Ultrafast Light-Induced Magnetoelectric Effect in van der Waals Magnetic Semiconductor Heterostructures

Roland K. Kawakami[1]
Wenyi Zhou,[1] Ravi Kumar Bandapelli,[2] Hari Paudyal,[3] Bangzheng Han,[1] I-Hsuan Kao,[2] Ziling Li,[1] Yuqing Zhu,[1] Durga Paudyal,[3] Jyoti Katoch,[2] Simranjeet Singh[2]
[1]*The Ohio State University, Department of Physics, Columbus, Ohio, USA*
[2]*Carnegie Mellon University, Pittsburgh, Pennsylvania, USA*
[3]*University of Iowa, Department of Physics and Astronomy, Iowa City, Iowa, USA*

kawakami.15@osu.edu

Atomic-scale heterostructures of van der Waals (vdW) magnets and semiconductors provide a unique environment for exploring magnetic dynamics. In contrast to typical photothermal excitation of precessional magnetization dynamics by a pump laser pulse, we find that ultrafast optical excitation of a $WS_2/CrGeTe_3$ (CGT) bilayer produces an opposite sign of magnetic torque compared to an isolated CGT film. Experimental observations by time-resolved magneto-optic Kerr effect (TR-MOKE) and theoretical analysis by density functional theory (DFT) and Landau-Lifshitz-Gilbert (LLG) simulations support a mechanism in which charge transfer of photoexcited carriers across the interface alters the perpendicular magnetic anisotropy, which in turn generates a torque on the magnetic layer to trigger precessional magnetization dynamics. These results provide new avenues for ultrafast manipulation of magnetization in vdW heterostructures with type-II band alignments. Lastly, we show that optically-generated spin currents from WS_2 into CGT can also trigger precessional dynamics via angular momentum transfer.

Figures

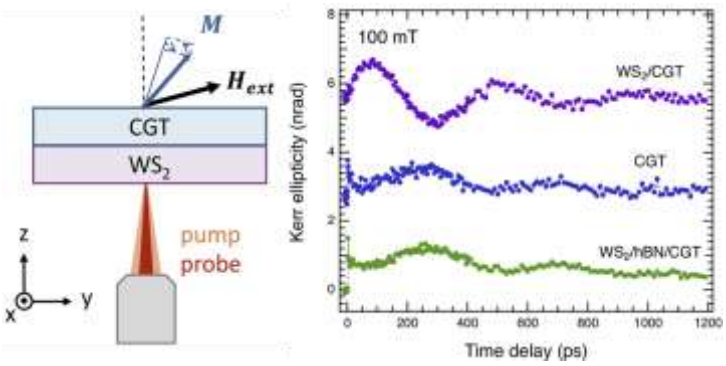

Figure 1: Time-resolved magneto-optic Kerr effect (TR-MOKE) measurements of magnetization dynamics in vdW magnetic heterostructures

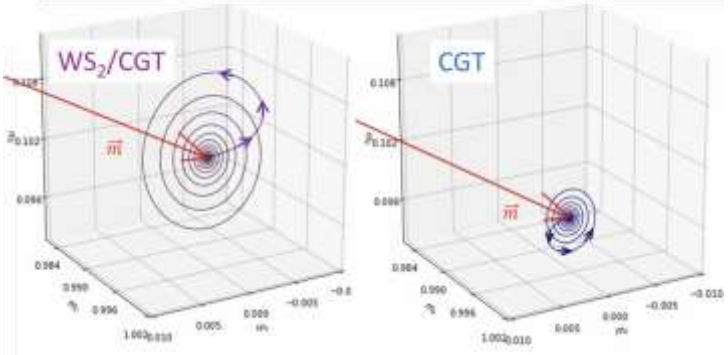

Figure 2: Landau-Lifshitz-Gilbert simulations of magnetization dynamics