X-ray Magneto-Chiral Dichroism

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Systems, in which fundamental symmetries of nature are broken, play a fascinating role not only in physics but also in chemistry and in life sciences. A symmetry breaking manifests itself in various optical phenomena and therefore interaction of light with matter is the most powerful tool to deepen our understanding of complex matter. Two most vivid examples are magneto-optical and natural optical activity. Although the underlying physics is fundamentally different, the two phenomena manifest themselves quite similarly in homogeneous media: a rotation of the polarization plane of light or a difference in absorption of circularly polarized light (circular dichroism). This resemblance has motivated many eminent scientists, starting from Pasteur himself, to look for a link between magnetism and optical activity, but in vain. The corresponding optical manifestation is magneto-chiral effect which was first predicted in 1962 [1]. It may only occur in systems where both inversion and time-reversal symmetries are simultaneously broken. These symmetry conditions are satisfied in magneto-electric media and chiral molecular magnets. The striking feature of this effect can be derived from the symmetry considerations that it is a property of unpolarized light. The first experimental evidence of the magneto-chiral effect has been given only in 1997 by G. Rikken and E. Raupach [2] using visible light. In the X-ray range, the effect was discovered soon after in magnetoelectric Cr_2O_3 single crystal at ID12 beamlinefollowing the discovery of natural optical activity in the X-ray range [3].
A fascinating interplay of magnetism and structural chirality is reported here with two illustrative examples. The first one deals with the archetypal Single Chain Magnets M(hfac)2NITPhOMe where M is 3d transition metal ions (Mn^{2+} or Co^{2+}) [4]. For the first time, all the three dichroism spectra (X-ray magnetic circular dichroism (XMCD), X-ray natural circular dichroism (XNCD) and X-ray magnetochiral dichroism (XMχD)) have been measured at the K-edges of transition metals. It was found that the amplitude of magnetochiral effect in the X-ray range is linked to an orbital magnetic moment carried by absorbing atom.

The second example concerns more recent detection of XMχD signal in a paramagnetic lanthanide coordination complex, namely, $Na_5[Ho(ODA)_3](BF_4)_2(H_2O)_6$ at low temperatures and under high magnetic field [5]. The magnetochiral dichroism signal was found to be surprisingly weak despite a large orbital moment carried by Ho^{3+} ion. This is due to a very weak hybridization of the strongly localized 4f states of the lanthanides which are responsible for magnetism in these ions.

References

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