Investigating exciton dephasing in strained GaAs films via four-wave mixing

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Excitons in GaAs films hold promising potential for quantum information applications. Mantaining their coherence is crucial for preserving quantum information over time. Therefore, studying exciton dephasing is essential because it provides valuable insights into the interaction between excitons and their environment, which is vital for the development of new composite GaAs based quantum materials.

We investigated the exciton dephasing in a 470-nm thick GaAs film on sapphire substrate using 3-beam spectrally resolved four-wave mixing (SFWM) in a lifetime configuration and heterodyne four-wave mixing (HFWM) in a photon echo configuration at a temperature of 14 K. The GaAs film reveals different biaxial tensile strain levels at different film locations. This property enabled us to study the impact of differing strain on the dephasing time of strain-split heavy- (hh) and light-hole (lh) excitons. At low strain level the SFWM spectra exhibit an additional signal which has a longer lifetime than the adjacent strain-split lh exciton. We assign this signal to an acceptor bound exciton A^0X transition.

The HFWM measurements provide evidence that exciton polarization is homogeneously broadened in the high strain region near the center of the GaAs film, while a small degree of inhomogeneous broadening is present in low strain regions at the edge of the film. The strain in the film also causes a splitting and shift in the energy levels of acceptor-bound excitons. Interestingly, we observe a prolonged exciton dephasing time for the lh exciton when its energy and that of the A^0X transition coincide, suggesting a coherent coupling between the two transitions. The HFWM experiments further show different hh-lh exciton quantum beat patterns for co- and cross-linear and -circular polarized excitations. Figure 1 shows a 2D contour plot of the HFWM amplitude as a function of the delay τ_{3ref} between pulse $\mathbf{k}_3$ and reference pulse $\mathbf{k}_{ref}$ versus the delay τ_{12} between pulses $\mathbf{k}_1$ and $\mathbf{k}_2$ for collinear polarized electric fields. To interpret the experimental studies numerical calculations based on the optical Bloch equation were performed. The calculations reveal that excitation induced dephasing plays an important role in the FWM process, indicating strong interaction between coherent excitons.

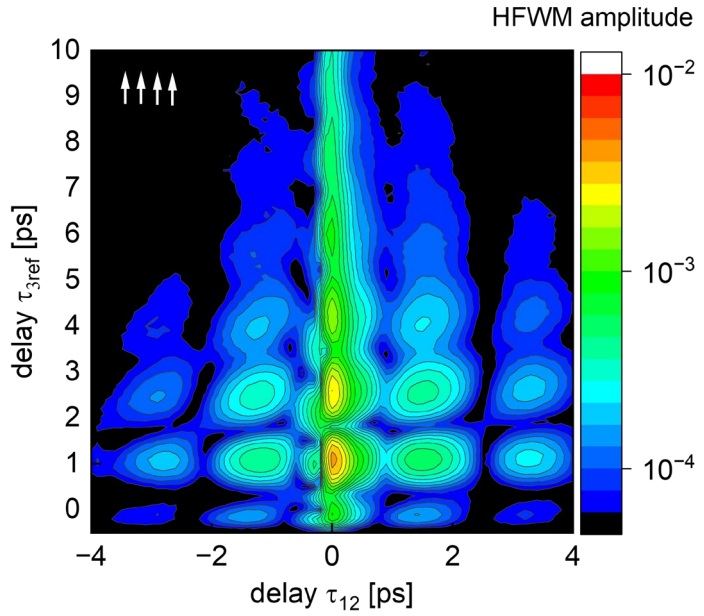

Figure 1: 2D Contour plot of the HFWM amplitude on a logarithmic scale at a fixed delay τ_{13} = 13 ps while varying τ_{12} and τ_{3ref}. The measurements were performed in co-linear configuration.

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