Quasiexcitons in photoluminescence of incompressible quantum liquids

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Photoluminescence (PL) spectra of a quasi two-dimensional electron gas (2DEG) in high magnetic fields B have been difficult to understand. At low concentrations (filling factors $\nu \ll 1$), they are determined by recombination of several competing states of an isolated trion ($X^- = 2e + h$). At higher ν, trions are subject to an electric field produced by a doping layer, and they interact with electrons. In realistic systems, the "hidden symmetry" is broken and PL combines information about the trion spectrum (so far only calculated in symmetric quantum wells[1]) and the correlations in a 2DEG. Discontinuities were observed[2] in the PL spectrum at $\nu = \frac{1}{3}$ and other quantum Hall fractions, but they have not been even qualitatively understood.

We report on realistic calculations for quantum wells of different widths, $w = 10$, 20, and 40 nm, doped on one side, with typical electron concentration $n = 2 \cdot 10^{11}$ cm^{-2} corresponding to a Laughlin filling $\nu = \frac{1}{3}$ at $B = 25$ T. In the energy spectra of up to 10 electrons and one hole, we identify a new fractionally charged "quasiexciton" (QX) state called $\mathcal{X}^{-1/3}$, formed from a trion X^- immersed in a 2DEG by Laughlin correlation with the surrounding electrons. The $\mathcal{X}^{-1/3}$ can capture one or two Laughlin quasiholes to become either a neutral $\mathcal{X}$ or a positively charged $\mathcal{X}^{+1/3}$. The binding and recombination of the three QX states depend on electron spin of the involved trion. As a result, we expect qualitative dependence of the PL spectrum at $\nu \approx \frac{1}{3}$ on the well width, in agreement with a recent experiment.[3] In particular, we predict no anomaly for $w = 10$ nm, a small (0.25–0.5 meV) splitting for $w = 20$ nm, and a different, larger one for $w \geq 40$ nm. The result for the medium well fits the (previously unexplained) splitting observed in Ref. 2.

[1] E.g., A. Wójs, J. J. Quinn, P. Hawrylak, Phys. Rev. B **62**, 4630 (2000).
[2] B. B. Goldberg et al., Phys. Rev. Lett. **65**, 641 (1990).
[3] M. Byszewski et al., Nature Physics (in press).