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It is demonstrated how diffraction methods can be used for experimental determination of the sign of the Dzyaloshinskii-Moriya interaction (DMI) in antiferromagnetic crystals with weak ferromagnetism. Previous attempts to measure this sign are carefully analyzed. It is shown that in this case the vector of DMI correlates with the sign of the *local chirality* of centrosymmetric crystal structure. In fact, the canting of atomic moments can be considered as a result of alternating right-hand and left-hand rotations of moments in accordance with alternating local chirality inside the crystal unit cell.

Three different experimental techniques sensitive to the DMI sign are discussed: neutron diffraction, Mössbauer γ-ray diffraction, and magnetic (resonant or non-resonant) x-ray scattering.

In particular, it is demonstrated that the DMI sign can be directly extracted from interference between magnetic X-ray scattering, sensitive to the phase of antiferromagnetic order, and charge scattering, sensitive to the phase of crystal structure. Classical examples of hematite (α-Fe_2O_3) and $FeBO_3$ crystals are considered in detail (see [1] for preliminary consideration). This interference distorts strongly the azimuthal dependence of forbidden reflections and was recently observed in hematite [2]. However, the results of [2] cannot be directly used for the sign determination because the orientation of the weak ferromagnetic moment was indefinite in that work. The application of external magnetic field, fixing the orientation of the weak ferromagnetic moment and (owing to the DMI) fixing the phase of antiferromagnetic order relative to the crystal structure, will be crucial for this type of experiments.

The expected details of azimuthal dependence are simulated using FDMNES codes [3] for x-ray scattering amplitude the near absorption edges of magnetic atoms. We hope that the DMI sign of $FeBO_3$ will be measured in July at XMAS beamline in Grenoble. Results for more complicated cases of the DMI in crystals of La_2CuO_4 and MnSi types are also presented.

Two other possible techniques, neutron diffraction and Mössbauer γ-ray diffraction, sensitive to the DMI sign, are carefully discussed in comparison with magnetic x-ray scattering. Advantages and disadvantages of different techniques are analyzed. For example, the analysis of neutron data is straightforward whereas for resonant x-ray diffraction one needs rather sophisticated programs [3].

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Keywords: X-ray magnetic scattering, neutron diffraction, dzyaloshinskii-moriya vector

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Magnetic structures of the Co^{+2} doped $Mn_{1-x}Co_xWO_4$ Wolframites

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New materials, in which magnetic and ferroelectric long range order coexist and strongly interact, have become of great interest due to the fact that magnetism can be controlled by electric fields and vice versa. The interest in these magnetoelectric multiferroic materials has been enhanced since a new class of multiferroics have been discovered: materials the complex magnetic structure of which induces ferroelectricity.

It is known that $MnWO_4$ belongs to this new class of multiferroics and exhibits large magnetoelectric effects [1-3]. When decreasing the temperature, it undergoes three successive phase transitions to three different long-range antiferromagnetic states [1,2]. Below T_N=13.5 K moments order in the *ac* plane, the spins are collinear and sinusoidally modulated. This phase is the so called AF3 and is paraelectric. The AF2 phase appears in the interval 7.5 K < T <12.5 K, presents an additional magnetic component along *b* and is ferroelectric. A spontaneous polarization along *b* axis coexists with an elliptical spiral-spin structure. These two structures have the same propagation vector: **k**=(-0.214, ½, 0.457). Below 7.5 K the system is collinear (*ac* plane) and commensurate with **k**=(±1/4,1/2,1/2) (AF1). This succession of magnetic states at low temperature is a consequence of geometrical magnetic frustration effects in the intrachain and interchain magnetic interactions.

By substituting Mn^{+2} ions by isovalent M^{+2} (M: transition metal) the magnetoelectric properties change [3, 5, 6]. Doping the sample with Co^{2+} is specially interesting: this doping is the only known that strongly stabilizes the multiferroic magnetic phase. According to preliminary data on powder samples [5] the incommensurate multiferroic AF2 phase is expected to substitute the commensurate AF1 ordering at low temperature for x>0.03.

We have studied the magnetic structure of the 10% Co doped composition by single crystal neutron diffraction. We confirm the disappearence of the paraelectric AF1 phase which is substituted by the multiferroic AF2* phase, which is different from the AF2 phase of the pure compound. Moreover, it was observed that at this doping the orientation of the magnetic moments in the AF3 magnetic phase changes as well. In addition, an external magnetic field was applied along the *c* axis and modifications of the magnetic structure of the multiferroic phase were studied: the rotation plane of the magnetic moments flips and the spins lay perpendicular to the applied field. This magnetically induced transition transforms a multiferroic phase into another one in which the electric polarization is also flipped compared polarization appearing in the zero-field structure. To summarize, we confirm that substituting Mn^{+2} by Co^{+2} is an efficient mechanism to stabilize the multiferroic phase in the $Mn_{1-x}M_xWO_4$ family, and that the application of magnetic fields modifies the cycloidal and polar orderings.

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Structural, magnetic and magnetocaloric properties of $CoMnGe_{1.95}Ga_{0.05}$

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The magneto-structural transformation materials, which experience the crystallographic and magnetic phase transition simultaneously, have attracted considerable attention not only for their importance in fundamental physics but also for their promising applications as multifunctional materials. Magnetic refrigeration based on the magnetocaloric effect (MCE) is a possible alternative to the current vapor compression technology [1]. Nowadays, most studies on magnetic refrigerants are focused on materials undergoing a first order phase transition because of their potential applications at room temperature.

The $CoMnGe_{0.95}Ga_{0.05}$ compound was prepared by arc melting by using high-purity elements. Synchrotron experiments were performed in the temperature range between 290 and 390 K on B2 in HASYLAB/DESY in Hamburg. A synchrotron X-ray wavelength of 0.688105 Å was used. Magnetic measurements were performed as functions of temperature and magnetic fields with Physical Properties Measurements System-PPMS between 5 and 350 K under magnetic field up to 7 Tesla.

Synchrotron experiments shows that this compound exhibits the structural transition from high temperature phase (orthorhombic-space group: Pnma) to low temperature phase (cubic-space group: $P6_3/mmc$) around the room temperature. According to Rietveld refinement, the unit cell volume of the high temperature phase is 77.3 $Å^3$ and the unit cell volume of low temperature phase is 160.9 $Å^3$ at 300 K.

According to temperature dependence of magnetization measurements, this compound has thermal hysteresis between FC and FH curves and this thermal hysteresis confirms the structural transition around T_C. While on FC mode the Curie temperature is 308 K, the Curie temperature is 319 K on FH mode. According to M(H) curves, this compound exhibit magnetic field induced structural transition. This magneto-structural transition makes this material very important for magnetic cooling technology. The magnetocaloric effect of this compound is estimated by using Maxwell equation. The magnetic entropy change is 4.5 J/kg.K and 30.9 J/kg.K for the magnetic field change of 1 Tesla and 7 Tesla, respectively.

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Keywords: synchrotron experiments, magneto-structural transition, magnetic measurements

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Magnetic space groups: database and extinction rules for magnetic diffraction

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Based on the recent compilations of magnetic space groups [1,2], a Magnetic Space Groups Database has been developed. This database is freely available on the Bilbao Crystallographic Server (www.cryst.ehu.es) [3], and includes useful data such as general positions (symmetry operations in matrix form), special Wyckoff positions, etc. Using this database and in order to facilitate the systematic use of extinction rules in magnetic non-polarized neutron diffraction analysis of magnetic structures, we have developed the computer tool MAGNEXT that is also freely available on the Bilbao Crystallographic Server. The derivation of the extinction rules for magnetic diffraction is somewhat more complex compared with that of non-magnetic diffraction because of the axial vector character of the magnetic structure factor and its different and more complicated relation to the intensity. In fact, there are no listings of magnetic diffraction extinction rules comparable to those available for non-magnetic diffraction. This program is a contribution for changing this situation. MAGNEXT provides the extinction rules for non-polarized neutron diffraction corresponding to any Shubnikov magnetic space group. Illustrative examples are provided to demonstrate the utility of the program. Although not having the strong resolving power of the extinction rules of conventional non-magnetic crystallography, the extinction rules for magnetic diffraction can be useful for the systematic analysis and determination of magnetic structures, since they may facilitate the identification of their magnetic space group.

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Keywords: extinctions, magnetic symmetry, Bilbao crystallographic server

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Magnetic structures of the family $R_mM_nIn_{3m+2n}$ of intermetallic compounds

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The family $R_mM_nIn_{3m+2n}$ (R = Ce - Tb; M = Rh, Ir or Co; m = 1, 2; n = 0, 1) has been intensively investigated because its close relationship with the interesting physical properties found in other compounds of this family, specially for the R = Ce compounds, for whose a heavy fermion behavior with unconventional superconductivity (USC) has been reported. [1,2]

In this work we present a systematic study of the physical properties and the determination of magnetic structures of a new series of isostructural compounds $R_mM_nIn_{3m+2n}$ (R = Gd, Tb, Sm; M = Rh, Ir; m = 1, 2; n = 0, 1) exploring their relationship with physical properties of Ce-based compounds from this family. The magnetic structures of tetragonal Gd_2IrIn_8, $GdRhIn_5$, $TbRhIn_5$, Tb_2RhIn_8, Sm_2IrIn_8 and cubic $GdIn_3$ compounds have been determined using x-ray magnetic scattering (XRMS) at the bending magnet XRD2 beamline of the Laboratório Nacional de Luz Síncrotron (LNLS), in Campinas, Brazil. All these systems order antiferromagnetically in commensurate structures below their Nèel temperatures (T_N) with propagation vectors (1/2,0,0), (0,1/2,1/2), (1/2,0,1/2), (1/2,1/2,1/2), (1/2,0,0) and (1/2,1/2,0), respectively [3-6]. The comparison between all the determined magnetic structures will be performed in terms of crystal field (CEF) effects along the series. The magnetic moments of rare earth ions are oriented in the tetragonal *ab*-plane for R = Gd and Sm_2IrIn_8 compounds, while for the Tb-based systems order along the *c*-axis direction. T_N is increased along the tetragonal Tb-based compounds (Tb1-1-5 and Tb2-1-8) when compared to the cubic $TbIn_3$ compound ($T_N \sim 32$ K), as has been found for Nd-based compounds from this family [7].