Magnetic Field Effects on the Exchange Instability of the 2D Electron Gas

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We have shown recently that a high-mobility two-dimensional electron gas (2DEG) formed in a modulation-doped GaAs/AlGaAs single quantum well structure undergoes a first-order phase transition, when the first excited subband becomes populated with electrons by raising the Fermi level with a gate voltage. The evidence is found in the abrupt renormalization of the energy of the excited subband and its sudden occupation, as determined from photoluminescence (PL) measurements [1]. Self-consistent density-functional calculations with *exact* exchange potential for a 2D electron system reveal that this transition is driven by intersubband exchange interactions and predict the spontaneous breakdown of the spin symmetry without magnetic field, which leads to the formation of spin-polarized domains [2]. PL spectra measured at 2 K and with very low laser powers exhibit a *new* peak (denoted as FP hereafter) below the energy E_1 of the optical transition from the first excited subband, which is associated with the ferromagnetic phase.

In this work we have studied the effect of a magnetic field applied in-plane as well as perpendicular to the 2DEG on the PL emission in the spectral region of the E_1 transition for the narrow stability range of the spin-polarized phase. For a perpendicular field $B_\perp$ the intensity of the FP peak decreases linearly with $B_\perp$ and quenches at about 1 T, thus indicating an in-plane spontaneous magnetization. In the case of a parallel field configuration ($B_\parallel$), the FP peak remains unaltered in intensity but an additional peak labelled P^* becomes apparent in PL spectra at the midgap energy between the E_1 and FP emission lines (see Fig. 1). We attribute this feature to radiative recombination processes from the lowest excited state of the spin-polarized domains, which might correspond to a sort of skyrmionlike excitation of the electron spins. From measurements of the degree of linear polarization of the FP peak in Voigt geometry as a function of $B_\parallel$ we are able to estimate the domain size to be roughly 150 nm.

[1] A.R. Goñi, U. Haboeck, C. Thomsen, K. Eberl, F.A. Reboredo, C.R. Proetto, and F. Guinea, Phys. Rev. B **65**, 121313R (2002).

[2] A.R. Goñi, P. Giudici, C. Thomsen, K. Eberl, F.A. Reboredo, and C.R. Proetto, submitted to Nature, (2003).

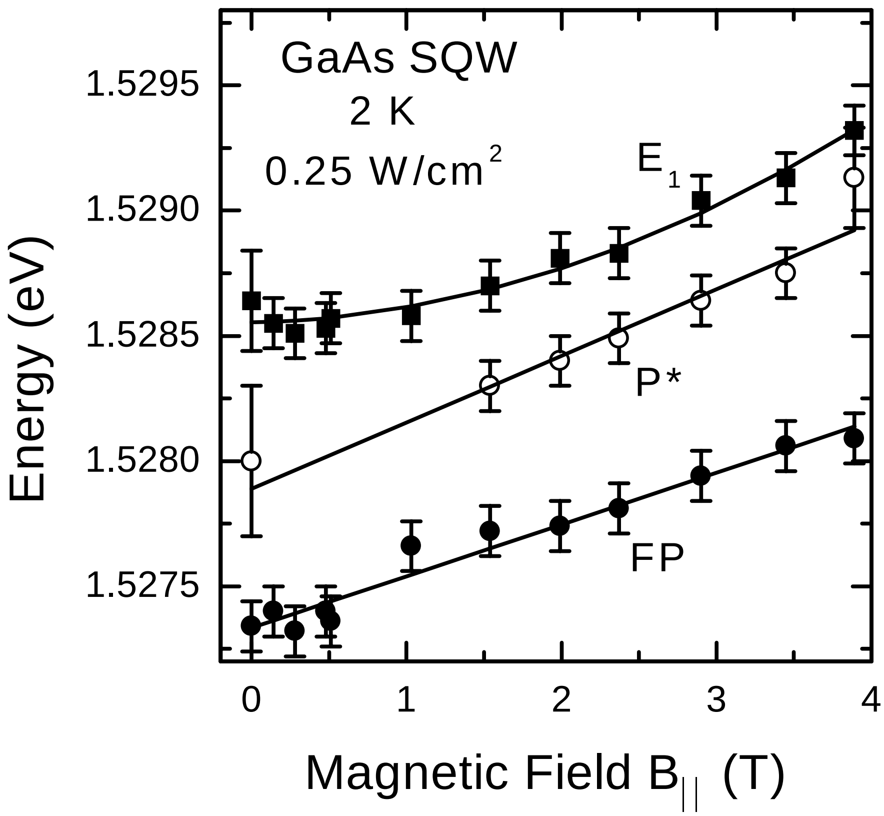

Figure 1: Energies of the peaks observed in PL spectra in the region of optical transitions from the first excited subband E_1. FP and P^* stand for the peak associated with the spin-polarized phase and its lowest excited state, respectively. The energy difference between P^* and FP is given by: $\Delta = \Delta_{x0} + s \cdot g \cdot \mu_B \cdot B_{\|}$, where Δ_{x0} is the exchange contribution, g is the g-factor, μ_B is the Bohr magneton and s is the effective number of spin flips involved in the excitation.