Evolution of the Fermi energy of a two-dimensional electron gas in strong in-plane magnetic fields

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We report results of our experimental and theoretical studies of interband optical absorption in a 2-D electron gas placed in an in-plane magnetic field up to 50 T. Our magneto-absorption experiments, performed on *n*-type modulation-doped $In_{0.2}Ga_{0.8}As/Al_{0.41}Ga_{0.59}As$ quantum wells in the Voigt geometry, show an initial red shift of the Fermi energy with increasing magnetic field, followed by a blue shift. This striking red-shit – blue-shift crossover occurs around 40 T. On the other hand, an undoped sample, with the same structure, showed only a blue shift of a clearly resolved excitonic transition over the entire field range. Both the red and blue shifts show quadratic dependences on the magnetic field strength.

Our theoretical explanation is based on the interplay between the increasing density of states with field (which causes a red shift) and the additional quantum confinement due to the field (which causes a blue shift). We observe, within this theoretical model, that significant effective mass anisotropy in the quantum well plane is induced by the strong in-plane magnetic field, making the system dimensionality more towards 1-D. The model predicts that the crossover may or may not occur, depending on a material parameter, i.e., the ratio of the zero-field Fermi energy to the energy separation between the first and second quantized levels in the conduction band of the QW, $E_F(0)/E_{12}$. The same parameter determines also the critical magnetic field, corresponding to the switch from the red to blue shift dependence of the Fermi energy. Specifically, if this parameter is larger (smaller) than 1/2, the crossover can (cannot) occur. Theoretical calculations are compared with the experimental results.

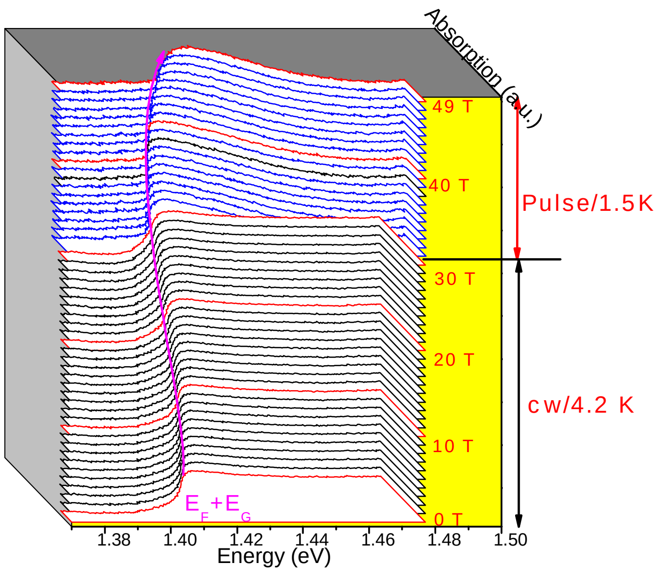

Fig. 1 Absorption spectra with increasing magnetic field up to 30 T (50 T) measured with a continuous resistive magnet (pulse magnet). A vertical solid line in the figure is a guide to eye on Fermi-edge.