Determining 2DHG Effective Mass in Gated GaAs/AlGaAs Heterostructures

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While electron systems have traditionally been studied for spin-based quantum computing applications, the weak spin orbit interaction (SOI) and hyperfine interactions between electron spins and nuclei of the material present challenges in terms of spin state decoherence [1,2]. However, it has been shown that by using positive charge carriers (holes), instead of electrons, it is possible to achieve at least an order of magnitude larger dephasing times, as well as larger SOI [1]. In this presentation, we study the effective mass of a 2D hole gas (2DHG) formed at the interface of a GaAs/AlGaAs system, with the intention of further developing single-hole quantum dots for spin-qubit applications. Using a double gated Hall bar structure to separately control the 2DHG density and ohmic contacts, we are able to achieve low charge carrier densities without compromising the electrical integrity of the ohmic contacts. We then measure Shubnikov-de Haas oscillations at low magnetic fields and varying temperatures to determine the effective mass of the carriers.

This systems valence band energy spectrum has three sub-bands: the Heavy Hole band (HH), Light Hole band (LH) and Split-Off band (SO) [2]. The SO band is considerably lower in energy than the HH and LH bands and is not relevant in transport measurements [2]. However, under a strong electric field, the HH band exhibits two different effective masses. Experimentally measuring them requires different techniques than if there were just one. We compare two techniques to extract the first effective mass: the method outlined in [3] that directly utilizes the amplitude of the Shubnikov-de Haas oscillations, and a Fourier transform method described in [4]. The second effective mass is calculated using the latter technique. Finally, we report on these two effective masses as a function of charge carrier concentration, which will allow us to further understand and develop this material system.

References:
[1] M.H. Kolodrubetz, and J.R. Petta. "Coherent Holes in a Semiconductor Quantum Dot." *Science* 325, no. 5936 (2009): 42–43.
[2] F. Nichele. "Transport Experiments in Two-Dimensional Systems with Strong Spin-Orbit Interaction." ETH Zurich, 2014.
[3] P.T. Coleridge, M. Hayne, P. Zawadzki, and A.S. Sachrajda. "Effective Masses in High-Mobility 2D Electron Gas Structures." *Surface Science* 361–362 (1996): 560–63.
[4] B. Habib, E. Tutuc, S. Melinte, M. Shayegan, D. Wasserman, S. A. Lyon, and R. Winkler. "Spin Splitting in GaAs (100) Two-Dimensional Holes." *Physical Review B* 69, no. 11 (2004): 113311.