Fractional Quantum Hall Effect in a Diluted Magnetic Semiconductor

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Since the discovery of the fractional Quantum Hall effect (FQHE) nearly 30 years ago experimental research was concentrated on investigating fractional states in nonmagnetic materials. Typically GaAs-based systems have been studied where the small Zeeman energy E_Z causes several fractional Quantum Hall (FQH) ground states to be spin unpolarized. More recently, the FQHE was reported in a CdTe quantum well (QW) [1] - a systems exhibiting spin-polarized fractional ground states due to their much larger g-factors compared to GaAs.

Magnetic manganese ions can easily be incorporated into CdTe based quantum structures, hence making this material system ideally suited for the search of fractional states in a Diluted Magnetic Semiconductor (DMS). $Cd_{1-x}Mn_xTe$ is one of the most thoroughly investigated members of the class with all its spin dependent properties being strongly enhanced due to spin exchange interaction between mobile carriers and localized magnetic moments (s-d exchange). Therefore, the Zeeman splitting of electronic states can not only be gigantic but may also be engineered both in magnitude, sign and field dependence.

Here we report on the observation of FQH states in the lowest Landau level (LL) of a 2DEG formed in two high quality 30 nm wide $Cd_{1-x}Mn_xTe$ quantum wells with 0.24% and 0.30% of Mn concentration and densities of $n_s = 3.9510^{11}/\mathrm{cm}^2$ and $2.7710^{11}/\mathrm{cm}^2$, respectively. Standard magnetotransport experiments were performed up to 34 T in a tilted magnetic field and at temperatures between 15 mK and 1 K. Due to the presence of Mn impurities the Zeeman energy is extremely high at low magnetic fields and is *reduced* when increasing the external field. We have designed our sample by adjusting the Mn concentration such that the Zeeman splitting vanishes at about 13.5 T. This gave us the unique opportunity to investigate spin effects in QH states emerging at these fields. By measuring activation energies at tilted magnetic fields we obtained the dependence on Zeeman energy of the excitation gaps at filling factors $\nu = 4/3$, 5/3, 7/5 and 8/5. By analyzing the excitation gap as a function of an in-plane magnetic field we demonstrate that exchange interaction between the Mn spins and the electrons crucially affects the properties, e.g., the spin polarization, of FQH ground states. This provides a recipe to tune the spin-splitting and hence the spin-polarization in a wide range, thus offering a novel means to manipulate fractional states. Using a simple model within the framework of Composite Fermions (CFs) [2] we extracted CF masses m_{CF} and g-factors in the vicinity of $\nu = 3/2$. A quantitative comparison between model and experiment considering deviations coming from disorder effects or LL broadening will be discussed[3].

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