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Coherent Spin-Lattice Dynamics for Ultrafast Magnetic Switching in 2D Magnets

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Two-dimensional magnetic materials provide a promising platform for ultrafast and energy-efficient spin control. In this talk, I will discuss how coherent lattice motion can be used to manipulate magnetic order on femtosecond to picosecond timescales under optical and terahertz excitation. Using first-principles real-time simulations, we reveal the coupled dynamics of spins, electrons, and phonons in nonequilibrium 2D magnets. In monolayer Fe3GeTe2, we identify coherent phonons as a key ingredient for ultrafast demagnetization and demonstrate a phonon-assisted spin-flip process occurring within a few hundred femtoseconds. The magnetic switching is accompanied by transient changes in the electronic topology. Extending these ideas to antiferromagnets, we further show that tailored terahertz pulses can drive switching between distinct antiferromagnetic orders in monolayer MnPSe3 through nonlinear phononic effects.
These results highlight coherent spin–lattice dynamics as a general route toward ultrafast magnetic switching and provide theoretical guidance for future optospintronic devices based on low-dimensional materials.