# MA 27: Focus Session: Magneto-Transport and Magneto-Optics of Higher Orders in Magnetization II

Magneto-transport and magneto-optic effects linear in the magnetization M (e.g. anomalous Hall effect (AHE), Faraday effect or magneto-optic Kerr effect (MOKE)) are important magnetic phenomena in spintronics and magneto-optics for the characterization of magnetic samples by vectorial magnetometry, microscopy, spectroscopy and pump probe experiments. However, already some time ago, it has been shown that the angular dependence of the anisotropic magnetoresistance and of magneto-optic effects contains higher-order-in-M terms. In the last decade, these effects beyond the linear dependence on M, e.g. quadratic effects proportional to $M^2$, have been mainly utilized to investigate antiferromagnetic materials.

Recently, the third-order MOKE proportional to $M^3$, so-called cubic MOKE, was reported to be sensitive to the structural domain twinning in thin-film samples of (111) orientation. By investigating AHE and MOKE of higher orders in M, the multipolar structure of the Berry curvature in magnetization space can be probed. These additional higher-order contributions in standard Hall or polar MOKE setup geometries are able to trace the in-plane magnetization while the linear effect keeps sensitive to the out-of-plane magnetic moment. This can be utilized, for example, to detect spin-orbit torques magneto-optically.

This Focus Session introduces the main magneto-transport and magneto-optic effects of higher orders in magnetization, draws connections between both research fields, distinguishes between already known and new higher-order effects and presents first applications beyond the study of antiferromagnets by quadratic effects.

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Time: Wednesday 15:00–15:45 Location: H18

MA 27.1 Wed 15:00 H18

**Quantifying magnetization multipole of Berry curvature in ferromagnets** — •Wenzhi Peng, Zheng Liu, Bin Xiang, Qian Niu, Yang Gao, and Dazhi Hou — University of Science and Technology of China

The anomalous Hall effect, originating from the Berry curvature in momentum space, typically manifests as a dipole behavior in magnetization. This implies that the anomalous Hall conductivity is parallel to the magnetization in most transport measurements. However, even in iron, the in-plane magnetization can also induce the anomalous Hall effect, which contradicts the predictions of the dipole term in a cubic lattice. This behavior can be understood within the framework of the Berry curvature multipole structure in magnetization space. In this work, we propose a paradigm to quantify the coefficients of the Berry curvature multipole by examining the angular dependence of the Hall resistivity, which matches well with first-principles calculations. Under certain conditions, the contribution of the magnetization multipole can even surpass that of the dipole term, dominating the AHE.

MA 27.2 Wed 15:15 H18

**Orthogonal faraday effect in garnet** — •Haolin Pan[1], Han Li[2], Qinhui Yang[2], and Dazhi Hou[1] — [1]University of Science and Technology of China, Hefei, China. — [2]University of Electronic Science and Technology of China, Chengdu, China.

Faraday effect, a transmissive magneto-optical phenomenon with a long history and diverse applications, has been be confined within parallel configuration between light and magnetization in experiments. This routine originates from the common assumption that the asymmetric components of dielectric tensor is in linear response to magnetization. However, our experiments in garnet materials reveal the nonlinear nature of Faraday effect with respect to magnetization orientation, which allows the orthogonal geometry between light and magnetization. The lattice angular dependence and spectroscopy results are in good agreement with theory of multipole structures of Berry curvatures in magnetization space. The observation of orthogonal Faraday effect provides new opportunities for magneto-optical studies and applications.

MA 27.3 Wed 15:30 H18

**Strong anisotropy of quadratic magneto-optical Kerr effect in FeRh** — •zeynab sadeghi, vladislav wohlrath, jozef kimák, peter kubaščík, eva schmoranzerová, tomas ostatnický, and petr němec — faculty of mathematics and physics, charles university, prauge, 121 16, czech republic

recently, we developed a technique that enables to measure magnetic anisotropy and anisotropy of quadratic magneto-optical Kerr effect (QMOKE) [1]. This technique is based on measurement of magneto-optical response in rotating magnetic field using series of incident light linear polarizations at normal incidence on the sample with a fixed position and, therefore, it can be applied also for samples placed in a cryostat. In this contribution, we report on measurements in FeRh, which is an interesting material with an antiferromagnetic (AFM) ordering at room temperature and a ferromagnetic (FM) phase at temperatures above 400 K. We show that in the FM phase QMOKE has a very strong wavelength-dependent anisotropy in the investigated spectral range from 460 nm to 1600 nm. We also discuss the possibility of investigation of the FeRh AFM phase using this technique. [1] wohlrath, w., sadeghi, z. et al. "quadratic magneto-optical Kerr effect spectroscopy: Polarization variation method for investigation of magnetic and magneto-optical anisotropies." arXiv:2409.20205 (2024).