# High-Field Terahertz Pulse Sources and Their Applications

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Femtosecond laser-based THz pulse generation and detection methods make it possible to measure easily the temporal shape of the field of the generated and transmitted or reflected THz pulses, and in this way, performing time-domain-terahertz spectroscopy (TDTS). TDTS measurements use THz pulses with only 10 fJ energy and 100 V/cm field, yet can, for example, simultaneously result in both absorption- and index of refraction spectrum. However, it does not make it possible to follow ultrafast changes.

The invention of tilted-pulse-front velocity-matching first made it possible to generate THz pulses with energy on the µJ and field on the 100 kV/cm level [1,2], suitable for following the ultrafast dynamics of electrons and lattice excitations (applying THz pump-probe and other nonlinear optical techniques) [3], controlling material excitations [4], and material structure [5].

Existing and foreseen THz pulse sources generate pulses with a few mJ energy and tens of MV/cm field strength [6]. Such powerful pulses could boost the energy of THz-driven ultrashort electron bunches from 10 keV to above 1 MeV [7,8].

This talk will comprehensively overview the high-field THz generation methods, explicitly focusing on setups using tilted-pulse-front velocity-matching. It will also overview the already demonstrated and expected applications of THz pulses with high and extremely high field strength.

**References**

[1] J Hebling, G Almási, I Z Kozma and J Kuhl, Opt. Express **10**, 1161 (2002); DOI: 10.1364/OE.10.001161

[2] J Hebling, K L Yeh, M C Hoffmann, B Bartal and K A Nelson, J. Opt. Soc. Am. B **25**, B6 (2008); DOI: 10.1364/JOSAB.25.0000B6

[3] M C Hoffmann, J Hebling, H Y Hwang, K L Yeh and K A Nelson, Phys. Rev. B **79**, 161201 (2009); DOI: 10.1103/PhysRevB.79.161201

[4] P Salén, M Basini, S Bonetti, J Hebling, M Krasilnikov, T Tanaka, G Mourou and T Tajima, Phys. Rep. **836**, 1 (2019); DOI: 10.1016/j.physrep.2019.09.002

[5] X Li, T Qiu, J Zhang, E Baldini, J Lu, A M Rappe and K A Nelson, Science **364**, 1079 (2019); DOI: 10.1126/science.aaw4913

[6] G Tóth, L Kocsis, I Juhász, Á Andrási, P Simon, A Hoffmann, M C Hoffmann, K Varjú, J Hebling and Z Ollmann, Light Sci. Appl. **12**, 256 (2023); DOI: 10.1038/s41377-023-01293-1

[7] J Ying, X He, D Su, *et al.*, Nat. Photonics **18**, 758 (2024); DOI: 10.1038/s41566-024-01441-y

[8] S Turnár, B Sarkadi, S W Jolly, J Hebling and Z Tibai, Appl. Phys. B **130**, 24 (2024); DOI: 10.1007/s00340-023-08157-x