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Terahertz spectroscopy of zero- and two-dimensional semiconductor nanostructures with the free-electron laser FELBE

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The free-electron laser facility FELBE in Dresden, a unique source of intense, quasi-cw, nearly transform-limited ps pulses in the mid-infrared and terahertz (THz) regimes, provides unique research opportunities. In high-quality semiconductor quantum wells, we investigate the dynamics of excitons, i.e. two-dimensional, hydrogen-like electron-hole quasi-atoms. Tuning FELBE in resonance with the transition between the excitonic 1s and 2p states (at ca. 2 THz) allows us to study the dynamics of intra-excitonic population transfer. Moreover, strong terahertz pumping results in a characteristic Rabi splitting of the 1s exciton state, which is a manifestation of the intra-excitonic Autler-Townes effect. In semiconductor quantum dots, resonant THz excitation between different sublevels is shown to produce an absorption contrast in aperture-less scattering scanning near-field optical microscopy (s-SNOM). This effect allows us to obtain functional s-SNOM images with deep sub-wavelength resolution, where the contrast originates from far-infrared absorption by single electrons. Quantum dots are also known to have very long electronic relaxation times caused by a reduced phase space for optical phonon scattering. We will report on THz four-wave mixing experiments demonstrating that the associated electronic coherence times approximately equal the population relaxation time at low temperatures. This property makes quantum dots promising for quantum optical applications at THz frequencies.

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