1 Newly Developed Experimental Facilities

1-1 Overview

High performance insertion devices and beamlines are currently highly in demand for increasingly sophisticated scientific research. Since the number of straight sections was initially limited at the Photon Factory, some beamlines were constructed as hybrid beamlines, where a single insertion device is used as an undulator for the soft X-ray region and as a multi-pole wiggler for the hard X-ray region (hybrid use). Although varied requirements could be met with hybrid use, which was a good style in the early days, beamtime and working space were restricted and experimental systems had to be changed frequently. With the growth of synchrotron sciences, it became essential to prepare application-specific beamlines and end-stations. We thus decided to modify the lattice of the 2.5-GeV PF ring and to assign five long and medium-length straight sections for experiments requiring soft X-rays, and the remaining medium-length sections and four short ones for those requiring hard X-rays. The straight sections in the PF-AR are also available for experiments requiring hard X-rays.

The straight sections upgrade project of the 2.5-GeV PF ring that aimed at creating more space for insertion devices (ID) was successfully completed in FY2005, as reported in previous issues of this report. Following the above-described strategy, some of the insertion-device beamlines have been reconstructed; BL-28A in 2004, BL-17A in 2005, BL-3A and 28B in 2006 and BL-16 in 2007. Among these, BL-17A and 3A use in-vacuum short-gap undulators (SGU) to provide hard X-rays from the 2.5 GeV storage ring.

The hybrid use of BL-16 ended in 2006 with the construction of a short-gap undulator at BL-3A. At BL-16, a new APPLE-II type undulator and a fast bump system consisting of five fast kickers were installed during the spring shutdown in 2008. Before the installation of the undulator, the beamline was reconstructed during the summer shutdown of 2007, and vacuum conditioning and beamline commissioning were carried out. Circularly, elliptically or linearly polarized soft X-rays with photon energies between 200 and 1500 eV can be provided at this beamline with a fairly high energy resolution, $E/\Delta E$ ~ 4000. The goal at this beamline is to install another undulator of the same type, to modulate the polarization at a frequency of 10 Hz or higher, and extract weak polarization-dependent signals by using the lock-in amplification method. The kicker system has been installed, and the second undulator will be installed in FY2010.

In order to construct new beamlines with ID sources, some of the dipole beamlines had to be moved or decommissioned. BL-8 was constructed by Hitachi Co., Ltd. in 1985, and was preferentially operated until FY2004. After that it was kindly donated to the Photon Factory and opened for public use. A new structural biology beamline was proposed based on the “Targeted proteins” national project, where the crystal structures of small crystals less than 10 μm in size are to be analyzed by utilizing the anomalous signal of sulfur. A short gap undulator was planned as the source, and BL-1 was chosen as an appropriate site. However, the transfer of the structural material science beamlines 1A and 1B were fairly active stations. Thus we decided to decommission BL-8 and move BL-1A and 1B to BL-8A and 8B. The decommissioning of BL-8 started in March 2008.

Setting up a beamline at the Photon Factory for Indian scientists was proposed by the Department of Science and Technology (DST) of the government of India in March 2007. After discussions, it was planned to lease the existing beamline BL-18B to the DST. The letter of intent concerning this project was welcomed by the Prime Ministers of both countries in a joint statement made in August 2007, when the Japanese Prime Minister at that time, Shinzo Abe visited India.

The beamlines in the NE experimental hall of the PF-AR were constructed in 1989 and 1990. Various scientific fields such as magnetic Compton scattering using the time-of-flight technique, and nuclear resonant scattering using quantum beats were developed at NE1 and NE3. These research fields grow up and new beamlines were constructed at the third-generation synchrotron facility SPring-8, where more sophisticated experiments can be carried out. Refurbishment of the PF-AR beamlines began in March 2008. A new structural biology beamline funded by a pharmaceutical company, Astellas Pharma Inc., is under construction at NE3. A station for X-ray diffraction in high-pressure and high-temperature environments, combined with nuclear resonance capabilities, is under construction at NE1, to where the activities now carried out at BL-13A are to be moved. These beamlines will be completed in FY2008, and opened for users from FY2009. A new beamline NE7 will also be constructed, to which the activities currently carried out at NE5A and BL-14C2 will be moved. At the same time BL-14C will be reconstructed and dedicated for phase-contrast imaging utilizing vertical polarization. All of the beamlines in the NE experimental hall will be closed between March and June 2008 in order to make the reconstruction work easier and for the safety of users. The movement of BL-13A to NE3 also presents the possibility of reconstructing BL-13 and solving its hybrid problem.

More detailed information on the newly-constructed beamlines can be found in the following pages.

1-2 BL-16A, A Variable Polarization Beamline for Soft X-ray Spectroscopy

BL-16A is a soft X-ray (200-1500 eV) undulator beamline aiming for fast polarization switching at a frequency of ~10 Hz [1]. The construction of the beamline optics, which consists of a variable-included-angle Monk-Gillieson mount varied-line-spacing monochromator [1,2], was completed in October 2007. Although two APPLE-II type undulators will be installed in a tandem configuration in order to achieve fast switching between left/right hand circular or horizontal/vertical linear polarizations, at first the upstream undulator only was installed in March 2008, and the commissioning of the undulator and beamline optics is now underway. User experiments have been partly started from October 2008 using the circular polarization mode and a photon energy range of 280-1000 eV, and the other polarization modes will be opened according to the progress in the commissioning.

During the commissioning of the beamline optics, we encountered a problem in the mirror holder; the mirror shape was distorted because the mirror was too tightly fixed. After an improvement of the mirror holder in March 2008, the problem has been solved. The X-ray absorption spectra for N_2 taken at the N K edge are shown in Fig. 1, these were recorded in order to check the energy resolution of the beamline. Although the beamline optics were not designed for ultimate energy resolution, E/ΔE of ~ 5000 and > 8000 are achieved for entrance slit (S1) widths of 50 and 25 μm, respectively. A typical X-ray magnetic circular dichroism (XMCD) spectrum is shown in Fig. 2. This spectrum was obtained from a several-μm thick Ni film in the total electron yield mode.

The fast polarization switching project has been adopted under the MEXT quantum beam technology program, and began in August 2008 as a collaboration between KEK, the University of Tokyo, AIST and Keio University. The second undulator will be installed in 2010 with the financial support from this program. After the achievement of fast polarization switching, the signal-to-noise ratio of XMCD and X-ray magnetic linear dichroism (XMLD) data will be improved by a factor of $\sim 10^3$, which will enable us to investigate, for instance, the near phase-transition phenomena of highly correlated electron systems, the origin of ferromagnetism in diluted semiconductor magnets and the interface magnetic structure of magnetic thin films. In addition, dynamic processes such as chemical reactions at surfaces will be able to be observed in one event by combining the fast polarization switching technique with the wavelength-dispersive X-ray absorption fine structure technique.

REFERENCES

[1] *Photon Factory Activity Report*, **24A** (2006) 65.
[2] K. Amemiya and T. Ohta, *J. Synchrotron Rad.*, **11** (2004) 171.

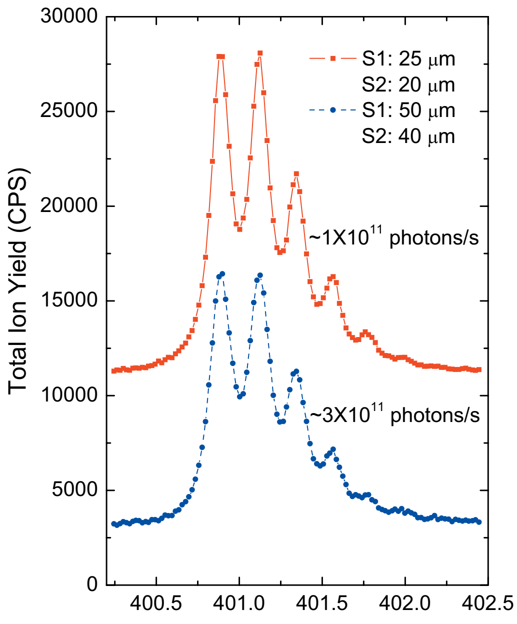

Figure 1
N K-edge X-ray absorption spectra of N_2 recorded in the total ion yield mode.

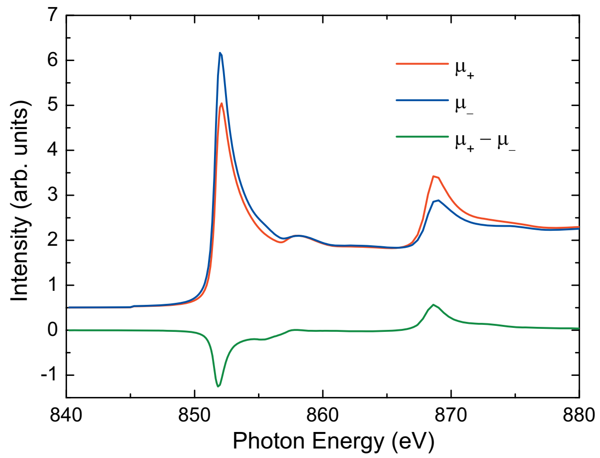

Figure 2
Ni L-edge X-ray magnetic circular dichroism spectrum of a Ni thin film recorded in the total electron yield mode.

1-3 Transfer of the Structural Material Science Beamline from BL-1B to BL-8B

The activities at beamlines BL-1A and 1B, dedicated to X-ray diffraction for structural materials science, are being transferred to reconstructed BL-8A and 8B respectively, in order to construct a new structural biology beamline with a short gap undulator at BL-1.

The old BL-8 was closed at the end of December 2007, and a new main hutch and experimental hutches for the new BL-8A and BL-8B were constructed in March 2008. After the spring cycle 2008, user operation at BL-1B was ended and the optical components, i.e., the monochromator, the mirror system, the shutters, the beam pipes as well as the imaging-plate diffractometer were moved from BL-1B to BL-8B.

The reconstruction of BL-8B was successfully completed during the summer shutdown period of 2008. The first beam was observed on October 7, 2008 and adjustments and setup of the beamline were successfully carried out.

The incident beam is monochromatized by a Si(111) double-crystal monochromator. The monochromatic beam is focused at the sample position located 25.658 m from the light source by a newly designed Rh-coated bent cylindrical quartz mirror located at 15.36 m. The glancing angle of the mirror is 3.2 mrad, thus the beamline optics of new BL-8B cover a photon energy range of 5 to 19 keV. The focused beam size and the typical photon flux at the sample position were 0.75 mm (H) × 0.45 mm (V) and 2.2×10^{11} photons/sec (12.4 keV). Structural analysis using a standard single crystal was carried out. The scale factor among the frames was calculated using the Rapid Auto software, and the resulting R-merge was 1.8%. The solved structure was correct, with an R-factor of 3.5%. The beamline was opened for user experiments from November 11, 2008.

BL-1A is scheduled to be closed at the end of December 2008 and transferred to BL-8A between January and April 2009.

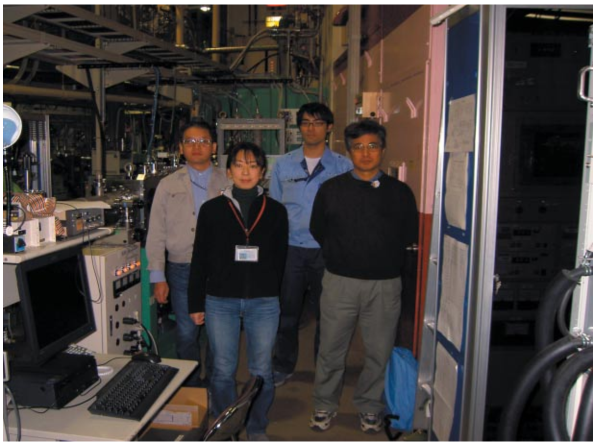

Table 1 Preliminary characteristics of the beam at the new BL-8B.

Horizontal Acceptance angle (mrad)	2
Photon Energy (keV)	5 - 19
Beam size (H (mm) × V (mm))	0.75 × 0.45
Photon Flux at sample position (phs/sec) 400 mA	2.2×10^{11} (12.4 keV), 7.9×10^{10} (18 keV)
Energy Resolution $(\Delta E/E) \times 10^{-4}$	~5