Anomalous Spectroscopical Effects in an Antiferromagnetic Semiconductor

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Permittivity tensor $\epsilon(\omega)$ of magnetically ordered systems contains information about a large number of effects, many of which had earlier been associated with ferromagnets: to name a few, anisotropic magnetoresistance (AMR), magneto-optical Kerr effect (MOKE) and x-ray magnetic circular dichroism (XMCD). More recently, it has been understood that these select effects also exist in antiferromagnets (AFMs). We focus on an AFM semiconductor MnTe: first, the DC ($\omega \to 0$) conductivity $\sigma_{xx} \propto \omega\epsilon_{xx}$ was found to be sensitive to Néel vector direction [1] (described by angle ψ) and next, the symmetry-constrained angular dependence of AMR [2] to include a $\rho^{(3)} \sin 3\psi$ term [3]. By then, it has been known that the anomalous Hall effect (AHE; non-zero σ_{xy} in the DC limit, odd in ψ) can also occur in systems with zero net magnetisation (specifically, non-collinear AFMs [4]) but collinear MnTe [5] (in hexagonal phase of NiAs-type) is appealing by its simpler magnetic structure.

In this context, we will discuss three interconnected effects in MnTe: (i) the AHE and its relation to weak net magnetic moment m induced along the c-axis [6], (ii) prediction of XMCD confirmed by recent experiments [7] and (iii) observation of MOKE. For (i), the degeneracy between ↑↓ and ↓↑ domains is broken by a Dzyaloshinskii-Moriya-type interaction and magnetic moments slightly cant out-of-plane. Magnetic field applied along c thus creates an imbalance between these two types of domains and AHE can be observed; we also show the multipolar character of the Berry curvature and discuss its consequences.

Next, we report on a prediction of XMCD spectra (obtained using dynamical mean-field theory calculations [8]) which has subsequently been confirmed by experiments [7] sensitive to $\epsilon_{xy}(\omega)$ at $\hbar\omega \sim 640$ eV. Since the role of m has now been clarified, it is safe to attribute this effect, within collinear AFMs, to a recently coined altermagnetic symmetry class; we will discuss its differences to ordinary AFMs (such as those endowed with $\mathcal{PT}$ symmetry).

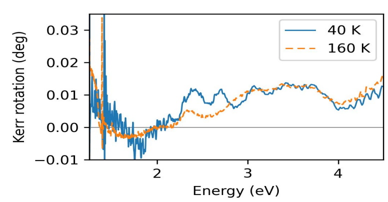

Fig. 1. MOKE spectrum of MnTe at two temperatures below Néel temperature T_N at saturation.

Our main focus will be on MOKE experiments in $\hbar\omega > 1.25$ eV range (Fig. 1). Even if symmetry considerations are the same as for XMCD, microscopical mechanism is different (no core levels are involved where the spin-orbit interaction is strong) and it turns out to be difficult to measure the effect. Nevertheless, we observe hysteresis (which is beyond reach in XMCD experiments). These advances concerning MnTe highlight the utility of this material (with T_N slightly above RT) with promising future in AFM spintronics [4].

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