| | Experiment title: | Experiment number: |
|---|---|---|
| ESRF | Checking magnetic control of chirality in copper metaborate | **HC-2677** |
| **Beamline:** ID 12 | **Date of experiment**: 25/10/2016 ï 01/11/2016 | **Date of report**: 24/02/2017 |
| **Shifts:** 18 | **Local contact(s)**: Andrei Rogalev | *Received at ESRF:* |

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## Report

### Scientific Background

Chirality of matter (the existence of the right- and left handed forms) is believed to be an internal property determined by atomic arrangement. The chirality is associated with broken of parity under space inversion **r** to **ï r** while the magnetic effects are parity-even but break the time-reversal symmetry. Therefore from the symmetry point of view the possibility to switch the chirality by the magnetic field is impossible. Nevertheless, in the papers published by M.Saito et al.[1] it was claimed that it is possible to govern the chirality of copper metaborate by the rotating an external magnetic field. There was an lively discussion on this topic in scientific literature ([2,3] and references therein), which did not end up with a conclusion, but recent studies have shown that the results obtained in [1] can be explained by antiferromagnetic linear dichroism. To disprove the statement by M.Saito we have measured the XNCD (X-ray Natural Circular Dichroism). XNCD is a probe of chirality due to E1E2 interference term in X-ray absorption. In the experiment X-rays wave vector was parallel the the four-fold axis of copper metaborate $CuB_2O_4$ crystal applying the magnetic field in the plane ab (in the same directions and done by M.Saito. Copper metaborate $CuB_2O_4$ crystallizes in the tetragonal space group *I*-42*d* [4], which forbids the XNCD along the four-fold axis. The absence of a XNCD signal under applied magnetic field definitely refuse the possibility to control the crystal chirality by magnetic field.

### Experimental details

Optically polished $CuB_2O_4$ single crystal with the surface parallel to the (001) plane was used for the experimental study. To determine the crystal axes in **ab** plane the azimuhal dependence of the 002 forbidden reflection was measured at the Cu K-edge (8979 eV). The XNCD signal was measured as a difference of absorption coefficients recorded with right- and left circular polarizations of the incident beam and the wave vectors along the **a**- and **b**- axes and at some other angles. We have used the second harmonic of the APPLE-II helical undlator. The circular polarization rate for these photon energies was more than 90% . The sample was placed on a cold finger of a constant flow He cryostat and cooled down to 15 K. The XNCD spectra along the four-fold axis (forbidden by a crystal symmetry) were measured in magnetic fields 500 Oe (enough for the magnetic saturation of the sample), which was applied in two opposite directions along the **a-, b-** axes and between. The inversion of magnetic field did not reveal any magnetic circular dichroism. Exactly the same experimental configuration was used by M.Saito, but for visible light/

## Results

The point group -42m of metaborate forbids the XNCD along the four-fold axis, but allow in the perpendicular plane. The measured angular dependence of the XNCD has shown that the signals along the **a**- and **b**- symmetry axes of the crystal have opposite signs and equal to zero between (fig. 1). This is in perfect agreement with theoretical calculations . The measurements of the XNCD along the four-fold axis at 15 K with magnetic field 500 Oe applied along the **a-, b**- axes and between (45° to **a** and **b**) have shown no observable signal. The inversion of the magnetic field direction also did not reveal any magnetic contribution. So, the XNCD along the c-axis remains forbidden under magnetic field application, which disproves the results by M.Saito obtained by the visible light. So, we conclude that the magnetic field does not influence the crystal chirality as it was proposed by M. Saito.

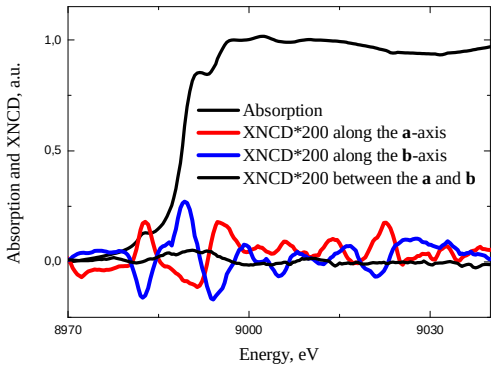


Fig. 1. Absorption (black) spectrum in copper metaborate and XNCD along the **a**-axis (red), **b**-axis (blue) and between **a** and **b.**

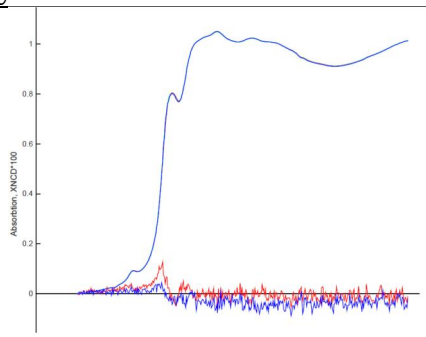

Fig.2. Absorption spectrum and XNCD*200 at 15 K along the four-fold axis with two opposite (red and blue curves) directions of magnetic field along the **b**-axis.

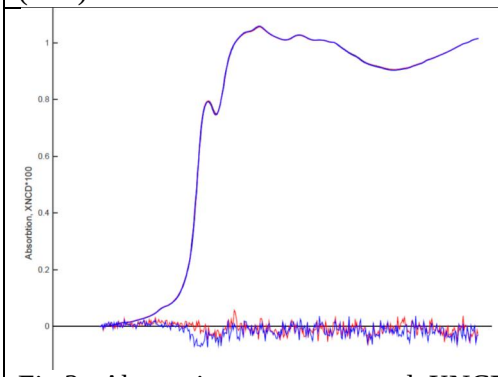

Fig.3. Absorption spectrum and XNCD*200 at 15 K along the four-fold axis with two opposite (red and blue curves) directions of magnetic field at 45° to the **a**-axis.

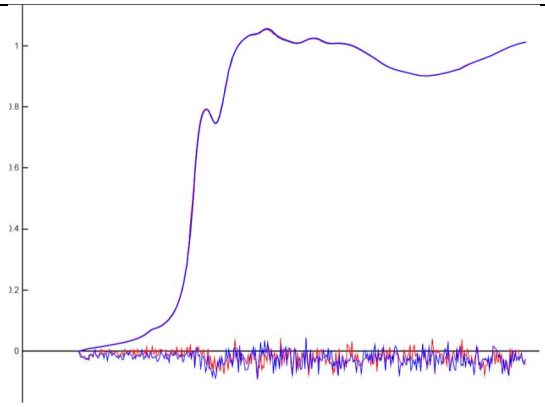

Fig.4. Absorption spectrum and XNCD*200 at 15 K along the four-fold axis with two opposite (red and blue curves) directions of magnetic field along the **a**-axis.


[1] M. Saito, et al. Phys. Rev. Lett. **101** (2008), 117402 ; M.Saito, et al. J. Phys. Soc. Japan **77** (2008),013705.
[2] S.W.Lovesey, U.Staub. J.Phys. Condens.Matter 21 (2009) 142201.
[3] K.N.Boldyrev, R.V.Pisarev, L.N.Bezmaternykh, M.N.Popova. Phys. Rev. Lett. 114 (2015), 247210.
[4] M. Martinez-Ripoll, S.Martinez-Carrera, S.Garcia-Blanco Acta Cryst. **B27** (1971), 677.
[5] E.N.Ovchinnikova, A.Rogalev, F.Wilhelm, et. al. JETP v. 123, n.1, p.27-32 (2016).


## Report Summary


The XNCD spectra in copper metaborate were measured with the wave vector in the plane perpendicular to the four-fold axis. The measurements of the XNCD along the four ï fold axis at the 15 K with magnetic field 500 Oe applied along the **a-, b**- axes and between (45° to **a** and **b**) have shown no observable signal and no magnetic contribution. So, the XNCD along the c-axis remains forbidden (in correspondence with a crystal symmetry) even under applied magnetic field. The conclusions drawn by M.Saito from optical circular dichroism measurements claiming a possibility to control the crystal chirality by external magnetic field are unambiguously disproved by the present experiment.