Spin Imbalance and Spin-Charge Separation in a Mesoscopic Superconductor

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What happens to spin-polarised electrons when they enter a superconductor? Superconductors at equilibrium and at finite temperature contain both paired particles (of opposite spin) in the condensate phase as well as unpaired, spin-randomised quasiparticles. Injecting spin-polarised electrons into a superconductor thus creates both spin and charge imbalances (respectively Q^* and S^*). These must relax when the injection stops, but not necessarily over the same time (or length) scale as spin relaxation requires spin-dependent interactions while charge relaxation does not. These different relaxation times can be probed by creating a dynamic equilibrium between continuous injection and relaxation, which leads to constant-in-time spin and charge imbalances. These scale with their respective relaxation times and with the injection current. While charge imbalances in superconductors have been studied in great detail both theoretically and experimentally, spin imbalances have not received much experimental attention despite intriguing theoretical predictions of spin-charge separation effects. These could occur e.g. if the spin relaxation time is longer than the charge relaxation time, i.e. Q^* relaxes faster than S^*. Fundamentally, spin-charge decoupling in superconductors is possible because the condensate acts as a particle reservoir. We present evidence for an almost-chargeless spin imbalance in a mesoscopic superconductor. These experiments allow us to explore transport scenarios in which spin and charge degrees of freedom are separately addressed.

These experiments yield an estimate of the spin imbalance lifetime based on fits to theory. We have recently been able to determine this quantity independently and more directly, using frequency domain measurements.

References

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