Researchers find unusual behavior in Josephson junction superconductor-topological insulator devices

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(Phys.org) -- Researchers at Stanford have been investigating the special properties of a Josephson junction when constructed as hybrid superconducting-topological insulator devices and have found what appears to be some unconventional behavior. In their paper published in *Physical Review Letters*, they describe how in applying a superconductor-topological insulator to a Josephson junction, the diffraction that occurs appears to differ from theoretical theories.

A Josephson junction is where a device is made that allows, theoretically, for an infinite electrical current to flow. This should be possible because superconductors, by their very name, conduct electricity so well that no energy is lost when electrons pass through them. To construct a Josephson junction, researchers couple two superconductors together with a weak link between them. What is interesting about the construction of such a device though, is when the two superconductors have different phase shifting properties which cause a phase shift in the electrons as they pass through. What's more if a magnetic field is applied, than that can cause a phase shift as well.

In this new research, the team applied a superconducting form of aluminum on top of a bit of bismuth selenide, which is a topological insulator. To create a Josephson junction, they left a little gap between the two and then applied a magnetic field and a small amount of current.

In measuring the results, they were surprised to find that the diffraction that occurred due to the phase shift didn't correspond to the conventional Fraunhofer pattern as expected. Instead they found that the valleys were higher, which they suggest could have been due to the size area of the junction being smaller. But they also found that the shape of the curve itself was different. Together the unconventional results suggest that something else is at work in the junction and the team suggests that it might just be due to the emergence of particles that show a remarkable similarity to Majorana fermions - charge neutral particles (fermions) that are their own antiparticles.

This new work goes a long way towards proving that Majorana fermions really can be created using superconductors, thus proving the theories true, and if that is the case, then actual devices should be able to be built that create and manipulate them at will, opening the door to all manner of applications that until now have existed only in science fiction stories.

More information: Unconventional Josephson Effect in Hybrid Superconductor-Topological Insulator Devices, *Phys. Rev. Lett.* 109, 056803 (2012) DOI:10.1103/PhysRevLett.109.056803

Abstract

We report on transport properties of Josephson junctions in hybrid superconducting-topological insulator devices, which show two striking departures from the common Josephson junction behavior: a characteristic energy that scales inversely with the width of the junction, and a low characteristic magnetic field for suppressing supercurrent. To explain these effects, we propose a phenomenological model which expands on the existing theory for topological insulator Josephson junctions.

Physics Viewpoint: An Extraordinary Josephson Junction