science done in the hard x-ray range for which PF has a well established and deserved reputation.

In summary, with regard to beam lines, the incoming PF management is urged to move swiftly to devise a strategic plan that consolidates the number of beam lines to 30-40, focused on 5-10 carefully selected areas of excellence.

3. Users' Experimental Programs, Scientific Activities

Overall, the Review Committee found the scientific productivity both excellent in quality and productivity. The scientific output for PF on a yearly basis compares very favorably with the best of similar facilities of its size and class worldwide. The Committee wishes to offer some specific comments on some of the scientific areas.

The structural biology program has developed dramatically and impressively in the past decade. BL-6A and BL-18B have been supporting protein crystallography research in Japan for many years and these beam lines have produced a number of very high quality publications. These well established beam lines are now complemented by two new ID high-throughput MAD beam lines, NW-12A and BL-5A. While the new beam lines have not been in operation for a long enough period of time to establish good statistical data on publication record, they have already produced a number of excellent results published in top journals in the past several years. The PX beam lines now have modern, user-friendly software and excellent hardware (*e.g.* CCD detectors). The number of users of these beam lines is increasing. The ID beam lines are highly competitive, and are not lower level in quality than ID beam lines of SPring-8 for most protein crystals. Protein crystallographers in eastern Japan preferably use the beam lines at PF rather than the SPring-8 beam lines because of their user-friendliness and easy access.

The PF has supported strongly Professor S. Wakatsuki to establish the structural biology group that performs their own biology, technical development and beam line support. The group has quickly created superior scientific results in structural biology. Since the group is working on biology, they produce excellent technologies that are rapidly implemented and can in turn satisfy demands from other users and biologists. This synergistic approach of in-house scientific research and technical development has produced not only highly competitive beam lines but also excellent structural biology outputs. The group gets an excellent reputation from users and users' support brings new financial support from the

government. The Review Committee notes that the collaboration of PF and SPring-8, which are different in physical location and beam characteristics, is indispensable for protein crystallography utilization and further development in Japan. The Review Committee wishes to acknowledge that this operation and the leadership of Prof. Wakatsuki is outstanding and offers a model for development of other scientific areas of excellence at PF. The PF management is to be congratulated on a most effective and visionary development.

Regarding the scientific activities in the area of materials and condensed matter, both structural and spectroscopic studies are equally important for continuing forefront science at the PF. It is important to recognize that the number of users may not be equal across these different disciplinary areas. The Review Committee found particularly noteworthy a number of highlights in the materials science area from research by in-house staff and users. A very important achievement is the development and application of resonant x-ray scattering, which is a novel means of electronic structure analysis that has proved to be very powerful in identifying the spatial pattern of orbital and/or charge ordering. This experimental methodology has recently been further developed and applied to studies on the orbital ordering under conditions of high pressure and magnetic field. Research has led to the identification of spatial patterns of charge ordering in molecular solids and oxides and of spatial charge density distribution in cages and in charge ordered molecular solids by x-ray diffraction/scattering techniques. The studies involving the search for the electronic states of buried layers at oxides interface by resonant PES and identification of direction of magnetization in ring-type nano-magnets by XMCD-PEEM were also viewed as excellent. Science at the PF has also had a traditional strength in methods based on absorption spectroscopy and has contributed significantly to developments in this area worldwide. It should continue to do so in the future.

4. The Role and Function of the Photon Factory in the Japanese Synchrotron Radiation Community

The Review Committee felt strongly that the PF is one of Japan's premier user-oriented research facilities, having a large base of geographically distributed users that include scientists from universities, industry and other laboratories. Its spectral coverage is complimentary to SPring-8 in some areas (VUV and soft x-ray) and overlaps in others (hard x-ray). On balance, the strong scientific user presence in the Kanto region, combined with the superb performance of the PF ring, continue to define a very important role for PF in the Japanese SR community. In particular, PF maintains a very important role as a national institute, because many of the research and educational fundamentals are based in universities. PF should continue to maintain a leadership role in this regard.

The most important recent development in the Japanese SR community is that the University of Tokyo has decided not to push forward with the project to construct a third generation soft x-ray SR facility. The University has revised its approach to focus on construction of several new beam lines, so-called "out stations", both in PF and SPring-8. As noted earlier, the PF has very successfully upgraded the 2.5 GeV ring to increase straight sections, but cannot afford to construct new undulator beam lines at an optimal rate to take full advantage of this upgrade without getting additional funds. The joint project

between PF and the University of Tokyo is thus reasonable and timely, offering perhaps the ability to leverage the important investment made by KEK in upgrading the PF ring.

The Japanese soft x-ray SR community has been suffering from the lack of ready access to high brightness beam lines and associated instrumentation. This has inhibited full development and application in some research subjects like spectromicroscopy and soft x-ray fluorescence spectroscopy. These areas are not competitive with other third generation soft x-ray synchrotron facilities (*e.g.*, those at ALS, ELETTRA, and BESSY2). Accordingly, PF should seek to find additional resources to develop soft x-ray beam lines and instruments that are competitive with other facilities in the world.

5. The Long-term Future Directions for the PF

Perspective and need for the next generation of light source at PF. Just as the invention of the high-powered lasers has created a multitude of new research avenues and new materials and techniques, having far-reaching benefits to all society, so too we can expect that the next generations of x-ray sources have the potential to be equally revolutionary. In many fields of science the development of probes – ranging from electron, nuclear, and light of all wavelengths – has played a direct role in the evolution of the field. Sometimes the benefits are not planned in advance. For instance, while the development of particle accelerators and VUV/SX/X-ray synchrotron sources were originally intended to study materials and basic physics, the impact on biology and structural biology has been huge and profound as is well evidenced by the numerous outstanding scientific contributions that have come from research at the PF.

Looking towards the future it is easy to see that specimen sizes are becoming smaller and smaller, into the nanoscale structures, and at the same time the need for more detailed electronic state information is growing. These trends call for a more brilliant light source. In addition, frontier efforts are underway to obtain information on non-crystalline materials and to understand dynamics and non-equilibrium states of matter. These argue for a highly coherent source with short pulses. As noted during the presentations to the Review Committee; 1) the ERL promises to have a small, round source size, making it optimal for focusing beams down to nanometer sizes; 2) it has extremely small emittance enabling production of very high-energy resolution beams; 3) it offers a high degree of beam coherence (diffraction-limited), enabling much improved coherent imaging and dynamics studies; and 4) it can produce sub-picosecond pulses which are needed for femtosecond time domain studies of chemical transition states and other structural dynamics on nanoscale dimensions.

Choice to develop an ERL light source at KEK. The choice to commence R&D and build an x-ray ERL source at the KEK site is very logical and an efficient and effective utilization of the considerable accelerator talent at KEK. First, the ERL source compliments the different capabilities of the XFEL source now funded and being built at SPring-8. The ERL can be seen as both part evolutionary and part revolutionary. Because the particle beams in an ERL accelerator only circulate once, the “phase space” of the particles is much smaller than in a storage ring and the resulting x-ray beams become much brighter. The total photon fluxes from the proposed ERL at PF would be comparable

to existing 3rd generation light sources, like SPring-8, APS, and ESRF. Parameters such as the spectral brilliance, source area, coherent flux, and pulse duration could be improved by several orders of magnitude depending on the particular property/configuration. As a generalization, most research at existing synchrotron sources could be moved to an ERL source without major modifications to technique or data collection strategies (assuming comparable performance in areas like beam stability). The benefit of the ERL will become most apparent to those experiments that make use of the very small source size, high brightness, and very short pulse nature of the ERL source. The smaller source emittance means that longer undulators with narrow gaps might be utilized when appropriate.

For the Japanese SR community that utilizes PF, an ERL source would provide continuity, advancement and support for the large research community (~3000 users per year) that is already established. The broad range of scientific research in fields of structural materials, biology, chemistry, and medical sciences can continue and advance. The education of students in all fields of science and technology, including accelerator and machine physics, can remain a key consideration, building upon the existing base. Equally important to developing the new ERL is growing the next generation of scientists who will use these machines for research. This is vital to keeping the Japanese SR community successful and competitive with the rest of the world.

The ERL plan as proposed and described to the Review Committee – a 0.3 GeV machine for VUV light (derived from the prototype) and a 5.0 GeV machine for higher x-ray energies – would position the PF as being among the world leaders in both VUV, soft and hard X-ray research capabilities and be a very logical and innovative step to follow on the PF 2.5 GeV ring which has been pushed about to its practical performance limit. Complementing the SPring-8 and XFEL sources, the ERL at PF/KEK would give Japan a full complement of the most advanced light sources in the world. The timeline proposed for R&D and implementation is aggressive, but is competitive with other efforts worldwide. Reaching the timeline milestones will depend heavily on the resources dedicated to this cutting-edge project. This Review Committee did not evaluate these resources in any detail, but the management at KEK and PF must make a careful plan in order to focus and keep this foremost in their accelerator R&D efforts, especially considering nationwide staffing reduction policies in place at present.

Machine and accelerator physics challenges for KEK/PF. Viewed by the international accelerator and machine physics community, the ERL is a revolutionary development due in part to the number of key technical advances that must come together to make a reliable, stable x-ray source. First and foremost, the brilliant properties of the x-ray source are mostly determined (or limited) by the electron source. Running a laser-excited photocathode in CW mode to produce 100 mA has never been done and challenges the technology down to our fundamental understanding of electronic emission from ultra-pure surfaces. Minimizing source emittance and preserving it during acceleration are new challenges as well. Circulating and then recovering the energy in high-Q superconducting cavities, though already done at low current and low energy for IR-FELs, have still to be proven possible for a 5 GeV-class machine. Some of these technical challenges are shared by XFEL development and by the high-energy physicists looking forward to the next international-scale linear collider. This is an exciting and revolutionary time for accelerator and machine physicists and the ERL project at KEK/PF provides the opportunity for the

outstanding accelerator physicists and scientists at KEK/PF to participate in this innovative new area of development.

Importance of the ERL 0.3 GeV prototype. The challenges mentioned above make it clear that significant R&D is needed to realize a stable, reliable light source based on ERL technology. The decision to invest in developing an ERL prototype machine is both prudent and wise. The KEK/PF ERL plan described for the Review Committee calls for a prototype machine with an energy up to 0.3 GeV to be built and, upon success and completion of the R&D program, to be converted into a dedicated VUV light source. This is an excellent strategy and the KEK/PF administration and staff should be applauded for their vision. The Review Committee urges that a solid commitment be made to go forward. The prototype is an opportunity for the accelerator group at KEK/PF to collaborate with JAEA on electron gun development. The prototype itself will provide the superconducting cavity group the opportunity to develop an energy recovery scheme at KEK. The photon science experts at PF will gain experience by developing the first diagnostic beam line(s) for low-energy photon extraction. The reuse of the prototype (possible with some expansion) as a dedicated VUV source will be very efficient in fiscal terms. Using an existing building for the prototype is also a low-cost means to get the project started quickly. The Review Committee is concerned, however, that the building site presently proposed will not be large enough for the dedicated light source. This may require renovation, expansion or relocation when or if that opportunity arises.

Importance of the ERL 5.0 GeV machine. The parameter list proposed for the high-energy ERL machine is adequate to cover the energy range most utilized by the PF community (up to ~30 keV) and with a coherent fraction on order of 20% at 10 keV. It is anticipated that the parameter list will evolve and refine over time as machine modeling proceeds. There are many technical issues, tradeoffs and electron source capabilities and limitations that are not yet fully understood. The development of the prototype machine will make these choices clearer as the project evolves.

The choice of scientific applications in the present scientific case are appropriate and well thought out. These include areas enabled by short pulses, like non-equilibrium dynamics, spin dynamics, chemical reactions and catalysis, photo-induced phase transitions and reaction processes in biomolecules. Areas enabled by coherent x-rays include structural studies of non-crystalline materials, phase contrast imaging, and studies of fluctuations by photon-correlation spectroscopies. The case for nanobeam applications correctly identifies that most existing measurement techniques will be extended to become local environment probes by illuminating nanometer-sized areas. Studies of small crystals, domains, interfaces, complexes, etc. are natural targets. It should be mentioned that some of the scientific opportunities can perhaps already be tested by running Spring-8 for short periods of time at around 3 GeV where the emittance would be significantly reduced. This would allow the ERL project to be better specified in relation to the scientific challenges.

The ERL project has now formally become a collaboration between KEK/PF and JAEA and an ERL project office will soon be formally created at KEK as understood by the Review Committee. In addition to the accelerator and machine groups, the Review Committee recommends that PF photon science experts, with both hard and soft X-ray backgrounds,

become an official and integral part of the ERL project office. Their participation will be vitally important to specifying and verifying that the ERL machine is a valuable light source research tool. The qualifications mentioned above concerning the evolution of the design and the compromises in the parameters and capabilities of the machine, require that light source users maintain a constant contact with the machine designers in order to prioritize and specify the goals of the project. Questions will arise, such as compromises between high bunch current and bunch size, or bunch size versus bunch length, that will need critical input from the experimentalists. The capabilities as well as the limitations of the ERL machine will be defined simultaneously during the design process over the coming few years. In parallel with the development of the accelerator, preliminary experiments to utilize the coherence, pulse structure, etc. should be performed and this will be facilitated by the integration mentioned above. The PF is also encouraged to organize a series of workshops on the science and technology of the ERL machines to further develop the proper approach and best develop consensus of the Japanese SR community.

6. The Role and Function of in-House Staff Scientists

Clearly the number of staff is insufficient for supporting the large number of beam lines distributed over the two rings. The Review Committee observes that the ratio of 0.5 to 0.8 staff scientists per beam line is not competitive on an international basis, where such ratios are typically between 2 and 4 for high quality, high productivity beam lines. The obvious option, namely increasing the staff, was ruled out by the PF management as being currently impossible in the Japanese system, due to severe restrictions on the number of public servants. Therefore a reduction of beam lines within the responsibility of the fixed size support staff is mandatory. The Review Committee strongly endorses plans for such a downsizing in number of beam lines but it should also be accompanied by a general “clean-up” and rearrangement of the experimental support structure for the 2.5 GeV ring. This will be a difficult task requiring an effective process as mentioned earlier in this report. The Review Committee strongly recommends that decisions on decommissioning of beam lines are presented to a standing international, scientific advisory committee for discussion and support.

The Review Committee feels that on average, the scientific output of the staff scientists needs to be increased. The situation at the PF is certainly not unique but is worse than at many comparable laboratories with usually more staff: staff scientists at synchrotron facilities are expected to support users and to advance instrumentation at the facilities. On the other hand, they are viewed as, and sometimes treated as, “super-technicians” by the users and, maybe more detrimental, have limited opportunities to move into university careers.

Establishing staff research groups exceeding a critical mass of scientists has proven to be very successful in the case of protein crystallography and should be extended to other fields identified by the PF as areas of specific focus. These groups should be directed by competent and talented group leaders with well defined duties, rights, and responsibilities. Such groups will have the potential to compete at the forefront of science provided the individual scientists have sufficient talent and are interested in science. However, development of instruments and user support must not be neglected, last but not least because the future of the PF laboratory with its plan for an ERL machine will depend on the

user community and their satisfaction with the PF.

Staff scientists must have a clear job description with an annual performance evaluation based on three main criteria: scientific output, instrument development, and user support. The degree of excellence will vary among the individual scientists and so will their competence in the three areas of evaluation. The plan proposed by the PF management, namely to establish only two categories, science-oriented and instrument/user-oriented staff, may cause friction within the PF-team. A more flexible approach based on the annual performance with the definition of clear goals may facilitate a transition with the existing staff from the current to situation to the new research-group oriented approach.

A long term strategy defining profiles for new staff members and including career plans for them is a necessary and noteworthy step. The PF laboratory should be highly attractive for young scientists but should also encourage and support mobility. As far as the latter is concerned, exchange or delegation of staff scientists to other facilities or universities should be strongly supported.

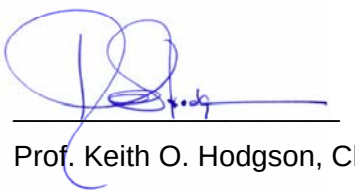
7. General Comments and Recommendations

The Review Committee strongly endorses the need for a regular and sustained high level scientific advisory committee for the science and technical program at PF. Having such a high level advisory committee is a greatly valued addition to all the other competitive synchrotron light sources worldwide. It is important to recognize the value of such a committee with international representation in providing unbiased advice to PF and KEK management on performance and strategic planning. Such a Committee, comprised of 10-12 scientists with experience and geographical distribution along the lines of the Committee established for this current review, could provide on-going advice in regard to questions including choice of scientific focus areas, global optimization of resources, and many other issues. To be effective, such a Committee must meet at least annually and many SR facilities have found that twice-yearly meetings are even more effective. It depends of course on the state of maturity and change of the specific facility, but with all that is happening at PF in the coming few years, twice-yearly meetings are likely more beneficial. One also gains the advantage of not having to “re-educate” the Committee at every meeting. The current Review Committee wishes to offer its support in near term decision making, strategic planning and in prioritization by the PF management and is willing to help in any way deemed appropriate by PF management.

The Review Committee was strongly impressed with the opportunities for world class science and accelerator development on the KEK site. The Committee urges IMSS and PF to work closely with the user community, the JSSRR and other interested parties to develop photon science as one of the main showcase activities on the KEK campus and to have this area fully reflected in the strategic planning. There is a remarkable opportunity to take advantage of the unique expertise at KEK/PF in accelerator science, together with strength in regional universities and institutes to build a truly world class and innovative program. If the development of science, new beam lines and the ERL program at PF can be realized, Japan will indeed have a suite of accelerator-based light sources that equals or exceeds any other region in the world (considering also the superb efforts at SPring-8 and the XFEL development).

Finally, the Review Committee wishes to congratulate the PF leadership in developing a strong strategic vision for the future of the PF and in having its scientific and technical staff and users present it to the Committee in a very clear and well organized manner. The Review Committee wishes to acknowledge the excellent job done by PF senior management during the past few years and the visionary choice made by KEK and IMSS for the new leadership which takes over on April 1, 2006. Finally the Committee most enthusiastically thanks the PF staff and users for their excellent support in advance of, and during, the Review Committee meeting.

This report is transmitted to the PF management on behalf of the PF Review Committee



Prof. Keith O. Hodgson, Chairperson

June 5, 2006

Appendix – Contained in the Appendix to the Review Committee Report are the following:

1. List of the members of the 2006 PF Review Committee

2. List of questions posed by the PF management for specific consideration by the Review Committee

3. Agenda of the PF Review Committee Meeting

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1. List of the Members of the 2006 PF Review Committee

Earnest Fontes – Cornell High Energy Synchrotron Source
Hidetoshi Fukuyama – Tohoku University
Keith Hodgson – Stanford University, Chairperson of Committee
Hiromichi Kamitsubo – Riken Wako Institute
Gerhard Materlik – Diamond Light Source
Toshiaki Ohta – University of Tokyo
Volker Saile – University of Karlsruhe
Neville Smith – Advanced Light Source
Hiroyoshi Suematsu – Riken Harima Institute
Tomitake Tsukihara – Osaka University

2. List of Questions Posed by the PF Management for Specific Consideration by the Review Committee

- Some suggested key points for consideration by the Committee -

I. The 2.5 GeV ring and the 6.5 GeV storage rings

1. Compare the operation of the two Photon Factory rings with the world standard level in view of operational hours, failure rates, stability, reliability and other aspects.
2. Evaluate the straight section upgrade of the 2.5 GeV ring: Will the 2.5 GeV ring be a competitive machine compared to other medium energy, medium size rings during the coming 5~10 years?
3. Comments on our strategy to operate the 6.5 GeV ring as a dedicated single bunch machine and the science it can enable.
4. Evaluate the further upgrade plans of the 2.5 GeV ring and the 6.5 GeV ring.

II. The beam lines

1. Evaluate the current status of the beam lines in view of the number and quality.
2. PF aims to make the best use of straight sections created and lengthened by the recent upgrade of the 2.5 GeV ring and intends to allocate resources for upgrade and construction of corresponding beam lines. Is the right strategic direction to refurbish and construct insertion device beam lines being followed? Is this likely to lead to world-class capabilities for these new beam lines?
3. The PF management feels that old and less competitive beam lines should be decommissioned (and hence the total number reduced). Staff could then be focused on supporting a smaller number of high quality beam lines. PF has an imbalance between the number of staff members and the number of beam lines and this is one strategy to improve the situation. Is this a sound strategy?

   Other suggestions by the Committee on this point would be most valuable.

   This point is also mentioned in the staffing considerations in VI. below.

III. Users' experimental programs, scientific activities

1. Are the numbers of users and experimental proposals, quality of user support in good shape? How do they compare with international standards?
2. Does the Photon Factory have satisfactory quality and quantity of experimental results for a facility of its size and scope?
3. Comments on the mechanisms for evaluation of the in-house scientific activities, their role in the scientific community and their evaluation and promotion would be

most valuable.

IV. The role and function of the Photon Factory in the Japanese synchrotron radiation community – Committee's comments on the following considerations would be valuable:

1. The future role and function of the Photon Factory in developing, enabling, and supporting the VUV and soft X-ray research activities in Japan.
2. The future role and function of the Photon Factory in developing, enabling and supporting X-ray research activities in Japan.

V. The long-term future directions for the PF

Evaluation of the plan for the ERL as the next generation facility: We recognize that the Photon Factory has to continue serving users for the coming decades and offer two different types of experimental opportunities, namely (1) highly advanced instruments and techniques for the most challenging, cutting edge sciences which need ultimate performance of the source and the beam lines and (2) user friendly and reliable instruments and experimental environments for a broad range of scientific disciplines and industrial applications. To meet such requirements in the future, around 10 years from now, our strategy is to operate an Energy Recovery Linac (ERL) as the next generation synchrotron radiation source at the Photon Factory.

VI. The role and function of in-house staff scientists

The number of staff members at PF is very limited; probably one-third or less compared to most western synchrotron radiation facilities. To maintain the high level of user support and also conduct higher level in-house scientific activities, we think that we need to reform the organization of the experimental facility division. We also have to seriously consider decommissioning old and less competitive beam lines and reducing the number of beam lines. We would appreciate comments and advice on these points from the Committee.

3. Agenda of the PF Review Committee Meeting

PF review committee meeting 2006

Date: March 13 – 15, 2006

Place: Room 244, Building No.4, KEK

PROGRAM

Mar 13 (Mon)

09:30-09:40	Welcome and charge to the committee	A. Koma
09:40-09:50	Introduction of the committee members	
09:45-10:05	Executive session	Committee
10:05-10:45	The Photon Factory – An overview	T. Matsushita
10:45-11:00	Coffee break	
11:00-11:30	Status of the 2.5 and 6.5 GeV storage rings and plans for their up-grade	T. Kasuga
11:30-12:10	Current status of the beam lines and near future plans	M. Nomura
12:10-13:00	Lunch	
13:00-13:40	Tour of the ring tunnel of the 2.5 GeV ring	
13:40-14:20	X-ray diffraction/scattering studies at the Photon Factory	H. Sawa
14:20-15:00	Structural Biology at the Photon Factory	S. Wakatsuki
15:00-15:40	X-ray spectroscopic studies at the Photon Factory	Y. Inada
15:40-16:00	Coffee break	
16:00-16:40	Photon Factory activities in the VUV-SX	A. Fujimori
16:40-17;00	Imaging science at the Photon Factory	K. Hyodo
17:00-17:20	Discussion and questions to PF	
17:20-18:20	Executive session	Committee
19:00-	Dinner	

Mar 14 (Tue)

09:00-09:30	Orbital ordering studied by resonant X-ray scattering	Y. Murakami
09:30-10:00	Combinatorial *in situ* growth-and-analysis with soft x-rays for oxide electronics -	M. Oshima
10:00-10:30	High-pressure and high-temperature experiments	

	at the Photon Factory	T. Yagi
10:30-10:40	Coffee break	
10:40-12:20	Facility tour (Beamlines of the 2.5 and 6.5 GeV rings)	
12:20-13:20	Lunch	
13:20-14:00	The next generation light source at the Photon Factory	H. Kawata
14:00-14:15	R&D program for the ERL at KEK	T. Kasuga
14:15-14:30	Super conducting RF cavity for the ERL project at KEK	T. Furuya
14:30-14:45	R&D program for the electron gun by the JAEA-KEK collaboration	R. Hajima
14:45-15:05	Discussion and questions	
15:05-15:25	Coffee break	
15:25-17:25	Executive session	Committee
18:30-	Dinner	

Mar 15 (Wed)

09:00-11:45	Executive session	Committee
11:45-12:00	Closing Remarks by the Chairman	K. Hodgson
12:00-	Lunch	
14:00	Departure	