Eugene Wigner Colloquium

joint event of GRK 1558 and SFB 910

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"Light-Field-Driven Landau-Zener-Stückelberg Interferometry in Graphene"

When the strength of the electric field of an incident light pulse is comparable to or exceeds that inside of matter/crystals/graphene, the interplay between the interband transition and the intraband motion starts to play a significant role. In particular, for the case of graphene under intense optical fields, electron dynamics around the Dirac point becomes well described by repeated light-field-driven Landau-Zener (LZ) transitions. The resultant transition probability is governed not only by the transition probability of each LZ transition, but also by their timings because the conduction- and valence-band electrons obtain different quantum-mechanical phases between two adjacent LZ events.

We experimentally show that electrons in monolayer graphene undergo this light-field-driven quantum-path interference, also known as Landau-Zener-Stückelberg interference, resulting from the repeated LZ transitions [1]. We observed that the current flowing in graphene after illumination of intense few-cycle laser pulses is sensitive to the carrier-envelope phase (CEP) of the laser pulse. The CEP governs the electric field waveform, and thus the quantum path length in between two-adjacent LZ transition events. The ensuing asymmetric population distribution in the conduction band leads to a residual current after the laser pulse is gone. By going from a linear to a circular polarization state of the driving field, we can steer the electrons such that this sub-cycle quantum-path interference is suppressed. In any situation, the induced currents depend on the carrier-envelope phase that fully determines the two-dimensional electron trajectory in momentum space on sub-femtosecond timescales. These results broaden the scope of light-field control of electrons in solids to an entirely new material class with ramifications for band structure tomography and light-field-driven electronics.

[1] T. Higuchi, C. Heide, K. Ullmann, H. B. Weber, and P. Hommelhoff, *Light-Field-Dirven Currents in Graphene*, Nature **550**, 224 (2017).

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