ESRF	**Experiment title:** Dzyaloshinskii-Moriya interaction in copper metaborate	**Experiment number:** **HC-2367**
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Report

Scientific Background

Copper metaborate CuB_2O_4 has attracted a lot of attention because of its complex magnetic structure and series of phase transitions at low temperatures: rearrangements of the spin system occur at temperatures of 20, 10, and 2 K [1]. At room temperature CuB_2O_4 is a tetragonal crystal, space group *I*-42*d*, with lattice parameters *a*=11.528 Å and *c*=5.607 Å [2]. The copper ions Cu occupy two nonequivalent positions: Cu(*b*) - the 4*b* position, point symmetry *S*4(0,0,1/2), and Cu(*d*) - the 8*d* position, point symmetry *C*2(0.0815,1/4,1/8). Two positions of Cu exhibits completely different magnetic ordering below 20K. Between the two transition temperatures, magnetic moments at the Cu(b) sites show commensurate easy plane antiferromagnetism with a canted ferromagnetic component due to the Dzyialoshinskiiï Moriya (DM) interaction, while the Cu(d) spins at B sites are disordered [3]. The gigantic optical magneto-electric effect observed in [4] is ascribed to the canted antiferromagnetic spin ordering of square-coordinated Cu(b) sites, where the local inversion is slightly broken. As it was shown in [] the sign of the DM interaction depends on the local crystal chirality and it can be determined from the resonant X-ray scattering using the interference between two scattering channels. In this experiment we have observed the interference between the multiple (Renninger) X-ray scattering and magnetic nonresonant scattering. The presence of a weak ferromagnetic moment allows to fix the direction of antiferromanetic moment on each copper atom, so that they can be easily governed by the external magnetic field.

Experimental details

Well polished crystal CuB_2O_4 with the surface parallel to the (110) plane was used for this experiment. It was put in the permanent magnetic field and cooled down to the 15 K. At this temperature this crystal possessed antiferromagnetic structure accompanying by a weak ferromagnetic component. The forbidden magnetic reflections 330 and 550 were observed at the incident radiation energy 5 KeV. The azimuthal dependence of the 550 reflection at this energy was measured with right- and left circular polarized X-rays. We have used the first harmonic of an HELIOS-II helical undulator. The circular polarization rate for these photon energies was about 90 %. We have observed a serie of the Renninger reflections for the angles between 0 and 180^o. The symmetry of the Renninger peaks positions has allowed to determine the directions of the crystal axes in the diffraction plane. The difference between the 550 reflection intensities measured with the right and left circular polarized beams is most obvious at the azimuthal angles between the Renninger reflections where the magnetic nonresonant scattering is more pronounced.

Results

The azimuthal dependence of the 550 reflection intensity at 15 K was measured in a wide range of angles at the energy 5 KeV with right and left circular polarization of X-rays. The serie of Renninger reflections were observed. Essential circular dichroism (the difference of the integrated intensity corresponding to the right and left polarizations) was observed mainly between the Renninger peaks where the slight magnetic nonresonant contribution is more pronounced. Rotating the crystal with permanent speed around the normal to the crystal surface we have observed the oscillations of the reflection intensity,

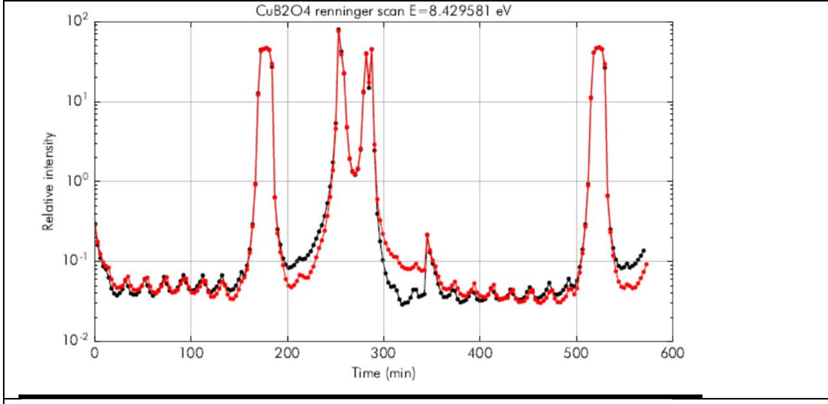

Fig.1 The azimuthal dependence of the 550 forbidden reflection intensity measured with right (black) and left (red) polarizations. The crystal was rotated with permanent speed. The spectrum demonstrates the 5-min oscillations between the peaks, which are in good correlation with the top-up operation of the beam.

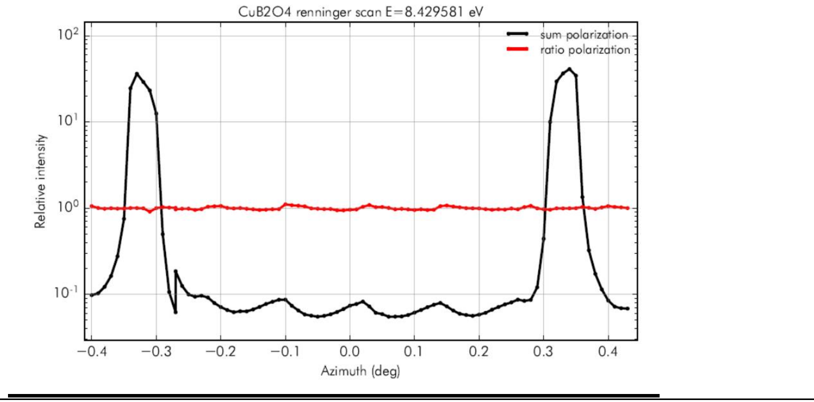

Fig. 2. The part of the azimuthal scan demonstrating the intensity of the 550 reflection summarized over two circular polarization and the ration of intensities corresponding to the right- and left polarizations.

which were in good correlation with time of the beam e^- injection (5 min). This slightly corrupted obtained results, taking into account that the magnetic contribution to the reflection intensity is weak. To reveal this contribution it is necessary to separate the structural circular dichroism from the magnetic one. The comparison with calculations makes this separation possible, especially exploiting the asymmetry of the azimuthal dependence of circular dichroism providing by magnetic contribution. This asymmetry was observed and extracted from the experimental results. Nevertheless, the results would be more reliable if the measurements for two opposite directions of magnetic field will be made.

References

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Report Summary

Azimuthal dependence of the 550 forbidden reflection was measured in copper metaborate at 15 K in applied permanent magnetic field with right and left circular polarized X-rays. The measurements were made at the incident radiation energy 5 KeV. The azimuthal dependence has demonstrated many Renninger reflections. Circular dichroism, which means the difference of the reflection intensity for the right- and left circular polarizations was observed mainly between the Renninger peaks.Very sophisticated calculations were made to separate the structural and magnetic contributions to the dichroism. Additional measurements with two opposite directions of magnetic fields are desirable to make the determined sign of the Dzyaloshinskii-Moriy interaction more reliable.