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EINLADUNG zum IFP-SEMINAR

Emergence in out of equilibrium systems: theoretical treatment of complex out-of-equilibrium dynamics and the ensuing phenomena

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Host: Karsten Held

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Abstract:

Emergence is the phenomenon by which a system with many heterogeneous degrees of freedom develops behaviours that are qualitatively different from its simpler parts. A famous example is life. Describing and predicting emergence requires handling the system in its full complexity: if simplified, or if degrees of freedom are removed, entire behaviours will simply not happen. Femtosecond laser pulse-generated out-of-equilibrium states of materials are a very fertile ground for emergence, as being away from the rather strict requirements of equilibrium or near equilibrium conditions frees up a large number of degrees of freedom. Spectacular examples of emergence in these cases are, among others, the superdiffusive spin transport, [1-4] spintronic THz emitters [4] and the giant spin injection in semiconductors. [5,6]
Such effects are the results of the complex interplay of the far-from-equilibrium state of the system, spin-, band- and momentum-dependent thermalisation, transport of excited quasiparticles and interaction with electromagnetic fields. To address the full complexity of the situation without losing the emergent behaviours, one has to move beyond usual treatments. We have developed the, so far, only available numerical algorithm to solve the full Boltzmann transport and scattering equation for realistic band structures, and, for the first time, no close to equilibrium approximation, as well as several essential computational properties. [7-9]

This allowed us, for instance, unprecedented insights in THz emission of carbon nanotubes, [10] where we have been able to describe the optical production of out-of-equilibrium excitonic population, its thermalisation including exciton dissociation and coupling with phonons, under the effect of a bias. More recently we have shown how disorder in carbon nanotubes can dramatically impact the thermalisation dynamics. [11] Interestingly the same numerical method can be employed to produce spectra and, in connection with time-resolved Boltzmann simulations, time- resolved spectra. [12] The developed approach allows us to tackle the thermalisation dynamics of different types of quasiparticles: we managed to describe and identify the unconventional thermalisation pathways in GeTe driven by spin-selective electron-electron and electron-phonon scatterings. [10]
Finally, more recently, we have been able to address the failure of generating lasing with carbon nanotubes. We showed that reaching the population inversion necessary for lasing to start at the main E11 exciton transition is not achievable. We have however shown that at frequencies corresponding to anti-Stokes phonon-assisted optical generation of excitons, lasing can be triggered way below the population inversion threshold.

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