ESRF

Experiment title:
The magnetic scattering cross section for hard x-rays above 100 keV

Experiment number:
HE-159

Beamline:
ID15A

Date of Experiment:
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24

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Report:

In this experiment, the high energy synchrotron radiation, produced by the new wavelength shifter, was used to perform a magnetic diffraction experiment on MnF_2 with photon energies up to 500 keV. The aim of the experiment was to probe the magnetic scattering cross section for high energies in the energy region, where low order relativistic approximations are no longer valid.
For high photon energies around 100 keV, the magnetic scattering cross section in the above approximations takes the following very simple form:

$$\left(\frac{d\sigma}{d\Omega}\right)_{magnetic} = r_0^2 \left(\frac{\lambda_C}{d}\right)^2 |S_\perp|^2 . \qquad (1)$$

Here, λ_C denotes the Compton wavelength, d the interplanar lattice spacing and r_0 the classical electron radius. It is proportional to the square of the spin-component perpendicular to the scattering plane only. We are not aware of a full relativistic treatment necessary for higher energies near 511 keV.

MnF_2 is a collinear antiferromagnet with one unique easy axis, the tetragonal c-axis. Therefore, at 300 keV we could align the spin direction along all three orthogonal directions and measure the cross section independently. With S parallel to the scattering vector Q, as is the case for (003), no magnetic intensity could be observed. The same is true, if S is perpendicular to Q and lays in the scattering plane. In fact, even at 300 keV we found (1) to be valid, see fig. 1.
In a second step, for S perpendicular to the scattering plane, we measured the magnetic form factor as a function of the photon energy. We had already investigated the magnetic form factor of MnF_2 with high energy photons in a previous experiment at ID15 A at 80 keV [l] and at HASYLAB up to 160 keV [2]. In this experiment now, we measured the magnetic form factor at 100, 160, 200, 300, 400 and 500 keV.

In order to calculate the magnetic form factor from the experimental data, we have to know the intensity of the incident beam. That was determined via the intensities of the charge reflections, measured with calibrated Fe-filters, see fig. 2. The incident flux was calculated using the structure factor of MnF_2. Fig. 3 shows the magnetic form factor of the (300) reflection of MnF_2 as a function of energy. Within the errorbars, the measured form factor remains constant with increasing energy.

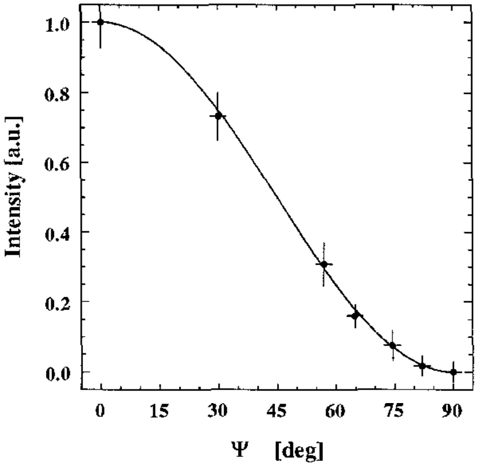

Fig. 1: Integrated intensity of the magnetic (300)–reflection as a function of the rotation of the crystal around the scattering vector (Ψ–rotation). The solid line represents eq. 1.

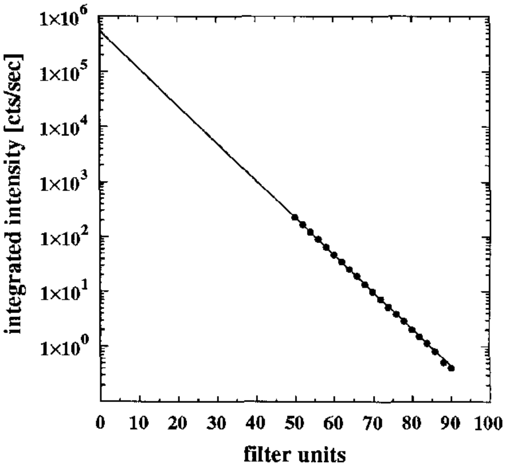

Fig. 2: Integrated intensities of the (400) charge reflection at 300 keV measured with different Fe-filters. The solid line shows the refinement with an exponential function.

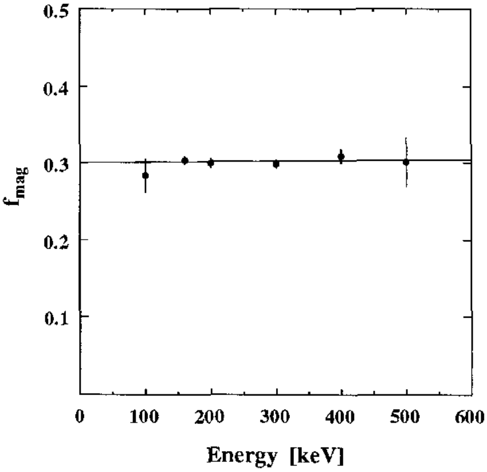

Fig. 3: Form factor of the magnetic 300 reflection measured at different energies up to 500 keV. The solid line shows a linear regression to the data not including the point at 100 keV.

[1] J. Strempfer, Th. Brückel, U. Rütt, J. R. Schneider, K.–D. Liss & Th. Tschentscher, Acta Cryst. A **52** (1996), 438–449.

[2] J. Strempfer, Th. Brückel, D. Hupfeld & J. R. Schneider, HASYLAB Jahresbericht, 1996, 636–637