Persistent spin currents in superconducting altermagnets

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Abstract

Superconductors are famously capable of supporting persistent electrical currents, that is, currents that flow without any measurable decay as long as the material is kept in the superconducting state. We introduce here a class of materials – superconducting altermagnets – that can both generate and carry persistent *spin* currents. This includes spin-polarized electrical supercurrent as well as pure spin supercurrent that facilitates spin transport in the absence of any charge transport. A key to this remarkable property is the realization that the leading superconducting instability of altermagnetic metals consists of two independent condensates formed of spin-up and spin-down electrons (Figure 1). In the non-relativistic limit the two condensates are decoupled and can thus naturally support persistent currents with any spin polarization, including pure spin supercurrents realized in the charge counterflow regime (Figure 2). Away from the non-relativistic limit spin-orbit interactions couple the two condensates thus potentially hampering spin transport. We analyze what happens in this situation and find that, generically, SOC causes spatial oscillations in the spin current but, importantly, no dissipation or decay. This is in stark contrast to spin currents in normal diffusive metals which tend to decay on relatively short lengthscales. We illustrate the above properties by performing model calculations relevant to two distinct classes of altermagnets and various device geometries. On this basis we conclude that persistent spin currents are a general and robust property of superconducting altermagnets.

References

1. Persistent spin currents, Kyle Monkman, Joan Weng, Niclas Heinsdorf and Marcel Franz, in preparation.

Figures

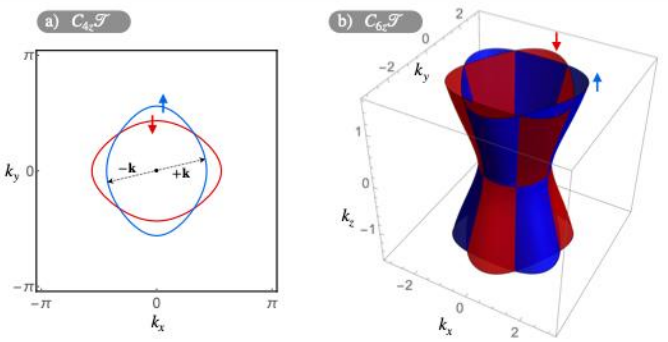

Figure 1: Spin split Fermi surfaces of typical (a) d-wave and (b) g-wave altermagnetic metals. Blue/red color distinguishes up/down spin projections and illustrates why altermagnets generically prefer equal-spin triplet pairing

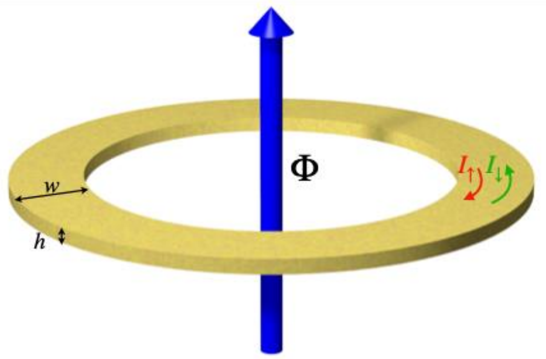

Figure 2: Realization of pure persistent spin current in a ring threaded by magnetic flux Φ. Red and green arrows illustrate the charge counterflow regime that becomes energetically favorable when Φ is close to a half-integer multiple of the SC flux quantum at weak SOC. In this regime the total electrical current vanishes and only spin current flows around the ring.