3-2. New Beamlines at PF-AR

As described in the preceding volume of the Activity Report, the reconstruction and reinforcement of the PF-AR were approved in the supplemental budget of 1999. We could start thus renewal of the accelerator (vacuum system, monitor system and magnet system etc.) and construction of an X-ray undulator beamline (AR-NW2) for protein crystallography as well as time-resolved XAFS experiments.

In 2000, a second supplemental budget was approved for the construction of a new experimental hall in the northwest part of the PF-AR, as well as one more X-ray undurator beamline (AR-NW12). Figure 2 shows a top view of the PF-AR including a new NW experimental hall. We thus decided that beamline AR-NW2 would be constructed as a dedicated beamline for XAFS experiments and that beamline AR-NW12 would be dedicated to protein crystallography based on the multiple-wavelength anomalous diffraction (MAD) method. Details of these beamlines are described below.

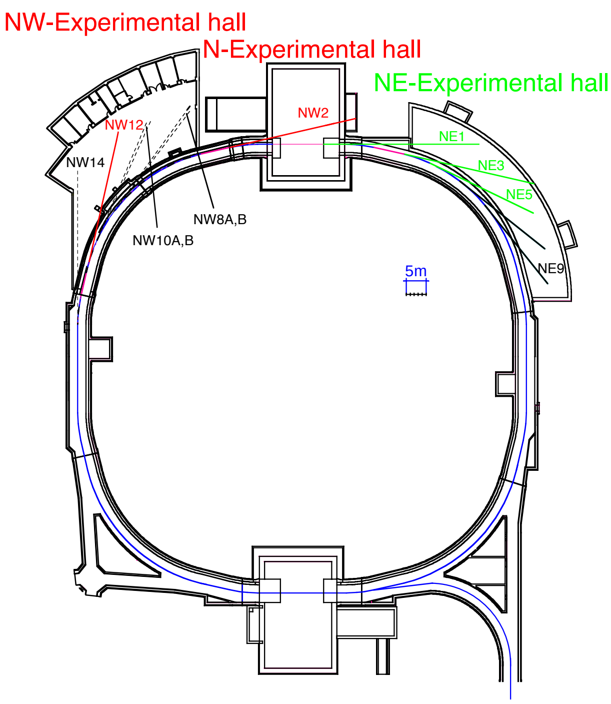

Figure 2.
Plan view of the PF-AR. Three beamlines in the NE experimental hall (NE1, NE3, and NE5) have been used for synchrotron-radiation experiments and coronary angiography and two (NW2 and NW12) are under construction in the new N and NW experimental halls.

AR-NW2 (XAFS beamline)

The specifications of this beamline are as follows:

(1) In order to conduct conventional XAFS experiments, it is essential to realize a good energy tunability in the 5 ~ 25 keV energy range.

(2) The photon flux of monochromated X-rays at the sample position should be at least 10^{13} photons/s for a beam size less than 0.5 × 0.5 mm^2.

(3) For time-resolved experiments with a dispersive XAFS arrangement, it is necessary to focus white X-rays in a vertical direction, which should have a relatively wider energy spread of the undulator radiation.

In order to achieve the above specifications, the beamline was designed as follows. Figure 3 shows the plan view of the beamline. The insertion device is an in-vacuum undulator at a period of 40 mm, and the number of periods is 90, which can cover an energy range of 5~25 keV by using the 1st, 3rd, and 5th harmonics of the undulator radiation. The device has an optional mechanics to make a tapered undulator in order to obtain a relatively wider energy

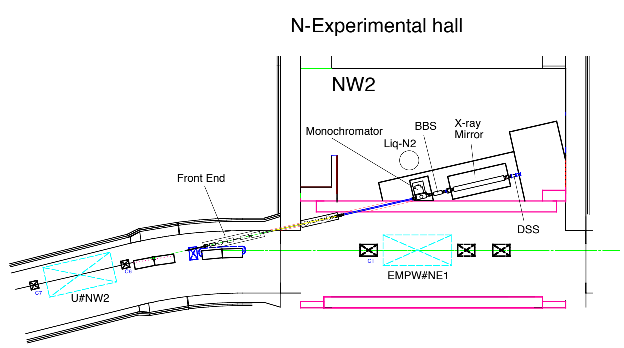

Figure 3.
Schematic layout of the new beamline AR-NW2.


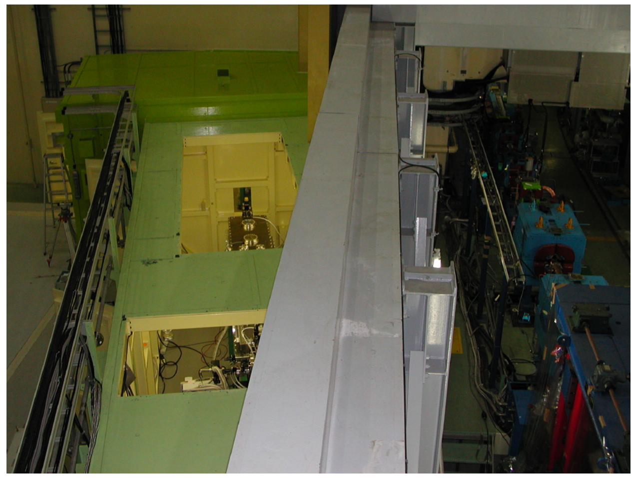

Figure 4.
Photographs of the AR-NW2. (Right) The double-crystal monochromator and mirrors have been installed in a hutch on the shield wall of the ring. The multi-pole wiggler for the beamline AR-NE1 (EMPW#NE1) is seen just inside the wall. (Left) Cryogenic cooling system for the monochromator crystal is set outside the hutch.

spread ($\Delta E/E \sim 10^{-1}$) for the 3rd harmonics. The front end consists of a fixed mask, a beam-position monitor, an absorber, a beam shutter, a graphite heat absorber, XY-slits for white X-rays and Be windows. The main optical components are a double-crystal monochromator and a focusing mirror system, which are located 22.5 m and 25 ~ 28 m from the center of the insertion device, respectively (Fig. 4). The double-crystal monochromator consists of flat Si(111) crystals, which are cooled with liquid nitrogen in order to reduce any deformation caused by the heat loads. The circulation of liquid nitrogen is realized by a closed-loop system with two GM-refrigerators, which has a cooling power of 170 W each. Thus, it is possible to handle the incoming heat power up to about 300 W. The focusing mirror system has 4 mirror assemblies: a bent cylindrical mirror for double focusing of X-rays, a bent flat mirror for vertical focusing, and a double-mirror system (cut-off mirrors) to reduce a contamination of the higher harmonics. When a doubly focused beam is necessary for high-flux XAFS experiments, a bent cylindrical mirror and a double-mirror system will be used. The double-focusing mirror is replaced by a flat mirror for time-resolved experiments in a dispersive XAFS geometry. Then, one of the cut-off mirrors will be bent at the meridian direction to allow vertical focusing of the white X-rays.

AR-NW12 (Protein-crystallography beamline)

The scientific purpose of this beamline is protein crystallography based on the MAD method. The following specifications should be achieved at this beamline:

(1) Good energy tunability in the 5 ~ 20 keV energy range as well as good energy resolution of 10^{-4} in order to perform MAD method.
(2) Photon flux at the sample position higher than 10^{12} photons/s under the conditions of a focused beam size less than 0.2 × 0.2 mm^2 and a beam divergence of less than 0.5 mrad.

Figure 5 shows a plan view of the beamline in the new NW-experimental hall. The insertion device is also an in-vacuum undulator with a period length of 40 mm; the number of periods is 100, which can cover an energy range of 7~16.8 keV by using the

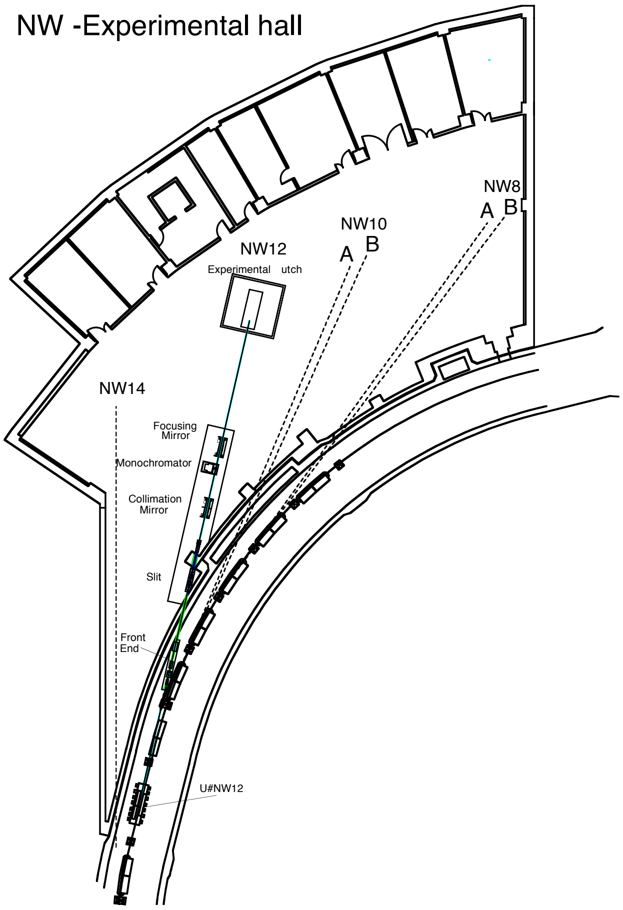

Figure 5.
Schematic layout of the new NW experimental hall. Beamline AR-NW12 for protein crystallography is now under construction.

3rd harmonics of the undulator radiation. The front end consists of a fixed mask, a beam-position monitor, an absorber, a beam shutter, a graphite heat absorber, XY-slits and Be windows. The design concept of these components is similar to that of the AR-NW2. The main optical elements are a vertical collimating mirror, a double-crystal monochromator and a re-focusing mirror, as shown in Fig. 5. A flat mirror is bent for vertical collimation to achieve good energy resolution. The double-crystal monochromator consists of flat Si(111) crystals, which are cooled with liquid nitrogen in order to reduce the deformation caused by the heat loads. The system is the same as that of AR-NW2. The re-focusing mirror is a bent cylindrical mirror in order to realize a doubly focused beam at the experimental hutch.

The experimental hutch is 4 m × 4 m, in which an experimental table will be installed. It is designed in such a way that two different detectors can be installed with a reasonably easy mechanism for exchanging the two. The larger detector can be up to 1 m across the active area. The objects around the sample, such as a beam stop, a fluorescent detector, and a scattering guard collimator, are retractable for easy mounting and removal of crystals. The one-circle diffractometer will have a diameter of rotation of a few microns with a CCD microscope and UV/visible illumination.

As shown in Fig. 5, there are also several rooms for preparing samples, housing detectors, vacuum assemblies, and data processing, and a storage in the new NW experimental hall.

The time schedule of the construction is as follows: The installation of the AR-NW2 will be completed by the end of November, 2001, in accordance with the improvements of the accelerator. After we commission the accelerator and the beamline, at the beginning of 2002 we hope to see the first beam at AR-NW2. On the other hand, the new NW experimental hall (Fig. 6) will be completed by the end of March, 2002, and AR-NW12 will be installed by the end of September, 2002. Thus, we will see the first beam at AR-NW12 in October, 2002.

Figure 6.
NW experimental hall is now under construction.