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Unconventional Electron Pairing and Topological Superconductivity in Proximitized HgTe Quantum Wells[1]

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Coupling s-wave superconductors to systems with exotic Fermi surface spin textures has been recently proposed as a way to manipulate the nature of the paired state, in some cases even leading to a topological phase transition. Recently, we studied the behavior of Fraunhofer interference in HgTe quantum well-based Josephson junctions, in the presence of a magnetic field applied in the plane of the quantum well. Here we theoretically analyze our system and compare the predicted behavior to our experimental results. We find that the in-plane magnetic field tunes the momentum of Cooper pairs in the quantum well, directly reflecting the response of the spin-dependent Fermi surfaces. This momentum tuning depends crucially on the type of spin-orbit coupling in the system. In the high electron density regime, the induced superconductivity evolves with electron density in agreement with our model based on the Hamiltonian of Bernevig, Hughes and Zhang. This agreement provides a quantitative value for g/v_F, where g is the effective g-factor and v_F is the Fermi velocity. Our new understanding of the interplay between spin physics and superconductivity introduces a way to spatially engineer the order parameter from singlet to triplet pairing, and in general allows investigation of electronic spin texture at the Fermi surface of materials.

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