First-principles theory for femtomagnetism

G. P. Zhang and Yihua Bai

Department of Physics, Indiana State University
Terre Haute, Indiana 47809, USA

Laser-induced femtosecond magnetism or femtomagnetism opens a new frontier for ultrafast magnetic storage [1,2], but its underlying mechanism remains illusive. We present a joint analytic and first-principles study to establish a paradigm for femtomagnetism. We show if a system has full rotational symmetry, the spin and orbital momenta are coupled, but there is no genuine magnetization change. In solids, this rotational symmetry is lifted by the translational symmetry; consequently, in contrast to popular belief, spin and orbital momenta changes decouple. The first-principles calculation in ferromagnetic nickel demonstrates that both spin and orbital moments drop on a similar time scale, but their net changes differ. The momentum-resolved spin moment change reveals that the femtomagnetism originates from pocket states close to the Fermi level but away from high-symmetry points in the Brillouin zone.

Supported by the U. S. Department of Energy under Contract No. DE-FG02-06ER46304, U. S. Army Research Office under Contract No. W911NF-04-1-0383, a Promising Scholars grant from Indiana State University. This research used resources of the National Energy Research Scientific Computing Center at Lawrence Berkeley National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. *gpzhang@indstate.edu

[1] E. Beaurepaire *et al.*, Phys. Rev. Lett. **76**, 4250 (1996); L. Guidoni *et al.*, **89**, 017401 (2002); J.-Y. Bigot *et al.*, **93**, 077401 (2004); C. Stamm *et al.*, Nature Mat. **6**, 740 (2007).

[2] W. Hübner and G. P. Zhang, Phys. Rev. B **58**, R5920 (1998); G. P. Zhang and W. Hübner, J. Appl. Phys. **85**, 5657 (1999); G. P. Zhang and W. Hübner, Phys. Rev. Lett. **85**, 3025 (2000); G. P. Zhang, Y. Bai, W. Hübner, G. Lefkidis, and T. F. George, J. App. Phys. **103**, 07B113 (2008); G. P. Zhang, W. Hübner, E. Beaurepaire, and J.-Y. Bigot, Topics Appl. Phys. **83**, 245 (2002).