Contract Beamline

BL12XU NSRRC ID

BL12XU is designed primarily for inelastic X-ray scattering (IXS) experiments on electronic excitations in correlated electron systems with variable energy resolution from 10 ~ 1000 meV. Major experimental capabilities have been developed for both *resonant* and *non-resonant* IXS experiments. The initial setup for *resonant* IXS (RIXS) experiments has a total energy resolution of ~ 1 eV and covers the K absorption edges of the late transition metals (Co, Ni and Cu). For *non-resonant* IXS (NRIXS) experiments, a total energy resolution of 70 meV has been achieved at the Si (555) near-backscattering energy of 9.886 keV. Furthermore, a 15-element multiple-analyzer system for NRIXS is available to increase the counting efficiency by up to 15 times. These experimental capabilities can be used to study a variety of fundamental problems in solid state physics, electronic properties in materials science, and phase transitions under extreme thermodynamic conditions. The secondary purposes of the beamline include high Q-resolution scattering, X-ray physics and optics development.

Area of research

Elementary electronic excitations, quasiparticle behaviors, and electron-correlation effects in correlated electron systems investigated using high resolution non-resonant or resonant inelastic X-ray scattering

Local electronic structure of molecular solids of low-Z elements (e.g., biomaterials) investigated by high resolution near-edge X-ray Raman scattering

Phase transitions under high-pressure, low and high temperatures

Materials science using high-resolution X-ray absorption and emission spectroscopy

X-ray physics and optics

Keywords

Sientific field

Inelastic X-ray scattering, Near-edge X-ray Raman scattering, X-ray resonant Raman scattering, Electronic excitations, Correlated electron systems, Pressure and temperature induced phase transitions, High-resolution X-ray absorption spectroscopy and X-ray emission spectroscopy.

Equipment

Triple axis spectrometer, Eulerian goniometer, Cryorefrigerator, Spherical crystal analyzers, Multiple analyzer system, AMPTEK X-ray detector, MCA, Microscope.

Source and optics

The radiation source is a SPring-8 standard 4.5-m long in-vacuum undulator with a magnet period of 32 mm. The minimum gap allowed is 8.1 mm with a front-end slit aperture of 0.5 (V) × 1.5 (H) mm^2. Within 8.1 ~ 19.3 mm gap range, the 1st harmonic covers 4.5 ~ 14 keV, the 3rd harmonic 13.5 ~ 42 keV, and the 5th harmonic 22.5 ~ 70 keV. At 100 mA ring current, the maximum on-axis brilliance reaches 1.2 × 10^{20} phs/s/mrad^2/mm^2/0.1%BW at 9 keV.

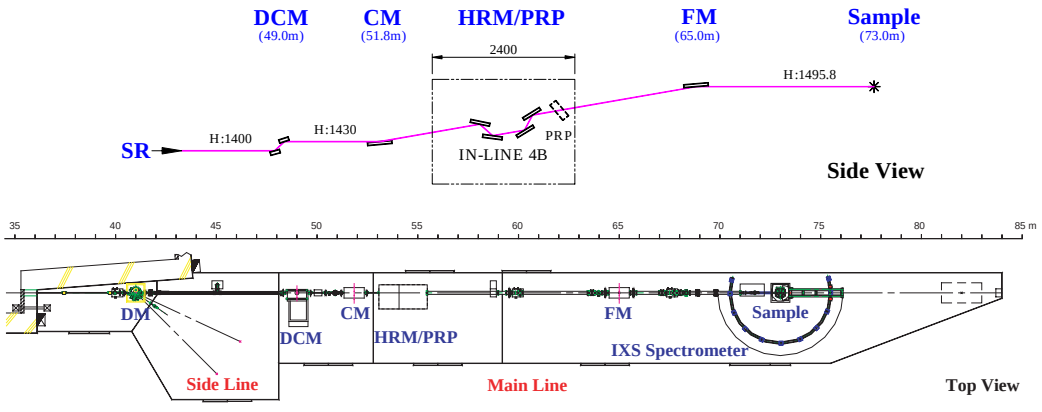


Fig.1. Schematic view of the beamline (upper panel) and the optical path (lower panel)

The beamline consists of a sideline and a mainline (Fig.1). The sideline, to be built later, operates in parasitic mode with a single-bounce diamond monochromator (DM). Monochromatic X-rays of about 1 eV width over 8 ~ 32 keV can be obtained using Bragg or Laue diffraction geometries of diamond (111) or (100) crystals for diffraction experiments or other emerging experimental techniques.

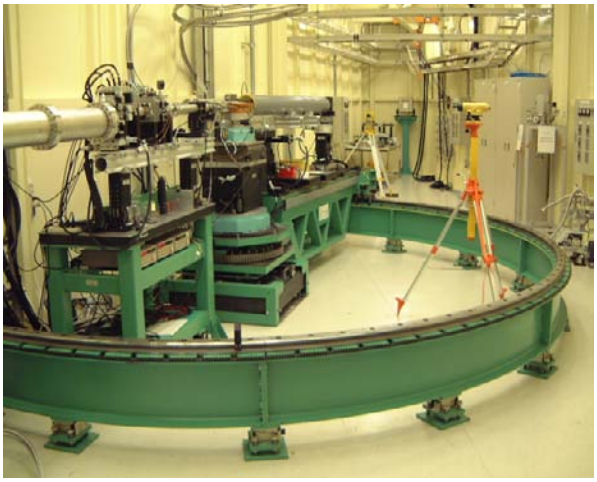
The mainline is designed primarily for inelastic X-ray scattering experiments. The optical system consists of five major elements, which include a high heat-load Si (111) double-crystal pre-monochromator (DCM), a cylindrical collimating mirror (CM), a high-resolution monochromator (HRM), a phase retarding plate (PRP), and a toroidal focusing mirror (FM). The Si (111) DCM operates over the energy range of 4.5 ~ 35 keV. The CM collimates the beam vertically. It also functions as a higher-order light filter by having two stripes: Si and Pt for the energy ranges of 5 ~ 12 keV and 12 ~ 30 keV, respectively. To achieve variable energy resolutions of 10 ~ 1000 meV, the HRM consists of two high-precision co-axial goniometers to form various combinations of 2-bounce or 4-bounce (inline or nested) channel-cut crystals. An in-line combination of two symmetric Si (333) or Si (400) channel-cut crystals are now available to provide energy resolutions of 50 or 153 meV, respectively, at 9.886 keV (see Table 1). Additional HRM crystals can be designed for different energy resolutions and scanning energy ranges. After the HRM and the PRP (to be implemented later), the beam is delivered to the Pt-coated focusing mirror and focused both vertically and horizontally to ~ 80 (V) × 120 (H) μm^2 at the sample position. Total flux obtained at the sample is 1.2×10^{13} phs/sec/1.4 eV at 9.886 keV scaled to 100-mA ring current with the DCM direct beam, and reduced proportionally with the HRM energy bandwidth.

X-rays at sample

Energy range	4.5 ~ 35 keV
Energy resolution ($\Delta E/E$)	1.4×10^{-4} after DCM; 10^{-5} ~ 10^{-7} after HRM (optics dependent)
Flux	~ 10^{10} photons/sec/meV below 26 keV after DCM; Optics dependent at sample

Experimental stations

The IXS spectrometer (Fig. 2) is custom designed and built to accommodate a wide range of experimental requirements. This instrument is basically a triple-axis spectrometer with a 3-m horizontal arm, and consists of a heavy-duty Eulerian goniometer tower designed to accommodate a range of sample environments with a load capacity for a cryomagnet. In addition, a custom designed cryostat provides a sample environment down to 4 K (Fig. 3). The 3-m horizontal arm supports the post-sample slits, the analyzer stage, the detector stage and the flight paths. Spherically bent crystal analyzers are used to analyze the inelastically scattered photons. The analyzer stage can be translated continuously along the arm to accommodate three radii of the analyzer for different resolution and angular acceptance requirements of the experiment. A 15-element multiple analyzer system is available to increase the counting efficiency by up to 15 times at the expense of momentum resolution (Fig. 3).



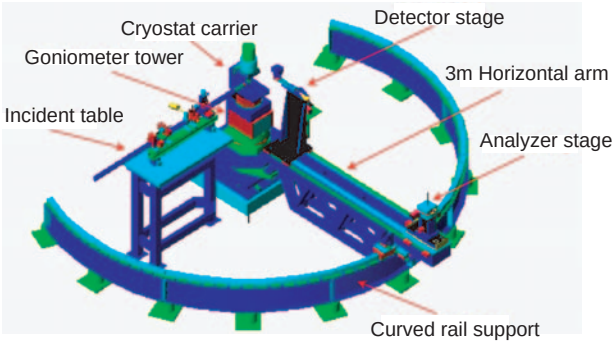


Fig.2. Schematic view of the IXS spectrometer and photo of the real thing

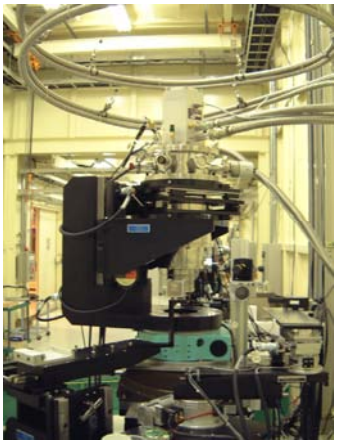


Fig.3. The 4-K cryostat and carrier (upper), and the 15-element multiple analyzer system (lower)

Endstations and sample environments

Custom-built 3 m arm triple axes spectrometer for IXS
CRYOMECH 4K PT407 pulse tube cryorefrigerator
Various sample chambers

Experimental facilities

Detectors

Gas-filled ionization chambers
Si PIN diodes
Scintillation detectors
AMPTEK X-ray detectors and pocket MCA for IXS
SESO CCD X-ray beam monitor

Beamline control & data processing

SPEC on LINUX PC for beamline and endstation control
Window PC'S for data proccessing
GPIB and VME counters
NIM timing modules

X-ray energy analysis

Various spherically-bent φ100 mm crystal analyzers with bending radius of 1, 2, or 3 m.
Multiple (15-element) analyzer stage for enhanced count efficiency

Sample manipulation

NIKON stereoscopic microscope SMZ1500

Table 1. Beamline and IXS spectrometer configurations

(a) NRIXS at the near-backscattering energy of Si (555) (9.886 keV) or Ge (555) (9.490 keV) analyzers

Beamline

HRM configurations	Flux ($\times 10^{11}$ photons/sec)	Bandwidth (meV)
Si (333)	1.5	50
Si (400)	5.7	153
None (DCM)	120	1250

IXS spectrometer

Analyzer	Relative efficiency (/meV/one analyzer)	Total energy resolution (meV)
Si (555) 2-m diced	25%	70
Si (555) 2-m bent		305
Ge (555) 1-m bent		1300

(b) RIXS at the K edges of Co, Ni and Cu

Beamline

DCM direct Beam (keV)	Flux ($\times 10^{11}$ photons/sec)	Bandwidth ($\Delta E/E$)
4.5 ~ 35	120 @ (9.886 keV)	1.4×10^{-4}

IXS Spectrometer

Analyzer	Energy range (keV)	Total energy resolution (eV)
Ge (444) 1-m bent	7.64 ~ 8.77	~1.2
Si (444) 1-m bent	7.96 ~ 9.13	~1.2
Si (553) 1-m bent	8.82 ~ 10.12	~1.2

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