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S-TI-S Josephson junction networks: a platform for exploring and exploiting topological states and Majorana fermions

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We are studying the transport properties of hybrid superconductor-topological insulator nanoscale devices fabricated by depositing superconductor electrodes onto the surface of topological insulators. In top-gated lateral Nb-Bi_2Se_3-Nb junctions, we have measured the Josephson supercurrent and conductance as a function of geometry, temperature, and gate voltage in order to determine the nature of the electronic transport. The supercurrent exhibits a sharp drop as a function of gate voltage that may be explained by the relocation of the topological surface state from above to below trivial conducting surface states formed by band-banding near the surface. We find that the magnetic field modulation of the supercurrent in Josephson junctions and dc SQUIDs exhibits anomalous features consistent with a 4π-periodic $\sin(\varphi/2)$-component in the junction current-phase relation that may arise from the nucleation of Majorana bound states in the junction. We are exploring circuits for imaging, manipulating, and braiding these exotic excitations and schemes for reading out their parity. In collaboration with Aaron Finck, Erik Huemiller, Cihan Kurter, Vladimir Orlyanchik, Martin Stehno, and Can Zhang.