Probing and controlling spin dynamics with ultrashort terahertz pulses

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In magnetic materials, many resonances and relaxation processes coincide with the terahertz (THz) range. Examples are the frequencies of magnons and phonons, and the spin-dependent rates of electron scattering. Consequently, THz electromagnetic radiation is currently undergoing development into a powerful tool for probing and even controlling spin-related phenomena in magnetic solids. Conversely, magnetic phenomena are attracting increasing interest for THz photonic applications.

This tutorial talk is supposed to provide an introduction to THz spectroscopy of magnetic materials. I will start with an excursion to the generation and detection of ultrashort THz electromagnetic pulses (duration <1 ps) by femtosecond lasers. Subsequently, general principles and instructive model cases will be presented of how the THz methodology can be used to gain insights into elementary spin motions on their natural, often ultrafast time scales.

Examples include spin precessions and spin currents in connection with recently discovered spintronic phenomena such as the spin Hall effect and the spin Seebeck effect. Finally, recent works will be discussed to show that strong THz electric and magnetic fields (~MV/cm and ~T) can even be used to gain control over magnetic order.