BL35XU High Resolution Inelastic Scattering

This beamline is dedicated to the study of the dynamics of materials using inelastic X-ray scattering (IXS) and nuclear resonant scattering (NRS) [Baron, et al, *J. of Phys. Chem. Solids* 61, (2000) 461]. IXS measures the dynamic structure factor, $S(Q,\omega)$, with ~ meV energy resolution and > $1 \mathrm{nm}^{-1}$ momentum transfers. This is particularly interesting for disordered materials and small samples, where neutron scattering has severe limitations. In particular, IXS allows access to ~ $1 \mathrm{nm}^{-1}$ momentum transfers and large (<0.5 eV) energy transfers with ~ meV resolution – a region inaccessible for most neutron spectrometers and of great interest for liquids and glasses (disordered materials). Meanwhile the beam size, ~ 100 μm diameter, makes small samples (<0.01 mm^3) readily accessible, a vast improvement over the ~100 mm^3 typically needed for neutron scattering. NRS allows access to element specific densities phonon of states on the meV level, and several other techniques for probing dynamics (NFS, NBS, TDI) at the neV level.

Area of research

Dynamics of materials including phonons, Glass transitions, Liquid dynamics, Diffusion, etc.
Methods of investigation include inelastic X-ray scattering (IXS) and nuclear resonant scattering (NRS).

Keywords

Scientific field

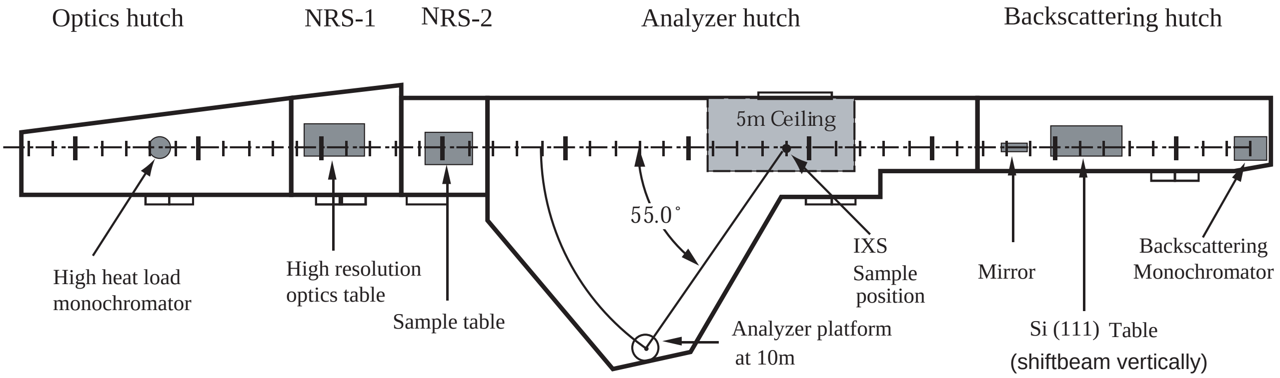
Inelastic X-ray scattering, Dynamics, Phonons, Dynamic structure factor, Collective modes, Liquids, Glasses, Disordered materials, Superconductors, Nuclear resonant scattering, Phonon density of states, Nuclear inelastic scattering

Equipment

Analyzes, meV, High Resolution, Backscattering, Optics, CZT detectors, Avalanche Photodiodes, Time Domain Measurements

Source and optics

BL35XU hutch layout



Beam path for inelastic X-ray scattering

(Vertical scattering plane)

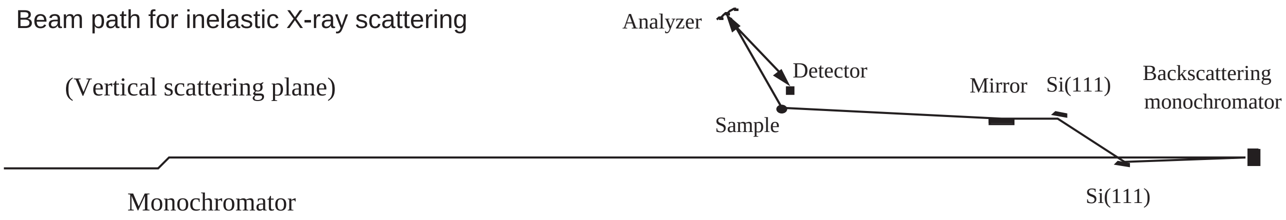


Table of IXS setup (horizontal arm)

X-ray energy (keV)	λ (Å)	$4\pi/\lambda$ (nm^{-1})	Ref order (nnn)	Spectrometer energy resolution (meV)	Maximum Q $2\theta = 55$ deg. (nm^{-1})	Analyzer spacing 0.67 deg. (nm^{-1})	Analyzer acceptance (0.12 to 0.54 deg) (nm^{-1})
13.839	0.8959	140.3	7	Not Tested	65	0.81	0.16 – 0.66
15.816	0.7839	160.3	8	6.0 meV	74	0.93	0.18 – 0.76
17.794	0.6968	180.4	9	3.0 meV	83	1.05	0.21 – 0.85
21.747	0.5701	220.4	11	1.5 meV	101	1.29	0.25 – 1.04
23.725	0.5226	240.5	12	Not Tested	111	1.41	0.27 – 1.14
25.702	0.4824	260.5	13	Not Tested	120	1.52	0.30 – 1.22

Experimental stations

Inelastic scattering (IX) horizontal scattering geometry (~1 to 100 nm^{-1})

Introduction & energy resolution

The horizontal scattering setup uses a 10 m arm to obtain good resolution and allow relatively large space at the sample location. The table shows various properties. Note that most work has been done with the Si 11 11 11 reflection at 21.75 keV (~ 1.5 meV resolution) and the Si 888 at 15.82 keV (~ 6 meV resolution), with some small amount of work at the Si999 at 17.79 keV (3 meV resolution). The others are provided for reference, and may be commissioned and made available for users at a later date. Changing the energy and energy resolution (silicon order) during the course of an experiment is generally not possible.

Momentum transfers

Four crystals mounted on the analyzer arm allow very efficient data collection from disordered materials and for longitudinal modes in crystals. The spacing between them is fixed at 0.78 degrees in two theta. The momentum resolution can be varied on all crystals simultaneously by using motor controlled slits. However, this can change the energy resolution so it should be re-measured at each slit size. Note that the minimum momentum transfer accessible in most setups is ~ 2 nm^{-1}. Smaller is possible, but may require a special sample container, and may restrict the number of analyzer crystals used. If this is needed, please consult with beamline staff.

Sample area

The default setup for this geometry puts the beginning of the flight path at 100 mm from the sample position and the two-theta slit at 60 mm from the sample. Enlarging this distance by as much ~ 120 mm (slit at 180 mm) is possible, however, it will generally degrade the energy resolution, and will require time to setup. Please consult with beamline staff if you need more than ~ 55 mm after the sample.

The beam spot size on the sample is typically about 100 μm diameter- with a best case size of ~ 60 × 80 μm^2 in the FWHM (V×H) and a worst case size of ~ 100 × 140 μm^2 in the FWHM. Typically, the 11 11 11 setup has a smaller beam size than the 8 8 8.

Samples for IXS may be mounted in an Eulerian cradle (Huber 512.1) or on separate stages. A mirror in a 9:1 focusing geometry reduces the spot size on the sample to ~ ϕ100 μm (FWHM), suitable for small samples and/or high pressure cells. A closed cycle He cryostat (mounted on the Eulerian cradle) is available to cool the sample (to ~10 K) and a furnace to heat the sample (to ~ 1000 K). Other special sample environments might be considered in collaboration with external user groups. In all cases users must take great care in choosing window materials and sample mounts in order to reduce backgrounds, especially for measurements at low q.

Inelastic scattering (IXS) vertical scattering geometry (~ 2 to 200 nm^{-1})

A relatively short (2.8 m) arm may be used in a vertical scattering plane to get to high momentum transfers (~180 nm^{-1}) without polarization losses. However, the shortness of the arm means the best possible energy resolution is ~3 meV (Si 11 11 11) and more typically one might use ~7 meV resolution at the 888 or 4 meV resolution at the 999.It also means that there are tight space constraints around the sample area.

Nuclear resonant scattering (NRS, ^{119}Sn and ^{161}Dy) :

High resolution monochromators are available for the 23.9 keV transition of ^{119}Sn and the 25.6 keV transition of ^{161}Dy, both using a transmission nested design [Baron et al, *J. Synchrotron Rad.* 8, (2001) 1127]. These have bandwidths of 0.7 meV (^{119}Sn) and 0.5 meV (^{161}Dy) and a throughput of ~2×10^8 photons/sec at 100 mA. They are complemented by various types of avalanche photodiode detectors [Baron, *Hyp. Int.* 125, (2000)] for both incoherent and forward scattering. Note that a small mirror is available (expected focus ~100 μm diameter) but not yet thoroughly tested. Samples can be mounted in a 4-circle (horizontally scattering) diffractometer (Huber 512.1 cradle) and on various smaller motion stages.

Contact information

Alfred BARON
SPring-8 / JASRI
1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5198
Phone : +81-(0)791-58-0832
Fax : +81-(0)791-58-0830
e-mail : baron@spring8.or.jp

Yoshikazu TANAKA
SPring-8 / RIKEN
1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5148
Phone : +81-(0)791-58-2931
Fax : +81-(0)791-58-2923
e-mail : ytanaka@postman.riken.go.jp