New Research Bridges the Gap Between Ultrafast Physics and Quantum Magnetism

The exploration of the quantum world presents enduring challenges in our quest to unravel the complexities of intricate phenomena like superconductivity, superfluidity, topological order, and entanglement. These phenomena arise from the interactions among multiple particles in physical systems, commonly known as "many-body" systems.

In the realm of condensed matter physics, quantum magnet materials offer a fascinating avenue for studying complex many-body physics. These materials comprise arrays of interacting quantum spins embedded within crystal solids, manifesting among the most extraordinary and highly entangled quantum effects. Harnessing efficient control over quantum magnetic materials on ultrafast timescales holds strong potential for applications in quantum technology. However, conventional methods based on ultrafast light are impractical for quantum magnets due to the weak interaction with spins and the delicate nature of their quantum phases.

In work led by Dr. Flavio Giorgianni (Nonlinear optics, IAP), which was performed in collaboration with Quantum Criticality and Dynamics group at the Paul Scherrer Institute, researchers have now experimentally demonstrated a new strategy to efficiently drive spin excitations on an ultrafast timescale in a prototypical quantum magnetic material.

The researchers used terahertz light pulses tuned to resonance with vibrations of the atomic lattice – called phonons - achieving a “magnetophononic” excitation of the spin dynamics. When the difference frequency of two phonons matches the spin-mode frequency, it creates a “singlet” excitation in which the fluctuating quantum spins oppose each other, showing no external magnetism and thus remaining hidden from many conventional detection schemes. This method of using phonons as an intermediary introduces a universal mechanism for controlling nonequilibrium quantum magnetic materials on ultrafast timescales, which provides broad potential both for fundamental studies of many-body systems and for applications in areas including optoelectronics, spintronics, and quantum information.