Carrier mobility and band structure within the bulk of a III/V topological insulator candidate

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Introduction:

- Within InAs/GaSb coupled quantum wells, tunnelling between the two wells creates a so-called “inverted” bandstructure, shown in Fig. 1 as solid lines.
- The gap created by this hybridisation is so radically different to the vacuum that there must be a transition at the edge of the material, characterised by helical, gap closing modes (Shown in Figs 1 and 2), protected against disorder by the topology of the system. [1]
- However, scattering reduces tunnelling probability, destroying the inverted bandstructure, leading to some trivial mid-gap states that mask the interesting edge modes, shown in Fig. 1 as dotted lines. Therefore, a detailed study of the scattering within this interesting material is of experimental interest. Particularly interesting is how an applied gate bias changes the scattering within the system.

![Fig. 1: Inverted bandstructure of an InAs/GaSb coupled quantum well. The electron-like states are shown in red, whereas the hole-like states are shown in blue and pink.](image)

Effects of a Gate Bias on Carrier Mobility

- In a) the second electron like subband (E2) should touch the first (E1), but instead a new anticrossing gap opens. This will prevent the second electron-like subband (E2) from being occupied until an even greater bias is applied, as in b).
- The proportion of these states within this new, hybridised subband with a hole like dispersion could be controlled by shifting the energies of the GaSb layer against disorder by the topology of the system. 
- Additionally, anticrossing between the second excited electron subband and the highest heavy hole subband results in the population of that subband being delayed until a higher carrier density is reached.

![Fig. 2: Schematic of the helical, spin filtered edge states present within a 2D topological insulator such as InAs/GaSb. From [1](arb. units)](image)

Selective Screening of Low Angle Scattering Events

- The fact that the quantum lifetime rises as the transport scattering time falls indicates that low angle scattering events are selectively screened against [2].
- By analysing the temperature dependent amplitudes of SdH oscillations, the quantum lifetime (a sum over all scattering events) can be deconvoluted from the classical Drude scattering time (weighted towards large angle scattering).

![Fig. 4 a) SdH oscillations as a function of carrier density within the same InAs/GaSb coupled quantum well as in Fig. 3 at 1.5 K. Note the change in envelope function at a carrier density of (21.7±0.2)×10^11 cm^-2, indicating that two subbands are present.](image)

Multiple Anticrossings and Delayed Subband Occupation

- Contrary to previous assumptions [4], we have shown that a back gate bias acting on the GaSb layer has a distinct effect on the transport when compared to a top gate acting on the InAs layer at all carrier densities.
- The states at the bottom of the hybridised, second electron-like subband will follow a hole dispersion relation, resulting in their low mobility, so they do not appear in the SdH oscillations in Fig. 4 a), but their screening is visible in the change in quantum lifetime in 4b) [2].
- The proportion of these states within this new, hybridised subband with a hole like dispersion could be controlled by shifting the energies of the GaSb layer with a back gate, resulting in the behaviour seen at high carrier densities in Fig. 3c).

References