CAP Sonderseminar

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Ultrafast emergence of ferromagnetism in antiferromagnetic FeRh

The nature of the counter-intuitive heat induced ferromagnetism in FeRh has been a subject of ongoing debates for about 60 years, resembling a dispute about the chicken-or-egg causality dilemma. FeRh is antiferromagnetic at low temperatures and becomes ferromagnetic, when heated above 370 K. These magnetic changes are accompanied by an expansion of the unit cell. It is, however, still unknown whether this a magnetic phase transition that drives the lattice expansion or a structural phase transition that causes the magnetic changes. To resolve this magnetism-or-lattice causality dilemma, we heated FeRh with femtosecond laser pulse and traced structural and magnetic changes by measuring reflectivity and the magneto-optical Kerr effect, respectively. Alternatively, we performed ultrafast magnetometry and traced formation of ferromagnetic domains with the help of double-pulse THz emission spectroscopy. We show that while a femtosecond laser pulse indeed generates ferromagnetic nuclei in FeRh, it takes of about 10 ps before the nuclei acquire a net magnetization. We argue that this latency is intrinsic to the phase transition from collinear antiferromagnetic to ferromagnetic states and must be present even in the case when the sign of the exchange interaction changes instantaneously. Using high magnetic fields up to 25 T, we could accelerate the magnetic phase transition and eventually discovered the fastest possible emergence of ferromagnetism in step with the lattice. As a result, we show that both spins and lattice evolve simultaneously. This finding practically resolves the magnetism-or-lattice causality dilemma.