

Ultrafast Optical Manipulation of Magnetization of Ferrimagnet by Femtosecond Pulsed Laser

A. Tsukamoto¹,

¹ College of Science and Technology Nihon University, 7-24-1 Narashino-dai, Funabashi, Chiba, 274-8501 Japan
Email:atsuka@ecs.cst.nihon-u.ac.jp

1. Introduction

For further progress in information processing and recording technology, the fundamental limit of the speed of magnetization reversal or understanding spin dynamics in magnetic materials is an issue of crucial importance. However, virtually nothing is known about the behavior of spins in a magnetic material after being excited on a sub-picosecond timescale. Here we report the summary of recent results of experimental studies of novel spin dynamics in ferrimagnetic GdFeCo-alloy excited by a femtosecond laser pulse. Two kinds of all-optical magnetic switching phenomena were demonstrated in ferrimagnetic GdFeCo alloys in the absence of an external magnetic field [1][2].

2. Experimental Approach and Results

For our experiments we have chosen GdFeCo, an amorphous ferrimagnetic rare-earth transition metal alloy that is widely used in conventional magneto-optical recording and known for its strong magneto-optical effects. Samples were grown by magnetron sputtering in a multilayer structure: glass/AlTi(10 nm)/SiN(5 nm)/GdFeCo(20 nm)/SiN(60 nm). The experiments were performed by placing a sample under a polarizing microscope. To excite the material we used regeneratively amplified pulses from a Ti:sapphire laser at a wavelength of 800 nm, pulse width < 90 fs and a repetition rate of 1 kHz.

The effect of polarized laser pulses on the magnetization is most readily demonstrated by slowly sweeping a laser beam across the surface of the sample. Figure 1 shows how two different sweeps with the laser beam right-handed circularly polarized (σ^+) and left-handed (σ^-) circularly polarized affect the initial domain pattern in different ways. The direction of this switching is determined only by the helicity of the light pulse. In further experiments, it was confirmed that the excitation by a single 40 fs laser pulse is sufficient to reverse the magnetization [1]. The most obvious explanation via the inverse Faraday effect (IFE)[3] could only very qualitatively account for the previously observed features. What is the origin of the helicity dependence in the all-optical switching?

Here we demonstrate experimentally another type of novel deterministic magnetization reversal phenomena in a same ferrimagnet system driven by an ultrafast heating of the medium without the presence of a magnetic field. Figure 2 shows the result of the action of a sequence of laser pulses on the continuous film of $\text{Gd}_{24}\text{Fe}_{64.7}\text{Co}_{9.3}$, initially in a single domain state with magnetization perpendicular to the sample surface. Looking at the Fig. 2,

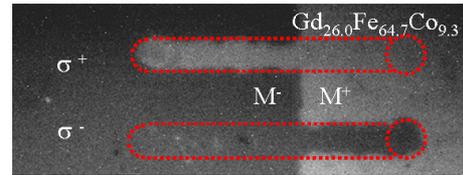


Fig. 1. The magneto-optical image of the magnetic film after exposure by sweeping of 90 fs circularly polarized laser pulses.

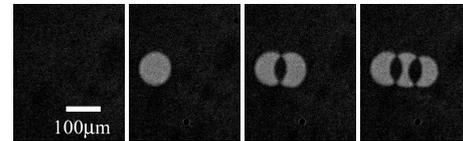


Fig. 2. The magneto-optical image of the magnetic film after excitation of the black region with the first pulse, one can see the formation of a white domain. The second pulse which excites slightly shifted position then reverses the magnetization of the excited area forming a reversed pattern. Every such pulse thereafter triggers this reversal. The above results show that ultrafast heating can act as a sufficient stimulus for magnetization reversal in a ferrimagnet with taking into account the multi-sublattice nature[2].

3. Conclusions

We demonstrated two kinds of all-optical magnetic switching phenomena in ferrimagnetic GdFeCo alloys. Importantly for technological applications, we show that these switching can occur when starting at room temperature.

4. Open Questions

- What is the origin of the helicity dependence in the all-optical switching?
- Is there other material that can show complete switching triggered by pulsed light?

Acknowledgements

The author thank many corroborator on references [1][2] for continuous collaborated research. This work is partially supported by Nihon University Strategic Projects for Academic Research.

References

- [1] C. D. Stanciu, F. Hansteen, A.V. Kimel, A. Kirilyuk, A. Tsukamoto, A. Itoh and Th. Rasing, Physical Review Letters., 99 (2007) 047601.
- [2] T.A. Ostler, J. Barker, R.F.L. Evans, R.W. Chantrell, U. Atxitia, O. Chubykalo-Fesenko, S. El Moussaoui, L. Le Guyader, E. Mengotti, L.J. Heyderman, F. Nolting, A. Tsukamoto, A. Itoh, D. Afanasiev, B.A. Ivanov, A.M.

Kalashnikova, K. Vahaplar, J. Mentink, A. Kirilyuk, Th. Rasing, and A.V. Kimel, *Nature Communications* **3**, (2012) 666.

[3] L. P. Pitaevskii, *Zh. Eksp. Teor. Fiz.* 39 (1960) 1450. [*Sov. Phys. JETP* 12 (1961) 1008]