Optical coherent control in semiconductors

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We study the influence of inhomogeneous broadening in semiconductors on CC results. Photoluminescence (PL) and the coherent emission in four-wave mixing (FWM) are recorded after resonant excitation with phase-locked laser pulses with wave vector $k$. For the FWM, a second beam with wave vector $k'$ is incident on the sample resulting in the coherent scattering of the emission in the direction $2k - k'$, see Fig. 1a. The sample is a narrow 28 Å GaAs single quantum well (SQW), surrounded by 250 Å $\text{Al}_x\text{Ga}_{1-x}$As barriers, grown by molecular-beam epitaxy with growth-interruptions on the barrier-well interfaces. This leads to formation of weak fringes, corresponding to the optical phase difference of two regions with thickness of 11 and 10 monolayers (ML) thickness; see sample characterization in Fig. 1c. Our main experimental results are shown in Fig. 1c and Fig. 1d with the spectrally resolved FWM. In the direction of observation for the FWM signal, we simultaneously record PL from the sample on the low-energy side. The strong fringes, corresponding to the optical period, of these optical signals are caused by the interference between the two polarizations excited by the phase-locked CC laser pulses. The striking difference in the time-delay dependence is evident from Fig. 1c at zero delay with no spectral variation of the PL and FWM signals, whereas for longer phase delay in Fig. 1d, the fringes in the FWM acquire a phase, dependent on the detected photon energy. For the latter, the PL signal appears to be proportional to the spectrally integrated FWM signal i.e. without any spectral variation.

Calculations of the FWM signal in the two-level approximation using CC pulses give an explanation of the spectral behavior of CC experiments in inhomogeneously broadened semiconductors. For large inhomogeneous broadening ($T \gg \tau_{\text{cc}}$), we show in Fig. 2(a) that the different spectral components have different phase within the chosen spectral window. In the other limit ($T \sim \tau_{\text{cc}}$), the FWM CC fringes have no spectral variation as shown in Fig. 2(f). However, in-between these two limits we find that the spectral wings of the FWM spectra have the same phase whereas an increasing part of the center acquires the phase change. This occurs as a result of the mixing of the Lorentzian part due to the homogeneous broadening, with constant phase $\omega_0\tau_{\text{cc}}$ and the Gaussian part with phase $\omega_\text{gauss}(\omega)$ due to the inhomogeneous broadening. This explains how inhomogeneous broadening influences CC experiments and in particular how the fringe contrast decay change with inhomogeneous broadening.

References