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Spin-dependent transport of spin-orbit coupled holes in GaAs nanostructures

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In undergraduate physics, we are often taught that holes in the valence band are just positively charged heavy electrons. But valence band holes are spin-3/2 particles, and this gives them very different properties to spin-1/2 electrons, particularly when confined to low dimensions. These differences show up as highly anisotropic spin properties, which can be directly probed with conventional transport measurements. We have fabricated high quality hole quantum wires that show clean and stable quantized conductance plateaus [1]. In contrast to 1D electron quantum systems, the spin-splitting in these hole wires is highly anisotropic [2], and depends only on the orientation of the in-plane magnetic field relative to the quantum wire [3]. However the orientation and k-dependence of the spin-splitting cannot be reconciled with existing theories, suggesting that more theoretical work is needed before we understand the physics of spin-3/2 holes, even on "simple" (100) surfaces. We have also studied spin-3/2 holes in quantum dots, which show characteristic signatures of Kondo physics. A clear zero-bias peak is observed in the differential conductance, which splits with an applied in-plane magnetic field. The splitting is twice as large as the splitting for the lowest one-dimensional subband, consistent with Kondo physics. Unlike electrons this splitting is highly anisotropic with magnetic field, due to the strong spin-orbit coupling [4].

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