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Invited

Metrological Applications of Single Electron Tunneling

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With the advent of single-electron-tunneling devices, new metrological standards based on counting electrons have been proposed. I will discuss this application and outline an experiment in progress at NIST that will give an intrinsic standard of capacitance and a new measurement of the fine structure constant. A critical component to the performance of this standard is the ability to transfer electrons through an electron pump with very small errors. I will discuss a recent experiment in which we have operated a 7-junction electron pump with an error for transferring electrons of approximately 15 parts in 10^9 and an average hold time of 600 s. Although the error rate is greater than expected and not completely understood, the performance is adequate for metrological applications.

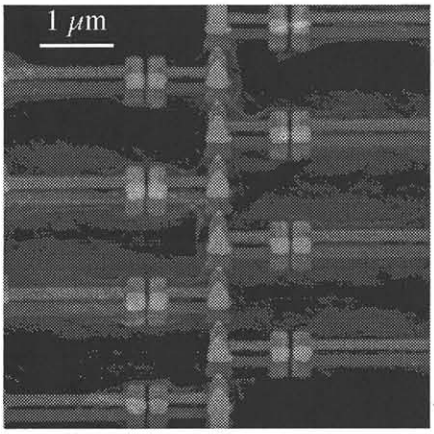

Fig. 1: Scanning force microscope image of the pump. The junctions are located at the bright spots where the tip of each island overlaps the island above it.

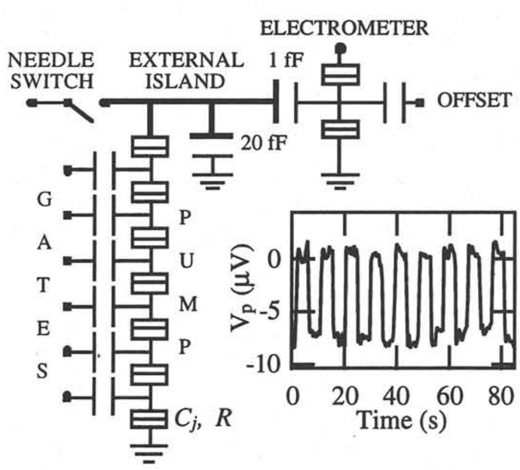

Fig. 2: Schematic of the circuit used to study the pump. When an electron is pumped onto the external island, a change of voltage $\Delta V_p = e/20$ fF is then detected by the electrometer circuit. All components except the needle switch were fabricated on a single chip. The entire circuit was placed in a copper box attached to the mixing chamber of a dilution refrigerator. Coaxial lines entering the box were heavily attenuated (gates) or filtered (others). The plot shows the pump voltage (on the external island) V_p *vs.* time when pumping $\pm e$ with a wait time of 4.5 s between electrons.

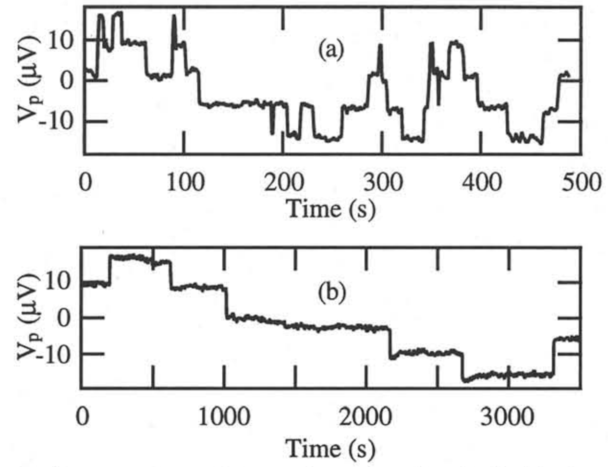

Fig. 3: Pump voltage V_p *vs.* time showing individual error events. (a) Pumping $\pm e$ at 5.05 MHz, average error per electron = 15 ppb. (b) Hold mode, average hold time ≈ 600 s. The device temperature is T_{mc} = 35 mK for both plots.

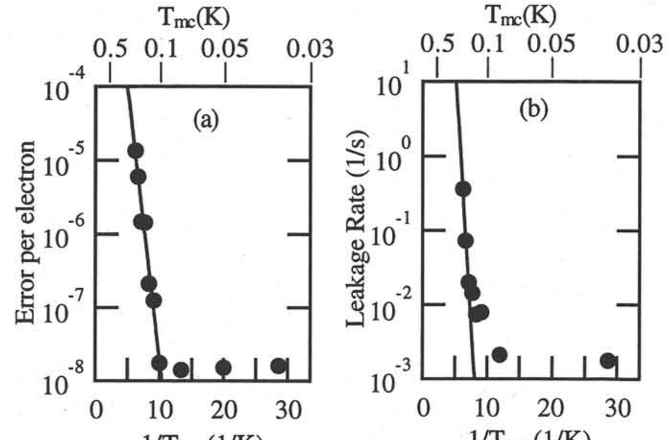

Fig. 5: Temperature dependence of (a) pumping accuracy and (b) leakage rate in the hold mode. Thermal smearing in the electrometer prevented measurements at T_{mc} > 160 mK. $V_p \approx 0$ for both plots.