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Tunable non-local entanglement of electrons probed by noise cross-correlation measurement[1]

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Nonlocal entanglement is crucial for quantum information processes. While nonlocal entanglement has been realized for photons, it is much more difficult to demonstrate for electrons. One approach that has been proposed is to use hybrid superconducting/normal-metal devices. When the distance between two normal-metal electrodes connected to a superconductor is comparable to the superconducting coherence length, theory predicts that two electrons in the normal-metal electrodes with opposite spin are entangled by Cooper pairs, leading to non-local entanglement of electrons. Such entanglement can be understood by a non-local process called crossed Andreev reflection (CAR), in which a Cooper pair splits into two coherent electrons with one in each normal-metal electrode, generating instantaneous current of the same sign, and inducing a positive current correlation. Experimentally, CAR is indicated by a negative non-local resistance. However, another non-local process, elastic cotunneling (EC), in which one electron tunnels through the superconductor from one normal-metal electrode to the other, contributes to a positive non-local resistance that cancels the contribution due to CAR, preventing us from measuring and control of the CAR component. Fortunately, EC leads to a negative current correlation with bias dependence different from that of CAR. Thus, noise correlation measurement is expected to be able to distinguish these two non-local processes. By cross-correlation measurements as well as measurements of the local and nonlocal resistance, we present here experimental evidence showing that by independently controlling the energy of electrons at the superconductor/normal-metal interfaces, nonlocal Andreev reflection, the signature of spin-entanglement, can be maximized, qualitatively in agreement with theoretical predication.

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