ABSTRACT

Ultrafast magnetism is an intensively evolving and highly relevant field of physics that focuses on understanding the mechanisms of interaction between ultrashort laser pulses and matter. Ability to manipulate magnetization solely using laser pulses holds tremendous potential for future technologies, facilitating the fastest data recording with minimal heat dissipation. The main objective of this thesis is to understand the coherent dynamics of nonthermal photo-magnetic switching by controlling the magnetic anisotropy in cobalt-doped garnet films across a wide temperature range. These investigations were conducted using a newly designed, prepared, and optimized experimental setup that employs a unique single-shot time-resolved imaging method to capture magneto-optical dynamics during precession and magnetization switching.

Taking full advantage of this experimental setup, a comprehensive examination of various coherent photo-magnetic switching scenarios was performed, considering a single-domain or multi-domain and single bubble-domain switching. A detailed analysis of the switching trajectories between multiple magnetic states revealed non-reciprocity in the dynamics of nonthermal magnetization switching. This non-reciprocity arises from the magnetocrystalline symmetry of garnets and the torque induced by a femtosecond laser pulse with orthogonal linear polarization directions. To explain the multi-state magnetization dynamics, a theoretical model was developed within the framework of the Landau-Lifshitz-Gilbert formalism, incorporating a tensor of photo-magnetic susceptibility.

Furthermore, this thesis reports, for the first time, the nonthermal, toggle-switching of magnetization. This effect is induced solely by the sequence of femtosecond laser pulses without changing their polarization direction. Previously, only a thermal demagnetization-based mechanism for toggle-switching was known to exist, and it was limited to metals. The new 'cold' toggle-switching was observed in garnet films with pure magnetocrystalline cubic symmetry over an exceptionally broad temperature range ± 100°C. The energy of toggle-switching can be adjusted by tuning the intensity of the laser pulse and magnetic anisotropy of garnets. However, the switching time and energy of heat load are found to be competing parameters. We demonstrated that by using a series of identical laser pulses and employing this newly discovered switching mechanism, one can toggle the magnetization of garnets at a frequency reaching 50 GHz. Such a high-frequency, large-amplitude magnetization switching with minimal heat dissipation in garnets, resulting in an increase in temperature of material of only about 0.6 K, opens up new possibilities in the field of topological opto-spintronics and cold ultrafast magnetic recording.