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Josephson supercurrent through a topological insulator surface state

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The long-sought yet elusive Majorana fermion is predicted to arise from a combination of a superconductor and a topological insulator. We present direct evidence for a Josephson supercurrent in superconductor (Nb) - topological insulator (Bi_2Te_3) - superconductor e-beam fabricated junctions by the observation of clear Shapiro steps under microwave irradiation, and a critical current modulation by magnetic field. The dependence of the critical current on temperature and electrode spacing shows that the junctions are in the ballistic limit on a length scale of 100 nm. Shubnikov-de Haas oscillations in magnetic fields up to 30 T reveal a topologically non-trivial two-dimensional surface state. We argue that the ballistic Josephson current is hosted by this surface state despite the fact that the normal state transport is dominated by diffusive bulk conductivity. Nanostructured SQUIDs containing topological Josephson junctions are realized experimentally. Clear critical current modulation of both the junctions and the SQUID with applied magnetic fields have been observed. We show that the SQUIDs have a periodicity in the voltage-flux characteristic of Φ_0 consistent with numerical expectations. We propose several strategies towards realizing a doubled periodicity, belonging to the presence of Majorana fermions.