Spin Effects in Quantum Hall Edge Channels and Quantum Wires

Grady Gambrel, Andreas Stier, Saskia Fischer and Bruce McCombe

1. Motivation

This collaborative study between Professor McCombe's Lab at the University at Buffalo with Professor Fischer's Lab at Humboldt Universitat zu Berlin seeks to understand the effects of the Spin-Orbit(SO) Interaction in one dimensional semiconductor systems. It is hoped that the SO Interaction will prove to be a viable means of manipulating electron spins. Such a capability is one of the requirements for spintronic devices, which strive to utilize the spin of electrons to relay information, enabling faster and more efficient devices. This research will improve our understanding of the SO Interaction, focusing upon Indium-Arsenide which has a strong SO Interaction, making it a potential material for spintronic components.

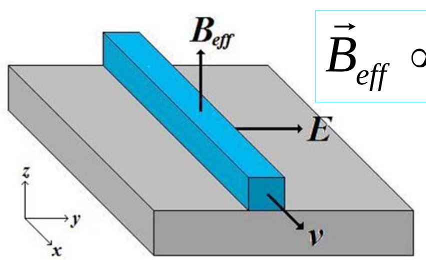
2. Theory

This research will deal with one-dimensional InAs-based semiconductor structures for the following reasons:

One-Dimensional:
1. Discrete energy levels
2. Well-defined current direction

Indium-Arsenide:
1. High mobility
2. Strong SO Interaction → possibility to manipulate spin with electric field

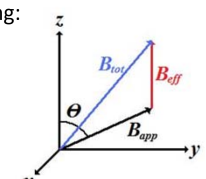
In the presence of an external potential gradient, the electron's movement causes it to experience an effective magnetic field:



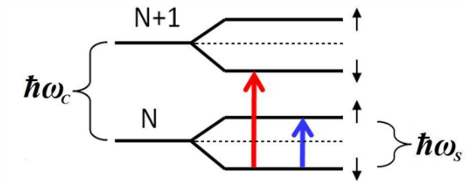
$$\vec{B}_{eff} \propto \vec{v} \times \vec{E}$$

This field is added vectorially to any external applied magnetic field. The total field then interacts with the magnetic moment of the electron, causing Zeeman Splitting:

$$\Delta H = -\vec{\mu} \bullet \vec{B}_{total} = \frac{1}{2}\hbar\omega_s$$



3. Theory (Spin Manipulation)

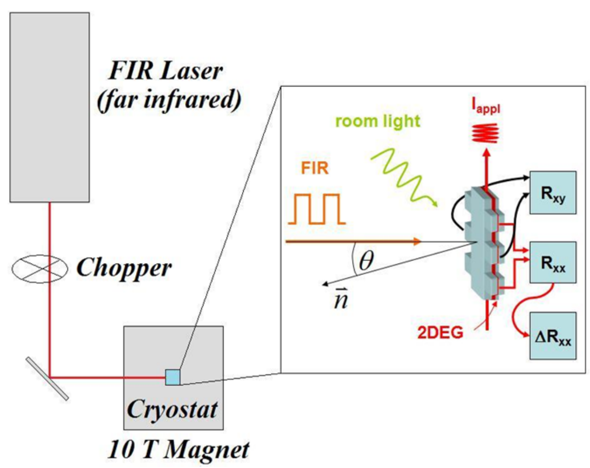


• Landau Level: eigenstates of 2D electron gas resulting from applied magnetic field (without spin)
• Zeeman Interaction: lifting of spin degeneracy
• Cyclotron Resonance (red arrow): allowed transition between Landau Level
• Spin Resonance (blue arrow): SO Interaction permits spin-flip transition without transition between Landau Levels

4. UB Experiments

Professor McCombe's group studies various materials with the use of:

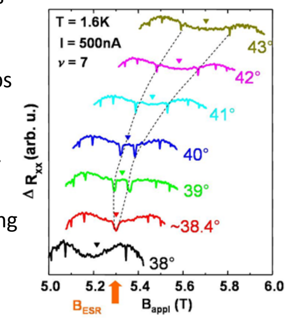
1. THz Spectroscopy/Photoresponse
2. High magnetic fields



THz Photoresponse Measurement Setup

1. THz (FIR) Source: molecular gas laser
2. Sample mounted in superconducting optical access magnet system.
3. Measure transverse (R_{xy}) and longitudinal (R_{xx}) resistance as well as photoresponse (ΔR_{xx}) simultaneously as a function of applied magnetic field.

5. Previous Results



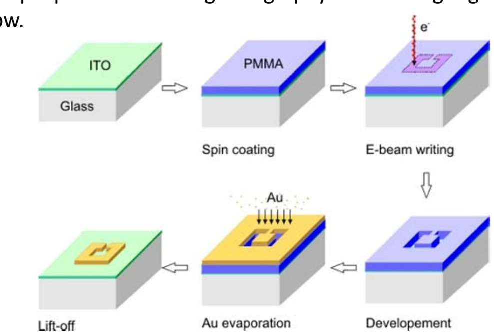
THz Photoconductivity in an InAs-2D electron gas in the integer quantum Hall regime.

1. Spin resonances occur as dips in the broad photoresponse
2. Central resonance feature appears at exact odd integer filling factor
3. Resonance splits by increasing the rotation angle

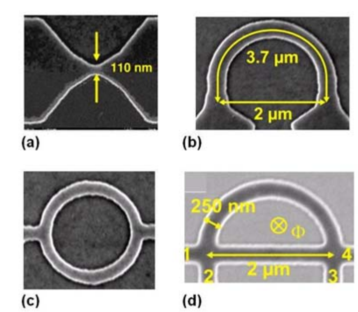
Multitude of resonances is associated with current flow in opposite directions.

6. Berlin Group

Professor Fischer's research group at Humboldt Universitat zu Berlin has extensive experience in fabricating one-dimensional and quasi one-dimensional structures by means of wet chemical etching and electron beam lithography.
A sample process involving lithography and etching is given below.



Sample Structures:



a) Quantum Point Contact b) Curved Quantum Wire
c) 2-Terminal Quantum Ring d) 4-Terminal Quantum Ring