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Basic Energy Sciences Synchrotron Radiation Center Undulator Sector at the Advanced Photon Source

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Abstract

The Basic Energy Sciences Synchrotron Radiation Center (BESSRC) Collaborative Access Team (CAT) has designed and built a multipurpose undulator beamline at Sector 12 of the Advanced Photon Source (APS). The first optical enclosure contains all the white light components including a high performance thin, cryogenically cooled Si (1 1 1) double crystal monochromator. All the experimental stations are equipped with an exhaust for reactive gases that allows in-situ studies of chemical reactions. The monochromatic windowless beamline is used for elastic and inelastic X-ray scattering, surface scattering, small-angle scattering, and spectroscopy research. Each of these activities is in general confined to one of the three experimental stations. The end station (12-ID-D) is a monochromatic enclosure that is used for surface scattering and includes MOCVD equipment for in-situ measurements. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Third generation synchrotron radiation sources open up the possibility of doing a wide range of new experiments. The main scientific programs associated with the 12-ID sector at the APS are surface structures; small angle scattering; atomic and molecular physics and time resolved experiments. The insertion device that fulfills the experimental requirements of this project is the Hybrid Undulator A designed by the APS staff. This undulator provides first harmonic tunability over the energy range of 3.2 to 13 keV. The third harmonic allows one to extend the range of energies covered by this undulator to about 39 keV. The sector consists of an undulator beamline with three stations in tandem. The first

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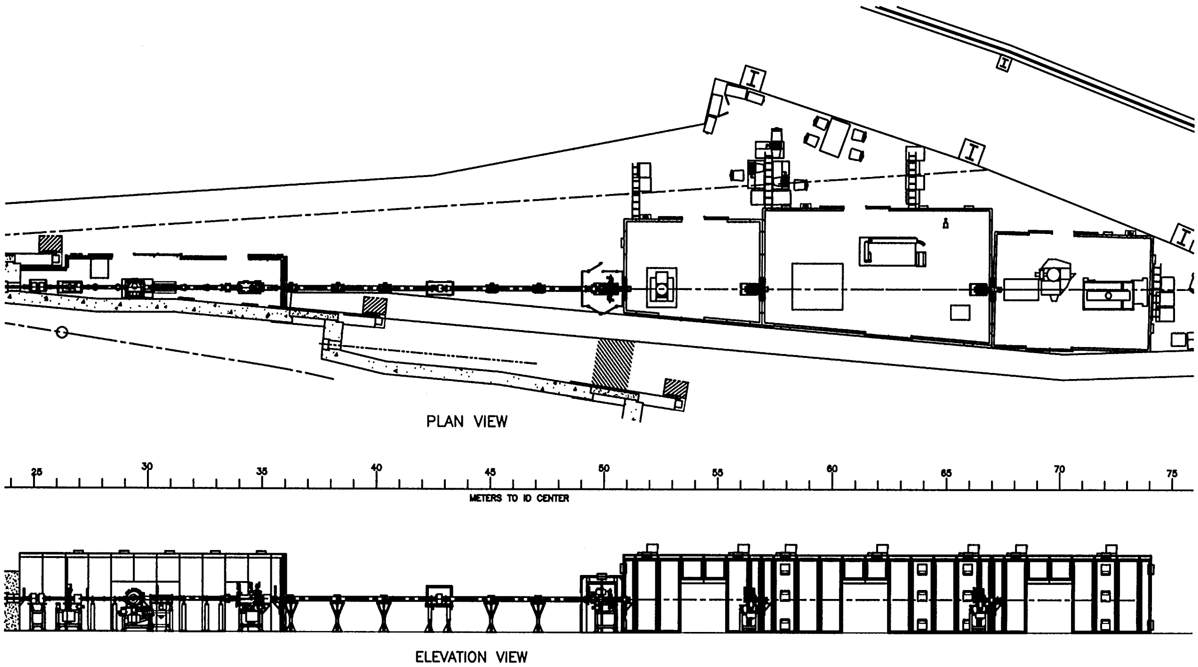

Fig. 1. Schematic diagram of the BESSRC undulator beamline 12 at the APS.

experimental station is dedicated to elastic and inelastic scattering. The second experimental station is dedicated to small angle scattering and atomic and molecular physics. The third experimental station is dedicated to surface scattering experiments (MOCVD, MBE, XSW). Fig. 1 shows the layout of sector 12 undulator at the APS.

2. Beamline optics

The front end is equipped with a fixed mask, photon shutter and photon beam position monitor for Undulator A. Photons from the insertion device, Undulator A, which pass through a 0.5 mm vertical by 1 mm horizontal aperture are monochromatized by a fixed-exit, 35 mm offset, double crystal monochromator. The Basic Energy Sciences Synchrotron Radiation Center (BESSRC) Collaborative Access Team (CAT) uses a common monochromator design [1] for all their beamlines at the Advanced Photon Source (APS). This design is a double crystal, fixed exit monochromator, which allows windowless operation of the beamlines.

The crystals are mounted on a turntable with the first crystal at the center of rotation. A mechanical linkage [2–4] is used to correctly position the second crystal and maintain a constant offset. The monochromator has a linkage with the center of rotation at the mid-point of the first crystal surface. The roller at the apex point moves the vertical slide for the second crystal while an in-vacuum stepper motor driven rack and pinion is used to drive the horizontal slide. The monochromator is designed with two adjacent vacuum chambers, one containing the drive mechanism, a vacuum compatible Huber goniometer, and another chamber containing a turntable on which the monochromator linkage and crystals are mounted. This design allows ultra high vacuum operation of the monochromator. The design of the monochromator is such that it can accommodate both water and liquid nitrogen cooling for the crystal optics. Fig. 2 shows a side view of the monochromator

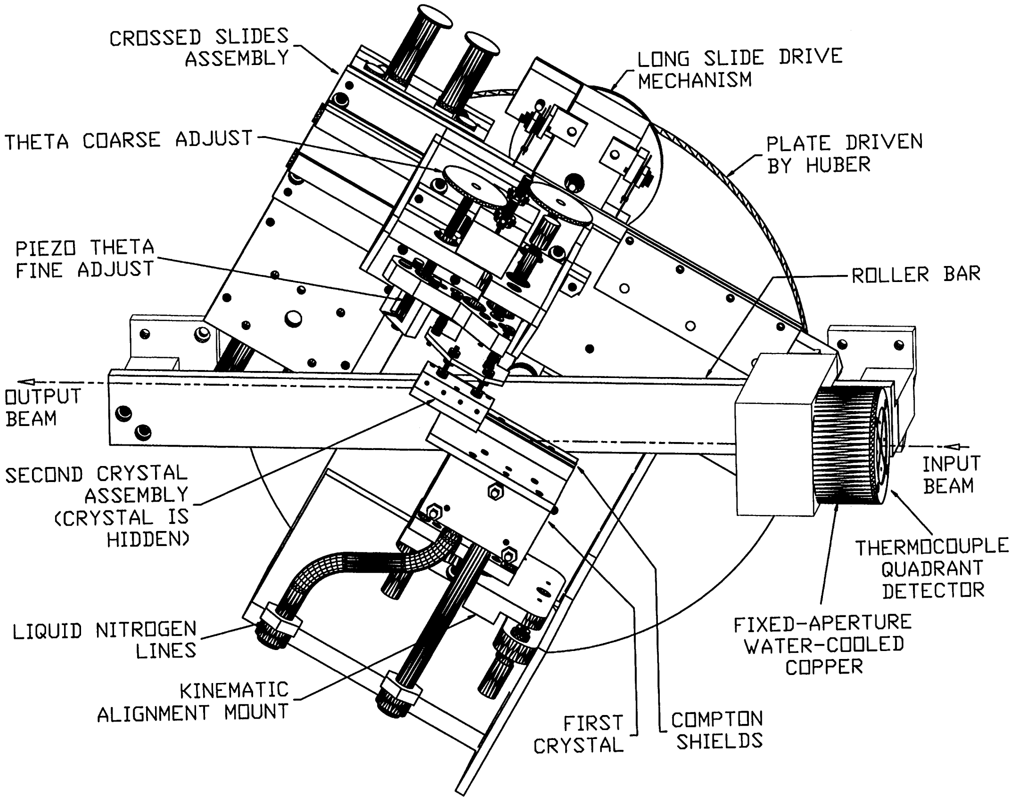

Fig. 2. Schematic view of the cryogenically cooled BESSRC monochromator.

mechanism. Internal liquid nitrogen channels cool the first crystal, Si (1 1 1). The second crystal is cooled by copper braid linking (not shown) it to the liquid nitrogen supply lines and maintains a temperature of approximately 150 K nearly independent of the undulator power. In-vacuum stepper motor driven micrometers drive the chi and theta rotations for the kinematic mount of the second crystal. In addition, an electrostrictive translator mounted in opposition to the theta micrometer provides nearly backlash free fine adjustment of the second crystal. The monochromator provides energies from 4 to 28 keV using the Si (1 1 1) reflex. Fig. 3 shows an example of a high-energy resolution scan of the elastic peak from plastic target. We use as incident beam the Si (3 3 3) reflex and as analyzer in the backscattering

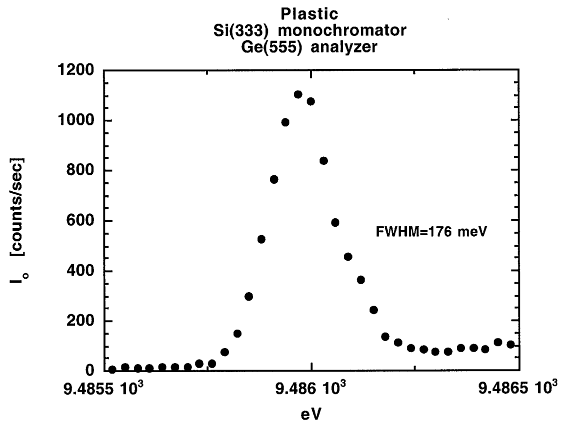

Fig. 3. Elastic peak from a plastic target with monochromatic X-rays from Si (3 3 3) and analyzed in the back-scattering geometry with Ge (5 5 5).

geometry Ge (5 5 5). An energy resolution of 176 meV was obtained; such arrangements are regularly used for X-ray inelastic scattering.

A four-quadrant molybdenum mask with temperature sensors in each quadrant located immediately upstream of the white beam fixed mask provides diagnostics of the white beam position. A removable quad photodiode located just down stream of the monochromator provides beam stability and positioning information for the monochromatic beam.

A removable flat monochromatic mirror is located midway between the first optic enclosure (12ID-A white beam station) and the first experimental station (12ID-B). The 40 cm long silica mirror has 1 cm wide strips coated with Pt and Pd separated by a flat silica surface. The mirror can be operated at an incident angle of 2.5–4 mrad and moved horizontally so that the critical angle can be adjusted to eliminate harmonics. The mirror is mounted in a 4-point bender, which can provide better than 100 μm vertical focus in the first experimental station.

3. Experimental stations

There are three monochromatic experimental stations at the BESSRC undulator beamline 12ID-B, 12ID-C and 12ID-D (see Fig. 1). The first of these, approximately 6 m long by 4 m wide is equipped with a spectroscopy table and an 8-circle Ψ-goniometer. We measured at the sample position using a calibrated pin diode 7.3×10^{12} photons/s-mm^2 at 21.5 keV, third harmonic. At 9 keV we measured at the sample 4×10^{13} photons/s-mm^2, undulator first harmonic.

The second experimental station which is approximately 10 m long and 5 m wide is used for small-angle scattering experiments and atomic physics. The ability to measure small angle scattering from samples in the 12ID-B enclosure at the rear of the 12ID-C station allows small angle scattering experiments to be done in the very small Q regime. The station is equipped with a high-resolution (3000 × 3000) large format mosaic CCD detector. High quality (low signal-to-noise) scattering images were obtained in coal and polymers with exposure times of < 100 ms. Time resolved experiments were done with rapid heating rates on a series of carbonaceous materials [5]. High-precision scattering patterns were collected for protein and surfactant micellar assemblies. In the mid-q region scattering patterns were collected with 8 s of acquisition time that had previously required 60 min of acquisition time using a 2-D wire detector. These results are significant since they demonstrate that this facility offers unprecedented opportunities for correlating chemistry with the fine structure and dynamics of macromolecular assemblies in non-crystalline, disordered media.

The end station, 12ID-D houses dedicated experimental setups for UHV-MBE X-ray standing wave and surface diffraction experiments as well as a MOCVD apparatus. The MOCVD has been used to study the growth of GaN [6] and more recently ferroelectric thin films (different type of reactor).

All the experimental stations are fully operational and have hosted more than hundred researchers the last two years.

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