

Macroscopic Quantum Tunneling in rf-SQUID based systems and resonant phenomena

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We present an experimental characterization in the quantum regime of Nb/AlO_x/Nb Josephson devices. Josephson Junctions and fully integrated Josephson devices consisting of a rf SQUID coupled to a readout system based on a dc SQUID sensor have been measured. Data on the decay rate from the metastable states show evidence of Macroscopic Quantum Tunneling¹ with a very low dissipation level and a high insulation of the probes from the external environment.

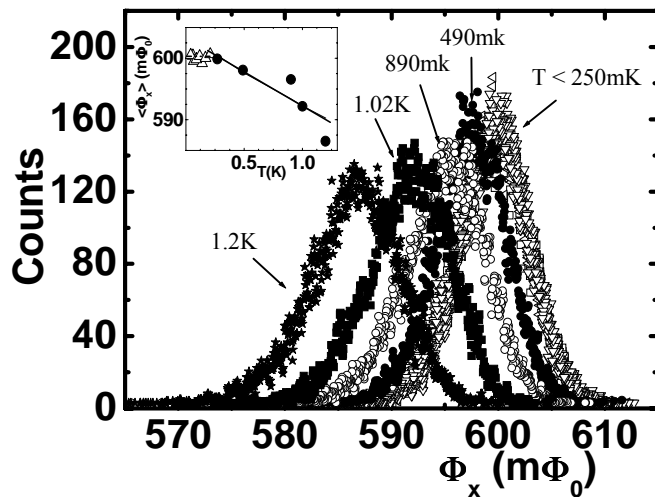
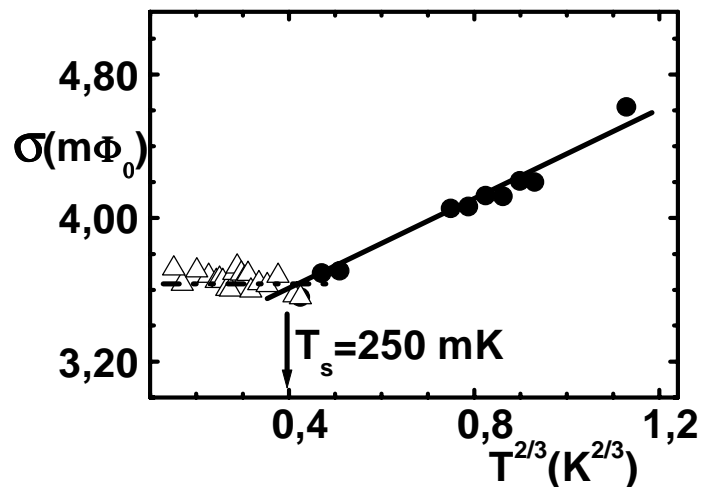


Figure 1 Experimental histograms of the switching flux distribution $P(\Phi_x)$ at different temperatures. The mean value of the flux distributions is reported in the inset as a function of T , together with the theoretical prediction in thermal (solid line) and quantum limit (dashed line). The rf SQUID parameters are $L=80$ pH, $C=2.3$ pF, $I_c=9$ μA , and $\beta_L=2$.

Figure 2. Data on the distribution width σ as function of $T^{2/3}$ is shown for the SQUID system. Experimental data in the thermal regime are compared with the theoretical prediction (dots and solid line) obtained for $R=1$ M Ω and $C=2.3$ pF. We also report the best fit line of the data in the quantum regime (triangles and dashed line). The interception of this line with the thermal curve gives an experimental extrapolation of the crossover temperature: $T_s=250$ mK.



Furthermore we consider the theoretical problem of resonant phenomena in the Macroscopic Quantum Tunneling for an rf-SQUID in presence of an external field². The transition probability between energy levels is studied by varying the parameters of the potential describing the system in a way that the pumping level in the left potential well is close to some level in the right potential well. The dependence of transition probability from the external drive of the system shows two resonance peaks, the former connected with *resonance tunneling* and the latter with *resonance pumping*. Relative position of peaks depends on the pumping energy and on the potential parameters.

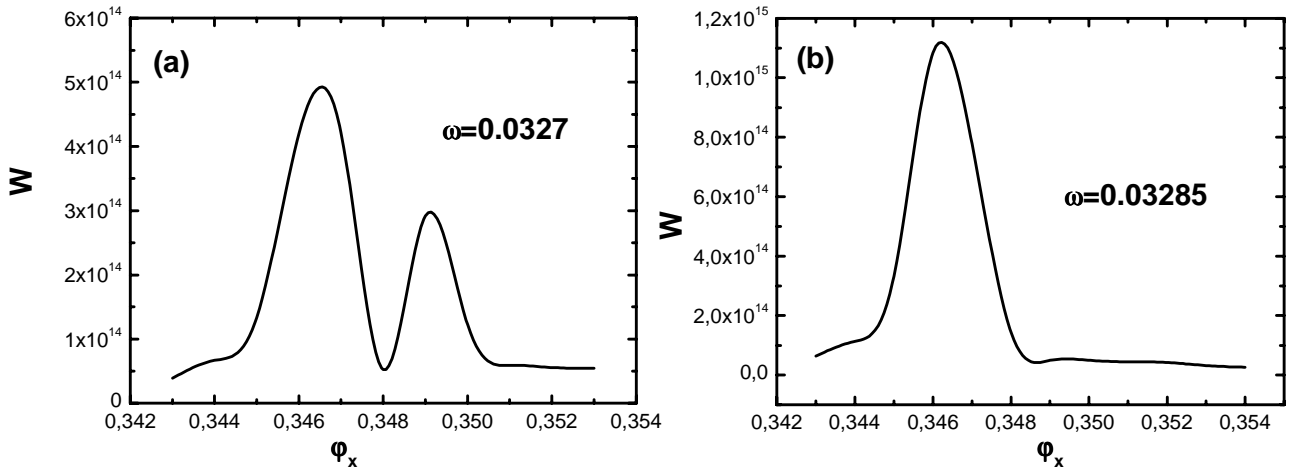


Figure 3. Transition probability W as function of the external magnetic flux φ_x . The curve is calculated for different values of the pumping frequency. The two peaks shown in a) and b) are connected with the effects of resonance tunneling between levels in different wells and the resonance pumping between levels in the same well. As predicted, the peaks due to the resonance pumping moves with the pumping frequency ω until it superimposes to the tunneling peak, as it is clear in Fig. 3b.

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