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Presentation Title

Towards realization of non-local entanglers

Abstract

Control of quantum entanglement is the most essential concept of quantum information processing. Separately manipulating entangled two qubit states allows us to perform various quantum algorithms such as teleportation and measurement-based computation. In this project, we are developing solid-state non-local entanglers using Andreev reflection at a superconductor/normal conductor junction as well as the surface acoustic wave (SAW) induced moving potential to split spatially two electrons of a spin singlet state. We focus on three kinds of non-local entangler devices: (a) two quantum dots parallel contacted to a superconducting lead, (b) two graphene ribbons contacted to a superconducting lead and (c) a two-electron quantum dot connected with a distant quantum dot through a depleted channel in which SAW potential brings only one of two electrons to the other dot.

(a) is based on the self-assembled InAs quantum dots. We had already observed supercurrent through a double-dot Josephson junction, in which two superconducting leads are connected to the parallel quantum dots. We found from recent analysis that the obtained supercurrent is not a simple summation of the current through each dot. This implies the existence of simultaneous particle transport in the two dots through the non-local spin singlet state split from a Cooper pair. Recently, we have also developed Nb Josephson junction devices to observe more clearly the Cooper pair splitting.

For (b), we need to establish robust electrical contacts between graphene and superconductor as well as high quality graphene sheets with low charge impurity density. Concerning the electrical contacts, we found that Pd/Al evaporated on graphene makes a robust superconducting contact. We

observed supercurrent at zero magnetic field in a single layer graphene based Josephson junction device, as well as the Fraunhofer pattern in the magnetic field dependence of the critical current (Fig. 1). To improve the quality of graphene, we also developed a technique to transfer a graphene sheet onto hexagonal Boron Nitride (h-BN). Graphene on atomically flat h-BN is known to suffer much less from charge impurities than that on SiO_2 after being annealed. However, it was also found that the electrical contacts with superconducting metals are often lost after the annealing. To avoid such loss, we are now developing a dry process in which contact metals are deposited through a stencil mask without use of wet chemicals, so that we do not have to anneal the device after the metal deposition.

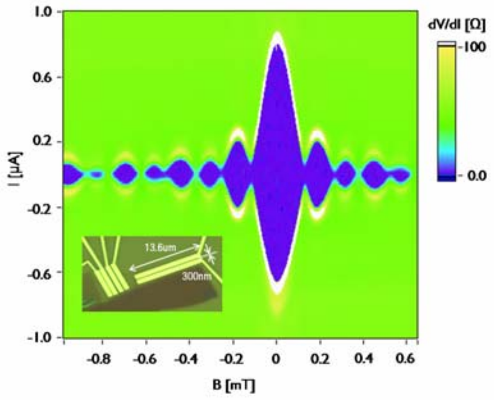

Fig.1 Magnetic field dependence of the critical current observed in a single layer graphene Josephson junction.

In (c), we employed two quantum dots connected via a 3 μm long depleted one-dimensional channel (see Fig. 2) on a GaAs/AlGaAs heterostructure. We prepared a situation where there are two electrons, i.e. the spin singlet state in the left dot, while no electron exists in the right dot. We then send SAW by applying a RF pulse on an interdigital transducer (IDT). SAW induces a moving electrostatic potential, traps one of the two electrons in the left dot into its potential minima, and sends it to the right dot through the 1D channel isolated from other electrons. The fidelity of this single electron transfer process was about 90%. It was achieved within 2 ns including the trigger time, which is much shorter than the spin dephasing time. We therefore expect that the two electrons separated in the distant dots are still in a spin-entangled state after the transfer. The next step will be to confirm preservation of the electron spin coherence during the transfer process.

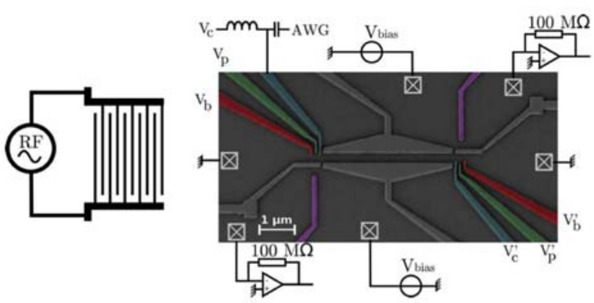

Fig.2 Device used for single electron transfer between distant quantum dots.