Quantum Dynamics of Josephson Junction Based Circuits

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Superconducting quantum circuits with Josephson junctions have shown in the last decade very rich and successful quantum experiments. They appeared as the most promising solid state scalable quantum system for quantum information processor. These superconducting circuits behave as artificial atoms and were extensively studied to test fundamental concepts of quantum mechanics. This research is always in strong development. After an introduction on Josephson junction circuits, I will detail a few quantum experiments realized in two different superconducting circuits: an inductive dc SQUID and a Josephson junction chain. The first circuit can be viewed as a single artificial atom and the second one as an artificial crystal.

The quantum dynamics of an inductive dc SQUID presents a very large variety of quantum phenomena. It can be described as a one-dimensional quantum anharmonic oscillator. It can behave as a phase qubit or a multilevel quantum system. Different properties will be discussed such as coherent multilevel dynamics, classical and quantum description, main decoherence processes, optimal control. When the inductance of the SQUID is large, its dynamics behaves as a two-dimensional quantum anharmonic oscillator. Recent measurements will be presented in this new limit.

In a last part, I will present quantum Josephson junction chains which could provide the basis for the realization of a new type of topologically protected qubit or for the implementation of a new current standard. By measuring the current-phase relation of these chains, we can determine the ground state properties which inform about the collective behaviour inside the chains. The measurements are well fitted by the theoretical predictions based on quantum phase-slip.