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Revealing topological superconductivity in extended quantum spin Hall Josephson junctions

arXiv:1403.2747

Quantum spin Hall-superconductor hybrids are promising sources of topological superconductivity and Majorana modes, particularly given recent progress on HgTe and InAs/GaSb. We propose a new method of revealing topological superconductivity in extended quantum spin Hall Josephson junctions supporting `fractional Josephson currents'. Specifically, we show that as one threads magnetic flux between the superconductors, the critical current traces an interference pattern featuring sharp fingerprints of topological superconductivity---even when noise spoils parity conservation.

Sangjun Jeon, Brian B. Zhou, Andras Gyenis, Benjamin E. Feldman, Itamar Kimchi, Andrew C. Potter, Quinn D. Gibson, Robert J. Cava, Ashvin Vishwanath, Ali Yazdani

Landau Quantization and Quasiparticle Interference in the Three-Dimensional Dirac Semimetal Cd3As2

arXiv:1403.3446

Condensed matter systems provide a rich setting to realize Dirac and Majorana fermionic excitations and the possibility to manipulate them in materials for potential applications. Recently, it has been proposed that Weyl fermions, which are chiral, massless particles, can emerge in certain bulk materials or in topological insulator multilayers and can produce unusual transport properties, such as charge pumping driven by a chiral anomaly. A pair of Weyl fermions protected by crystalline symmetry, effectively forming a massless Dirac fermion, has been predicted to appear as low energy excitations in a number of candidate materials termed three-dimensional (3D) Dirac semimetals. Here we report scanning tunneling microscopy (STM) measurements at sub-Kelvin temperatures and high magnetic fields on one promising host material, the II-V semiconductor Cd3As2. Our study provides the first atomic scale probe of Cd3As2, showing that defects mostly influence the valence band, consistent with the observation of ultra-high mobility carriers in the conduction band. By combining Landau level spectroscopy and quasiparticle interference (QPI), we distinguish a large spin-splitting of the conduction band in a magnetic field and its extended Dirac-like dispersion above the expected regime. A model band structure consistent with our experimental findings suggests that for a specific orientation of the applied magnetic field, Weyl fermions are the low-energy excitations in Cd3As2.

F. Dettwiler, J. Fu, S. Mack, P. J. Weigele, J. C. Egues, D. D. Awschalom, D. M. Zumbühl

Electrical spin protection and manipulation via gate-locked spin-orbit fields

arXiv:1403.3518

The spin-orbit (SO) interaction couples electron spin and momentum via a relativistic, effective magnetic field. While conveniently facilitating coherent spin manipulation in semiconductors, the SO interaction also inherently causes spin relaxation. A unique situation arises when the Rashba and Dresselhaus SO fields are matched, strongly protecting spins from relaxation, as recently demonstrated. Quantum computation and spintronics devices such as the paradigmatic spin transistor could vastly benefit if such spin protection could be expanded from a single point into a broad range accessible with in-situ gate-control, making possible tunable SO rotations under protection from relaxation. Here, we demonstrate broad, independent control of all relevant SO fields in GaAs quantum wells, allowing us to tune the Rashba and Dresselhaus SO fields while keeping both locked to each other using gate voltages. Thus, we can electrically control and simultaneously protect the spin. Our experiments employ quantum interference corrections to electrical conductivity as a sensitive probe of SO coupling. Finally, we combine transport data with numerical SO simulations to precisely quantify all SO terms.

M. I. Alomar, David Sanchez

Thermoelectric effects in graphene with local spin-orbit interaction

arXiv:1403.2178

We investigate the transport properties of a graphene layer in the presence of Rashba spin-orbit interaction. Quite generally, spin-orbit interactions induce spin splittings and modifications of the graphene bandstructure. We calculate within the scattering approach the linear electric and thermoelectric responses of a clean sample when the Rashba coupling is localized around a finite region. We find that the thermoelectric conductance, unlike its electric counterpart, is quite sensitive to external modulations of the Fermi energy. Therefore, our results suggest that thermocurrent measurements may serve as a useful tool to detect nonhomogeneous spin-orbit interactions present in a graphene-based device. Furthermore, we find that the junction thermopower is largely dominated by an intrinsic term independently of the spin-orbit potential scattering. We discuss the possibility of cancelling the intrinsic thermopower by resolving the Seebeck coefficient in the subband space. This causes unbalanced populations of electronic modes which can be tuned with external gate voltages or applied temperature biases.

Sebastian Mehl, Hendrik Bluhm, David P. DiVincenzo

Two-Qubit Couplings of Singlet-Triplet Qubits Mediated by One Quantum State

arXiv:1403.2910

We describe high-fidelity entangling gates between singlet-triplet qubits (STQs) which are coupled via one quantum state (QS). The QS can be provided by a quantum dot itself or by another confined system. The orbital energies of the QS are tunable using an electric gate close to the QS, which changes the interactions between the STQs independent of their single-qubit parameters. Short gating sequences exist for CNOT operations.

S. Sangtawesin, T. O. Brundage, J. R. Petta

Fast Room Temperature Phase Gate on a Single Nuclear Spin in Diamond

arXiv:1403.3311

Nuclear spins support long lived quantum coherence due to weak coupling to the environment, but are difficult to rapidly control using nuclear magnetic resonance (NMR) as a result of the small nuclear magnetic moment. We demonstrate a fast ~ 500 ns nuclear spin phase gate on a 14N nuclear spin qubit intrinsic to a nitrogen-vacancy (NV) center in diamond. The phase gate is enabled by the hyperfine interaction and off-resonance driving of electron spin transitions. Repeated applications of the phase gate bang-bang decouple the nuclear spin from the environment, locking the spin state for up to ~ 140 microseconds.

Tobias Meng, Jelena Klinovaja, Daniel Loss

Renormalization of anticrossings in interacting quantum wires with Rashba and Dresselhaus spin-orbit couplings

arXiv:1403.2759