

# Terahertz Magnonics

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# Abstract

The potential of terahertz time domain spectroscopy has until recently been neglected in the field of the ultrafast magnetism. At the same time this technique can serve as a useful complementary tool with respect with conventional methods to investigate ultrafast magnetization dynamics. This thesis aims to implement time domain terahertz spectroscopy to observe high frequency spin waves excited optically in different magnetic systems.

This work covers several distinct phenomena related to the study of spin waves (magnonics) at terahertz frequencies. The generation of transient broadband nonlinear magnetization via inverse Faraday effect in terbium gallium garnet is described in chapter 4. We demonstrate a remarkable discrepancy of at least two orders of magnitude between the strengths of the direct and inverse Faraday effects, thereby challenging the commonly accepted understanding of their relationship. Additionally, a striking nonlocality of the optical response is found.

In chapter 5 the results of THz absorption spectroscopy of the terbium gallium garnet are reported. The garnet exhibits an intricate paramagnetic state with several magnetic sub-lattices at cryogenic temperatures under the application of strong magnetic fields. Some precessional modes of these sub-lattices were measured. The components of the g-tensor of terbium ions were extracted from the data.

In chapter 6 the ultrafast magnetization dynamics of thulium orthoferrite, studied my means of terahertz spectroscopy, is described. It is demonstrated that terahertz response of the orthoferrite provides crucial additional information with respect to the

optical pump-probe signal. A novel exchange driven mechanism of optical manipulation of the magnetic state is demonstrated.

Finally, chapter 7 is a theoretical discussion of so called planar magnonic metamaterials. It is shown that the arrays of ferromagnetic films may exhibit negative refraction index at sub-terahertz frequencies, provided the mechanism of spin wave quantization is introduced.

The thesis ends with a brief conclusions chapter where a short summary of the results is given. Some possible future extensions of the conducted research are drawn as well.

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## Definitions

THz	Terahertz ( $10^{12}$ Hz)
TGG	Terbium gallium garnet ( $\text{Tb}_3\text{Ga}_5\text{O}_{12}$ )
GGG	Gadolinium gallium garnet ( $\text{Gd}_3\text{Ga}_5\text{O}_{12}$ )
YIG	Yttrium iron garnet ( $\text{Y}_3\text{Fe}_5\text{O}_{12}$ )
IFE	Inverse Faraday effect
OKE	Optical Kerr effect
OIAO	Optically induced anisotropic polarization
QFMR	Quasiferromagnetic resonance
QAFMR	Quasiantiferromagnetic resonance
EOS	Electro-optical sampling
MC	Magnonic crystal
ac	“Alternating current”, time-varying
dc	“Direct current”, time-independent