Spin dimensionality in chromium trihalides

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Ferromagnetism in layered van der Waals materials that preserve up to the monolayer regime attracts the exceptional attention of scientists [1]. Intensively examined chromium trihalide compounds (CrX_3, where X=I, Br, or Cl) are layered magnetic materials of ferromagnetic order within a layer. $CrBr_3$ layers are ferromagnetically coupled, while CrI_3 and $CrCl_3$ possess antiferromagnetic coupling. Furthermore, the spins in $CrBr_3$ and CrI_3 are preferentially aligned in the out-of-layer direction, whereas in $CrCl_3$ they are characterized by the in-plane orientation [2].

In this work, we study the spin dimensionality of CrX_3 compounds by applying the magnetic field in the out-of-plane (Faraday) and in-plane (Voigt) configurations in reference to the sample, see Figure (a). Magnetization was studied by the polarization-sensitive photoluminescence technique. Circularly polarized excitation and detection were used to evaluate circular dichroism in CrX_3 arising from unequal absorption coefficients for photons characterized by opposite circular polarization.

The inspection of the PL intensity as a function of applied out-of-plane magnetic field sweeping in both directions for CrI_3 and $CrBr_3$ revealed the hysteresis as seen in Fig. (b,c). Hysteresis indicates intrinsic ferromagnetic ordering. $CrCl_3$ not present hysteresis due to strong in-plane orientation of spins, see Fig. (d). Magneto-PL intensity in Voigt configuration reveals complex hysteresis with unusual shape, see Fig. (e)-(g). The comparison of coercive fields in both configurations of the magnetic field provides information about spin dimensionality, which is consistent with theory [2]. $CrBr_3$ can be described by an isotropic Heisenberg model with 3D spin dimensionality. CrI_3 has a greater out-of-plane anizotropy than $CrBr_3$, which suggests an 1D spin dimensionality described by an Ising model. $CrCl_3$ presents the 2D spin dimensionality described by an XY model.

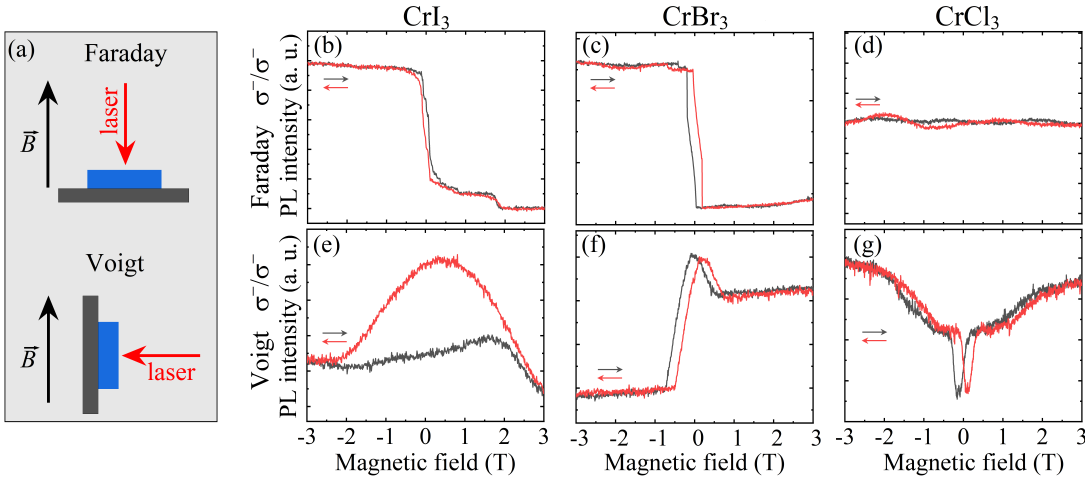

Figure: (a) The schemes of Faraday and Voigt configurations of placement sample in magnetic field. The magneto-PL intensity in Faraday (b,c,d) and Voigt (e,f,g) configurations.

[1] M. Gilbertini, et. al., *Nature Nano.* **14**, 408 (2019).
[2] R. Yadav, et. al., *arXiv:2208.02195* (2022).