Theory of superconducting proximity effect in hole-based hybrid semiconductor-superconductor devices

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Hybrid superconductor-semiconductor systems have received a great deal of attention in the last few years because of their potential for quantum engineering, including novel qubits and topological devices. The proximity effect, the process by which the semiconductor inherits superconducting correlations, is an essential physical mechanism of such hybrids. Recent experiments have demonstrated the proximity effect in hole-based semiconductors [1-6], but, in contrast to electrons, the precise mechanism by which the hole bands acquire superconducting correlations remains an open question. In addition, hole spins exhibit a complex strong spin-orbit interaction, with largely anisotropic responses to electric and magnetic fields, further motivating the importance of understanding the interplay between such effects and the proximity effect.
In this work [6], we analyze this physics with focus on germanium-based two-dimensional gases. Specifically, we develop an effective theory supported by full numerics, allowing us to extract various analytical expressions and predict different types of superconducting correlations including non-standard forms of intraband and interband pairing mechanisms with non-trivial momentum dependence; as well as different Zeeman and Rashba spin–orbit contributions. This, together with their precise dependence on electric and magnetic fields, allows us to make specific experimental predictions, including the emergence of f-type superconductivity, Bogoliubov Fermi surfaces, and gapless regimes caused by large in-plane magnetic fields.

References

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Figures

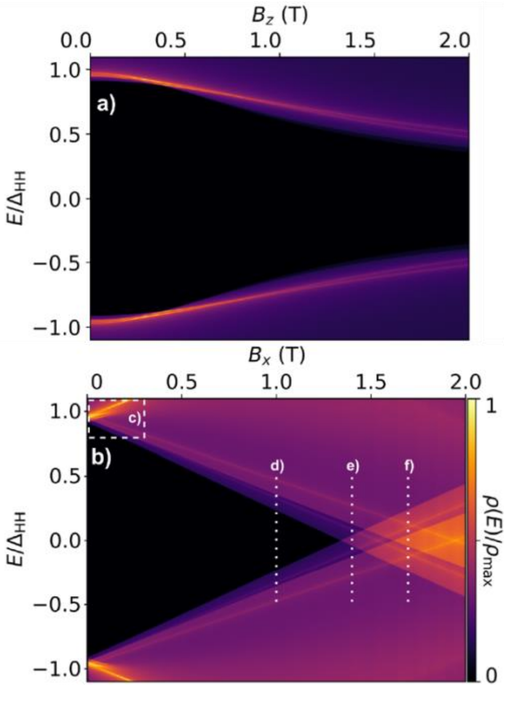

Figure 1: Density of states around E=0 as a function of vertical (a) and in-plane magnetic fields (b). Singularities are marked in (c, d, e, f)