Ultrafast dynamics of THz excitations: from observation to coherent control

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Low-energy elementary excitations, such as plasmons, phonons, magnons, or excitons, play a pivotal role for the femtosecond dynamics of solids and their surfaces. Phase-locked single-cycle pulses in the terahertz (THz) spectral domain and field-sensitive detectors have been harnessed to trace these excitations on a sub-cycle time scale [1]. In addition, THz fields of more than 10 GV/m have become available [2] to study condensed matter under unprecedented bias conditions and set the quantum state of quasiparticles by coherent control. Examples are:
(i) Resonant THz pulses promote 1s para excitons in the semiconductor Cu_2O into the 2p state, by internal Rabi cycles [3]. The results point out a promising route towards ultracold exciton gases and potential Bose-Einstein condensation.
(ii) Intense THz transients coherently control collective magnon oscillations in antiferromagnetic NiO [4]. Being triggered by Zeeman interaction with the magnetic field of the THz pulse, this approach opens up a novel and most direct gateway to the ultrafast dynamics of electron spins in the electronic ground state.
(iii) Finally, we explore a new limit of non-adiabatic quantum electrodynamics: Intersubband cavity polaritons in a semiconductor quantum well waveguide structure are photogenerated by 12-fs near-infrared pulses. Multi-THz transients trace the abrupt conversion of bare photons into cavity polaritons. Our structure represents the first sub-cycle switching device of ultrastrong light-matter coupling and paves the way towards non-adiabatic quantum optics [5].

[1] see e.g. R. Huber et al., Nature **414**, 286 (2001).

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