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Cooper Pair Mediated Coherence Between Normal Metals

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Two electrons bound in a singlet state have long provided a conceptual and pedagogical framework for understanding the nonlocal nature of entangled quantum objects. As bound singlet electrons separated by a superconducting coherence length of up to several hundred nanometers occur naturally in conventional BCS superconductors in the form of Cooper pairs, recent investigations have focused on whether electrons in spatially separated probes placed within a coherence length of each other on a superconductor can be quantum mechanically coupled by the singlet pairs. We present experimental evidence for this phase-coherent, nonlocal coupling between electrons in normal metals probes linked by a superconductor. By embedding one normal metal probe in a hybrid normal-superconducting loop, the phase of the electrons in this probe can be tuned by an externally applied magnetic flux. Under appropriate non-equilibrium conditions the change in phase results in a corresponding change in voltage on the embedded normal metal probe. This phase-dependent change can also be observed on a second normal probe, even though this probe is not embedded in any loop or intersecting any current path, but rather is coherently coupled to the first probe through a superconducting section shorter than the coherence length.