Ultrafast coherent exciton nonlinearities and dynamics in individual quantum dots - phonons, coherent coupling, and cavity quantum electrodynamics

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Excitons are the fundamental optical excitations of semiconductors, determining their optoelectronic properties important for present devices such as light emitting diodes and semiconductor lasers. Furthermore, they are promising for future devices in quantum information processing and communication, based on single-photon nonlinearities and optically addressable qubits. The coherent dynamics of the excitonic excitation is determined by coupling to phonons and photons. The three-dimensional confinement in quantum dots (QDs) creates a finite excitation volume, yielding a discrete excitonic spectrum and phonon-assisted transitions which are enhanced with decreasing volume. The zero-phonon transition dynamics can be dominated by radiative coupling at low temperatures [1], and inserting the QDs into an optical cavity the quantum strong coupling regime of cavity quantum electrodynamics can be reached [2, 3]. Spatially separated excitons can be coupled via an optical cavity [4], or for weakly confined excitons via a two-dimensional continuum [5]. The results were obtained on QD ensembles and individual QDs [6] using nonlinear optical spectroscopy [7], including heterodyne detected photon echo and two-dimensional spectroscopy using heterodyne spectral interferometry [8]. The investigated structures cover both epitaxial and colloidal QDs of different material systems (InAs/GaAs, CdSe/CdSe/ZnS, PbS)

References

[1] W. Langbein et al. Phys. Rev. B 70, 033301 (2004)
[2] J. Kasprzak et al. Nature Materials 9, 304 (2010)
[3] J Kasprzak et al. New J. Phys. 15, 045013 (2013)
[4] F. Albert et al. Nat. Commun. 4, 1747 (2013)
[5] J Kasprzak et al. Nature Photonics 5, 57 (2011)
[6] J Kasprzak et al. New J. Phys. 15, 055006 (2013)
[7] W. Langbein, Rivista del Nuovo Cimento 33, 255 (2010)
[8] W. Langbein et al. Optics Letters 31, 1151 (2006)

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