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Attosecond-fast electron dynamics in graphene

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Abstract:
We will discuss strongly driven electrons inside of the semi-metal graphene. We observe coupled intra-band motion and interband transitions when we focus intense phase-stable two-cycle laser pulses at a graphene stripe. The underlying mechanism is identified as Landau-Zener-Stückelberg interference, leading to a waveform-dependent injection of a net current. Furthermore, we will introduce a new concept to measure attosecond-fast charge transfer times across a graphene-based interface.

Graphene with its Dirac cone dispersion relation represents an ideal two-level system to study intricately coupled intraband motion and interband transitions [1, 2, 3]. In particular, when the influence of the intra-band dynamics to the interband transition cannot be neglected, these combined dynamics turn into a novel non-perturbative light-matter interaction regime. We observe repeated coherent Landau-Zener transitions between valence and conduction band separated by around half an optical period of ~1.3 fs. Because of the extremely fast dynamics, fully coherent Landau-Zener-Stückelberg interferometry manifests itself in an ultrafast current injection.

In the second part of the talk, we discuss the combination of graphene with the wide-bandgap semiconductor silicon carbide (SiC) and show that charge transfer across the graphene-SiC solid-state interface can take place within 300 attoseconds (1as = 10^{-18}s), representing the fastest charge transfer across a solid-state interface. To reveal the attosecond dynamics, we apply femtosecond laser pulses and use saturable absorption in graphene as an intrinsic clock to determine the lifetime of a photoexcited electron prior to charge transfer into SiC or inelastic scattering [4].

[1] T. Higuchi, C. Heide, K. Ullmann, H. B. Weber, P. Hommelhoff, Nature 2017, 550, 224–228.

[2] C. Heide, T. Boolakee, T. Higuchi, H.B. Weber, P. Hommelhoff, NJP 2019, 21 045003.

[3] C. Heide, T. Higuchi, H. B. Weber, P. Hommelhoff, PRL 2018, 121, 207401.

[4] C. Heide, M Hauck, T. Higuchi, J. Ristein, L. Ley, H.B. Weber, P. Hommelhoff, submitted for publication.

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