# MQC

## An Experiment for Detecting Macroscopic Quantum Coherence with a System of SQUIDs[a]

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The quantum mechanics (QM) behavior of microscopic quantum states has been successfully established after about 70 years of experimental results obtained mainly in the field of elementary particle physics. However, problems concerning consistency of QM predictions with causality, relativity, and macroscopic behavior have been raised and discussed since the very beginning of QM.

In the view of realizing experiments to detect the quantum behavior of macroscopic coherent states, as investigated in several papers,[1–3] the quantum behavior of an rf-SQUID has been analyzed. This device, consisting of a superconducting loop interrupted by a Josephson junction, is described by a single macroscopic degree of freedom (the phase difference of the Cooper pairs across the junction) moving, under proper bias conditions, in a double-well potential. Each well corresponds to a definite macroscopic state, with a definite value of magnetic flux (say, $\Phi_-$ and $\Phi_+$). In

[a]This work was supported by the Istituto Nazionale di Fisica Nucleare (INFN), Italy.

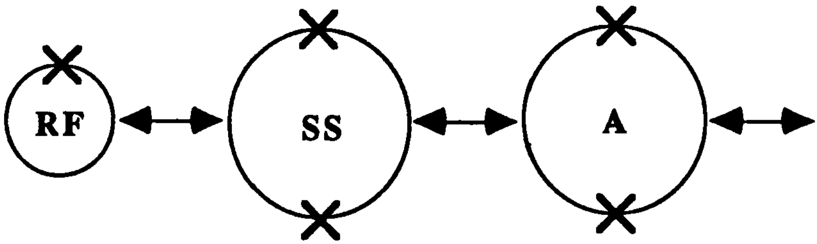


**FIGURE 1.** Scheme of the experimental apparatus.

principle, it is possible to perform an experiment to detect coherent tunneling oscillations from one well to the other, provided that we are able to fulfill all the experimental constraints necessary to get a coherent oscillation for a time interval of the order of a few microseconds.

The scheme of the experiment is shown in FIGURE 1, where RF represents the rf-SQUID under study. To read the status of the rf-SQUID, a superconducting switch (SS) is used. This consists of an hysteretic dc-SQUID that can either make a transition in the normal state or remain superconducting, depending on the sign of the circulating current in the rf-SQUID. A linear amplifier (A), in turn, reads the status of the switch.

The experiment that we present here is a modification[4,5] of the original one, discussed by Leggett and Tesche. Here, we want to present a very short description of the proposed measurements (see FIGURE 2). Suppose that the rf-SQUID has been

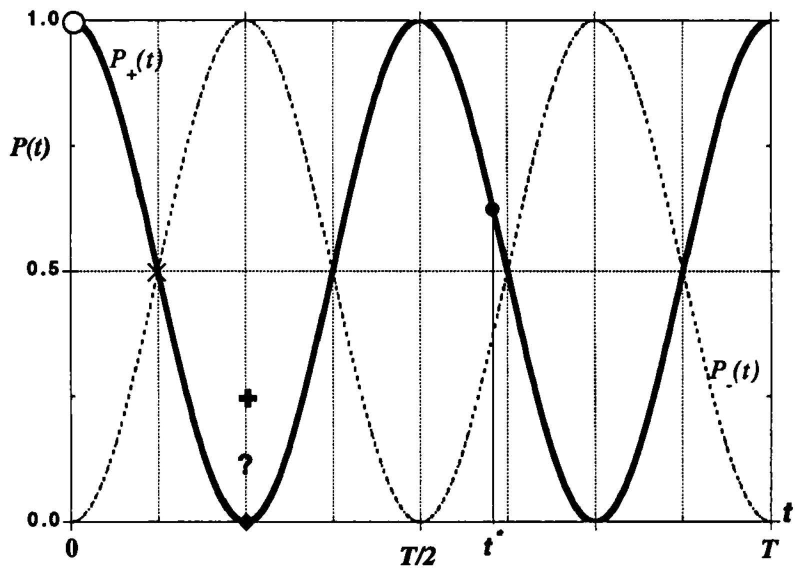


**FIGURE 2.** Quantum behavior of the probabilities to find the system in the plus or minus flux state.

prepared in the state $\Phi_+$ at $t = t_0$ and is oscillating back and forth between $\Phi_+$ and $\Phi_-$ with frequency $\omega_\tau$. We want to perform the following flux measurements on the system:

(A) Make a measurement at a generic time $t^*$. Repeat the measurement for different times $t^*$. The expected probability of finding the system in the state $\Phi_+$ is

$$P_+(t^*) = \cos^2[\omega_\tau(t^* - t_0)].$$

This test should check the existence of the oscillations according to the QM formalism. If not observed, it would mean that QM predictions are violated at the macroscopic level.

(B) Make a measurement at a time $t = T_\tau/2$ and another at $t^* \geq T_\tau/2$. If the measured $P_+(t^*)$ is equal to that found in the absence of the measurement at $t = T_\tau/2$, the noninvasivity of the measurement (NIM) in the strict quantum definition is therefore proven.

(C) Make a measurement (with the same technique used in part B to perform an NIM) at $t = T_\tau/8$. Retain only the measurements where $\Phi_{rf} = \Phi_+$. Make a new measurement at $t = T_\tau/4$. If the system had a restart due to the first measurement, then one expects to find

$$P^+\left(\frac{T_\tau}{4}\right) = \frac{1}{4}.$$

In contrast, the above probability should be 0 if no restart has taken place. The $P = \frac{1}{4}$ result should then be evidence for the nonclassical behavior of our macroscopic system.

The realization of such an ambitious experiment is related, of course, to the fulfillment of all the experimental constraints necessary to maintain the coherence of the oscillation. The major problem at the moment seems to be the correct interpretation of the "quantum dissipation" that, in increasing the entropy of the system, should bring the oscillation from the coherent into the incoherent state. Work is in progress to evaluate the quantum dissipation associated with the rf-SQUID from both the experimental and theoretical point of view.

## REFERENCES


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