Ballistic edge states in Bismuth nanowires revealed by SQUID interferometry

Anil Murani[1], Alik Kasumov[1], Shamashis Sengupta[1], François Brisset[2], Raphaëlle Delagrange[1], Alexei Chepelianskii[1], Richard Deblock[1], Sophie Guéron[1], Hélène Bouchiat[1]

1 Laboratoire de Physique des Solides, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay Cedex, France
2 IInstitut de Chimie Moléculaire et des Matériaux d'Orsay, Univ. Paris-Sud, Université Paris-Saclay, CNRS, 91405 Orsay Cedex, France

Ballistic conduction may occur in conductors with small carrier concentrations, such as semi-conducting heterostructures or graphene, but is much rarer in disordered metals. One dimensional ballistic conduction is even rarer, occurring in carbon nanotubes or in topologically protected edge states, such as the edge states of the quantum Hall effect or the more recently discovered quantum spin Hall phases of two-dimensional topological insulators. In this report, we demonstrate one-dimensional ballistic conduction in a monocrystalline bismuth nanowire, via the measurement of the characteristic sawtooth current-phase relation of a Josephson junction made with a bismuth nanowire with (111) facets as the weak link. Modifications by the magnetic field of this current-phase relation, such as phase-shifts pi-phase jumps, also illustrate the power of spin orbit interactions, that, when strong enough as in bismuth, can, by coupling the kinetic moment of the electron to its spin, turn a 3D conductor into a one dimensional conductor whose transport of Cooper pairs is controlled by a magnetic field.