Antiferromagnetic switching driven by the collective dynamics of a coexisting spin glass

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Abstract

The theory behind the electrical switching of antiferromagnets is premised on the existence of a well-defined broken symmetry state that can be rotated to encode information. A spin glass is, in many ways, the antithesis of this state, characterized by an ergodic landscape of nearly degenerate magnetic configurations, choosing to freeze into a distribution of these in a manner that is seemingly bereft of information. Here, we show that the coexistence of spin glass and antiferromagnetic order allows a novel mechanism to facilitate the switching of the antiferromagnet $Fe_{1/3+\delta}NbS_2$, rooted in the electrically stimulated collective winding of the spin glass. The local texture of the spin glass opens an anisotropic channel of interaction that can be used to rotate the equilibrium orientation of the antiferromagnetic state. Manipulating antiferromagnetic spin textures using a spin glass' collective dynamics opens the field of antiferromagnetic spintronics to new material platforms with complex magnetic textures.

Entangling light and matter for future electrooptics

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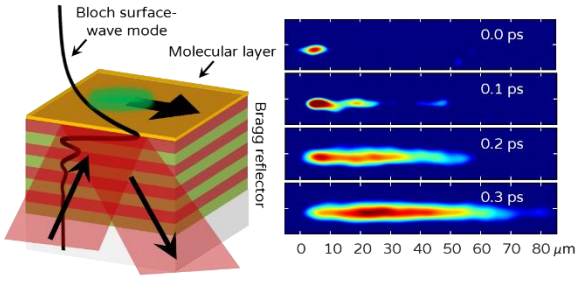
When an excitonic material is embedded within a resonant photonic structure, its wavefunctions can be hybridized with the photonic ones to create composite quantum states which are partly photonic and partly excitonic. The entanglement between light and matter and hybrid excitations which emerge, known as polaritons, provide a novel pathway toward controlling material properties and chemical reactions [1]. Specifically, in recent years it has been realized that hybridizing excitons with light in photonic nanostructures can enhance the transport properties of the material, which has far-reaching technological implications for electrooptics. However, the enhancement mechanism and the transport nature of these composite light-matter excitations still remain elusive.



Here, I will present our recent work in which we utilized ultrafast microscopy to fully map the dynamics of the enhanced transport and gained access, for the first time, into the transport mechanism of polaritons. We revealed how the creation of the hybrid polaritonic excitations first leads to a 10^6 enhancement in the diffusion coefficient and even, once the coupling with light completely overcomes the effect of disorder, to ballistic transport at two-thirds the speed of light over ~100μm distances [2]. These results provide crucial information on the mesoscopic quantities governing cavity-enhanced transport and pave the way towards novel electrooptic devices harnessing the coherent interaction between light and matter.

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Pressure Tuning of Berry curvature in $CrGeTe_3$

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The integrated Berry curvature is a geometric property that has dramatic implications on material properties [1]. In this study, we tune the integrated Berry curvature of the ferromagnetic insulator $CrGeTe_3$ by deforming its band structure using hydrostatic pressure. We investigate the integrated Berry curvature through its intrinsic contribution to the anomalous Hall effect, which is absent in the insulating phase of $CrGeTe_3$ and evolves with pressure in a dome-like fashion as it undergoes the metal-insulator transition. At higher pressures, the band deformation nullifies the integrated Berry curvature contribution, leaving only extrinsic scattering sources to the anomalous Hall effect, which are retained even up to room temperature.

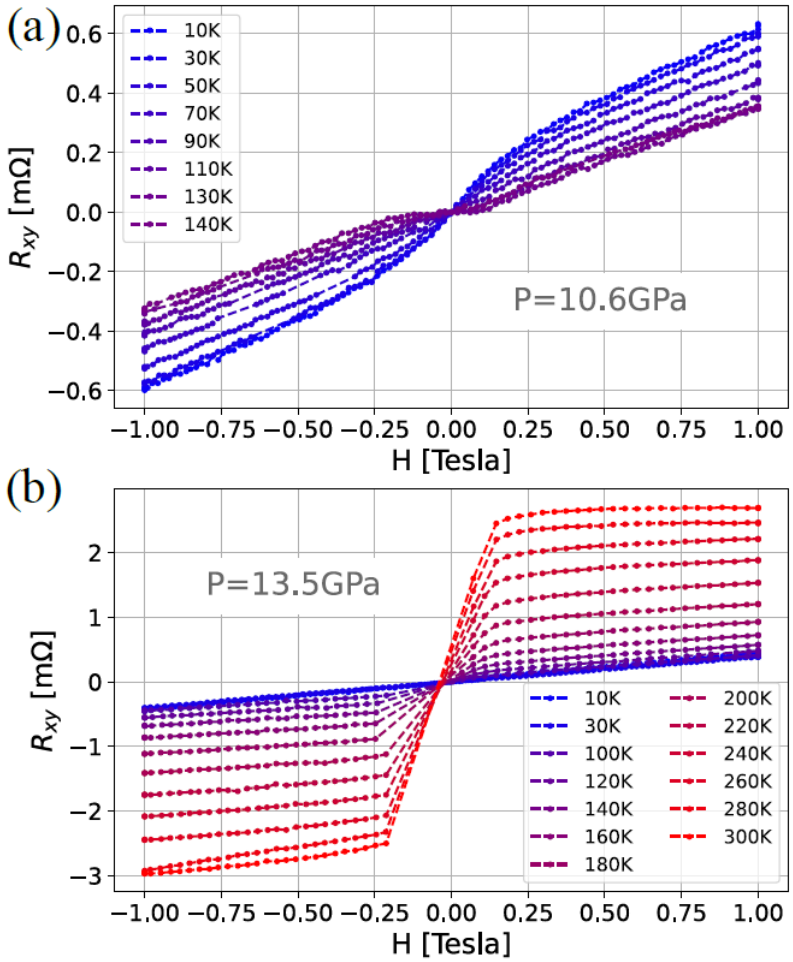

Fig. 1: Measurements of the Hall effect at different temperatures at pressures of 10.6 GPa (panel (a)) and 13.5 GPa (panel (b)). The steep slopes at low fields are due to the AHE.

Plasmonic cavities and individual quantum emitters in the strong coupling limit

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The strong interaction of individual quantum emitters with resonant cavities is of fundamental interest for understanding light–matter interactions. Plasmonic cavities (PCs) hold the promise of attaining the strong coupling (SC) regime even under ambient conditions due to their deep subdiffraction volumes. We previously showed that we can observe SC in the limit of a single quantum emitter positioned within a plasmonic cavity[1,2]. Scattering spectra, measured by dark-field spectroscopy and registered from individual PCs containing one to a few colloidal quantum dots (QDs) showed vacuum Rabi splitting, indicating that the SC regime was approached in these systems.

To verify and generalize our findings, we turned to Electron Energy Loss (EEL) spectroscopy. In contrast to other techniques, the electron beam couples to the plasmons in the near field, probing the out-of-plane component of the electric field around a plasmonic device with a subnanometer spatial resolution. This enables us to probe SC not only to the bright modes of plasmonic structures but also to dark, subradiant modes, which may be of significant interest for quantum optical studies, particularly since they are expected to have longer lifetimes[3].

We recently used Hanbury Brown and Twiss interferometry to demonstrate the quantum nature of photoluminescence (PL) from QDs within PCs, verifying that the measurements are indeed from one to three QDs. Further spectroscopic studies of QD-PC systems in fact manifested several surprising features, indicating discrepancies between scattering anf PL spectra. These observations point to the involvement of a dark excitonic state of the QD. Given that bright and dark excitonic states couple to the cavity with different degrees of coupling strength, the PC affects in a different manner each excitonic state. This yields complex relaxation pathways and interesting dynamics[4].

Currently we are working on increasing the QD-PC coupling deeper into the SC regime. This can be acheived either by optimizing the materials properties of the plasmonic system or by forming hybrid plasmonic-photonic modes. This will pave the way to exciting applications including the generation of single-photon sources and studies of cavity-induced coherent interactions between emitters.

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Vapor Phase Deposition of Chiral Thin Films by Atomic and Molecular Layer Deposition Showing Spin Selective Transport

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Vapor phase deposition of chiral thin films with molecularly controlled chirality and film thickness is highly desirable yet challenging to obtain. A combined atomic and molecular layer deposition (A/MLD) methodology deliver highly controlled deposition of hybrid organic-inorganic chiral thin films. These films were utilized as a spin filter layers in spintronic devices using chiral induced spin selectivity effect (CISS). The A/MLD process utilize enantiomeric pure D/L-Alaninol as a molecular precursor, combined with trimethyl aluminum (TMA) and water precursors, resulting in a uniform, low roughness, and chiral thin films. The chirality of the thin films was further characterized by circularly polarized light plasmonic nanodevice recently reported [1]. The chemical composition, uniformity and homogeneity of the thin layers were characterized by XPS, FTIR, and AFM. Combining the chiral thin films with common fabrication methods led to fabrication of magnetic field-controlled spin selective device, showing high spin polarization (close to 100%).

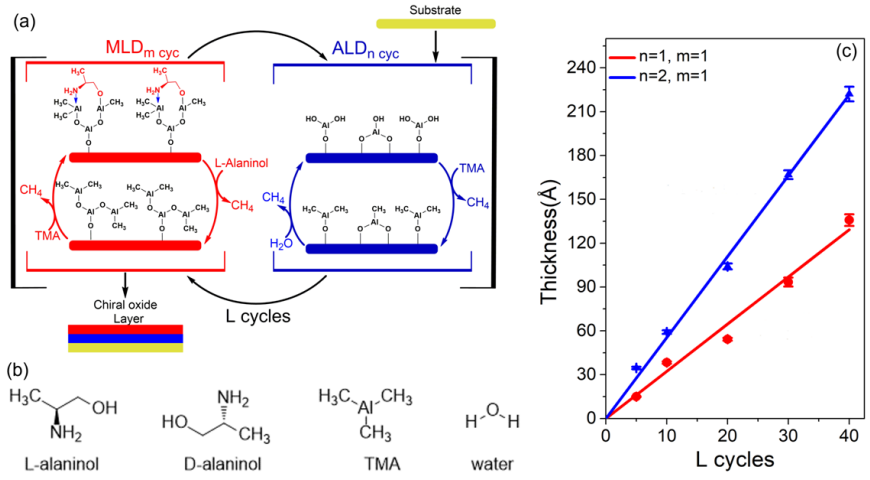

Figure 1 *A/MLD deposition of hybrid organic-inorganic chiral thin films. (a) Schematic of the deposition process depicted with L-Alaninol precursor, (b) Precursors used in the process, (c) Film thickness vs. number of cycles for A/MLD deposition sequence[2].*

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