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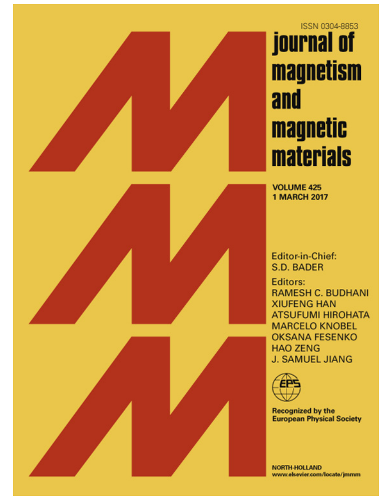

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M. Fähnle

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Comparison of Theories of Fast and Ultrafast Magnetization Dynamics

M. Fähnle[1]

Max Planck Institut for Intelligent Systems, Heisenbergstrasse 3, D-70569 Stuttgart

Abstract

In the present Letter to the Editor the theories of magnetization dynamics for different situations are compared: The fast dynamics close to the adiabatic limit (Gilbert equation), a somewhat faster dynamics (Gilbert equation supplemented by an inertial damping term), and the ultrafast dynamics (combination of Boltzmann's rate equation with Fermi's golden rule).

Key words: Fast magnetization dynamics, Gilbert equation, inertial damping, ultrafast magnetization dynamics, Boltzmann's rate equation, Fermi's golden rule.

In a simple situation where the contribution of magnons to the magnetization is neglected and where a homogeneous system is considered, the total magnetic moment $\mathbf{M}(t)$ of the electronic system is given by

$$\mathbf{M}\left(t\right)=\sum_{i}n_{i}\left(t\right)\mathbf{m}_{i}, \tag{1}$$

where the sum runs over all electronic states i, $n_i\left(t\right)$ is the number of electrons in state i, and $\mathbf{m}_i$ is the magnetic moment of the electron in state i, which is composed of an orbital magnetic moment $\mathbf{m}_{\mathrm{l},i}$ and a spin magnetic moment, $\mathbf{m}_{\mathrm{s},i}$,

$$\mathbf{m}_i=\mathbf{m}_{\mathrm{l},i}+\mathbf{m}_{\mathrm{s},i}. \tag{2}$$

The time-derivative $\frac{d\mathbf{M}}{dt}$ is given by

$$\frac{d\mathbf{M}}{dt}=\sum_{i}\frac{dn_{i}}{dt}\mathbf{m}_{i}. \tag{3}$$

For the fast magnetization dynamics on time scales up to typically ps (e.g., vortex dynamics [1]) Gilbert's equation of motion [2, 3] is used which is an equation close to the adiabatic limit. The damping term in this equation can be derived by making a relaxation-time ansatz for $\frac{dn_i}{dt}$,

Email addresses: faehnle@is.mpg.de (M. Fähnle)

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