Oscillator strength for neutral, charged and scattered excitons in CdTe quantum wells containing a 2-D electron gas

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At the previous workshop of this series (St Petersburg), we tried to interpret magneto-optics of modulation doped quantum wells in a "strong magnetic field" description. Excitonic and exchange effects were considered only as perturbations on free carrier transitions between valence band and conduction band Landau levels $n = 0, 1, 2, \ldots$. But the difficulties encountered and recent developments suggest that this description may be quite wrong for CdTe QWs with n_e varying up to at least $4 \times 10^{11}\text{cm}^{-2}$ (which is still only $0.2/a_B^2$), and perhaps by extension for GaAs wells at 4 times lower n_e. At the Warsaw workshop we will attempt to explain absorption spectra, in both zero field and under magnetic field B, by taking the contrary approach of a "strong exciton, low n_e, low B" model. This is a few-body description where screening and phase-space filling are very weak or negligible. The absorption transitions then correspond to creation of essentially unperturbed trions and excitons combined with scattering of one or two background electrons.

As is well known, in the absorption spectrum for low n_e, the exciton resonance peak (X) broadens asymmetrically to higher energy and loses intensity, and a trion resonance peak (T) appears at lower energy. We find that the total absorption intensity integrated over the trion and exciton bands decreases by only ≈5% up to $n_e = 1 \times 10^{11}\text{cm}^{-2}$. This fits with new, three body theories of the optical processes where X either scatters or binds one background electron, simultaneous with the exciton creation event. Indeed, Esser et al [Phys. Stat. Sol. (b) 227, 317 (2001)] have predicted that the oscillator strength is redistributed between processes X, X^- and e-X scattering as n_e increases, provided $n_e << 1/a_B^2$. In second order of $n_e a_B^2$, four body (h+3e) or "quatron" processes (Esser et al. ICPS Edinburgh 2002) broaden the zero-field trion resonance. This implies that we should relabel asymmetrically broadened trion peaks, seen from $n_e \approx 1 \times 10^{11}\text{cm}^{-2}$ for CdTe QWs, as a quatron band, not a many-body "Fermi Edge Singularity".

Under magnetic field, the electron gas is quantized and the 3- and 4-body scattering wings resolve into distinct peaks : the Combined Exciton and Cyclotron (X&CR) process [Yakovlev et al, Phys. Rev. Lett. 79, 3974 (1997)] and the Combined Trion and Cyclotron (T&CR) process [Kochereshko et al, Phys. Stat. Sol. (c) 0, 1463 (2003)], respectively. Sharp T and X resonance peaks are also resolved. The 4 peaks T&CR, T, X&CR, X appear successively at or near integer filling factor values ν, taking intensity from each other as B increases. At fixed $B = 8$ T, we see attenuation of X and increase of T and X&CR as we increase n_e . Peak X transfers intensity mainly to T in σ^+ and mainly to X&CR in σ^-. The total absorption intensity decreases by <10% to $n_e = 1 \times 10^{11}\text{cm}^{-2}$, in agreement with the zero field result. We think now that the fan-pattern of multiple absorption peaks seen for our samples with n_e up to $4 \times 10^{11}\text{cm}^{-2}$ corresponds to quatron processes T&CR$_1$, T&CR$_2$, T&CR$_3$, etc. In this view, scattering processes contain the initial excitonic intensity of the empty QW; the scattering is so efficient that the T and X resonances themselves are invisible for all $\nu > 2$ at n_e of a few 10^{11}cm^{-2}.