Cherenkov-type terahertz emission spectroscopy of ultrafast optomagnetic effects

M.I. Bakunov, S.D. Gorelov, S.B. Bodrov, E.A. Mashkovich, M.V. Tsarev
University of Nizhny Novgorod
Nizhny Novgorod, Russia
bakunov@rf.unn.ru

R.V. Mikhaylovskiy
Institute for Molecules and Materials
Radboud University Nijmegen
Nijmegen, The Netherlands

Abstract—We put forward measuring Cherenkov-type terahertz emission from a moving pulse of magnetization as a method to explore ultrafast magnetic phenomena triggered in solids by femtosecond laser pulses. By applying the method to terbium-gallium-garnet, we discover the paramagnetic nature of ultrafast inverse Faraday effect in this material with the Verdet constant 3-10 times smaller than its table quasistatic value.

Keywords—terahertz; spectroscopy; femtomagnetism

Ultrafast magnetic phenomena triggered in solids by femtosecond laser pulses have attracted much interest in recent years both from the point of view of the physics of magnetism and due to their potential applications in information storage and processing technologies [1]. The observations of ultrafast demagnetization of ferromagnets and spin reorientation in antiferromagnets were interpreted in terms of laser-induced heating. Non-thermal optomagnetic phenomena, such as laser-triggered spin oscillations in rare-earth orthoferrites, are attributed to the inverse Faraday effect (IFE). This phenomenon, which consists in the generation of magnetization by circularly polarized light, was observed for 30 ns laser pulses about 50 years ago [2]. Nowadays, the mechanism of the effect on the subpicosecond time scale, i.e., ultrafast IFE, is under intense debate.

One of the experimental approaches to study ultrafast optomagnetic phenomena is the terahertz emission spectroscopy, i.e., measuring terahertz emission from optically excited magnetic materials [3]. This technique, however, measures the aftereffects of the optical excitation rather than the transient magnetization produced via IFE during the action of the laser pulse.

For direct probing ultrafast IFE, we propose the concept of Cherenkov-type terahertz emission spectroscopy [4,5]. In this method, the pump laser pulse propagates in a slab of a magnetooptic material, for example, terbium gallium garnet (TGG), and produces magnetization via IFE. The moving magnetization generates Cherenkov cone of terahertz waves in the output Si-prism attached to the slab (Fig. 1). Analysis of the terahertz waveform emitted from the prism provides valuable information about IFE. To align the spectrometer, strong terahertz signal from the lithium niobate (LN) layer is used.

Fig. 1. Experimental setup.

Contrary to some theoretical expectations, the polarity of the observed terahertz radiation from TGG unambiguously demonstrates the paramagnetic, rather than diamagnetic, nature of the ultrafast IFE. From measuring the radiation field, the Verdet constant of TGG in the subpicosecond regime is found to be 3-10 times smaller than its table quasistatic value. This result is in striking contrast with the previous all-optical pump-probe measurements. Thus, the proposed technique can help to elucidate the unclear mechanism of the ultrafast IFE.

REFERENCES