technische universität
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Spintronic emitters in the terahertz regime

Applied optical spectroscopy

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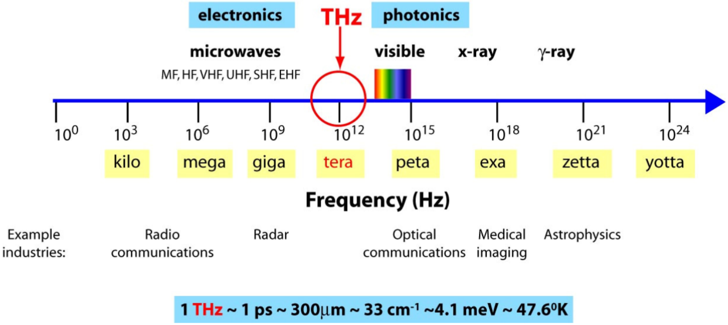
Outline

The Terahertz Gap



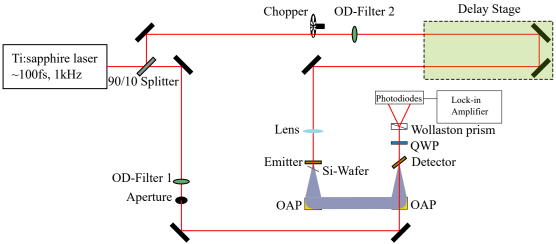
The electromagntic spectrum from G. P. Williams, Rep. Prog. Phys, **69** (2005) .

Terahertz

So why do we need terahertz radiation?

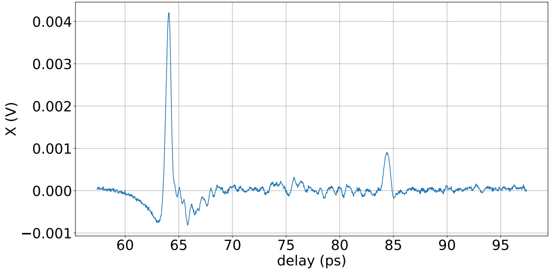
- medicine
- security
- data transmission & saving
- physics

Introduction



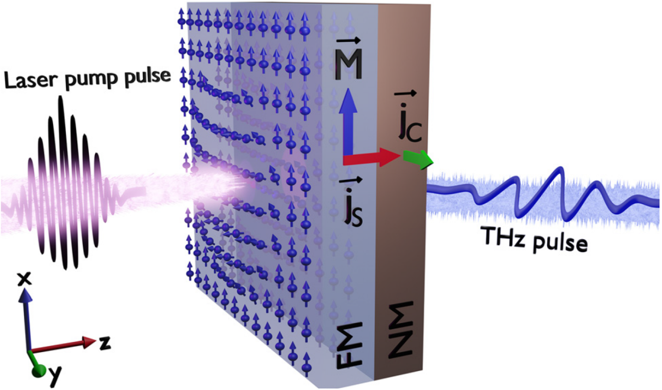
Common emitters:

- Photo conductive antenna
- Non linear crystals



What are Spintronic emitters?

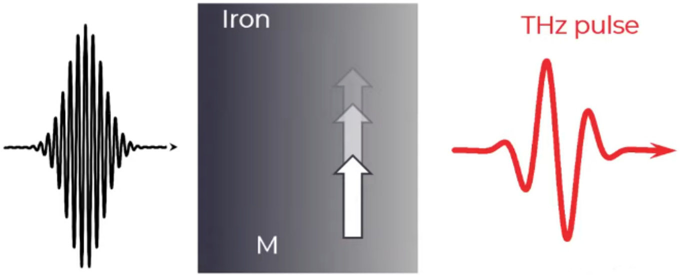
- Ferromagnetic Material (FM)
- Non Magnetic (NM)
- Magnetic field



THz spintronic emitters from E. Th. Papaioannou, Nanophotonics, (2005) .

How does it work?

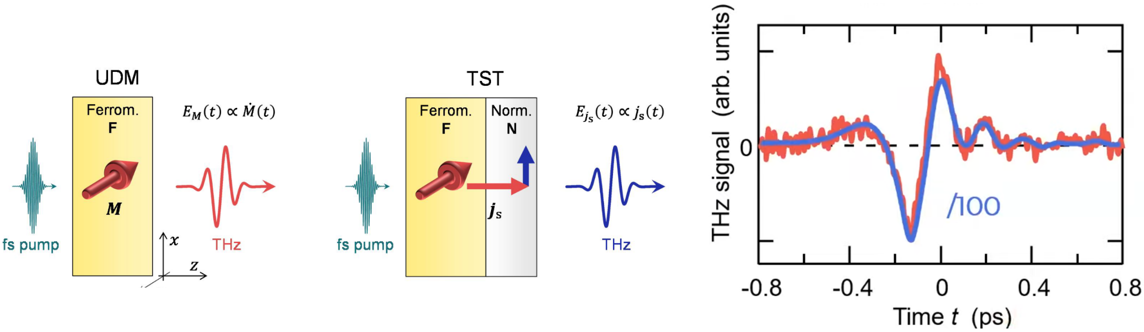
How and why do Spintronic Terahertz Emitters work? from T. S. Seifert, THz group Berlin



$$E_{\mathrm{THz}} \propto \dot{M}(t)$$

Change in magnetization $\rightarrow$ electric field

But we need more fieldstrength

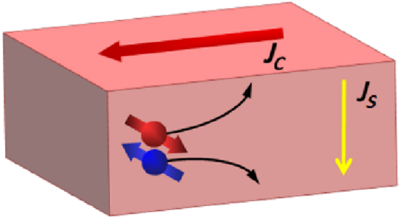


Laser-induced terahertz spin transport in magnetic nanostructures arises from the same force as ultrafast demagnetization from R. Rouzegar, L. Brandt et. al., arXiv.

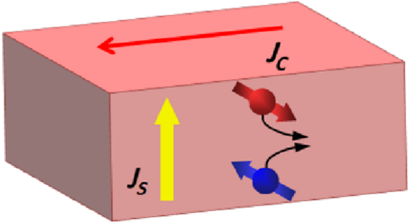
Stronger if we attach **NM**-layer

Where does the current come frome?

Spin Hall effect



Inverse Spin Hall effect



How and why do Spintronic Terahertz Emitters work? from T. S. Seifert, THz group Berlin

Inverse Spin Hall effect generates current

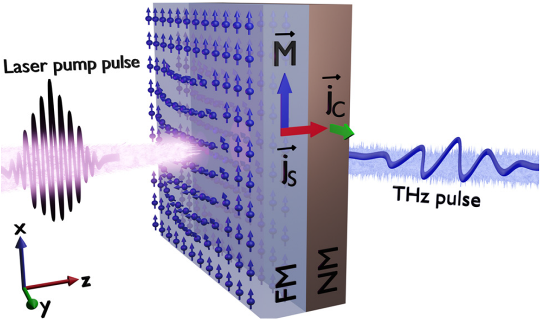
Summary

An overlook:

- FM with magnetization
- spin current j_s through fs-laser pulse
- spin current to charge current

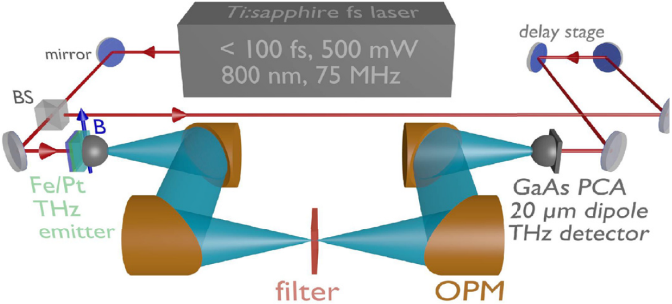
$$j_c = \gamma j_s$$

- charge current generates THz-Field



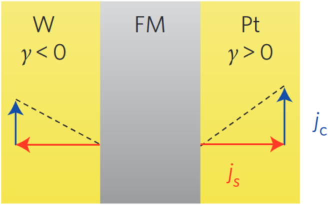
Setup

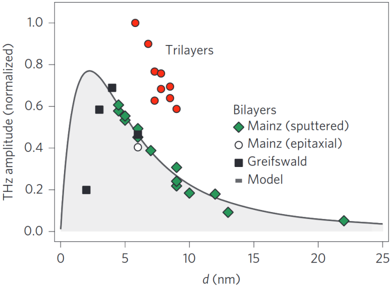
- Just change emitter
- Apply B-Field
- Put *Si*-lens behind crystal



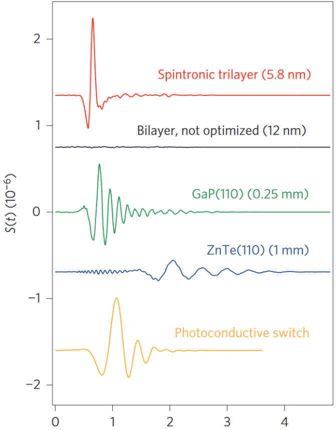
THz spintronic emitters from E. Th. Papaioannou, Nanophotonics, (2005) .

Two Layers are not the end



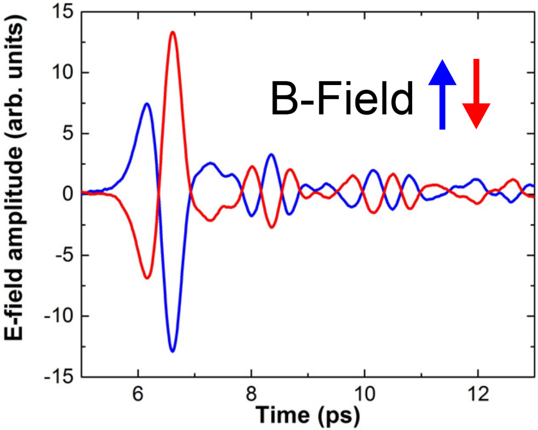


Efficient metallic spintronic emitters of ultrabroadband terahertz radiation from T. Seifert, S. Jaiswal et. al., Nat. Photon, (2016).



Polarization

- Change in B-Field changes THz-Field Polarization
- No filter needed
- Easy change of THz-Field Polarization

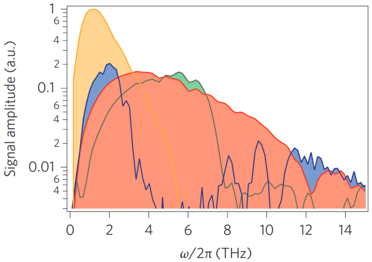


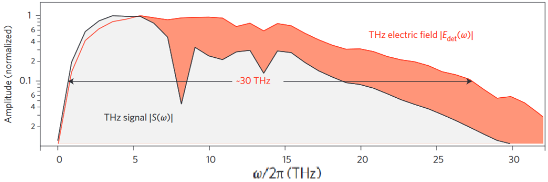
THz spintronic emitters from E. Th. Papaioannou, Nanophotonics, (2005) .

Broadband

Efficient metallic spintronic emitters of ultrabroadband terahertz radiation from T. Seifert, S. Jaiswal et. al., Nat. Photon, (2016).

- Super Broadband Signal
- Achieved with $W/Co40Fe40B20/Pt$ (5.8 nm)





Conclusion

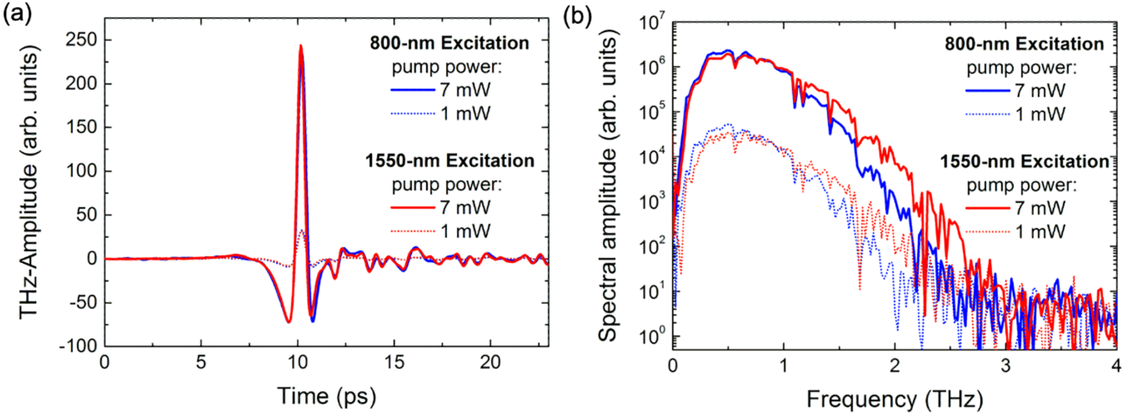
- Easy to setup
- Cheap to produce
- High damage threshold
- Easy change in Polarization
- Very Broadband (no phonon modes)
- No problems with phasematching

	THz emitters commonly used in THz-TDS	Key characteristics desired in a THz emitter			
		Electric field > 100 kV/cm	Bandwidth > 10 THz	Gapless spectral coverage over 0.1 - 10 THz	Photoexcitation with nJ - pulse energies
PCAs	GaAs	✓ R1	✓ R2	✗	✓ R3
	InGaAs	✗	✗	✗	✓ R4
Inorganic Crystals	ZnTe	✗	✓ R5	✗	✓ R6
	GaP	✗	✗	✗	✓ R7
	$LiNbO_3$	✓ R8	✗	✗	✗
Organic Crystals	DAST	✓ R9	✓ R10	✗	✓ R11
	DSTMS	✓ R12	✓ R13	✗	✓ R14
	OH1	✓ R15	✓ R16	✗	✗
	Air plasma	✓ R17	✓ R18	✓ R19	✗
	Spintronic	✓ R20	✓ R21	✓ R22	✓ R23

Spintronic terahertz emitters: Status and prospects from a materials perspective from C. Bull, S. M. Hewett et. al., APL Materials, (2021).

Thank you all for your attention!

Only power matters



[1] Gwyn P Williams. "Filling the THz gap—high power sources and applications." In: Reports on Progress in Physics 69.2 (2005), p. 301.

[2] Y. P. Ashish et al. "Terahertz technology and its applications." In: Drug Invention Today 5.2 (2013), pp. 157–163. ISSN: 0975-7619. DOI: https://doi.org/10.1016/j.dit.2013.03.009.

[3] L. Hai-Bo et al. "Detection and identification of explosive RDX by THz diffuse reflection spectroscopy." In: Opt. Express 14.1 (2006), pp. 415–423. DOI: 10.1364/OPEX.14.000415.

[4] K. Rikkinen et al. "THz radio communication: Link budget analysis toward 6G." In: IEEE Communications Magazine 58.11 (2020), pp. 22–27.

[5] K. Olejník et al. "Terahertz electrical writing speed in an antiferromagnetic memory." In: Science advances 4.3 (2018), eaar3566.

[6] I. Wilke and S. Sengupta. Nonlinear Optical Techniques for Terahertz Pulse Generation and Detection—Optical Rectication and Electrooptic Sampling. CRC press, 2017, pp. 59–90.

[7] Evangelos Th. Papaioannou and René Beigang. In: Nanophotonics 10.4 (2021), pp. 1243–1257. DOI: doi:10.1515/nanoph-2020-0563. URL: https://doi.org/10.1515/nanoph-2020-0563.

[8] R. Rouzegar et al. "Laser-induced terahertz spin transport in magnetic nanostructures arises from the same force as ultrafast demagnetization." In: (2021). DOI: 10.48550/ARXIV.2103.11710. URL: https://arxiv.org/abs/2103.11710.

[9] Tom Seifert et al. “Efficient metallic spintronic emitters of ultrabroadband terahertz radiation.” In: Nature photonics 10.7 (2016), pp. 483–488.