Anisotropy of spin–orbit coupling and enhancement of the effective Lande factor in semiconductor nanowires

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Semiconductor nanowires are attracting growing interest for spintronics and topological quantum computing applications. In particular, InSb- and InAs-based nanowires exhibit strong Rashba spin–orbit coupling (SOC), which, in the presence of an external magnetic field applied, leads to the formation of a helical gap, a key prerequisite for the emergence of Majorana bound states. Despite extensive experimental and theoretical efforts, the quantitative determination of SOC strength in semiconductor nanowires remains an open issue, with reported Rashba coefficient spanning nearly an order of magnitude.

In this talk, we present a comprehensive theoretical analysis of gate-controlled SOC and Zeeman effect in semiconductor nanowires. Using $k \cdot p$ theory within the envelope-function approach, we evaluate the Rashba SOC induced by external electric and magnetic fields, explicitly accounting for the prismatic symmetry of realistic nanowire cross sections. We analyze the dependence of SOC on wire size, carrier density, and doping, and demonstrate that at high carrier densities the SOC exhibits a strongly non-linear susceptibility to the applied electric field [1,2]. We further investigate the effective Landé g-factor in confined nanowires. While the Roth–Lax–Zwerdling mechanism predicts a reduction of g^* with increasing confinement, we show that orbital contributions arising from spin–orbit interaction can dominate, leading to an enhancement of g^* by a factor of 2–3 [3,4]. Finally, we discuss the anisotropy of both the Rashba coupling and the g-factor with respect to magnetic field orientation [3,5], finding qualitative agreement with recent experiments on InSb and InAs nanowires.

References:

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