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Spin-Orbit Coupling and Spin Polarization in 2D Hole Systems

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The spin degree of freedom of the charge carriers in semiconductors is the subject of great current interest both in fundamental physics and also in applied research due to possible novel applications in the field of spintronics. While electrons in the conduction band have spin $S = 1/2$, the holes in the valence band of semiconductors like GaAs are characterized by an effective spin $S = 3/2$. The dynamics of these hole systems is governed by a strong spin-orbit interaction within the space of $S = 3/2$ states [1] which gives rise to a splitting of heavy and light hole states in 2D systems. A detailed understanding of hole systems is very important in the context of ferromagnetic semiconductors like GaMnAs where the ferromagnetism is mediated by the $S = 3/2$ holes in the valence band. We study the spin dynamics of hole systems at magnetic field $B = 0$ and $B > 0$. It is shown that $S = 3/2$ hole systems behave very different from $S = 1/2$ electron systems. Due to a competition between spin-orbit coupling and the Zeeman term in an in-plane magnetic field B, the spin polarization of 2D hole systems can change its sign at a finite value of B [2]. While $S = 1/2$ electron systems are fully spin polarized when the Zeeman energy splitting becomes larger than the Fermi energy of the system, the spin polarization of $S = 3/2$ hole systems typically remains much smaller than one in this regime. We discuss possible applications in the field of spintronics. [1] R. Winkler, *Spin-Orbit Coupling Effects in 2D Electron and Hole Systems* (Springer, Berlin, 2003). [2] R. Winkler, Phys. Rev. B **70**, 125301 (2004); R. Winkler, cond-mat/0401067.