The Photon Factory – An Overview –

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1. Introduction

Since 1982 the Photon Factory (PF) has been serving as a national facility for synchrotron radiation research covering a wide range of wavelength from vacuum ultraviolet to hard X-rays. PF is the second dedicated synchrotron radiation source in Japan, and the first to become operational in support of X-ray users. PF currently operates two rings, namely the original 2.5 GeV ring and more recently the 6.5 GeV ring. The 2.5 GeV ring was constructed in 1982 as a second generation synchrotron radiation source, and the 6.5 GeV ring, which was originally constructed as a booster for the 30-GeV TRISTAN main ring, had been used as a synchrotron radiation source in a parasitic mode since 1986 and later in 1997 it was converted to a dedicated single-bunch electron storage ring for synchrotron radiation research.

Parameters of these two rings are summarized in Table 1. Operation of the two rings is around 5,000 hours each annually over the last several years except for 2005 during which the straight section upgrade of the 2.5 GeV ring was implemented. Ninety-six to ninety-eight percents of the scheduled user beamtime has been delivered for experiments. The emittance of the 2.5 GeV ring was originally 400nmrad, but this has been reduced to 36 nmrad by having made lattice rearrangements (twice in 1987 and 1997). Furthermore, the number of straight sections for insertion devices has been increased to 13 from the original 7 by replacing and rearranging quadrupole magnets in 2005. The 6.5 GeV ring was upgraded in 2001 by replacing the vacuum system components completely, resulting in the increased life time of the electron beam.

There are 60 and 10 experimental stations each on the 2.5 GeV and 6.5 GeV rings, respectively, when tandem and time-shared experimental stations are counted as individual stations, and 49 and 8 stations among these can be used individually at the same time. Eight beam lines on the 2.5 GeV ring are equipped with insertion devices; three being soft X-ray undualtors, one short period X-ray undulator, one superconducting magnet wiggler, one permanent magnet multipole wiggler and two permanent magnet undulator/multipole-wiggler. There are five insertion devices on the 6.5 GeV ring; four in-vacuum undulators and one multipole-wiggle/undulatorr for production of elliptically polarized hard X-rays. There have been 650 ~ 700 active proposals and 2,500 ~ 3,000 registered users every fiscal year.

For taking care of these storage rings and beamlines, we have 18 scientists and 16 technicians (11 permanent staff and 5 temporary contractors) in the light source division and 38 experimental scientists and 16 technicians (10 permanent staff and 6 temporary contractors) in experimental facilities divisions. The Accelerator Laboratory of KEK is officially

	PF	PF-AR
Operations since	1982	1986
Energy	2.5-3.0GeV	6.5/5.0GeV
Circumference	187 m	377 m
Type of lattice	FODO	FODO
Initial current	450mA	60mA
Beam filling pattern	280 bunches	single bunch
Emittance	36 nm rad (H) 0.11 nm rad (V)	294 nm rad (H) 1.5 nm rad (V)
Beam size	0.7 - 2.0 mm (H) 0.04-0.13 mm (V)	2.3-2.9 mm (H) 0.29-0.46 mm (V)
Beam lifetime	30hrs at 450 mA	15-20 hrs at 60 mA
Insertion device straight sections	13 2 x 8.9 m, 4 x 1.5 m, 4 x 5.7 m, 3 x 5.1 m	5 3 x 5.5 m, 1 x 5.0 m 1 x 8.76 m
Insertion devices in operation	8	5
Operational experimental Stations	60	10
Typical operation hours / year	5,200 - 5,300	5,000 - 5400

Table 1. Parameters of the two Photon Factory storage rings. The electron beam life time of the 2.5 GeV ring is recovering gradually to the level of 60 hours as the integrated storage ring current increase after the straight section upgrade.

responsible for the operation of the 6.5 GeV ring, thus the 6.5 GeV ring is practically operated in a collaboration between the PF light source division and a group in the KEK Accelerator Laboratory. We share administrative man power with other programs in KEK.

The Photon Factory is a part of the Institute of Materials Structure Science and major scientific policies of the Photon Factory are discussed by the Advisory Committee of the Institute consisting of 14 members from KEK and 10 members from outside of

KEK. The Program Advisory Committee for the Photon Factory is positioned under the Advisory Committee and is responsible for reviewing and evaluating user experimental proposals. .

We have had two major external reviews of the Photon Factory (in 1996 and 2001) and the present review is the third one. In the current review, we would like to receive any advice and comments on our facilities, scientific activities, our near term plans and long term strategies. A separate short paper is being provided with our charge to the review Committee as for "key points" for evaluation and recommendations.

2. Users experimental programs and scientific activities

We have five categories of experimental proposals that fall into the following categories.

Type G: General proposal valid for 2 years. Proposals are received twice a year; the first Fridays of May and November.

Type P: Preliminary experiments and/or inexperienced users. Valid for 1 year.

Type U: Urgent and important experiments. U category proposals can be submitted any time in the year and is valid for half a year.

Type S1; Proposals for major projects including the construction of a beamline, a part of it or large scale experimental apparatuses. Valid for 3~5 years depending on the scale of the project and evaluation by the committee. A hundred percent beam time is assigned until the beamline construction and commissioning are completed, and after the commissioning up to fifty percent of beam time can be assigned to the project team. A review of the project is made annually at the occasion of the PF users meeting.

Type S2; Proposal for major projects with a special and higher priority in assigning beam time. Valid for 3 years and up to 50 % of the beam time of the relevant experimental station can be allocated. A review of the project is made annually at the occasion of the PF users meeting.

Table 2 shows annual trends and changes of these proposals. The number of registered users has varied between 2,500 and 3,000 during the last several years, and they are distributed nation wide with some increase of density in Kanto area near Tokyo. Among about 700 active proposals, 15 ~20 percent of those proposals request beam time on VUV/SX beamlines and the others on X-ray beamlines.

year	G	P	S1	S2	U	TOTAL	users
2000	631	17	2	9	0	659	2545
2001	647	18	2	8	5	680	2786
2002	660	16	0	8	3	687	2721
2003	639	9	1	7	2	658	2710
2004	700	13	2	7	4	726	2975
2005	685	10	2	8	0	705	2599*
2006	701	11	1	9	0	722	-

Table 2. Numbers of active experimental proposals and users registered as radiation worker. * The number registered for the period of April, 2005 – January, 2006.

The number of published papers based on experiments at the Photon Factory has remained constant around 500 every year during the last several years. Contribution of in-house members to those published papers is not limited just offering support and assigning beamtimes, but in-house staff members are co-authors on more than 20 % of the published papers.

During last 5 years we have tried to strengthen our activities in several areas. One of them is in structural biology, especially protein crystallography and its related biochemical research activities.

The anomalous diffraction method to study orbital ordering in highly correlated electron system was first developed at the Photon Factory and since then intensive and extensive research activities have sustained at the Photon Factory.

To make best use of the pulsed X-rays from the 6.5 GeV ring operated in single bunch mode, time resolved experiments are widely conducted, including nuclear Bragg scattering, dispersive XAFS for studying chemical reaction in catalytic materials, and time-resolved diffraction experiments of photo-induced phase transition.

The Photon Factory has traditionally promoted high pressure physics and geosciences. Structural studies of conditions found at the inner-core of the earth have been extensively carried out using a diamond anvil cell and laser heating.

The sensitivity of detecting light element molecules in X-ray diffraction has been enhanced with recent improvements of experimental and analytical techniques (Maximum Entropy Method), and detection of hydrogen molecules encapsulated in fullerene molecules was successfully done at the Photon Factory.

In the VUV and soft X-ray regions, atomic and molecular science has been supported with some emphasis. We have recently promoted extensive programs of photon electron spectroscopic studies including nano-structured materials, multiferroic materials and highly correlated electron systems.

More detailed reports of scientific activities are found in another material being prepared for this review (to be sent in early March) and also in our activity reports that can be found at http://pfwww.kek.jp/pfacr/index.html.

3. Position and role of the Photon Factory in the Japanese synchrotron radiation community

(a) Upgraded performance of the 2.5 GeV ring

Upon completion of the straight section upgrade in October 2005 as described in 4-(a), the Photon Factory 2.5 GeV ring is operated with an initial beam current of 450 mA, an emittance of 36 nmrad and 13 straight sections for insertion devices including four small beta sections for the installation of small gap X-ray undulators. Although the emittance is almost twice as compared with those of many other modern medium-energy, medium-size rings such as SPEAR3, the Canadian Light Source and the Australian Synchrotron, other parameters are comparable with those of modern rings. We currently operate eight insertion device beamlines and continue our effort to construct more insertion device beamlines to make the best use of newly created and lengthened straight sections. It can be said that the Photon Factory ring will be competitive with those modern light sources mentioned above if excellent and capable beamlines are build in a timely manner.

(b) Uniqueness of the 6.5 GeV ring as a dedicated single bunch operated light source

The 6.5 GeV ring has a unique characteristic in that it is always operated in a single bunch mode with an initial current of 60 mA and thus provides 100 picoseconds X-ray pulses every 1.26 micro-seconds. We have also been focusing our efforts on realizing time-resolved studies using pulsed X-ray beams for various kinds of experiments such as nuclear scattering, time resolved X-ray absorption spectroscopy, and time resolved diffraction. Although the emittance of the ring is quite large, it is still very powerful in providing X-ray beams using in-vacuum undulators as shown for the case of the protein crystallography beamline on NW-12. A fairly large X-ray source is also advantageous in obtaining large two dimensional X-ray beam for two dimensional imaging for angiography.

(c) National facility to support VUV, Soft-X-ray and X-ray users

The distribution of the Photon Factory users is nation wide with some tendency to have more users from Kanto area (near Tokyo). This shows that the Photon Factory functions well as an important national user facility even after 23 years of its operation and even after 7 years operation of the SPring-8. Among 700 active proposals, 80~85 percent of those proposals request beam time on X-ray beamlines and the others on VUV/SX beamlines. This reflects that the Photon Factory is still functioning as an excellent X-ray facility. Also, by taking into account the recent decision of the University of Tokyo to abandon their proposal to build a third generation VUV/Soft X-ray light source, we strongly recognize that the Photon Factory should maintain and even strengthen its effort to support VUV/SX activities. Hitherto, approximately one third of resources have been allocated to VUV/SX beamlines and two thirds to X-ray beamlines.

The Photon Factory has been providing experimental opportunities not only to experienced and mature scientists, but also to inexperienced scientists and students. In fact, 305 doctoral theses and 297 master theses have been written during the last 10 years based on experiments conducted at the Photon Factory. The Photon Factory will emphasize the continued support of students and provide experimental opportunities for them to develop into the next generation of users.

(d) Maintaining and upgrading beamlines

Beamtime allocation on most of the insertion device beamlines is tight reflecting that such beamlines are competitive in performance compared to those of other modern synchrotron radiation facilities. Most of the bending magnet beamlines are still functioning as good user-friendly daily tools for various kinds of experiments: but, on some bending magnet beamlines, beam time requests are not so demanding because of degraded performance compared with the higher intensity/brightness insertion-device-based beamlines.

By taking into account of users' needs and circumstances surrounding the Photon Factory in Japan, we consider that the Photon Factory should proceed into the following directions.

(1) The Photon Factory should upgrade existing insertion device beamlines (eight on 2.5 GeV and five on 6.5 GeV rings) and construct new ones to make the best use of 13 and 5 straight sections on the 2.5 and 6.5 GeV rings, respectively
(2) Bending magnet beamlines should be reviewed carefully. We should seriously consider decommissioning the less competitive and inactive beamlines and concentrating our resources on more competitive beamlines.
(3) For supporting research activities using the VUV and soft X-ray wavelength region, the Photon Factory should allocate its resources for constructing and upgrading a number of undulator beamlines especially taking into account the fact that the University of Tokyo has abandoned its plan to build a third generation VUV/SX source. The Photon Factory undulator beamlines are and will remain competitive

with those beamlines on typical third generation 2-3 GeV class storage rings and the construction of such beamlines will partly compensate the loss and negative impact caused by the abandonment of the proposal of the Univ. Tokyo for a new VUV/SX high brilliance light source.

(4) As for the X-ray wavelength region, the Photon Factory should aim for construction of in-vacuum undulator X-ray beamlines, and improvement of multipole wiggler beamlines on the 2.5 GeV ring and in-vacuum undulator beamlines on the 6.5 GeV ring. It is also important to carefully select research projects which would benefit significantly from using those beamlines.

(5) The 6.5 GeV ring has a unique feature that it is always operated in a single bunch mode, delivering X-ray pulses of 100 pico-second duration with a time interval of 1.26 micro seconds. The Photon Factory should maintain and strengthen its activity of time resolved studies of reactions in materials.

(e) The next generation light source at the Photon Factory

With such efforts mentioned above, we believe that the Photon Factory will remain an excellent and competitive synchrotron radiation research facility in Japan as well as in the world for the coming 5 ~ 10 years. However, for the longer term competitiveness, the Photon Factory should design and build the most advanced light source to meet ever progressing and demanding user requirements and scientific opportunity. We consider that an Energy Recovery Linac (ERL) could be a good candidate as the next generation light source to be built at the Photon Factory and have recently started organizing R&D groups consisting of people from the PF, KEK accelerator laboratory and a group from the Japan Atomic Energy Agency.

4. Facility upgrades and instrumental developments during last 5 years.

(a) Straight section upgrade of the 2.5 GeV ring

In 2005, we upgraded the 2.5 GeV ring in such a way that the number of straight sections has been increased from 7 to 14, among which 4 straight sections has been created and 10 straight sections lengthened. Except one straight used for electron beam injection, we now have 13 straight sections available for insertion devices instead of the previously available seven: 2 straights of 8.9 m long, 4 of 0.5 m long with a beta function of 0.5 m, 4 of 5.7 m long, 1 of 5.1 m long and 2 of 5.1 m long straights where by moving RF cavities approximately 2 m long straight will be available for installation of insertion devices.

This upgrade was conducted during six and a half months shutdown of the 2.5 GeV ring by replacing and relocating quadrupole magnets between bending magnets in two thirds of the circumference of the storage ring without the necessity to rearrange existing beamlines. The beta functions of the four new straight sections are as small as 0.5 m and thus making them suitable for installation and operation of short-period small-gap undulator. We have already constructed and commissioned one in-vacuum small gap undulator beamline on BL-17.

On this occasion of the straight section upgrade, we also renewed and refurbished several ring components such as vacuum chambers, control systems of RF and magnets and the power supply system for the quadrupole magnets. These improvements were aimed at ensuring reliable operation of the ring for the coming 10 years.

Re-commissioning of the ring started on September 19, 2005 and it was confirmed on September 24 that the maximum current of 450 mA was successfully stored. User experiments started on October 18 and are now being routinely carried out.

(b) Upgrade of 6.5 GeV ring

The 6.5GeV ring was originally constructed as a booster off the 30 GeV TRISTAN main ring, and later in 1997 converted into a dedicated single-bunch operated synchrotron radiation source. However, it had a number of problems such as insufficient beam life time caused by insufficient vacuum system performance, low reliability due to old and degraded ring components, and imperfect closed orbit controllability due to lack of reliability of beam position monitors. In 2001, all of the ring vacuum chambers and beam position monitors were replaced and the ring was re-commissioned in early 2002. As a result, the initial beam current was increased to 60 mA, and the life time of the electron beam was improved to 15 hours allowing us to realize an electron beam injection interval of 12 hours. A number of other ring components were refurbished on this occasion of vacuum upgrade including power supplies of steering magnets and their control system, beam position monitors, etc. The beam stability was very much improved and users were very much satisfied with such improved performance.

A new experimental hall was also constructed in 2001 at the north-west corner of the ring and two new insertion devices and their associated beamlines were constructed.

The 6.5 GeV ring is now routinely operated as a unique source providing 100 picoseconds X-ray pulses every 1.26 microseconds. It is also functioning as a high intensity X-ray machine with its four in-vacuum undulator sources (for two of which the magnetic period (λu) is 40 mm and the number of periods (N) is 90, for one λu=40 mm and N=95 and for the other λu=36 mm and N=80) and an elliptical multi-pole wiggler (λu=16 mm and N=21) for the production of elliptically polarized hard X-rays in the 50 –

100 keV region.

(c) Beamline reconstruction and new beamlines

In order to identify beamlines that need major improvements and/or those that should be closed, most of the beamlines were categorized in four categories listed below. This assignment was made in 2002 – 2003, just after the review of the Photon Factory in 2001.

The category S is for those beamlines to which we provide a maximum level of support and significant capital investment such as those under construction or under major improvement.

The category A is for those beamlines for which we provide a high level of support and proper capital investment to support the experiments.

The category B is for those beamlines for which we provide reasonable level of support and investment.

The category C is for those beamlines for which we provide a modest level of support and investment. If significant investment is further required to maintain the performance and the safety of those beamlines, a further investigation will be made to discuss the possibility of decommissioning of the beamlines.

At that time seven beamlines were categorized as S, 6 as A, 13 as B and 24 as C. For other beamlines, we found that more detailed investigation and discussion were necessary.

Following the guideline explained in part 3 of this report, we have refurbished and upgraded existing beamlines and constructed new beamlines during the last five years by focusing our efforts mostly on insertion device beamlines. To make such refurbishments and reconstructions, eight beamlines were decommissioned and four more will be decommissioned in the next two years by taking into account the categorization made in 2002-2003. Six beamlines were newly constructed or reconstructed during the last five years as following.

NW-2: An in-vacuum, tapered undulator beam line on the 6.5 GeV ring targeted at time-resolved X-ray absorption spectroscopy. Operational since February, 2002.

NW-12: An in-vacuum undulator beam line on the 6.5 GeV ring dedicated to protein crystallography. With a modern instrumentation, the overall performance of the beamline is comparable to those on typical third generation storage rings. Operational since May, 2003

BL-5: A multi-pole wiggler beamline on the 2.5 GeV ring dedicated to protein crystallography. Comparable performance with NW-12. Operational since October, 2003

BL-28: A soft X-ray beamline dedicated to Photoelectron spectroscopy. The undulator itself is an old one which can produce circularly/linearly polarized light. The optics has been renewed with a slitless type monochromator having a varied line spacing grating covering 30~300 eV. The resolving power of the optics exceeds 30,000 in the 30 eV regions. An overall resolution of 6.7 meV was attained at 40 eV for the photoelectron spectrum from a Au film. Operational since October, 2004.

NW-14: An in-vacuum undulator beamline on the 6.5 GeV ring for time-resolved diffraction, scattering and absorption studies of materials, especially photo-induced phase transitions in highly correlated electron systems. This beamline was constructed with external funding. Operational since October, 2005.

BL-17: In-vacuum, short period undulator beamline on the 2.5 GeV ring dedicated to protein crystallography. This beam line is the first short period undulator on the 2.5 GeV ring producing hard X-rays. Under commissioning since October 2005.

NW-10: A bending magnet beamline on the 6.5 GeV ring dedicated for the X-ray absorption spectroscopy. This beamline will cover a rather high energy region up to 50 keV. Under commissioning. since January, 2006.

In addition to the above mentioned beamlines, we are planning to construct two more insertion device beamlines in 2006-2007.

BL-3: The second in-vacuum short period undulator beamline on the 2.5 GeV ring. Design of the beamline is now completed and manufacturing of beamline components is in progress. X-ray activities now supported on BL-16 will be transferred to this beamline. Diffraction and scattering studies of atomic and electronic structures of exotic materials such as highly correlated electron systems, multiferroic materials and molecular crystals will be done on this beamline. Commissioning of this beamline is scheduled in October, 2006.

BL-16: Soft X-ray beamline with the capability to quickly change the polarization of the radiation. This beamline will be equipped with two undulators providing oppositely polarized radiation and by quickly exchanging the electron orbit the polarization can be switched in 10 Hz. The construction will start in 2006and the commissioning of this beamline is scheduled in October, 2007.

(d) Structural biology center

In 1997~1998, we decided to build up an in-house structural biology group whose activities include constructing and maintaining protein crystallography beamlines and supporting users, as well as biology and biophysics research activities. This group now has 7 permanent staff and 28 limited-term staff who are responsible for maintaining biological facilities, developing crystallization and crystal mounting robots in addition to maintaining three insertion device and one bending magnet protein crystallography beamlines.

5. Further upgrades of existing facilities

5-1 Light sources

(a) Improved operation of the 2.5 GeV ring with small gap undulators

In October 2005, we have experienced for the first time operation of the 2.5 GeV ring with our first short period small-gap undulator and are still gaining experiences with this new mode. In the coming years we intend to install three more small gap undulators, hence will require more extensive machine studies.

(b) Top-up injection of the 2.5 GeV ring

Since we share the injector LINAC with the KEK-B rings, it is not possible now to have top-up injection of the electron beam to the 2.5 GeV ring. From 2006, we will realize the top-up injection of electron beam to the 2.5 GeV ring in three phases. In the first phase which will be realized in fiscal 2006, the electron beam can be injected to the ring every 20 minutes. In the second phase, we will establish pulse to pulse and multi-energy fast switching system for the LINAC thus realizing top-up injection when the LINAC is operated in electron injection mode, but not in the positron injection mode. In the third phase, the simultaneous acceleration of electron and positron beam will beam realized allowing 24 hour top-up injection to the 2.5 GeV ring. We plan to finish the three phases of this upgrade in two years.

(c) R&D for the production and utilization of very short X-ray pulses

As a natural extension of our effort on time resolved X-ray studies of materials, users want to study materials with higher time resolution. In fact, we have users who have specimens which show drastic changes in visible light reflectivity in sub pico-seconds. To study such fast phenomena in materials and also to acquire experience in techniques for producing and handling very short pulses, we plan to install an undulator at the end of our injection line from the LINAC and produce sub picoseond X-ray pulses. A design study is now in progress.

(d) Medium emittance operation of the 6.5 GeV ring

The emittance of the 6.5 GeV ring can be reduced down to 160 nmrad, half of the present value, just by rebuilding power supplies for the quadrupole magnets. With such an improvement, the brilliance of undulator sources can be enhanced approximately by a factor of four which is significant in a number of experiments.

5-2 Beamline upgrade, construction of new beamlines and decommissioning plan for old beamlines

To make the best use of the lengthened and newly created straight sections of the 2.5 GeV ring, we will further continue our efforts to reconstruct and newly construct insertion device beamlines.

BL3: We have started the construction of in-vacuum small-gap undulator beamline on BL-3 for the materials science.

BL-16: We have just finished designing BL-16 where we can realize fast switching of the polarization of soft X-ray beam, and will start the construction in 2006.

BL-2: A 3.6 m long planar undulator, the longest and oldest at the Photon factory, is the source for this beamline. Upon completion of the straight section upgrade of the ring, this straight section has been lengthened to 8.9 m and we plan a new, longer undulator for providing soft X-ray source of higher brilliance (10^{19}Photons/mm^2/mrad^2/0.1%B.W.), and a new high resolution optics. A collaboration between the PF and the University of Tokyo is now being sought for the renewal of this beamline.

BL-19: The beamline 19 is equipped with undulators having four sets of magnets having four different periods (revolver undulator), thus covering a wide energy range, and is operated by the Institute of Solid State Physics of the University of Tokyo. This beamline is also being considered for reconstruction.

BL-1 and BL-15: On BL-1 and BL-15, we shall be able to install in-vacuum small gap undulators and we plan to construct one more protein crystallography beamline hopefully starting in early 2007. A new beamline is now discussed for BL-15 and the small angle scattering/ microbeam beamline is one of the possible candidates. To proceed to the construction of new undulator beamlines on BL-1 and BL-15, we have to transfer existing activities to other bending magnet beamlines.

BL-4 and BL-18: Between bending magnets B17 and 18 and also between B3 and B4, RF cavities are in place now, but by shifting their positions towards one of neighboring bending magnets, we can create two straight sections. We are now discussing the possibility of installing short multi-pole wiggler beamlines.

BL-14: We have a super conducting vertical wiggler on BL-14, and the most important on this beamline is the phase-contrast imaging that needs large irradiation area and vertical polarization. Most of the other activities using high energy X-rays can now be transferred to beamlines on the 6.5 GeV ring and this beamline could be reconstructed as an undulator beamline for soft X-rays.

Some of bending magnet beamlines have dual problems that the design concept and the hardware itself have become old and also that the number of published papers has diminished significantly. We will re-evaluate those bending magnet beamlines and scrap some of them to concentrate our resources on the more competitive beamlines.

6 Long term future plan - a new light source -

We believe that the Photon Factory can be an excellent and competitive facility over the coming 5 ~ 10 years by upgrading its facilities along with strategies described above in section 3. Nevertheless, we think that the renewal of the light source will be inevitable in the coming decade since the concept, design and hardware of 2.5 and 6.5 GeV rings will become old and less competitive after 30 years of operation. We started discussing the necessity of a new light source at the Photon Factory in collaboration with users and accelerator scientists all over Japan. We recognize that we should have two fold roles and functions. One is that the Photon Factory should have the most advanced facility in order to offer users opportunities to carry out the most advanced and cutting edge experiments requiring ultimate performance of the light source and the beamline. To meet those demanding experiments in the coming years, we think that the abilities to provide sub-pico second long X-ray pulses, spatially coherent X-ray beam and micro- to nano-sized beam is very important. Another is that we should also have capabilities to support a variety of user needs in very broad and wide scientific and even industrial disciplines with the state-of-the-art experimental instruments and beamlines under very user friendly conditions. We consider that an Energy Recovery Linac could be a good candidate to fulfill those two different requirements with a single machine and have recently decided to aim the realization of an ERL as the next generation synchrotron radiation source at the Photon Factory.

We have just started organizing an R&D group consisting of PF staff members and Accelerator group members of KEK. We aim to design, construct and test a 200 MeV prototype accelerator during 2006-2009 and hope to start construction of the 5 GeV class ERL machine from 2010. In addition to the Photon Factory staff members, the Accelerator Facility of KEK is now officially involved in this project. We have also started a collaboration with the JAEA (previously JAIRI) group who is also proposing the realization of an Energy Recovery Linac. As the first step, we have just started a design study of a prototype ERL of 200 MeV assuming that the existing neutron lab building will be available for installation. We hope that we will complete this prototype ERL by the end of fiscal 2008 and gain operational experience in 2009. Further, we hope that we shall be able to start the construction of a 5 GeV class ERL from 2010.

7 Role and function of the in-house staff scientists

Currently, we have 70 experimental stations and almost 3,000 users annually. Those users visit the Photon Factory 2~3 times a year and stay about 10 days a year on average. On the other hand, we only have 37 experimental scientists and 15 technicians for maintaining, improving and constructing beamlines, and supporting users' experimental activities. In most Japanese large facilities, the number of staff members is much smaller, typically one-third or less compared to those of typical western research facilities. We believe that there are too few staff to support the number of experimental stations (or alternatively there are too many experimental stations for the available level of staffing). Also, there are some experimental stations with less activity, and we feel that we have to reallocate our man power and budgetary resources to more active stations. We will reevaluate the beamline performance and activities on relevant stations, then categorize those beamlines and seek ways to concentrate our efforts and resources on a reasonable number of experimental stations. This strategy should lead to a more competitive position over an extended period.

We recognize that the role and function of a synchrotron radiation research facility is not only providing photon beams to users, but to create and offer advanced, new and/or convenient and user friendly experimental opportunities. This requires development of experimental techniques and methods. At the same time it is sometimes necessary and very effective to appeal to inexperienced or potential users to demonstrate how powerful synchrotron radiation is by showing excellent scientific output with in-house research activities, i.e. serving as a "show-case". In regard with the last point, we have formed a structural biology research group and raised our capability to carry out our own biological research projects in the past several years. In combination with the results of such activities and excellent performance of recently built protein crystallography beamlines, in-house and users' research activities in relevant fields have become very active and have been expanded. Although our man power resources are very limited, we consider that we should form a few more excellent and strong in-house research groups which will have a critical mass to conduct focused and visible research activities and catalyze users' research activities in relevant fields.

For maintaining existing facilities, developing new instruments and supporting many users, a lot of technical, engineering and administrative work is shared by in-house staff scientists because no engineer positions are available and administrative man power is limited in our system. We feel that without such work shared by our staff scientists, we might not be able to maintain our facility and our user support program would collapse.

Hitherto, staff scientists of the experimental facility divisions have been asked to play dual roles mentioned above. However, it is sometimes observed that it is not easy for a single staff member to conduct excellent and visible work both in scientific activities, and engineering type work and user support. We are recently discussing a possibility of dividing experimental facility divisions into two; one group being more oriented towards scientific activities and the other towards beamline instrumentation and user support. We consider that such a reformation of the experimental facility group will be useful and effective in activating both in-house and users' research.

8. Summary

We believe that the Photon Factory has played an important role in the Japanese synchrotron radiation research community covering a wide wavelength range from VUV to X-rays. We feel it should continue to do so for the foreseeable future. The recently upgraded 2.5 GeV ring and the single bunch operated 6.5 GeV ring are3 unique, important and powerful resources for the coming 5~ 10 years if state-of-the-art insertion device beamlines are constructed in a timely manner. For longer term, we will aim at constructing an Energy Recovery Linac as the next generation light source at the Photon Factory to replace the 2.5 GeV and 6.5 GeV rings and to play dual roles of providing experimental opportunities with beams of ultimate performance as well as those for wide and broad range of application with reasonable performance.