**Optical Control of Magnetization Dynamics in Magnetic Heterostructures**

**Abstract:**

Manipulating magnetism with a femtosecond (fs) laser pulse is the fastest method known in condensed matter physics, which has great prospects in ultrafast spintronic applications. In the past 30 years, great efforts have been made in understanding spin dynamics based on the well-known three temperature model, which roots on complex interactions between electrons, spins and lattice accompanying substantial transfer of momentum and energy in the ultrafast timescale. However, the microscopic mechanisms of the fs magnetism are still in strong debates. For example, ultrafast spin current transport across magnetic heterostructures is not yet exclusively demonstrated. Such that, ultrafast spin current generated by a fs laser pulse is not considered as a major force of ultrafast spin dynamics as compared to the local spin-flips.

Here, in a typical Gd/Fe bilayer heterostructure, we demonstrate for the first time at a microscopic electronic level that spin current transport can alone dominate the ultrafast demagnetization process. In a reverse order of Fe/Gd bilayer, a transient increase in the Fe spin polarization is confirmed, again proving that the spin current induced by femtosecond lasers is transmitted from the Gd layer to the Fe layer [1]. Later, a [Co/Pt]-based perpendicular magnetic anisotropy (PMA) synthetic antiferromagnet (p-SAF), we drive a reduction of the RKKY coupling and the PMA. This concomitant control is attributed to the optically smeared Fermi wave vector of the Ru layer, which both mediates the exchange coupling between the constituent ferromagnetic layers and cause electron redistributions in the 3d orbitals [2].

In conclusion, we have demonstrated optically excited spin-polarized hot electrons across a magnetic heterostructure play a key role in governing ultrafast spin dynamics.

**References:**

[1] Liu, B.; Xiao, H.; Weinelt, M. Microscopic Insights to Spin Transport–Driven Ultrafast Magnetization Dynamics in a Gd/Fe Bilayer. Sci. Adv. 2023, 9 (20), eade0286.

[2] Ma, M.; Wu, J.; Liu, B.; Wang, L.; Li, Z.; Ruan, X.; Hu, Z.; Wang, F.; Lu, X.; Liu, T.; Du, J.; Xia, K.; Xu, Y. Optical Control of RKKY Coupling and Perpendicular Magnetic Anisotropy in a Synthetic Antiferromagnet. Nat Commun 2025, 16 (1), 4401.