Diversity of Ultrafast Spin Dynamics Near the Tricritical Point in a Ferrimagnetic Gd/FeCo Multilayer

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Ultrafast magnetism is a rapidly evolving field of physics that explores spin dynamics launched in magnetically ordered materials by ultrashort stimuli lasting only a few picoseconds or less. Among all classes of magnetic materials studied in ultrafast magnetism (ferro-, ferri-, and antiferromagnets), ferrimagnets are most promising for the ultrafast and efficient control of magnetic properties. Ferrimagnets, characterized by antiferromagnetically coupled spins with non-equivalent magnitudes, exhibit a nonzero net magnetization dependent on temperature and can have their magnetic structure tuned by external magnetic fields, resulting in a rich H-T phase diagram. In particular, when reaching a large critical field, the spins undergo a spin-flop transition to a noncollinear spin configuration [1]. Prior studies of ferrimagnetic rare-earth (RE) transition-metal (TM) alloys have revealed a new dimension in ultrafast magnetism related to this noncollinear phase [2]. However, due to relatively strong exchange interaction between the sublattices, the critical field is strong and the studies required exceptionally high magnetic fields up to 30 T, hampering further detailed investigations.

Here, we overcome this obstacle by fabricating a high-quality synthetic ferrimagnet – a Gd/FeCo multilayer [3]. In such a heterostructure, the reduced number of nearest neighbors from different species (RE/TM) compared to the alloy is expected to significantly lower the RE-TM exchange interaction as well as the critical field. We found that subtle changes in temperature and magnetic fields below 1 Tesla result in dramatic changes in the ultrafast response of spins to a femtosecond laser excitation. Six distinct types of spin dynamics (see Figure 1) were identified and explained by considering the spin-flop transition to the noncollinear phase and the concept of a "tricritical point" [4, 5] in the H-T phase diagram [6], where the phase transition changes from being discontinuous to continuous. We highlight exchange-driven reversal as a particularly interesting type of dynamics, providing new insights into the tricritical point. The latter is found to separate two thermodynamically distinct noncollinear phases with the TM magnetization pointing on adjacent sides of the anisotropy plane.

References

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Figures

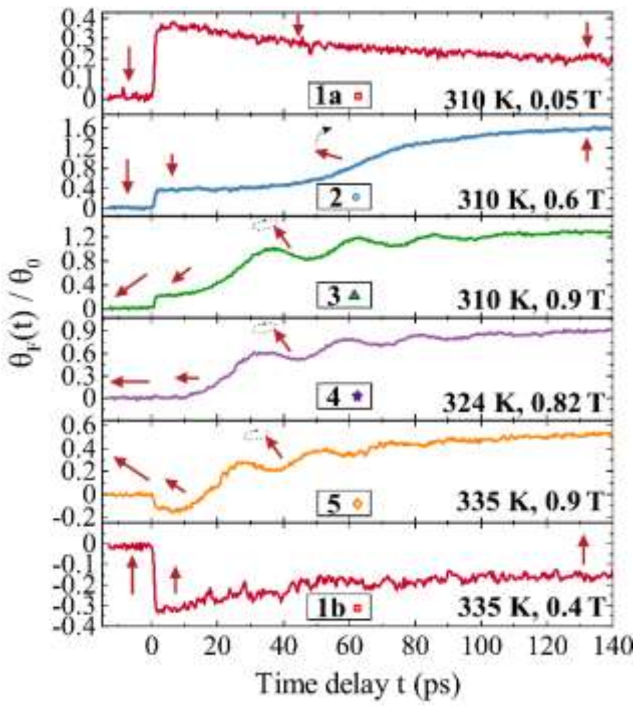

Figure 1. The six distinct types of laser-induced magnetization dynamics in Gd/FeCo measured by the time-resolved magneto-optical Faraday rotation using 100 fs probe pulses at a central wavelength of 800 nm, recorded at different temperatures and external magnetic fields applied along the out-of-plane easy axis of anisotropy. The observed Faraday effect is known to be proportional to the out-of-plane magnetization of the FeCo sublattice. The Faraday effect was normalized such that a full 180-degree reversal of the FeCo magnetization corresponds to a signal value of 2. The arrows provide a pictorial description of the FeCo magnetization based on our interpretation of the data.