Excitonic signatures in photoluminescence and terahertz absorption

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Abstract: By measuring THz absorption and time-resolved photoluminescence on the same GaAs quantum well sample we confirm the recent prediction of Kira that PL at the exciton frequency does not require a population of bound excitons.

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Recently, the intuitive notion that a peak in the PL spectrum at the exciton frequency indicates a population of excitons has been called into question. Kira et al [1] studied a microscopic model of a plasma of *unbound* electron-hole pairs, which included Coulomb correlations but not the possibility of formation of incoherent excitons. They found that within this model a sharp photoluminescence(PL) peak at the exciton frequency developed as the carriers relaxed to the bottom of their respective bands.

Here we present results from two direct experiments to resolve this issue and find that indeed excitonic PL spectra *can*, as predicted by Kira[1], be produced without the presence of excitons. First we detect the presence of excitonic bound states by measuring the THz absorption of photo-excited excitons using a far infra-red free electron laser tuned to the 1s-2p transition energy (150 μm, 8.3 meV, or 2.0 THz). Second, we perform time resolved photoluminescence under essentially the same excitation conditions to measure the onset of PL at the exciton energy. The sample is a GaAs/AlGaAs multiple quantum well with 120 wells of 6.5 nm width with clear heavy and light hole exciton absorption peaks at 1.594 eV and 1.615 eV respectively (Fig. 1). All experiments were performed in a continuous flow liquid helium cryostat.

We measure the transmission of the $\sim$15 ps FIR pulse as a function of the pump-probe delay. When pumping with a 100fs pulse at 1.56 eV, well below the interband exciton peak, no change in transmission is seen (Fig. 2, curve (a)) confirming that coherent interactions produce no measurable signal. Pumping resonantly into the exciton, curve (b), a strong induced absorption is seen immediately after the pump pulse. This reflects the creation of geminate excitons and their subsequent excitation by the FIR pulse from the 1s to the 2p state. This induced absorption is shows no decay over the 500 ps window afforded by the FEL setup. Pumping well above the gap at 1.658 eV, curve (c), the absorption change becomes substantially less but there is no delay in the onset of absorption. That there is no increase in 1s-2p absorption during the 500 ps time window implies that the exciton formation time must be longer than 2 ns.

Time resolved photoluminescence measurements at the exciton frequency were also performed (Fig 3). The above band-gap excitation at 1.66 eV closely matches the pump-probe excitation of Fig. 2, curve (c) both in wavelength and in photoexcited carrier density. A biexponetial fit gives times of 570 ps (rise) and 1640 ps (decay). As this rise time is well below the lower limit of exciton formation time as deduced from our transmission measurements, the observed PL cannot be due to the formation of a population of incoherent excitons.

Thus we have experimentally verified the remarkable prediction of Kira et al that PL at the exciton energy may be observed *without* the existence of a excitonic plasma.

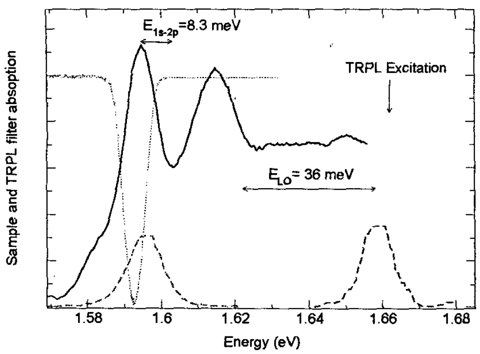

Fig. 1 Linear absorption spectrum of the sample (solid curve). Also shown (dashed) are the spectra of the interband pump pulses centered at 1.596 eV and 1.658 eV. The dotted line depicts the spectrum of the bandpass filter used in the TRPL.

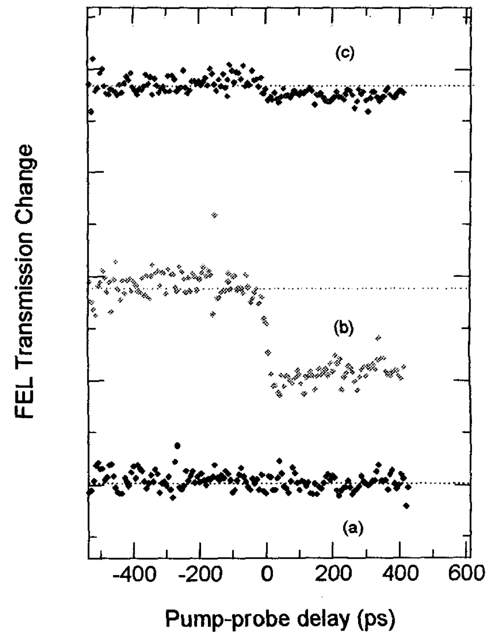

Fig. 2 Transmission change of the FIR probe pulse as a function of pump-probe delay. The pump is tuned at (a) 1.560 eV (below resonance), (b) 1.596 eV (on resonance) (c) 1.658 eV (above resonance). The traces have been offset vertically for clarity.

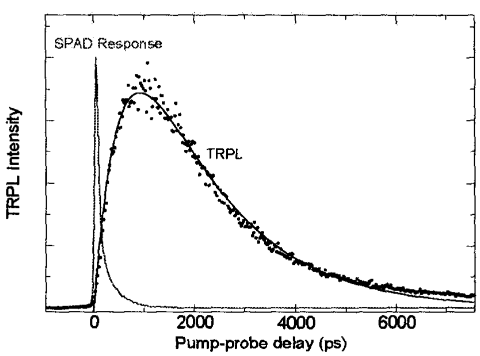

Fig. 3 TRPL intensity at the exciton frequency as a function of time and SPAD response profile. The solid line is a biexponential least squared fit as described in the text.

References

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