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Hot Carriers and Photoresponse in Graphene

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The photoresponse of materials, which determines the performance of optoelectronic devices, is governed by energy relaxation pathways of photo-excited electron-hole pairs. In graphene, with the electron-lattice coupling strongly quenched by the vanishing electronic density of states, a novel transport regime is reached in which the photo-generated carrier population can remain hot while the lattice stays cool. In this talk, I will first show that light is converted to electrical currents in graphene p-n junctions through the hot-carrier assisted thermoelectric effect [1]. The relaxation processes are subsequently examined by photocurrent measurements at different lattice temperatures, in which we observe a non-monotonic temperature dependence that can be understood as resulting from the competition between two hot electron cooling pathways: momentum-conserving normal collisions that dominate at low temperatures and disorder-assisted supercollisions that dominate at high temperatures [2]. The peak temperature depends on carrier density and disorder concentration, thus allowing for an unprecedented way of controlling graphene's photoresponse. I will also show our observations of giant long-range photocurrent response in high-quality graphene transistor devices, which peaks at the charge neutrality point and exhibits highly ordered anti-symmetric spatial patterns with alternating photocurrent signs as a function of laser position. These patterns are strongly sensitive to device size and quality and occur in the absence of internal electrostatic or material interfaces, which may be related to the symmetry breaking on sample boundaries assisted by long-range hot carrier propagation [3]. **[1]** N. Gabor, J. Song, Q. Ma, N. Nair, T. Taychatanapat, K. Watanabe, T. Taniguchi, L. Levitov and P. Jarillo-Herrero, Hot carrier–assisted intrinsic photoresponse in graphene, Science **334**, 648 (2011). **[2]** Q. Ma, N. Gabor, T. Andersen, N. Nair, K. Watanabe, T. Taniguchi and P. Jarillo-Herrero, Competing channels for hot-electron cooling in graphene, Phys. Rev. Lett. **112**, 247401 (2014). **[3]** Q. Ma, N. Gabor et al., Giant long-range photocurrent patterns near the charge neutrality point in graphene, in preparation.