Microscopic view on the ultrafast carrier dynamics in graphene

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Graphene is a unique structure to study the efficiency of carrier relaxation channels. Its linear and gapless band structure (Fig.1(a)) gives rise to distinct ultrafast phenomena, such as the technologically promising carrier multiplication (CM) and transient optical gain [1-3].

The talk gives a microscopic view on the carrier dynamics in graphene after optical excitation. The applied theoretical approach is based on Bloch equations providing access to time-, momentum-, and angle-resolved carrier-carrier and carrier-phonon relaxation channels [1]. This allows us to track the way of optically excited carriers towards the equilibrium distribution. Combining the theoretically predicted results with high-resolution pump-probe experiments, we obtain a fundamental understanding of the carrier dynamics in graphene.

In this talk, we focus on specific ultrafast phenomena characterizing the dynamics including: (i) main relaxation steps from optical excitation to carrier thermalization and carrier cooling, (ii) the appearance of a highly anisotropic carrier population and the efficiency of relaxation channels along and across the Dirac cone (Fig. 1 (b)-(d)), (iii) crucial role of Auger processes giving rise to a technologically promising multiplication of optically excited carriers, (iv) appearance of a phonon-induced transient population inversion in the strong excitation regime suggesting emission of coherent laser light, and (v) Coulomb- and phonon-induced carrier dynamics in Landau-quantized graphene in the presence of a magnetic field.

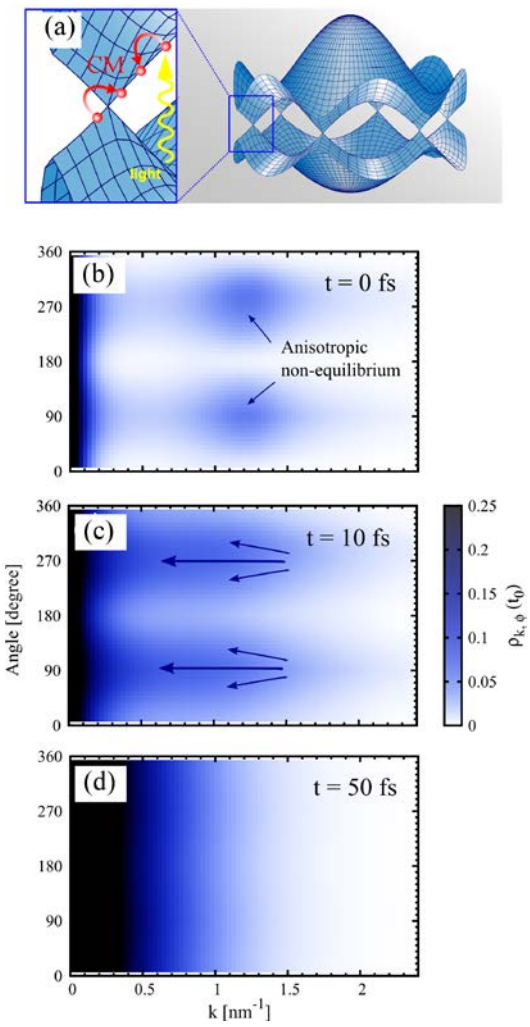

Fig. 1: (a) Electronic band structure of graphene. (b)-(d) Temporal evolution of the carrier occupation as a function of momentum and angle around the Dirac cone. Illustration of the ultrafast Coulomb- and phonon-induced relaxation channels leading to an isotropic equilibrium distribution already after 50 fs [1].

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