Ultrafast Imaging of Electrically-Controlled Laser-Induced Spin Dynamics

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Mechanisms allowing to control of magnetization using electric rather than magnetic fields have long been in a focus of fundamental research in magnetism and considered as an essential step toward the development of future energy-efficient spintronic nanodevices [1,2]. Aiming to increase the operational frequency of the devices, it is natural to focus on electric control of ultrafast magnetization dynamics, in particular.

Here we report on an experimental study of how an applied electric field can control ultrafast laser-induced spin dynamics in the epitaxial film of ferrimagnetic iron garnet known to show strong magneto-electric effects [3]. The studied $(BiLu)_3(FeGa)_5O_{12}$ film was grown on a (110) oriented $Gd_3Ga_5O_{12}$ substrate. Applying a nearly in-plane magnetic field and exciting the sample with a femtosecond laser pulse, we launched spin dynamics, which was monitored with the help of an all-optical pump-probe technique. We found that the excited spin dynamics is strongly affected by an external electric field of 0.5 MV/m (Fig. 1). Surprisingly, the effect of the electric field on the amplitude of the dynamics seems to be as large as in the case of 2D materials, which are known to be strongly susceptible to electric fields [4].

We have shown that the electric field plays the role of the effective external magnetic field due to the linear magnetoelectric effect, and thus gives control over the amplitude and frequency of oscillations. Moreover, the electric field was found to affect the spatial distribution of magnetization dynamics (Fig. 1a, b). In particular, we discovered that without any applied electric field, laser pulse induces a non-homogeneous pattern of spin dynamics in a form of rings. We believe the formation of such rings is a very general phenomenon originating from the interplay of several contributions to magnetic anisotropy. The electric field, being responsible for an additional effective magnetic field, can thus affect this interplay and result in changes of the inhomogeneous pattern.

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References

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Figures

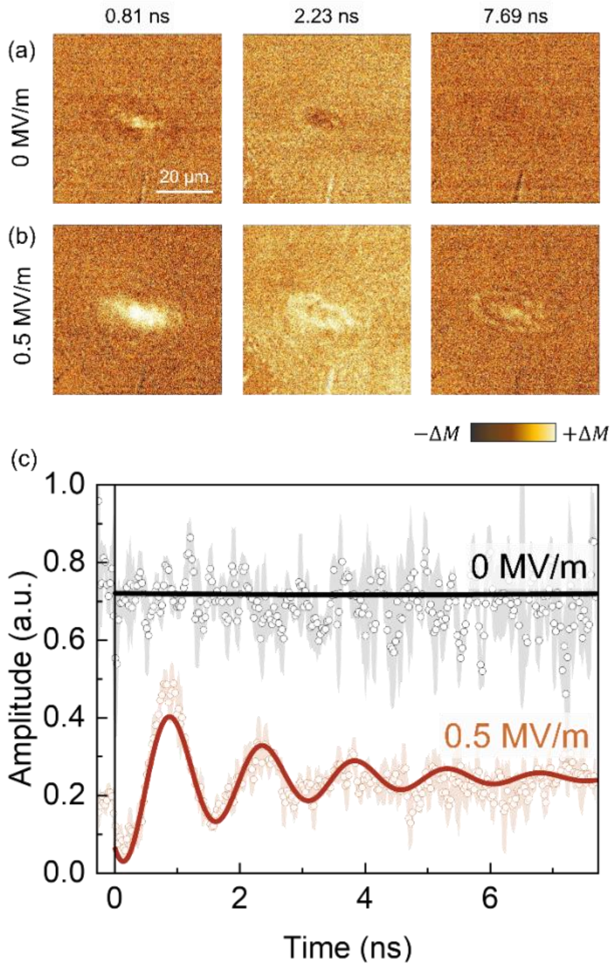

Figure 1. (a, b) Time-resolved magneto-optical images of electric field-controlled laser-induced spin dynamics. The images were captured at different moments of time without (a) and with the applied electric field (b). (c) Magnetization dynamics traces extracted from the time-resolved magneto-optical images without (black curve) and with an applied electric field (orange curve). A magnetic field of Hext = 30 mT was applied in all experiments. The laser fluence was 36 mJ/cm^2.