Dynamic Pathways in
Multidimensional Landscapes

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Investigating the role of spin-lattice coupling in the ultrafast demagnetization of GdTb alloys

Content :

In ultrafast demagnetization of ferromagnetic metals after femtosecond laser excitation, a central question is how spin angular momentum can be transferred under the optically excited nonequilibrium conditions. One would expect this to happen on the timescale of spin-lattice relaxation, which has however been found to be on the order of 100 ps for Gd [1], much slower than ultrafast demagnetization.

We aim to clarify the role of spin-lattice coupling in femtosecond laser-induced demagnetization by investigating Gd, Tb and their alloys as a model system. By alloying Gd and Tb, the strength of spin-lattice interaction can be tuned from the weak 4f-lattice coupling of pure Gd, which is mediated by the 5d conduction electrons, to the strong direct spin-lattice coupling of pure Tb. Pure Gd and Tb show laser-induced demagnetization in two steps, with the time constant of the second, slower step depending on the strength of coupling of the 4f magnetic moments to the lattice [2].

In time-resolved magneto-optical Kerr effect measurements on GdTb alloys, we see a decrease of the time constant of the second demagnetization step from 33 ps to 9 ps with the Tb content increasing from 0 to 70%, which we assign to the continuous increase of spin-lattice coupling due to the growing Tb fraction. In time- and element-resolved x-ray magnetic circular dichroism measurements at the BESSYII Femtoslicing concomitant dynamics of the Gd and Tb 4f magnetic moments is observed. Compared to pure Gd, the Gd magnetic moments in the alloy experience a coupling to the lattice which is increasing with the Tb content. Consequently, the second step of demagnetization of Gd in the alloy is accelerated compared to the pure material. In contrast, the time constant of the first demagnetization step, which is found to vary between 1.8 ps and 1.2 ps, is not correlated to the amount of Tb in the alloy. These results are in good agreement with our previous conclusion [2] that the faster demagnetization time constant is determined by relaxation of 5d electrons, while the slower timescale is set by the efficiency of spin-lattice coupling and the transfer of the angular momentum change to the lattice.

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[1] A. Vaterlaus et al., PRL 67, 3314 (1991).

[2] M. Wietstruk et al., PRL 106, 127401 (2011).

Primary authors : Dr. ESCHENLOHR, Andrea (Uni Duisburg-Essen)

Co-authors : Dr. SULTAN, Muhammad (Uni Duisburg-Essen) ; Dr. MELNIKOV, Alexey (Fritz-Haber-Institut der MPG) ; Dr. BERGEARD, Nicolas (Uni Duisburg-Essen) ; Mr. WIECZOREK, Jens (Uni Duisburg-Essen) ; Dr. KACHEL, Torsten (Helmholtz Zentrum Berlin) ; Dr. STAMM, Christian (Helmholtz Zentrum Berlin) ; Prof. BOVENSIEPEN, Uwe (Uni Duisburg-Essen)

Presenter : Dr. ESCHENLOHR, Andrea (Uni Duisburg-Essen)

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