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Attosecond x-ray transient absorption in graphene

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New technologies emerging during the last decade allow for the production of petahertz laser fields, which may be used to drive ultrafast currents in periodic systems. It is then important to design schemes to extract time-resolved information about the electron dynamics in this short time scales.

In attosecond X-ray transient absorption (ATA) spectroscopy, an attosecond probe laser pulse is used to promote electrons from core to valence/conduction bands during the coherent dynamics of the electrons under an IR petahertz laser pulse. Since core bands are almost flat, see Fig. 1a, all the retrievable information can be linked to the band energy dispersion that the electrons feel during their light-induced trajectories. Furthermore, ATA could also contain information of the intraband Berry phase acquired during the electron propagation. We perform the first theoretical exploration of attosecond X-ray transient absorption spectroscopy in graphene by evolving the time-dependent density matrix of the system [1,2]. We show in Fig. 1b the calculated transient absorption when pump and probe pulses maximally overlap, showing important features around the Dirac points and van Hove singularities. The features around the Fermi level reflects the complex carrier dynamics near the Dirac cones. The features around the van Hove singularities, far from the Fermi level, can be explained by the coherent dynamics of the core electrons injected into the conduction by the probe pulse. We have developed a semiclassical theory [2] that allows us to correlate the ATA features around these singularities with the intrinsic properties of the material.

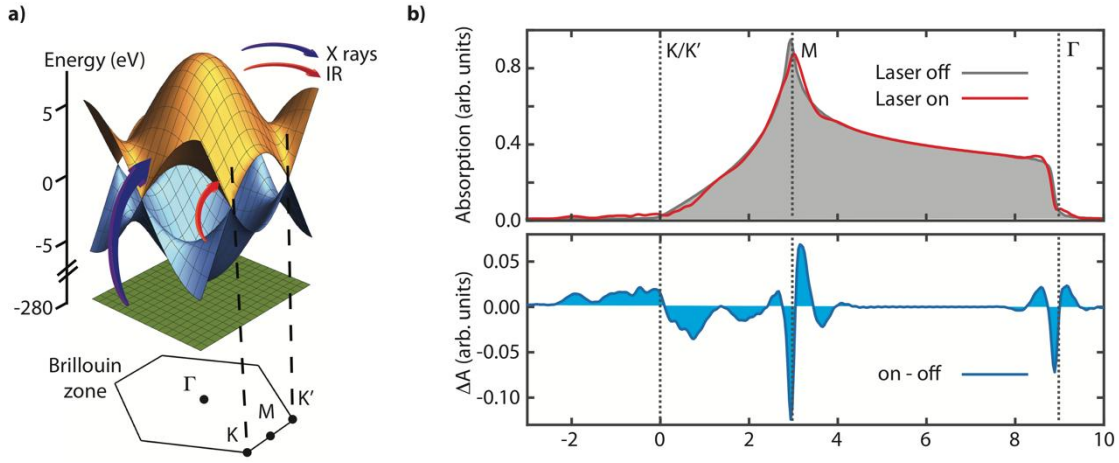

Figure 1: a) Valence, conduction, and core energy bands of graphene. b) Transient absorption when the pump (IR) and probe (X rays) pulses maximally overlap.

[1] A. Picón, L. Plaja, and J. Biegert, New. J. Phys. **21**, 043029 (2019)

[2] G. Cistaro, L. Plaja, F. Martín, and A. Picón, Phys. Rev. Research **3**, 013144 (2021)