Superconducting Quantum Devices with Ultraclean Carbon Nanotubes

L. Bretheau

PMC, Ecole Polytechnique, CNRS, IPP, Palaiseau, France

The Josephson effect, which describes the coupling between two superconductors through a weak link, is the basis of several quantum devices. While it was mainly harnessed in tunnel junctions, hybrid Josephson junctions – in which quantum conductors are used as weak links – offer a rich physics to explore. Among them, carbon nanotubes (CNT) are particularly promising owing to their one-dimensional nature. These elementary quantum conductors combine structural simplicity with potential coherence enhancement. In this seminar, I will review a series of experiments performed on CNT-based Josephson junctions. They are based on our ultraclean nanofabrication technique that exploits hexagonal boron nitride both as a pickup substrate and a pristine dielectric environment, which enables integration in superconducting circuits.

In a first experiment, we measured the supercurrent of a CNT Josephson junction via low-frequency quantum transport. The gate-dependence of the critical current exhibits sharp variations associated with quantum phase transitions of the fermionic Andreev ground state of different parities, owing to the competition between superconducting pairing and Coulomb repulsion. Going further, these measurements reveal a distinctive fourfold periodic modulation linked to the combined spin and orbital degeneracy of CNTs. In a second experiment, we implemented a CNT-based gatemon qubit, which is integrated into a circuit quantum electrodynamics architecture. The measured qubit spectrum can be tuned with a gate voltage over more than 4GHz and reflects the underlying Andreev physics. Going further, we demonstrate coherent control of this gatemon qubit through Rabi and Ramsey protocols, with T2* coherence times up to 200 ns, marking a significant milestone for carbon nanotube-based quantum devices.

References

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