Coherent processes in
Superconducting quantum interferometers and qubits

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ABSTRACT

In this thesis we present theoretical investigations of the effects of Andreev bound states on the current transport in superconducting interferometers. We also investigate the slow dynamics of the Andreev states in a superconducting point contact, and the possible application as a quantum bit.

We consider superconductor-normal metal-superconductor (SNS) and normal metal- superconductor (NS) interferometers, where the contact region is a Y-shaped normal metal wave guide, and the two connection points to the same superconducting electrode can have different phases. The electric current in the interferometer is calculated as a function of the applied voltage and the phase difference ϕ. Andreev reflection in SNS and NS interferometers incorporates two features: interference in the arms of the Y-shaped normal region, and interplay with Andreev resonances. The latter feature yields rich phase dependent current structures in the subgap voltage region. The interference effect leads to a suppression of the current structures at $\phi = \pi$.

We investigate the effects on the Josephson current in NS interferometers due to current injection from the normal electrode. The two main effects of the nonequilibrium situation are: nonequilibrium population of the Andreev levels, which can result in enhancement, suppression, or even sign reversal of the Josephson current, and an anomalous interference Josephson effect, which gives rise to a long range Josephson effect, increasing with the voltage eV up to the superconducting gap Δ.

The two Andreev states in a superconducting quantum point contact can be accessed for manipulation and measurement by embedding the point contact in a superconducting loop. We calculate an effective Hamiltonian for the slow dynamics of the Andreev two-level system in the ring. Furthermore, we discuss methods of manipulation of the Andreev levels, and coupling of qubits. The state of the Andreev two-level system can be read out by monitoring the macroscopic quantum tunneling in a current biased Josephson junction, which is embedded in the superconducting ring of the qubit. We discuss the effects on the qubit, the readout scheme and the signal-to-noise ratio.