Time-resolved Spectroscopy of Hetero-Epitaxial BTO-BFO Films and Nanorods

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Introduction

The magnetoelectric (ME) effect in multiferroics creates a coupling between a material's magnetization and electrical polarization. This coupling creates a potential pathway for a host of possible new technologies in which the electrical polarization may be controlled with a magnetic field or, alternatively, the magnetism tuned by an applied electric field either at dc or optical frequencies. These capabilities have been identified as significantly important for applications in magnetic data storage and/or other spintronic devices.

Bismuth ferrite (BFO) is one of few known room-temperature multiferroics[1]. In the bulk phase, BFO exhibits ferroelectricity and G-type antiferromagnetic (AFM) order. The AFM order of BFO is interrupted by a weak ferromagnetic component due to the well-known Dzyaloshinskii-Moriya (DM) interaction. Nonetheless, at least in bulk crystals, a spin cycloid develops that averages the weak ferromagnetic moment to zero. Unfortunately, the static ME coupling in BFO is weaker than in other transition metal compounds where the electrical polarization occurs due to the magnetic order. In BFO, the ferroelectric effect and magnetic order originate from different ions. Furthermore, the spin cycloid prevents any linear ME effect, at least in magnetic fields up to 20 T at which point the spin cycloid is quenched[1-4].

Experimental

Using short-pulse optical excitation, it has been possible to excite coherent magnons whose dynamics can be tracked with a time-delayed near-infrared optical pulse. From these studies one can obtain important interaction energies that characterize various coupled dynamics, for example, the DM interaction energy. Given the important ME enhancement in our films, a similar study in these samples can provide a quantitative analysis of the ME interaction in the BT-BFO films and nano-rods. We began our analysis of BTO-BFO using time-resolved magneto-optical transmission experiments.

Results and Discussion

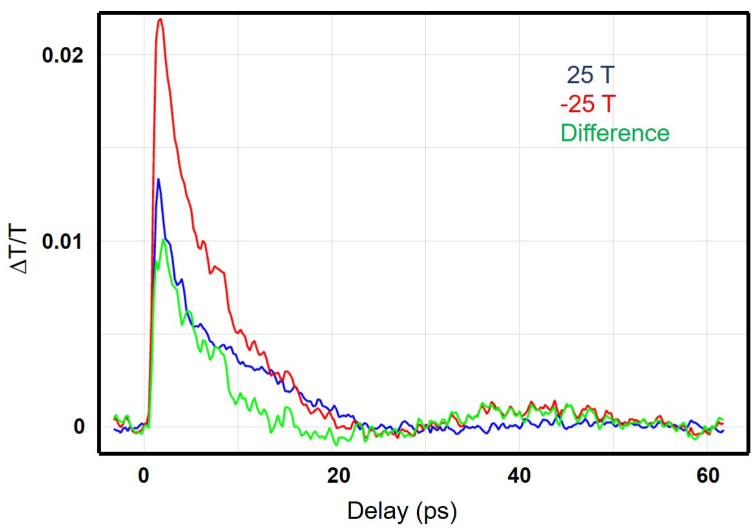

Figure 1 400nm/800nm Pump Probe optical transmission.

In this first magnet time, we used time-resolved optical transmission spectroscopy to observe the field-induced effects on a potential optically-induced magnon in BTO-BFO nanorods. In Fig. 1, we show the magnetic field-induced change in the periodic response of the charge dynamics to an optical excitation at 400 nm. Though the nano-rod shape enhances the effects of the applied optical field, the linear magneto-electric effect is weak as demonstrated by the small difference between the scans taken at +/- 25 T in the Split-Florida Helix. Nonetheless, this is an important first observation that points towards the observed optical phenomenon as a magnon where the periodicity of the signal is likely influenced by an additional precession of the excited moments that changes sign when the magnetic field is reversed. The periodic signal appears to continue after the carrier relaxation has completed at about 20 ps.

Conclusions

The nano-rods enhance the coupling of the optical field to the linear ME effect since films did not repeat the behavior.

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References

[1] Catalan, G., *et al.*, Adv. Mater., **21**, 2463 (2009).
[2] Ederer, C., *et al.*, Phys. Rev. B, **71**, 060401 (2005).
[3] Sosnowska, I., *et al.*, J. Phys. C: Solid State Phys., **15**, 4835 (1982).
[4] Doig, K. I., *et al.*, Phys. Rev. B, **88**, 94425 (2013).