Resonant Elastic and Inelastic Soft X-Ray Scattering (REIXS) Beamline 10ID-2

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Beamline Overview

Status	Construction
Source	Elliptically Polarizing Undulator (EPU)
Monochromator	Variable Line Spacing Plane Grating Monochromator
Energy range	80 – 2000 eV
Flux	3×10^{11}~1×10^{12} photons/s/100mA
Resolving power	E/ΔE > 5000
Spot size	RSXS: 90 µm × 50 µm RMS XES: 20 µm × 5 µm RMS

Introduction

The REIXS beamline 10ID-2 is a state-of-the-art soft X-ray scattering facility dedicated to photon-in and photon-out experiments. The research activities are primarily focused on novel and advanced materials, by using resonant elastic scattering, resonant inelastic scattering and coherent scattering.

The resonant soft X-ray scattering (RSXS) technique combines diffraction methods with spectroscopic techniques to develop a new structural characterization method in the soft X-ray regime. The highly monochromatic, coherent, polarized and variable energy X-ray radiation allows us to zoom in on a particular atom in a specific local environment. The extreme sensitivity to local charge, spin and structural changes will allow us to study the interplay of charge, spin, orbital and lattice degrees of freedom in strongly correlated electron systems, and to investigate the phenomena such as superconductivity, charge order, orbital order, and various types of magnetism. The use of circularly polarized X-rays will enable a nanometer scale study of magnetic structure in materials such as monolayer films and multilayers, the formation of magnetic domains and domain walls.

The random interference from a disordered object, illuminated with coherent radiation, is known as coherent scattering, or speckle. This technique can be used to deduce the spatial distributions of chemical elements in disordered systems, as well as the electron charge and spin densities in non-crystalline systems.

The XES endstation for resonant inelastic scattering will be a synchrotron-based tool to study the electronic structure of new materials. It will allow access to new information on chemical state, electronic structure or best possible synthesis of the systems. This research will ultimately lead to novel devices like sensors with advanced and tailored optical, electronic, magnetic and catalytic properties.

Science

The REIXS beamline will be used for an extremely broad variety of research, from fundamental research to technologically important problems. The different projects that will be carried out on the REIXS beamline include the study of systems such as:

- Biomaterials that will ultimately be applied in reliable self-assembling molecular electronics to be built on the nanoscale.

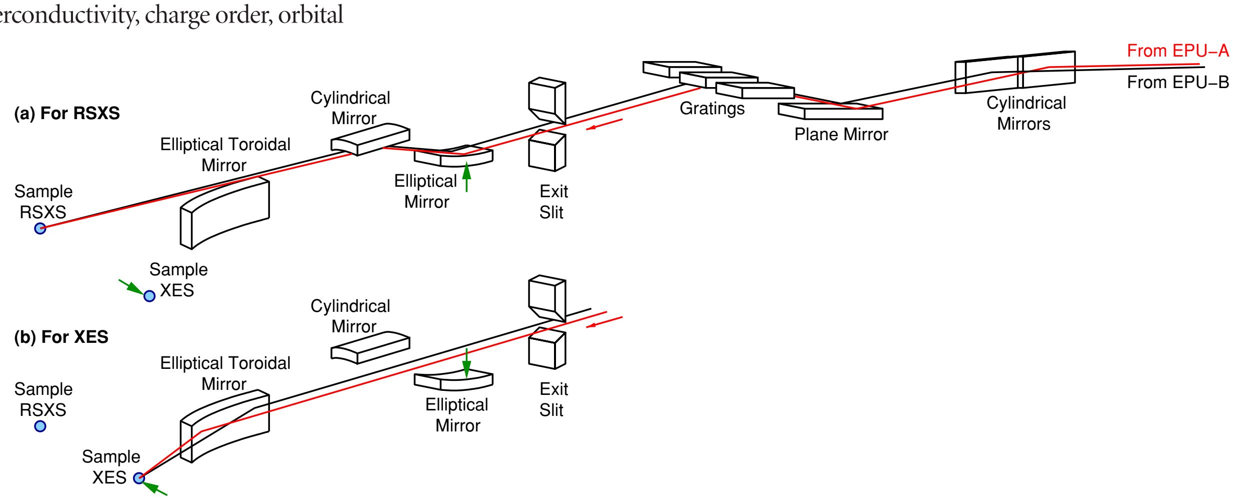

Figure 1: Optical layout of REIXS beamline.

- Ultra-hard C- and Si-based systems where the origin of hardness is still not understood.
- Half-metallic systems which are ferromagnets that exhibit metallic character for the majority-spin electrons but display a semiconducting gap for the minority-spin electrons. Therefore, one can expect 100% spin-polarization at the Fermi level, making such materials promising candidates for spin-polarized emitters. This will find different applications in spin injection devices or magnetic random access memory.
- Quantum materials composed of mainly transition metal and rare earth compounds exhibiting a strong interplay between the spin charge and orbital degrees of freedom. These materials in thin film and multilayer nanostructured form are expected to be main players in the next generation of quantum devices.

Beamline Layout and Instrumentation

The REIXS beamline is designed to achieve high flux, high brightness, moderate resolution and full polarization control. The source of the beamline is an Elliptically Polarizing Undulator (EPU) which will produce photons of linear polarization in any direction, as well as circular or elliptical polarization. The two pre-focusing mirrors collimate the light for the entrance-slitless plane-grating monochromator (PGM).

Figure 2: SM EPU and REIXS EPU (right) in 10ID straight.

The monochromator has one plane mirror and three gratings to cover the whole energy range from 80 eV to 2000 eV. By combining different mirror coatings and gratings, high order harmonics can be effectively suppressed without sacrificing the flux.

Due to the different requirements of spot size and beam divergence, two sets of refocusing mirrors are used for the two endstations. Switching between the two endstations can be done without breaking vacuum. The endstations are located in an experimental enclosure to ensure the cleanliness of the sample environment,

To facilitate beamline commissioning and future analysis of problems should they occur, multiple diagnostic assemblies

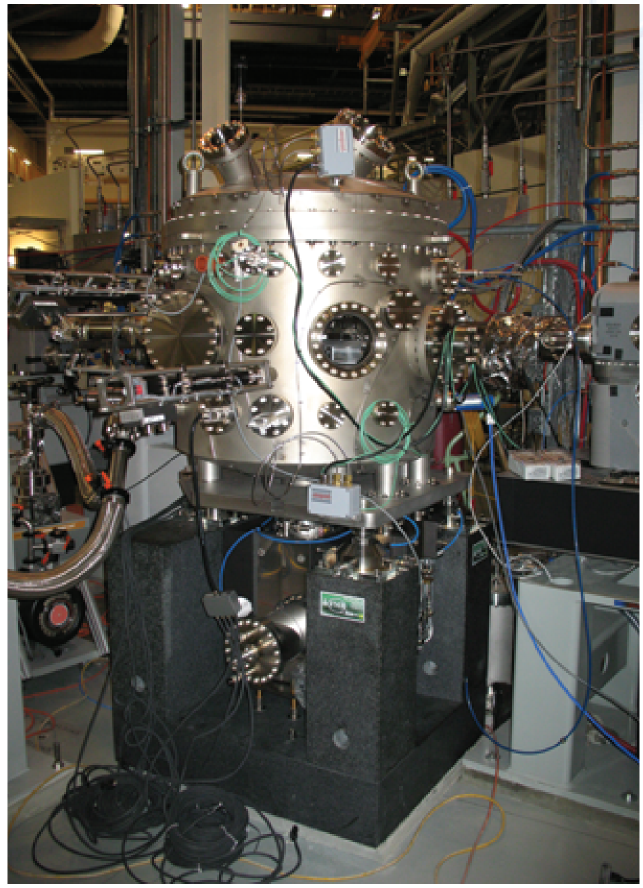

Figure 3 REIXS monochromator.

have been built into the beamline. Several apertures and 4-jaws are also included in the beamline in order to define the optimum beam acceptance at different sections.

The REIXS beamline has been designed with the capability to accept light from the two EPUs in the 10ID straight section. The two beams are spatially separated by the chicane magnets in the straight section. The unique double collimating mirror design will compensate for the different source distances and ensure accurate collimation for both beams. All following optical elements are capable of handling two beams; therefore, the two beams have equivalent high performance. In the two beam mode, a rotary chopper is used to select which beam reaches the sample in the endstation. When the two EPUs are generating light with different polarizations, rapid switching of the polarization can be realized. The REIXS EPU and PGM have been installed and are in final testing. As of December 2007, all other major beamline components have been ordered, with expected deliveries in March and April of 2008. Installation and commissioning will follow.

The RSXS Endstation

The RSXS endstation for soft X-ray scattering consists of four UHV chambers. The main scattering chamber is connected to the beamline. It houses a sophisticated in-vacuum 10-motion diffractometer to manipulate the samples as well as to position and switch the detectors. A microchannel plate (MCP) detector is mounted on the detector arm for the scattering experiments.

Several other types of detectors are available for measuring the electron yield, fluorescence yield and total yield. The sample stage can be cooled by a continuous flow cryostat. The detail design of a magnet system which can provide up to a 2 T magnetic field in arbitrary orientation at sample position is currently underway. The coherent scattering experiments are also carried out in this chamber.

The preparation chamber has all the facilities to grow thin films, to monitor the growth process and to prepare samples. Primary components include evaporation sources and gas sources for MBE, temperature and thickness monitors, LEED and RHEED. The analysis chamber has an XPS system and a variable temperature STM for sample characterization. A transfer chamber serves as the interconnection between the chambers. Samples can be transferred between the chambers under vacuum.

The XES Endstation

The Moewes group has started the construction of the XES/RIXS endstation. At the core of the endstation is a large custom designed Rowland circle spectrometer. It will use 4 diffraction gratings to cover an energy range of 50 eV – 1100 eV with good efficiency and resolving powers (E/ΔE) in excess of 2500 at the C, N and O $K\alpha$ – emission edges. Two additional gratings, specifically designed to operate in the third diffraction order, will provide resolving powers in excess of 10 000 at those emission edges. The spectrometer will use a high resolution microchannel plate detector, mounted inside a 2 m long vacuum chamber to allow it to reach the large focal distances required by the third diffraction order gratings.

The optical design was carefully optimized using a novel approach employing software and analysis techniques developed specifically for this project. By considering the diffraction efficiency and dispersion characteristics of each grating, a spectrometer design with extremely high resolving power (2500 to 14 000) and high throughput (diffraction efficiency between 2 and 60 %) was achieved.

Along with the spectrometer for soft X-ray emission spectroscopy (XES) and Resonant Inelastic X-ray Scattering (RIXS), the endstation will include instrumentation for soft X-ray Absorption Spectroscopy (XAS) using Partial- and Total- Fluorescence Yield (PFY & TFY) and Total Electron Yield (TEY). In addition to the synchrotron light, an electron gun will be available as a secondary excitation source.

The sample manipulation system will be capable of heating and cooling from -175°C to 1000°C during experimentation. A range of *in situ* material preparation and analysis techniques will be available including heating, cooling, ion bombardment/sputtering, cleaving, LEED and Auger electron spectroscopy.

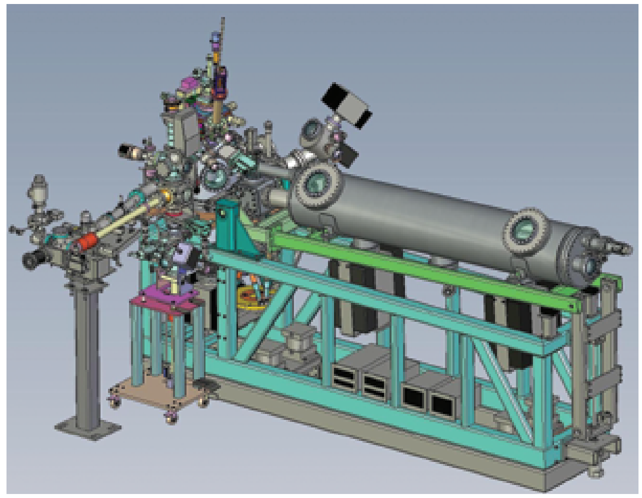

Figure 4: The XES Endstation, spectrometer and sample chamber.

Table 1 10ID-2 REIXS Beamline Milestones

Oct 2005	CDR approved.
Jun 2006	PDR approved.
Oct 2006	Monochromator ordered.
Mar 2007	Mirrors and gratings ordered.
Sep 2007	Endstation enclosure finished.
Oct 2007	Mirror tanks ordered.
Nov 2007	Apertures/slits ordered.
Nov 2007	Monochromator installed.
Dec 2007	EPU installed in the storage ring.
Apr-May 2008	Installation of other major beamline components

Table 2 REIXS Beamline Design Team

Feizhou He	**Beamline Scientist**
Siyue Chen	Engineering and Technical Services Lead
Tony Wilson	Controls and Instrumentation Lead
David Muir	Science Associate

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