High Resolution Inelastic Scattering (BL35XU)

1. Introduction

The conceptual design for BL35XU was completed during 1998, providing the basis for the technical specifications of beamline components (completed in fiscal 1998). In this contribution, we describe this design, focussing on items unique to BL35XU. The purpose of the beamline is the investigation of sample dynamics, via inelastic X-ray scattering (IXS) and nuclear resonant scattering (NRS). Additional description of the beamline, including more references to related work, may be found in [1].

It is worth noting that this beamline is very much a second generation beamline at SPring-8, as it relies on the availability (and proven reliability) of many standard components. While receiving little note in the body of this short contribution (as most standard components are described elsewhere) it is of great practical importance in the design of the beamline.

2. Undulator, Front End and Optics Hutch

Most of the components upstream of the first experimental hutch will be standard ones, including the insertion device [2], front end [3], and transport channel [4]. Variations from the standard undulator design were considered, but calculations [5] suggested they would give only modest (< 25%) gains in flux below 25 keV at the cost of higher heat load (requiring re-design of the front end) and sensitive dependence of the available energies on the minimum gap (storage ring beta function. One important difference from the standard configuration is the use of a cryogenically cooled Si (111) monochromator, as a prototype has been recently demonstrated at SPring-8 [6].

3. Inelastic X-Ray Scattering

The inelastic scattering spectrometer dominates the beamline design (see Fig. 1.). We have chosen to use a backscattering monochromator similar to [7] and [8]. Other designs were considered, and have been used [9], but a single back-reflection seemed the most efficient (flux preserving) option. The use of a backscattering monochromator has two important consequences for the remainder of the spectrometer. One is that the monochromatic beam is reflected nearly on top of the incident beam: in order to separate them, we will use a pair of Si 111 crystals to shift the beam after the backscattering monochromator 370 mm in the vertical (see Fig. 1). In addition, having fixed the geometry, we must use thermal expansion of the Si crystals to vary the measured energy transfer. The lattice constant of silicon changes by about 2.5 parts in 10^6 / K near room temperature, so scans with ~ mK precision and few degree range become necessary. The feasibility of such scans has been demonstrated by the ESRF group [8].

The sample position is 19 m from the backscattering monochromator. This is to allow space for the Si 111 crystals and for focussing the beam. A small spot size at the sample is needed both to reduce the geometrical contributions to the energy resolution and to allow investigation of small samples. A conventional (though very high quality) bent cylindrical mirror (a 9:1 focusing geometry) should provide a spot size smaller than $150 \times 150\ \mu m^2$. Samples may be mounted on a large Eulerian cradle (Huber 512.1) equipped with a closed cycle He cryostat to control the temperature. It is also possible to remove the Eulerian cradle and use

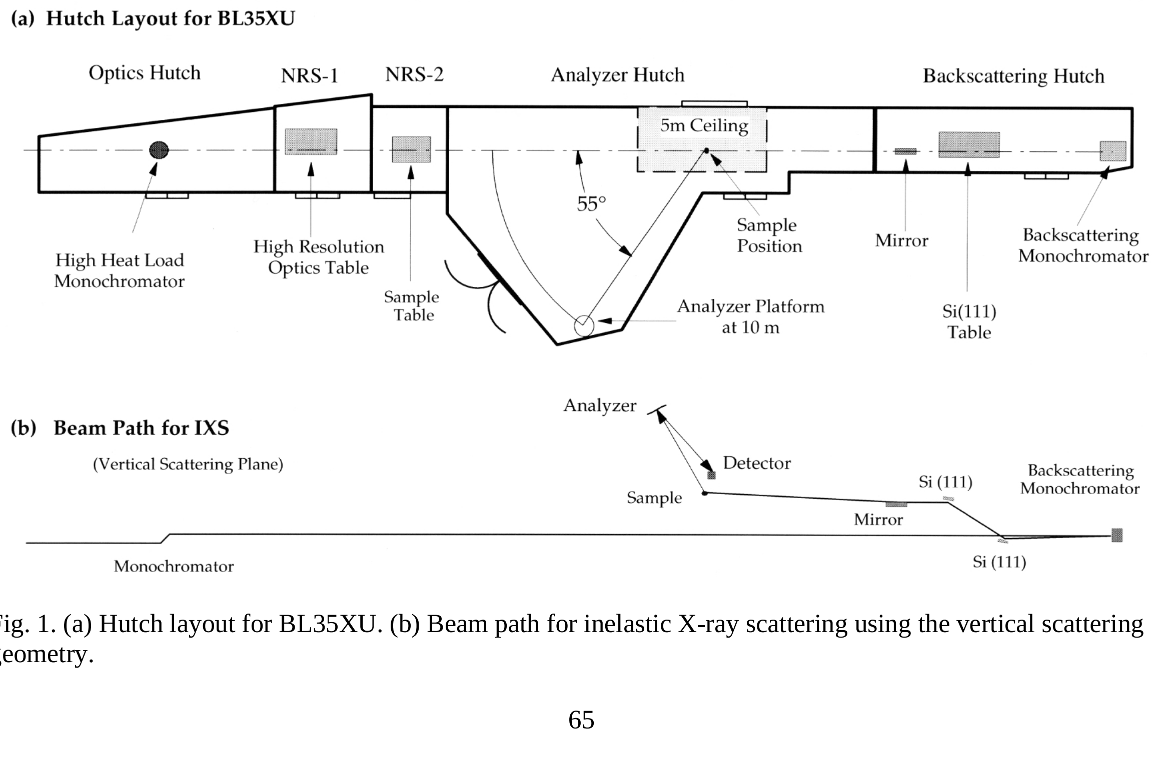

Fig. 1. (a) Hutch layout for BL35XU. (b) Beam path for inelastic X-ray scattering using the vertical scattering geometry.

separate stages to mount the sample, allowing heavy (< 200 kg) and large (diameter < 0.5 m) objects to be mounted (*e.g.* high pressure cells). The spectrometer will have two separate analyzer arms (both built by Huber Diffraktionstechnik GmbH). One arm, with a vertical scattering plane, will allow high momentum transfers to be studied with few (say 4 - 10) meV energy resolution. A longer (10 m) arm in a horizontal scattering geometry will allow higher resolution (~meV) studies at lower (< $10Å^{-1}$) momentum transfers. Precise motion of these arms (~30(15) μrad tolerances for the vertical (horizontal)) is required to preserve the proper orientation of the analyzer crystals relative to the sample and detector.

The analyzer crystals, to be mounted in a backscattering geometry at the end of the analyzer arms, are perhaps the single most difficult component of the beamline. They will be fabricated by NEC, in a manner similar to that described in [10], by gluing many (> 10,000) small blocks (~$0.7 \times 0.7 \times 3$ mm^3) of highly perfect silicon to a spherically polished substrate. A bent crystal can not be used because the strain from the bending will degrade the energy resolution. Likewise, thick (3 mm) crystals are needed to obtain the required energy resolution: to achieve resolution of $\Delta E/E \sim 10^{-8}$ one requires $E/\Delta E \sim 10^{8}$ planes of silicon. Presently, there is collaboration between SPring-8 and NEC to optimize analyzer crystal fabrication and performance.

4. Nuclear Resonant Scattering

Nuclear resonant scattering (NRS) [11] offers a variety of different techniques that may be used to investigate sample dynamics on different energy scales. Specific techniques for resonant samples include inelastic nuclear absorption measurements [12,13] (giving information about phonon densities of states on an meV energy scale) and nuclear forward scattering [14] which may be used to investigate, *e.g.*, diffusion on a neV scale [15]. For non-resonant samples, it is possible to do meV resolved IXS using a nuclear analyzer [16] and ~ neV resolution time domain interferometry experiments [17].

Two hutches (NRS-1 and NRS-2) will be optimized for nuclear resonant scattering experiments. The first hutch will be primarily for high resolution optics (*e.g.* [18-20]) while the second hutch will be for samples. This separation is to allow access to the sample without any disturbance to the high resolution optics. Stages in the second hutch will allow simple diffraction experiments and positioning of the samples. A heavy-duty motorized table will also permit xz positioning of large (> 200 kg) objects (*e.g.* cryostats or magnets). The detectors and electronics will be similar to those used at other NRS beamlines [21].

5. Conclusion

We have presented the conceptual design of BL35XU. The specifications have now been completed (all contracts awarded) and commissioning will start in the spring of 2000. While being similar to some existing facilities, it is expected that BL35XU will provide new capabilities due both to the design of the beamline and the high flux available from the SPring-8 storage ring.

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