Carl von Ossietzky
Universität
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Institut für PHYSIK

PHYSICAL COLLOQUIUM

INVITATION

Monday, 15.05.2023, 4.15 p.m., Room No. W02 1-148

speaks

Jacek Kasprzak
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about

"Electronically tunable exciton confinement probed with nonlinear spectroscopy"

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Optical spectra of semiconductors display resonances below the absorption edge, which are attributed to the excitons, i.e. pairs of electrons and holes, correlated by the Coulomb interaction. For decades, epitaxial growth provides modulated nano-structures, where a smaller bandgap material is surrounded by a higher bandgap one. Such growth-designed, static potentials restrict the motion of the charge carriers in one, two or three dimensions in so-called quantum wells, wires and dots, respectively, and their energies consequently become quantized. Engineering the quantum confinement of excitons is a key to control the light-matter interaction dynamics in semiconductors, where the electron-hole overlap integral along with the Fermi golden rule govern the radiative lifetime T1, spanning from 10-13 to 10-6 second. Another relevant optical observable is coherence, describing the phase relation within the exciton polarization, vanishing beyond the dephasing time T2. Recently, electrically controlled quantum confinement of neutral excitons has been achieved in a MoSe2 monolayer [1], by exploiting strong interactions between excitons and free charges, on top of gate defined in- plane electric fields. Using such a device, we here demons trate control of the exciton coherent dynamics and inter-exciton couplings via dynamical tuning of their quantum confinement. To this aim, we perform ultrafast nonlinear spectroscopy, in particular heterodyne-detected four-wave mixing (FWM) microscopy [2]. This approach permits us to focus onto a carrier-depleted region of the gate-induced lateral p-i-n junction with a 300nm resolution and distinguish the response of the 1D and 2D excitons via their drastically distinct radiative decay rates, and thus overcoming the limitations of linear absorption largely dominated by the response of the 2D excitons. With increasing the gate voltage, and thus generating the in-plane potential well, we clearly observe an increase of the exciton T1 (Fig.1 a,b) and T2 (Fig.1 a,b) times, indicating the crossover from the 2D to 1D quantum confinement regime. The subsequent decrease and modulations (not shown) could be due to increased exciton ionization at higher in-plane electric fields. For higher gate voltages, several 1D confined states can be formed. Their coherent coupling is indicated by quantum beats observed in the coherence dynamics (not shown). Our work thus opens the field of exciton coherent control under tunable confinement.

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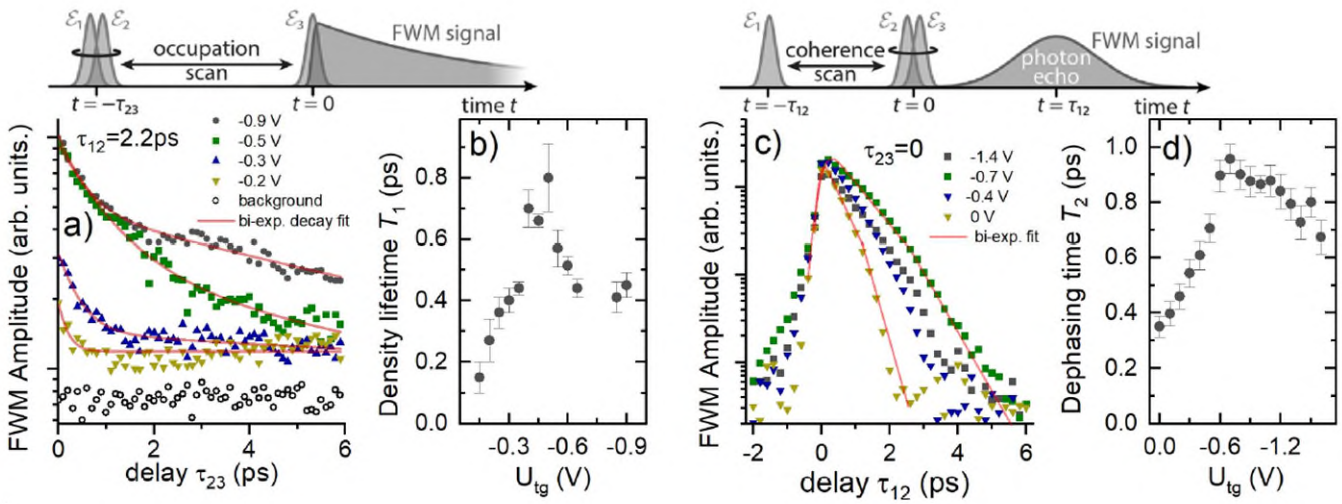

Fig. 1 – Four-wave mixing spectroscopy of a dual gated $MoSe_2$ heterostructure. Top: pulse sequences employed to probe the excitons' density and coherence dynamics. Abottom gate voltage, supplying 2Delectron gas was fixed to +1V, whereas the top-gate voltage U_{tg}, supplying 2D holes was varied, as indicated. (a,c) FWM versus delays, probing exciton density and coherence, respectively, measured for different top-gate bias. (b, d) Extracted exciton's T_1 and T_2 for varying top-gate bias.

[1] D. Thureja et al., Nature 606, 298 (2022), [2] W. Langbein and B. Patton, Phys. Rev. Lett. 95, 017403 (2005)

All interested persons are cordially invited.

Prof. Dr. Christian Schneider