The ultrafast dynamics and conductivity of photoexcited graphene

Klaas-Jan Tielrooij
Andrea Tomadin, Sam Hornett, Euan Hendry, Marco Polini, and Frank Koppens

1 ICFO – The Institute of Photonic Sciences, Barcelona Institute of Science and Technology, Castelldefels, Spain
2 Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, Genova, Italy
3 School of Physics, University of Exeter, Stocker Road, Exeter, United Kingdom

Klaas-jan.tielrooij@icfo.eu

Graphene is a particularly promising material for optoelectronic applications, such as photodetection and data communication, owing to its ability to absorb light of any color, and to generate a carrier-heat-induced photoresponse on an ultrafast timescale after absorbing light. In order to realize such applications, it is essential to properly understand carrier heating and the conductivity of photoexcited graphene.

Here, we present a unified and intuitive physical picture of the ultrafast photoinduced dynamics and the conductivity of substrate-supported graphene, which is exclusively based on electronic effects [1]. In particular, we show optical pump–terahertz probe studies, where the terahertz probe is sensitive to graphene’s conductivity directly after photoexcitation, while varying the Fermi energy. We compare the results with numerical calculations using the Boltzmann equation.

Regarding the ultrafast carrier heating dynamics, we identify two regimes:

1) For $E_F < 0.1$ eV, the carrier distribution broadens directly (within tens of femtoseconds) after light absorption, where it involves interband transitions from the valence to the conduction band – interband heating. In this regime, carrier multiplication can occur [2].

2) For $E_F > 0.15$ eV, the carrier distribution also directly broadens, however now this only involves intraband transitions within the conduction band – intraband heating. In this regime hot-carrier multiplication can occur [3, 4].

Interestingly, in both cases carrier heating is efficient, with only a small fraction of the absorbed energy from light going to the phonon system (during the first ~100 femtoseconds), while the largest fraction remains in the electronic system.

Our numerical calculations show that, in regime 1, the ultrafast increase in conductivity comes (partially) from the additional free carriers created by interband heating. In regime 2, the decrease in conductivity comes from the reduced screening of charged impurities, leading to increased momentum scattering.

We thus find that we can explain many experimental results using this simple and intuitive physical picture that is based solely on electronic effects.

References


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