Evolution of 2DEG-free Hole to Exciton Photoluminescence in modulation-doped GaAs/AlGaAs quantum wells

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Appearance of high-energy photoluminescence (PL) bands at filling factors $\nu < 1$ [1, 2] is one of the most remarkable features of the low-temperature PL spectrum of a two dimensional electron gas (2DEG) under magnetic field. Previously, these PL bands were assigned to a radiative recombination of the photogenerated hole with fractionally charged 2DEG quisiparticles [2-4]. Recently, similar PL lines were attributed to neutral and negatively charged (spin-singlet, bright and dark spin-triplet) excitons, X^0, Xs^-, Xt^- respectively [5, 6]. However, the origin of the PL bands at $\nu < 1$ has not been fully established yet [5-7]. Therefore, a comprehensive understanding of the PL evolution from the 2DEG-free hole to X^0, Xs^-, Xt^- PL with varying magnetic field, B, and 2DEG density, n_{2D}, is required.

We study the spectral evolution of the PL in a high quality, single-sided modulation doped, 25 nm wide GaAs quantum well (MDQW) at 1.8 and 0.3K. A magnetic field (up to 12T) was applied perpendicularly to the 2DEG layer, and n_{2D} was varied by optical depletion in the range of n_{2D}^0 = (2-20) x10^{10} cm^{-2}. We observed the appearance of a wide PL H-band (linewidth of 0.5meV) at ν =1 and an emerging of two additional narrow PL lines (Xt^- and X^0) from this H-PL band with increasing B or decreasing n_{2D} (see Figs. 1. 2b). The H-PL intensity increases at T=0.3K in contrast to that of Xt^- and X^0 (Fig.2a). The integrated intensity, the degree of circular polarization and the PL peak energy dependensies on B and n_{2D} were studied, and this allows us to attribute the broad H-PL band to free hole - 2D electron recombination assisted by a spin-wave excitation [8]. As ν decreases below 0.5, the Xt^- and X^0 intensities start to increase while the H-band intensity decreases (Fig. 2b). We associate such an evolution of the 2DEG-free hole into Xs^-, Xt^- and X^0 PL with an appearance of areas containing localized electrons, localized neutral and charged excitons.

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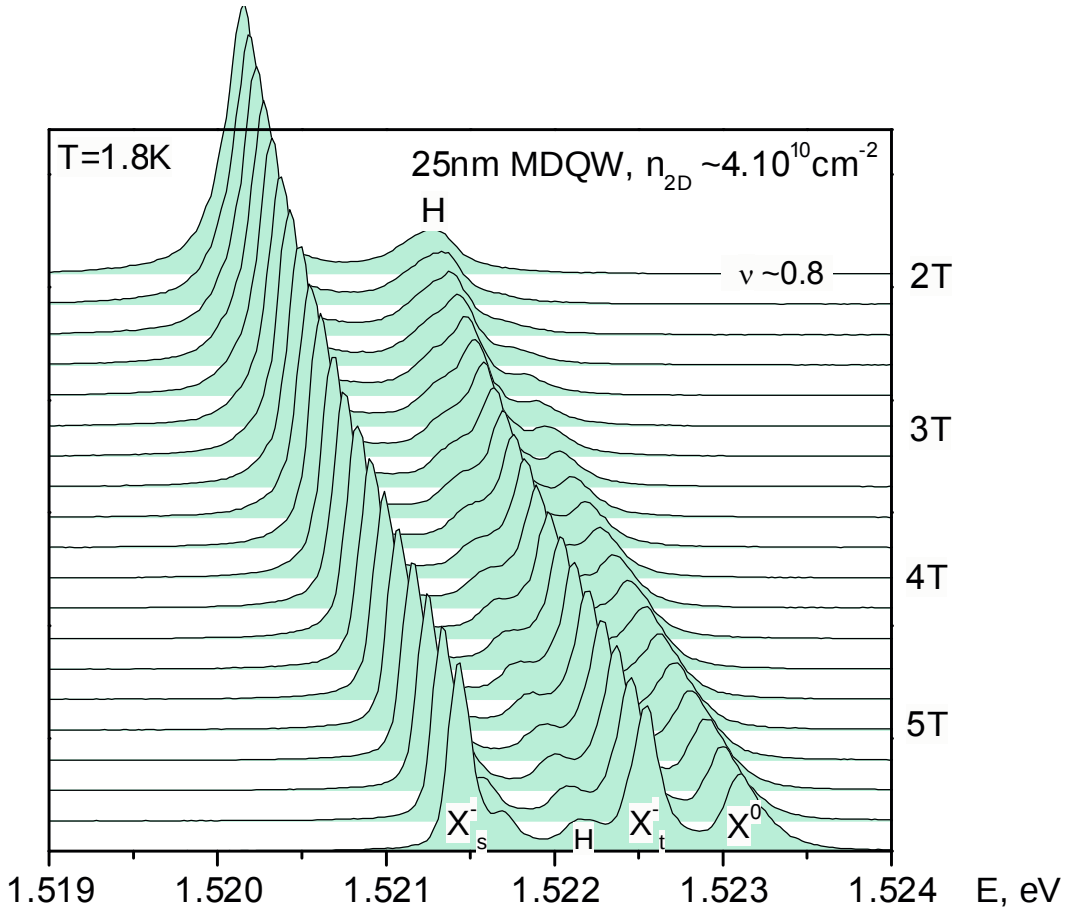

Fig.1. PL evolution with increasing magnetic field from 2 to 6T.

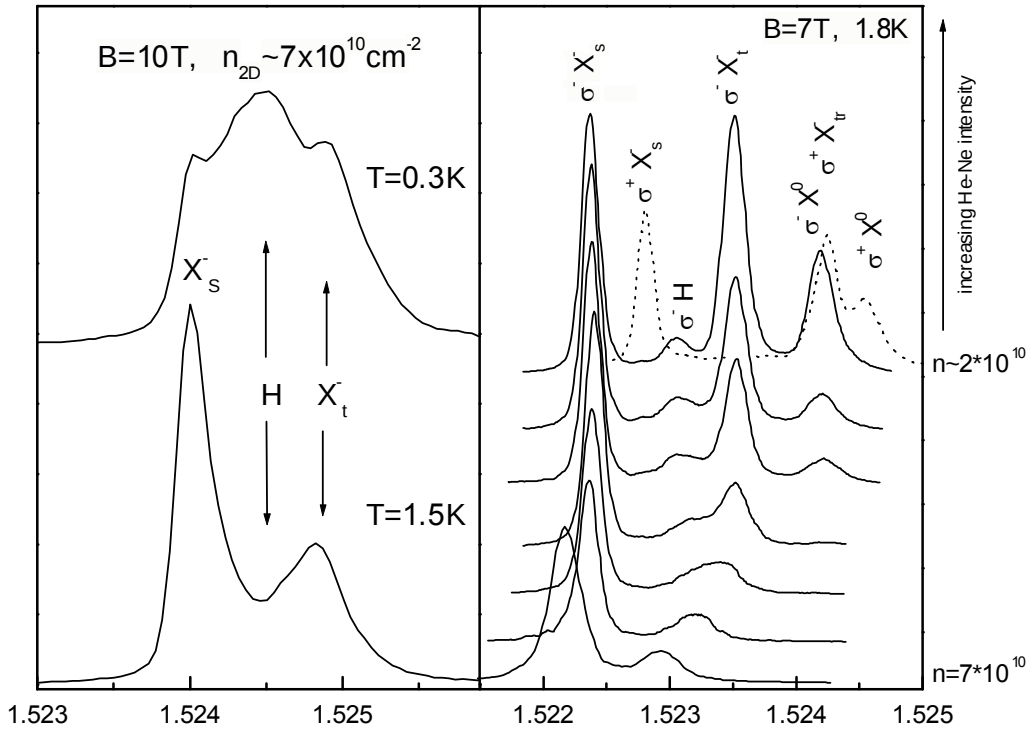

Fig. 2. a). PL spectra at B=10T: T_L=0.3 and 1.5K. b) PL evolution with decreasing n_{2D} at B=7T