Expected Ability of a Compton Scattering Beamline

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1. Experimental Utility

Circularly polarized 300 keV x-rays from an elliptical multipole wiggler can be used in BL08W beamline. An asymmetric Si(771) Johann-type monochromator will focus the x-rays with a beam spot of 1 mm wide and 3 mm high at the sample position. The reasons for selecting the energy 300 keV are as follows:

(1) Compton-scattering cross sections of most elements do not change much up to 500 keV. While the photoelectric absorption cross section significantly reduces in a high energy region. Then the effective thickness of a sample for a Compton-scattering experiment increases, and the Compton-scattering counting rate increases particularly for samples containing heavy elements.

(2) An observed Compton profile can be separated from any characteristic fluorescent x-rays from a sample, even if it contains actinide elements.

(3) The spin-dependent Compton scattering cross section is larger for higher energy x-rays.

(4) A solid-state detector is going to be used as an energy analyzer for Compton scattered x-rays. An expected momentum resolution of a Compton profile is better for higher energy x-rays.

(5) An elliptically polarized photon flux from the wiggler is estimated to be about 10^{11} photons/s/0.1%b.w. at 300 keV, and decreases to 10^{9} at 500 keV.

(6) The energy resolution of a Ge detector deteriorates by increasing its volume to obtain sufficient detection efficiency for high energy x-rays above 300 keV.

A superconducting magnet is under construction. A maximum field 3 T will be generated with a current of 79 A. The sign of the magnetic field can be altered within 5 s from +3 T to -3 T, or vice versa. The size of the coil is 140 mm long, 130 mm in outer diameter and 86 mm in inner diameter. A room temperature bore has a diameter of 51 mm. The coil reactance is 1.3 H. The homogeneity of the field at the center is better than 2%. The magnet is effective to magnetize hard magnetic samples such as those containing 4f rare earth elements. The magnet is designed to be equipped with two different liquid He condensers (one has 3 W cooling power at 4.2 K for He-gas recondensation and the other 12 W at 20 K for radiation protection), and will be free of maintenance of liquid He for over a week. A sample will be cooled by another refrigerator (4.7 W at 20 K) at any temperature between room temperature and 10 K.

A Ge solid-state detector system, which will be used to analyze energy spectra of Compton scattered x rays, consists of 10 Ge sensors, 10 preamplifiers, 10 amplifiers, 10 ADCs, 10 MCA and one computer. The effective area of a Ge crystal is 100 mm^2. For the magnetic Compton-profile (MCP) measurement, a scattering angle is desirable to be as close as possible to 180°. The Ge crystals are therefore circularly arranged around a hole (11 mm in diameter) through which the incident x-rays are introduced to the sample. The diameter of the circle of the sensors is 42 mm. The distance between the detector and the sample will be 1 m. A trigger signal to reverse the magnetic field direction is given from the computer synchronized with the change of the memory address of the data from MCAs.

There is another hutch, in which 100-150 keV doubly focussed monochromatized x-rays will be introduced, and high resolution Compton scattering experiments will be made.

The experimental utility of this branch will be available after the construction of the 300-keV branch. A doubly bent monochromator is now designed. The beam spot at the sample position is designed to be less than 1 mm^2. A momentum resolution of 0.1 atomic units is highly required for Fermiology. A relative energy resolution of 10^{-4} is thus required of the monochromator. A Chaucois-type crystal analyzer system is now investigated, in which a position sensitive detector having a spacial resolution better than 200 μm will be installed. A CdZnTe detector is considered to be promising.

2. Scientific Program

Investigation of magnetism based on the momentum density distribution (MDD) of magnetic electrons in ferro-, ferri- and para-magnetic materials is the most important program in the 300-keV branch. Magnetic materials containing heavy atoms such as 4f, 5d and 5f elements will be widely studied. The following subjects will be actively investigated: (1) magnetic transition and MDD, (2) weak ferromagnetism and MDD, (3) amorphous magnetic materials and MDD, (4)MDD of paramagnetic spins at low temperatures under a high magnetic field,
(5) 3-dimensional reconstruction of MDD of spin moments of ferromagnetic metals and alloys.
From the point of view of the statistical accuracy, an averaged magnetic moment about 0.1 μ_B/atom will be a practical limit of the MCP measurement. It should be emphasized that the spin-dependent Compton-scattering cross section depends only on the intrinsic electron spin and independent of the orbital angular momentum.

Beside the experiments for magnetism mentioned above, (6) high Tc superconductors and MDD, (7) heavy Fermion system and MDD, (8) high pressure phenomena such as metal/insulator transition and MDD will be interesting subjects which can be also studied by using 300-keV x-rays. A small sample with a dimension less than 0.1 mm can be measured owing to a focussed beam and high counting efficiency of the solid-state detector system. In these experiments, the isolation of the back ground due to a holder or a medium should be seriously considered.

3. Collaboration with other FaciHities

In the near future, at least 3 or 4 SR facilities will provide beamlines in the world for Compton scattering experiments. Among them the BL08W will offer the monochromatized highest energy x-rays. Thus this beamline takes on importance for the measurements on heavy elements, and such experiments should be given overriding priority on the beam-time sharing. It is very important to collaborate with other Compton beamlines so as to make the best of the special feature of each facility. An international collaboration system will be effective under which collaborators can choose the most suitable facility for their experiments .