実験技術

The Australian National Beamline Facility at the Photon Factory

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1. Introduction

During the 1980's, rapid expansion in the use and availability of x-ray and UV radiation from dedicated or 'second generation' synchrotron radiation facilities has provided many areas of physics, chemistry, biochemistry and medicine with indispensable tools and techniques. Even though there is no such facility in Australia, Australian scientists from many fields have made extensive use of synchrotron radiation through collaborations and the general user programs run by facilities in Japan, Europe and the USA.

The Australian National Beamline Facility (ANBF) was set up and is funded by a consortium of government organisations to provide Australian scientists with routine access to synchrotron radiation at the Photon Factory in Tsukuba, Japan. When the management of the Photon Factory generously offered the use of bending magnet port BL-20B, the Australian consortium committed funding and personnel over a three year period for the planning, construction and operation of an x-ray beamline. Part of this commitment has included stationing two scientists permanently at the beamline, establishing office accommodation and providing a communal area for beamline users.

2. Beamline Overview

The facility has been designed to accommodate the needs of the majority of Australian x-ray users on a single beamline. The beamline will be capable of delivering either a white beam, or a monochromatic beam in the 5-20keV range, to one of two experimental stations. The primary station will be a versatile, multi-configuration vacuum diffractometer. An optical table situated behind the diffractometer will act as the second experimental station.

Figure 1 shows an elevation view of the complete beamline with monochromator, diffractometer and optical table. Construction of the beamline components commenced in Australia midway through 1991, and the hutch was assembled at the Photon Factory later that year. The white beamline was installed at the Photon Factory during July/August 1992, and certified for white beam use in October 1992. The beamline is currently capable of delivering white beam (up to 2.5 mRadians horizontally) to experiments mounted on an optical table in the hutch. In the next phases of construction, the monochromator and diffractometer will be added to the beamline in 1993.

The beamline and diffractometer will be controlled by a commercial diffractometer software package

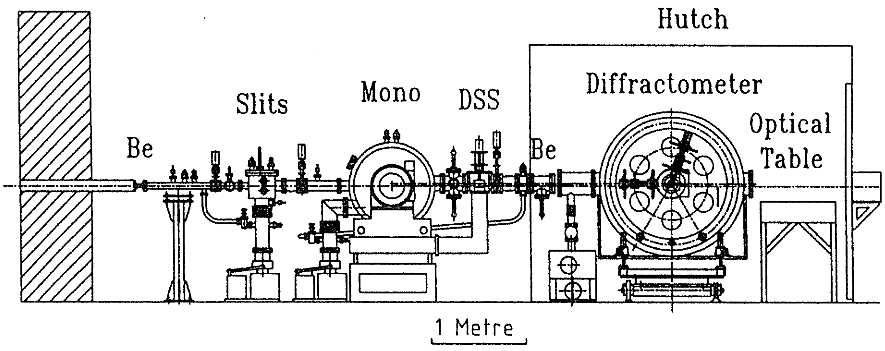

Fig.1 The Australian National Beamline at BL-20B, Photon Factory, KEK, Japan. DSS indicates the down-stream shutter and Be indicates the beryllium windows.

running under the Unix operating system on a 486 PC. Most hardware interfacing will be accomplished via Camac modules, in particular the control of the many stepping and DC motors in the diffractometer. The software is easily configurable to operate the many diffractometer modes planned.

3. Monochromator

As the most critical component of a synchrotron beamline, the monochromator optics must be carefully designed and precisely fabricated to maximise the X-ray flux at the sample. Monochromator development for the Australian beamline is proceeding in two phases. The first phase monochromator will utilise a water cooled channel-cut Si (111) crystal: a monolithic double-crystal monochromator [1]. As the Two Si (111) reflection faces are prefectly aligned, energy selection can be achieved with a single rotation axis, resulting in a simple, stable mechanism. This monochromator is scheduled to be installed in January 1993.

The Second phase monochromator is being designed to address two limitations in the phase one beamline optics. Firstly, the exit beam height of the channel-cut monochromator varies with the energy selected; secondly, the relatively short length available for the beamline precludes the use of focussing mirrors to concentrate the x-ray flux at the sample. The phase two monochromator will incorporate a relatively complex mechanism to move the first crystal, maintaining a fixed exit heght [2], and a saggital bender on the second crystal to provide focussing at the sample. This monochromator is due to be completed by late 1993.

4. Multi-Purpose Diffractometer

The multi-purpose diffractometer has been designed to provide a large range of diffraction techniques with little compromise in resolution. It is anticipated that it will be installed at the beamline just prior to the Photon Factory summer shutdown in 1993. The diffractometer combines a two circle goniometer with a large radius Weissenberg camera. The whole instrument in housed in a large chamber which can be evacuated or filled with helium to avoid air scatter.

The two-circle goniometer incorporates incremental angle encoders on both axes; these provide an independent angle readout with a resolution of better than one arc-second. Optical rails will be mounted along the incoming beam, and on the two-theta arm, allowing many configurations of slits, analyser crystals and detectors. It will also be possible to increase the intensity at the sample by mounting a condensing channel-cut monochromator [3] before the sample. The diffractometer will be used in two-circle mode for conventional high-resolution powder diffraction, and single crystal diffraction.

The Weissenberg camera consists of a 570mm radius cassette which uses a novel clamping system to allow the mounting of up to 8 Imaging Plates (IP) covering 330° of scattering angle. The IP cassette will be mainly used for powder diffraction and protein crystallography with the cassette translating along the horizontal (Weissenberg) axis. In powder diffraction mode, a screen mounted inside the cassette will allow time resolved data to be acquired by translating the cassette behind the screen. For protein crystallography, a He enclosure will be mounted inside the cassette allowing a He atmosphere to be maintained around the beam-path while the IPs are exchanged. As both monochromators will be easily tuneable, it will be possible to collect Multiple-wavelength Anomalous Dispersion (MAD) data.

The diffractometer can also be used to acquire small angle scattering data. An extension will be fitted to the vacuum chamber to increase the sample-detector distance, and either an IP or a 2-D electronic detector will be used. It will also be possible to simultaneously collect wide-angle scattering data with the IP cassette.

5. Other Experimental Configurations

The exit slits on the back of the diffractometer chamber will allow the x-ray beam to pass through to the optical table. A number of techniques will be accommodated on this secondary experimental station. Monochromatic beam experiments such as XAFS are planned and a liquid surface reflectometer is currently under construction. White beam techniques such as topography and Laue diffraction are currently in use at this station. Microbeam techniques such as a fluorescence microprobe and micro-tomography are also planned. Tapered capillary condensing optics, for increasing the flux in a microbeam, are being investigated.

6. Current Status

The first white beam was brought into the hutch at BL-20B on October 7, 1992. In the following weeks, a white beam experimental station was established incorporating both a Laue camera using IPs and an energy dispersive solid-state Si(Li) detector for fluorescence experiments.

In the past two months several groups of users from Australia have taken advantage of the facility at BL-20B. The first experiments consisted of a study of the changes seen in successive Laue patterns collected from an ageing sample of a martensitic AuCuZn alloy. Other experiments have included: x-ray fluorescence of InTl and metal alloys, grazing-incidence topography of HgCdTe epilayers and GaAs crystals, Laue and grazing incidence topography of ion-implanted silicon, micro-Laue photography using nuclear emulsion plates, and energy dispersive powder diffraction studies of an aluminosilicate perovskite under high pressure in a diamond-anvil cell. Studies of rare earth and transition metal ferromagnets using x-ray topography are scheduled.

7. Acknowledgments

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8. References

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