Giant spin-orbit splitting in inverted InAs/GaSb double quantum wells

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Introduction

Band structure of InAs/GaSb

Relative shifts of the bands in energy and momentum can be tuned by quantum well thickness and electrical fields.

In band inverted regime, topological phase is expected.

F. Qu et al., PRL 115, 036803 (2015)
Spin-orbit splitting I

Numerically calculated band structure

Top gate voltage $V_{TG} = -0.4$ V

All the measurements were done inverted regime regardless of applied voltages.

Small spin-orbit splitting far away CNP

Giant spin-orbit splitting (>10meV) near band crossing

Spin dependent hybridization gaps

Anisotropic hybridization gap

The Fermi level can be positioned so that it crosses a single branch of the spin split bands. In this case, the system contains both electrons and holes, and the carriers of the same kind are fully spin-orbit polarized.
Spin-orbit splitting II

Fermi contours at energy levels II and III

Spin texture of electron like states:
spin orientation is nearly perpendicular to the momentum direction

Hole like states are highly anisotropic.
Magnetotransport Measurements

Multiple resistance peaks:
- Band inversion

Coexistence of both electrons and holes
Shubnikov de Haas (SdH) Oscillations

With spin orbit splitting subbands contributing to transport in parallel, SdH oscillations show a beating pattern with different $1/B$ periodicity.

π phase slip

Regular electron like Landau levels with Zeeman splitting at high fields

CNP
Power Spectrum Analysis

f: peak frequency of \( \rho_{xx}(1/B_\perp) \)

Carrier density: \( n = \frac{fe}{h} \)

Hall density: \( n_{\text{Hall}} = \frac{1}{eR_{xy}} \)
Phase Offset of SdH Oscillation

Spin orbit polarization:
\[
\frac{n_1 - n_2}{n_1 + n_2}
\]

Orange: step (< 3T) \(2e^2/h\)

Red: step \(e^2/h\)

Fully spin orbit polarized

Non zero Berry phase:

\[
\nu + \varphi = \frac{nh}{eB_\nu} \frac{1}{1}
\]

\(\varphi\): 0 for conventional 2DEG

\(\varphi\): 0.5 for symmetric Dirac cone

It is only measured on the electron side. \(\varphi = 0.33 \pm 0.05\)
Spin orbit splitting has been investigated via magnetotransport measurements in an inverted InAs/GaSb double quantum well as a function of top gate voltage.

- A large band splitting occurs near the hybridization gap.
- The Fermi energy can be tuned across a single spin resolved band, and 100% spin-orbit polarization is reached.
- In the fully polarized regime, non zero Berry phase is observed.
Thank you