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## Report

### Scientific Background

MnSi, FeSi and many other examples of TMSi structures (TM stands for Transition Metal) are the crystals with non-trivial B20 structure and with unusual physical properties, magnetic and electronic. Structurally they are related with icosahedral quasicrystals, whereas their unusual magnetic properties are managed by the competition between exchange and spin-orbital interactions (Dzyaloshinskii-Moriya, magnetoelastic, etc.) resulting either in simple one-dimensional spirals or in rather exotic two- and three-dimensional magnetic patterns like Skyrmions [1,2]. MnSi crystal is metallic whereas FeSi is a narrow-band semiconductor with the so-called topological energy gap [3]. Magnetic spirals with a very short period (30 Å) have been recently found in MnGe crystals [4] that implies strong chirality effects. It is widely believed that the unusual properties of crystals with B20 structure is the result of non-centrosymmetric character of their $P2_13$ space group. X-ray natural circular dichroism is expected to be very small in B20 crystals because the E1E2 contribution vanishes in cubic structures and the E1M1 contribution is at least 60 times smaller than usual E1E2 contribution in the hard x-ray energy region [5]. Therefore the macroscopic chirality effects like X-ray circular dichroism and optical rotatory power are practically impossible to detect. In contrast, the circular dichroism in diffraction is not vanishing [6] and can be used for studying both dipole and quadrupole terms in the resonant scattering amplitude.

One would expect that the E1E2 terms, described by the third-rank tensors, could be observed for forbidden reflections $00l$, $l$=2n+1. The antisymmetric terms are particularly interesting because, contrary to the symmetrical terms, they could not be imitated by the thermal-motion-induced E1E1 contribution. However, the symmetry analysis shows that only the symmetrical E1E2 tensor gives contribution to the forbidden reflection (together with the E1E1 term) and neither these terms nor their interference produce the diffractional circular dichroism. Therefore we should study *allowed* reflections where interference between the conventional Thomson scattering and antisymmetric part of E1E2 resonant scattering could result in diffractional circular dichroism.

### Experimental details

Untwinned single crystals of MnSi was oriented and fully characterized (we are grateful to V.A. Dyadkin and D. Chernyshov for their help).

The problem with allowed reflections is that the crystal is non-centrosymmetric and for the most of allowed reflections the diffractional circular dichroism can be caused by the E1E1 term itself. The latter is not the case only for the *hhh* reflections where the threefold axis prevents circular dichroism for the E1E1 events. Our preliminary simulation (with the FDMNES code [7]) of the resonant diffraction in MnSi crystals have shown that the relative difference of reflection intensities for the left-handed and right-handed incident circular polarizations $(I_{left}-I_{right})/(I_{left}+I_{right})$ is expected to be of about $10^{-3}$ for the 111 reflection and $10^{-2}$ for the 222 reflection. Thus we have performed very careful measurements of the circular dichroism (available only at the ID12 beamline) for the resonant 222 reflections across the absorption edge of Mn. To avoid at least a part of possible systematic errors, for each energy we have measured the rocking curve of 222 reflection four times with right-left-right-left initial polarization, then integrated all the rocking curves and calculated the diffraction circular dichroism.

**Results**

The plot of intensities of 222 reflection for different circular polarization is shown in Fig. 1. It is obvious that in spite of all efforts the dichroism curve is rather noisy and the measurements should be further improved. As a byproduct, these measurements give a novel method to determine the absolute atomic configuration of B20 crystals because the signs of circular dichroism are expected to be opposite in crystals with opposite absolute configurations. We plan to check this in the future when we will have a MnSi crystal with the opposite absolute configuration.

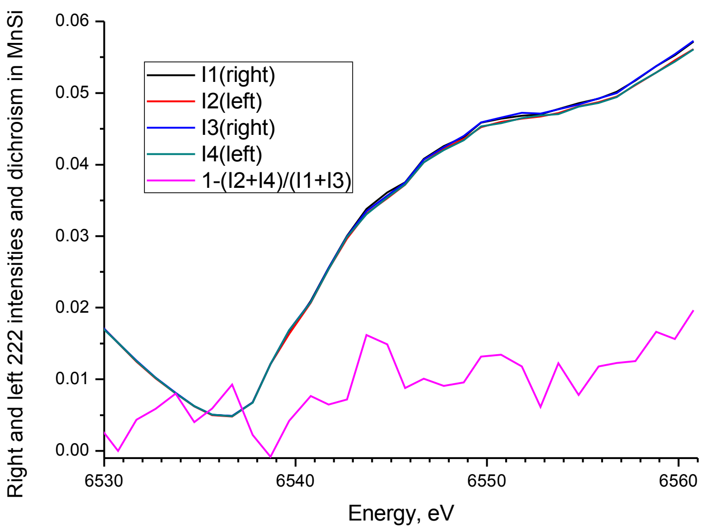


Fig. 1. The intensities of 222 reflection for different circular polarization and averaged circular dichroism.

On the other hand we do not observe the same agreement for the case of the La L-edges (see, fig.4). A plausible explanation could be the extended nature of both empty 6p and 4f orbitals of La ion.

**References**

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**Report Summary**

The circular dichroism in diffraction on MnSi cubic crystals with B20 structure has be studied for the near-edge x-ray energies using interference of E1E2 and E1E1 resonant x-ray scattering and non-resonant Thomson scattering for allowed 222 reflections.