Topological pumping in superconducting wires with Majorana fermions

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A periodic modulation of two or more independent parameters in a quantum system may give rise to a dc flow of charge in the absence of any applied bias voltage. This transport mechanism is known as charge pumping and it is termed adiabatic when the pumping period is much larger than any characteristic time scale of the system. In his pioneering work, Thouless [1] showed that quantized adiabatic pumping can occur through one-dimensional insulating systems as a consequence of the topological properties of the Hamiltonian. In this work we study adiabatic pumping in a class-D topological superconductor which support Majorana fermions.

It has been recently suggested that class-D superconductors can be realized in spin-orbit coupled semiconducting nanowires in a magnetic field with proximity-induced s-wave superconducting pairing [2,3]. Here we show that topological adiabatic pumping of charges occurs in a class-D superconducting nanowire connected to a metallic lead, provided that a single mode of the latter is affected by the presence of Majorana fermions present at the endpoints of the superconducting nanowire [4]. This is the case, for example, when the lead supports a single propagating mode or when the nanowire is coupled to the lead through a quantum point contact. The topological nature of pumping consists in the fact that any continuous deformation of the pumping path in parameter space does not change the charge pumped in a cycle. The necessary condition to achieve a finite quantized value of the pumped charge is that the phase diagram presents a non-simply connected structure, where isolated non-topological regions are surrounded by connected topological ones. This is possible by allowing both a non-uniform pairing amplitude and a tilted Zeeman field. Non-contractible pumping paths in parameter space can thus be identified within the topological phase. We have furthermore verified that the quantization of the pumped charge is robust against disorder.

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