Terahertz Laser Pulse Boosts Interlayer Spin Transfer in Two-Dimensional van der Waals Magnetic Heterostructures

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Abstract: Light-induced ultrafast dynamics in two-dimensional (2D) magnetic systems demonstrate substantial advancements in spintronics, but high laser energies present specific challenges.[1] Terahertz (THz) radiation provides a low-energy alternative, yet its theoretical exploration remains incomplete. Two-dimensional (2D) magnetic materials and van der Waals heterostructures offer significant potential in spintronics.[2] However, there are still unanswered questions regarding the dynamics of spin transfer between layers and the impact of laser pulse frequency. Here, using the real-time density functional theory (rt-TDDFT),[3] we applied laser pulses with various frequencies, from terahertz (THz) to optical pulse, to systematically study the interlayer spin transfer dynamics in 2D van der Waals nonmagnetic-ferromagnetic heterostructures, including graphene-Fe3GeTe2 (Gr/FGT) and silicene-Fe3GeTe2 (Si/FGT). Our results demonstrate that low-frequency THz pulses are particularly effective in facilitating interlayer spin injection from the ferromagnetic FGT layers to the Si or Gr layers. However, this process is hardly influenced by high-frequency optical pulses. Such effect is attributed to the low-frequency THz pulses induced in-phase oscillations of the electron charge density around atomic centers, leading to a highly efficient interlayer spin transfer. Our results provide new insight into ultrafast THz radiation control intralayer spin transfer and magnetic proximity dynamics in 2D limit.

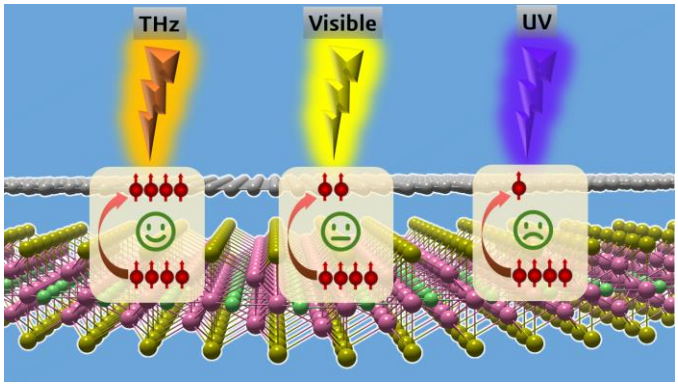

Figure 1. Spin dynamics process of heterojunction Gr/FGT under different frequency laser pulses

Reference:

(1) Willems, F et al. Nat. Commun. **2020**, 11 (1), 871.
(2) Huang, B et al. Nature **2017**, 546 (7657), 270-273.
(3) Li, M.; He, J. *J. Phys. Chem. Lett.* **2023**, *14* (50), 11274-11280.