Terahertz spin dynamics

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Understanding how spins move at pico- and femtosecond time scales is the focus of much of contemporary research in magnetism. In this tutorial, I will go through some basic and more advanced concepts in the exciting emerging field of terahertz (THz) magnetism, where electromagnetic radiation in the 0.1-10 THz range, the so-called THz gap, is used to probe or to control spin dynamics at these time scales.

First, I will give an overview of the fundamentals of the interaction between light and matter at THz frequencies [1], with focus on magnetic materials of relevance for modern research. Then, I will continue the presentation concentrating on the interaction of THz radiation with so-called meta-materials [2], which can be used to locally enhance the THz electric or magnetic fields [3].

Finally, I will give an overview of the current research in THz magnetism. As illustrating examples, I will show how low-intensity THz radiation can be used to probe the fundamentals of spin-dependent transport in the linear regime [4], while intense THz fields can be used to drive coherent and incoherent ultrafast spin dynamics in nonlinear regimes [5].

Frequency	0.1 THz	1 THz	10 THz
Wavelength	3 mm	300 μm	30 μm
Energy	0.4 meV	4 meV	40 meV

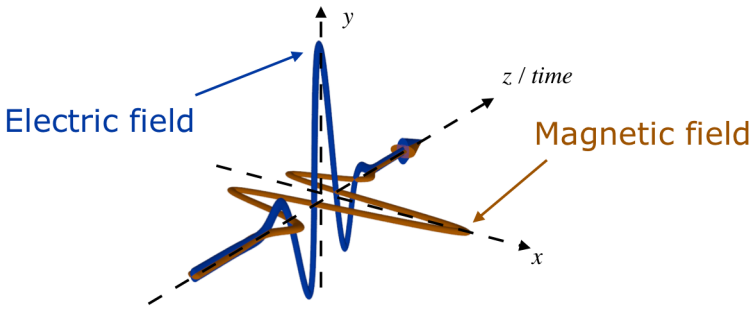

Figure 1. (Top) Frequency/wavelength/energy table for electromagnetic radiation in the so-called “THz gap”. (Bottom) Schematic of a single-cycle THz pulse.

[1] J.D. Jackson, *Classical Electrodynamics*, *3rd edition*, Chapter 8, J. Wiley & Sons, (1999)
[2] Hou-Tong Chen et al., *Terahertz Science and Technology* **1**, 42 (2008)
[3] D. Polley, et al. *under review Journal of Physics: Condensed Matter* (2017), arXiv:1711.01234
[4] Z. Jin et al., *Nature Physics* **11**, 761 (2015)
[5] S. Bonetti et al, *Physical Review Letters* **117**, 087205 (2016)