**Substrate-enhanced photocurrent in graphene**

**Romain Parret**, Achim Woessner, Michela Badioli, Klaas-Jan Tielrooij, Sebastien Nanot, Gabriele Navickaite, Tobias Stauber, F. Javier García de Abajo and Frank H. L. Koppens

ICFO-The Institute of Photonic Sciences, Mediterranean Technology Park, Av. Carl Friedrich Gauss, 3, 08860 Castelldefels (Barcelona), Barcelona
frank.koppens@icfo.eu

The mid-infrared frequency range is extremely interesting for both fundamental studies and a variety of applications. It is the fingerprint region of many molecules and the frequency range of choice for thermal imaging for defense or medical purposes. Graphene opens new avenues in the field of infrared photo-detection due to its broadband absorption, tunability of optical properties and its flexibility [1, 2]. Furthermore, it is the energy scale that corresponds to the mid-infrared frequencies gives access to graphene's (tunable) Fermi energy, as well as graphene optical phonons and substrate phonons. This recently led to the observation of several interesting phenomena such as tunable plasmon excitations [3] and plasmon-phonon hybridization [4, 5]. However, the role of substrate phonons on graphene photoresponse is not fully understood.

Here, we measure spatially resolved photoresponse on a very broad spectral range of illumination (1000-1600 $cm^{-1}$). We clearly observe a difference in the amplitude and spatial extent of the signal generated by light on and off resonance with the $SiO_2$ transverse optical (TO) phonon band: on resonance the generated photocurrent is both larger in intensity and broader regarding its spatial extension from the contacts. Furthermore we also observe electrically tunable graphene transmission and photocurrent. By controlling the polarization we can excite the surface optical phonon (SO) of the substrate, associated to a strong concentration of the optical fields, leading to a strong photoresponse.

From these observations we conclude that graphene photocurrent generation in the mid-infrared originates from two processes. The first comes from light absorption in the substrate: substrate phonons absorb light and heat up carriers in the graphene, leading to a temperature gradient over the device that results in a photo-thermoelectric voltage [6]. The other mechanism is due to hot carrier generation via direct absorption in the graphene, and can be strongly enhanced via electric field localization.

Our results open new avenues for using graphene in compact and cheap room-temperature operating mid-infrared sensors.

[1] F. Bonaccorso et al., Nature Photonics 4,611-622 (2010)
[2] T. Low and P. Avouris, ACS Nano 8, 1086-1101 ( 2014)
[3] J. Chen et al. , Nature 487, 77-81 (2012)
[4] V. W. Brar et al., Nano Letters 13, 2541-2547 (2013)
[5] H. Yan et al., Nature Photonics 7, 394-399 (2013)
[6] P. K. Herring et al., Nano Letters 14, 901-907 (2014)