

## Nonlinear ultrafast studies at TeraFERMI beamline

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TeraFERMI is a beamline built up in 2015 at the Free Electron Laser (FEL) FERMI at Elettra in Trieste (Italy). FERMI is a seeded FEL that works in a single pass-single bunch mode at 10 or 50 Hz, covering the spectral range from 100 to 4 nm. TeraFERMI is based on a Coherent Transition Radiation source that provides high intense THz electric field in the multi MV/cm range. Such a THz electric field can push nonlinear materials well into their nonlinear regime. The beamline experimental setup fulfils the capability to address nonlinear regime by measuring the fluence-dependent transmission/reflection spectra or the pump-probe response, in both the single-colour (THz pump - THz probe) and the two-colours (THz pump - IR probe) configuration, even in extreme conditions (low temperature). Condensed matter is widely investigated at TeraFERMI: Two-dimensional materials, Dirac materials, semiconductors, oxides and superconductors are only some examples. Bio-chemical samples, like water, can also be studied at the beamline. Here, we will focus mainly on a study carried on a topological insulator, a particular type of Dirac materials. Topological insulators, indeed, show nonlinear THz behaviour similar to the case of graphene, thanks to the linear dispersion of their surface Dirac massless carriers. In particular, we show the nonlinear response of the Dirac plasmon of topological insulator Bi<sub>2</sub>Se<sub>3</sub> thin films.

[1] Di Pietro P. et al., Synchrotron Radiation News, 30 - 4, 36-39 (2017).

[2] Di Pietro P. et al., Nature Nanotech., 8, 556-560 (2013).

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

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