Comparing the Anomalous Hall Effect and the Magneto-optical Kerr Effect through Antiferromagnetic Phase Transitions in Mn_3Sn

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Introduction

Non-collinear antiferromagnets such as Mn_3Sn and Mn_3Ge have recently emerged as a fascinating class of materials that can exhibit a large anomalous Hall effect (AHE) despite having a vanishingly small net magnetic moment. The AHE can arise in these and related antiferromagnetic (AF) materials when the underlying spin order not only breaks time-reversal symmetry but also lacks certain spatial symmetries. Together with spin- orbit coupling, this can lead to a band exchange splitting and a non-zero value of the integrated Berry curvature over the occupied bands, even in the absence of net magnetization. A related phenomenon that is also traditionally associated with the presence of a net magnetic moment is the magneto-optical Kerr effect (MOKE), wherein linearly-polarized light rotates and/or becomes elliptically polarized upon reflection from a material's surface. Although MOKE is inherently a much more surface-sensitive probe than AHE, both phenomena ultimately derive from the off-diagonal (antisymmetric) components of the material's conductivity tensor. As such, anomalously large MOKE signals were also predicted in certain non-collinear antiferromagnets, and indeed they were very recently observed in Mn_3Sn. Both the AHE and MOKE are of practical interest as they can enable simple electrical and optical probes of non-collinear AF order, analogous to their widespread use to study ferromagnets. More fundamentally, both effects provide experimental tests for theoretical models that predict the influence of spin structure on measurable properties, based on underlying symmetry considerations.

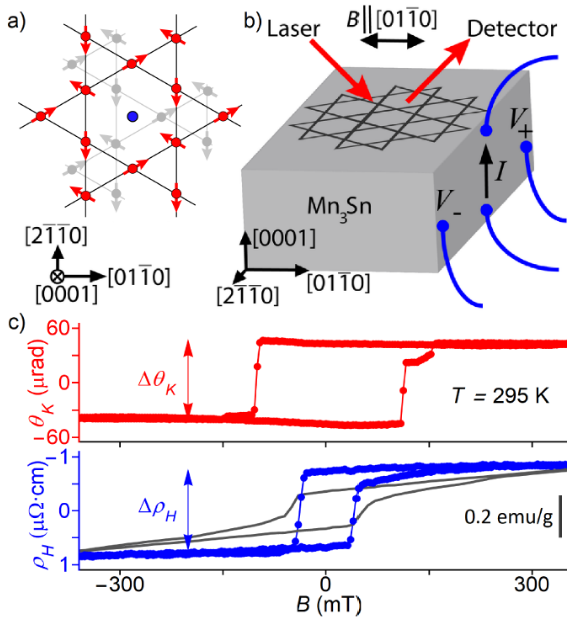

Figure: a) Non-collinear inverse-triangular AF spin structure of Mn_3Sn (at room temperature). Red arrows indicate Mn spins, the blue dot represents Sn. The crystal plane beneath the (0001) surface plane is depicted with reduced (grey) contrast. b) Experimental setup. Longitudinal MOKE is measured on the (0001) surface while the AHE is sensed along [2-1-10] direction using current along the [0001] direction. Magnetic fields B are applied along [01-10]. c) Simultaneous measurements of MOKE (red, top) and AHE (blue, bottom) at room temperature, versus B. Magnetic hysteresis is observed. Note the very different AF switching (coercive) field. The grey loop is the bulk magnetization measured via SQUID.

Results and Discussion

In the non-collinear antiferromagnet Mn_3Sn, we compare simultaneous measurements of the anomalous Hall Effect (AHE) and the magneto-optical Kerr effect (MOKE) through two magnetic phase transitions: the high-temperature paramagnetic/antiferromagnetic phase transition at the Neel temperature (T_N ~420 K), and a lower-temperature incommensurate magnetic ordering at T_1 ~270 K. While both the AHE and MOKE are sensitive to the same underlying symmetries of the antiferromagnetic non-collinear spin order, we find that the transition temperatures measured by these two techniques unexpectedly differ by approximately 10 K. Moreover, the antiferromagnetic switching (coercive) field measured by MOKE is significantly larger than that measured by AHE. These results point to a difference between the bulk and surface magnetic properties of Mn_3Sn.

References

[1] Balk, A. L. *et al.*, *Applied Physics Letters, accepted and in press* (2018).