

Signatures of Landau level crossings in a Two-Dimensional Electron Gas

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A two-dimensional electron gas (2DEG) under a magnetic field $\vec{B} = B \cos(\theta)\hat{x} + B \sin(\theta)\hat{z}$ is studied. Here θ denotes the angle that \vec{B} makes with the 2DEG plane. In addition to the Zeeman energy, the system is assumed to be under an asymmetric potential which is described by the Rashba term. The eigenvalues are solved analytically assuming that crossing Landau levels (LL) share equal probabilities [1]. In order to predict the behavior of thermodynamic quantities, the density of states (DOS) is simulated which take the form of a series of Gaussian.

The ratio of the DOS over its zero-tilt value DOS_0 is shown in Figure 1. We focus on the large tilt angles ($\theta > 80^\circ$) where novel phenomena are observed.

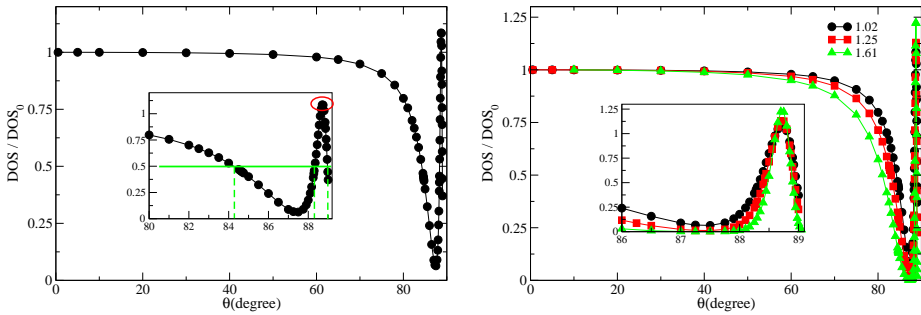


Figure 1: Left: The evolution of the peak height at $B_z \simeq 1.02$ T with increasing tilt angle. As indicated by the ordinate label, what is plotted here is the ratio of $\text{DOS}(\theta)$ over $\text{DOS}(0^\circ)$. The trend shows an increasing depth (or spin splitting) until it reaches a maximum around 87.5° . This is the angle where simultaneous LL crossings occur [3] and this phenomenon was observed experimentally [2]. Aside from the usual beating patterns, here we discover another way of detecting LL crossing imprint. The green solid line marks $\text{DOS}/\text{DOS}_0 = 0.5$ with three corresponding angles $\theta_{ps} \approx 84.2^\circ, 88.3^\circ, 88.9^\circ$. At around these same angles do we observe the DOS phase reversal accompanying a minimized DOS amplitude [3]. One remarkable feature of this plot is the maximum peak surpassing DOS_0 around 88.7° as indicated by the red circle. This is contrary to expectations if one considers solely the prefactor of the DOS being proportional to B_z . In the perspective of LL crossing, however, this θ coincides to another crossing point (verified in the simulations although no longer shown here). Right: Qualitatively the same trend is followed by other Landau level peaks (found at other values of B_z) where the extrema are located at exactly the same values of θ .

[1] R. Gammag, C. Villagonzalo, Solid State Commun. **152**, 757 (2012).

[2] A.T. Hatke, M.A. Zudov, L.N. Pfeiffer, K.W. West, Phys. Rev. B **85**, 241305(R) (2012).

[3] R. Gammag, C. Villagonzalo, Solid State Commun. **156**, 16 (2013).