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Terahertz time resolved spectroscopy: The case of the TeraFERMI beamline at FERMI free electron laser

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Terahertz (THz) time-resolved spectroscopy is a powerful tool for investigating light-matter interactions in quantum materials, where the interplay among charge, spin, lattice, and orbital degrees of freedom gives rise to rich and often exotic phenomena. Following an overview of tabletop THz sources and THz time-domain spectroscopy, this work introduces accelerator-based THz beamlines, with particular emphasis on TeraFERMI, the THz beamline at the FERMI free-electron laser in Trieste, Italy. TeraFERMI exploits the properties of the FERMI electron beam to generate short (sub-ps), intense (up to 2.5 mW), and broadband (0.2-5 THz) THz pulses, which are used as pump beam for ultrafast nonlinear spectroscopy experiments [1].

TeraFERMI enables the investigation of nonlinear THz responses in materials through fluence-dependent transmission and reflection measurements, as well as pump-probe experiments in both single-color (THz pump-THz probe) and two-color (THz pump-infrared/visible probe) configurations. In the latter case, the probe is provided by two synchronized laser systems—a C-fiber MENLO laser and a Legend amplifier—covering wavelengths from 350 to 1560 nm. The use of these non-degenerate probes makes it possible to study a variety of effects, including THz-induced time- and spectrally resolved transient reflectivity and absorbance, as well as THz-induced second-harmonic generation (SHG). The beamline is primarily used to investigate quantum materials such as topological insulators, two-dimensional materials, functional oxides, superconductors, multiferroics, heterostructures, and biochemical samples. Representative case studies include nonlinear THz plasmonics in Bi_2Se_3 topological insulator [2], THz saturable absorption in black phosphorus [3], and THz-induced polaronic response in oxygen-deficient TiO_2 [4].

[1] P. Di Pietro et al., *Synchrotron Radiation News* **30**, 4, 36 (2017).

[2] P. Di Pietro et al., *Phys. Rev. Lett.* **124**, 226403 (2020).

[3] N. Adhlakha et al., *Phys. Rev. Applied* **20**, 054039 (2023).

[4] P. Di Pietro et al., *Phys. Rev Research* **7**, 023011 (2025).

Für diese Zeit steht eine Kinderbetreuung nach vorheriger Anmeldung zur Verfügung.

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