LANDAU LEVEL SPECTROSCOPY OF BAND-ENGINEERED INAS/GASB QUANTUM WELLS

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Recently, a new type of quantum spin Hall insulator has been realized in inverted InAs/GaSb quantum wells [1], following the initial theoretical prediction of Ref. [2]. This quantum well system exhibits a unique band alignment: the bottom of the conduction band in InAs lies below the top of the valence band in GaSb. Consequently, a hybridization gap forms in the inverted region, leading to a topologically protected quantum spin Hall phase when the Fermi level lies inside the gap. Band structure engineering of this material is crucial for its future development.

Here we present a combined experimental and theoretical study of the low-energy electronic band structure of InAs/GaSb quantum wells. The band structure engineering is achieved via varying the relative width of the InAs quantum well [Fig. 1(a)], given that the well width of GaSb is fixed. Figure 1(b) illustrates the evolution of the electronic bands from the normal to the inverted region (quantum spin Hall region) through a phase transition at critical width (critical region). Experimentally, the critical width was determined using Landau level spectroscopy in high magnetic fields up to 17 T. In the normal and critical regions, only a single cyclotron resonance (CR) is observed [Fig. 1(c)], while multiple CRs as well as anti-crossing behavior are present in the inverted region [Fig. 1(d)]. Theoretical analysis of the Landau levels dispersion using Pidgeon-Brown method based on an eight-band k.p model unravels that our observations can be attributed to the mixing of the electron and hole Landau levels, which is greatly enhanced in the inverted region. Finally, we show that the low-energy electronic band structure of InAs/GaSb quantum wells can be quantitatively described by the eight-band k.p model, making it a valuable tool for future band engineering of similar materials.

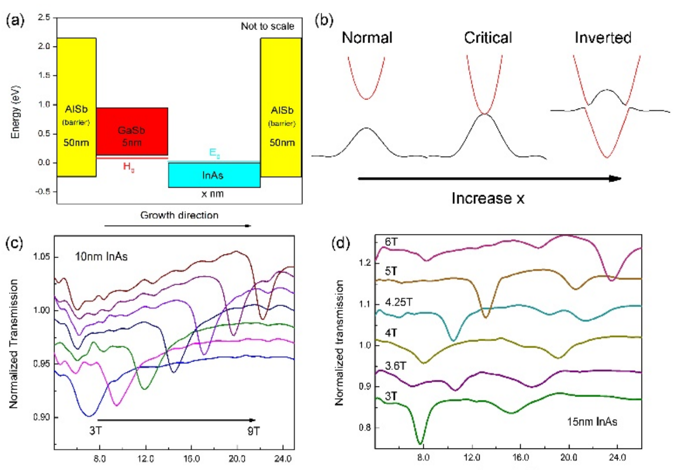

FIG.1: (a) Band diagram and width of each quantum well material.The H_0 and E_0 represent hole and electron subbands in different wells, respectively. (b) Evolution of the conduction (red) and valence (black) band alignment from normal to inverted region with increasing width x of InAs quantum well. (c,d) Normalized transmission spectra in normal/critical (c) and inverted (d) regions at selected magnetic fields.

Reference:
[1] I. Knez *et al*. PRL **107**, 136603 (2011).
[2] C. Liu *et al*. PRL **100**, 236601 (2008).

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