Optimized semiconductor single electron pumps for metrology and quantum technology

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Since the 2019 revision of the SI systems of units the international units are defined by fixed numerical values of a set of natural constants. With respect to electricity, the base unit of the electrical current, the Ampere, is defined by the value of the electrical charge of the electron of e = 1.602 176 634 x 10^{-19} As.

As a consequence, a primary quantum standard for the Ampere can be realized using so-called single electron pumps (SEPs) [1]. These are based on single electron transistors that are driven by an oscillating gate voltage with frequency *f*. During one oscillation cycle one electron is captured from source and later ejected to drain thereby generating a quantized current $I = ef$ only given by the applied frequency and the defined value *e*.

So far, the best demonstrated quantization accuracy of such an SEP has been obtained in gated quantum dots in a GaAs/AlGaAs heterostructures where a quantised current of about 100 pA has been found equal to *ef* within an uncertainty of 1.6 x 10^{-7} [2]. This extreme accuracy is not only relevant for metrology but also for spin qubits, where the clocked transport of electrons is discussed as a quantum link between neighbouring qubits [3].

In the talk I will first summarize the state of quantum current metrology based on single electron pumps. Then, I will discuss an optimized gate designs and a reliable fabrication process for these devices [4] and will show how single- and double gate operation during pumping allows to shift the single electron capturing process from the so-called back-tunneling (or decay cascade) regime to the thermal regime where the capturing error is determined by the fermi distribution of the source [5].

References

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Figures

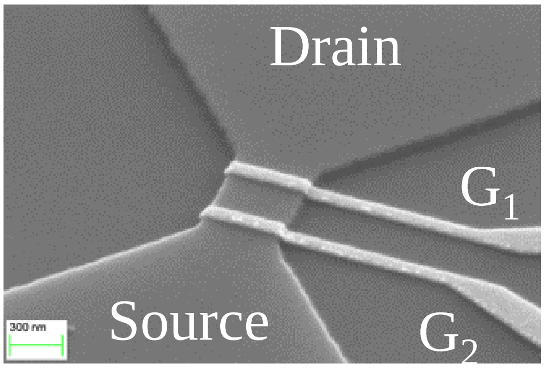

Figure 1: Single electron pump fabricated from an etched GaAs/AlGaAs heterostructure with top gates G defining a single electron transistor between source and drain. Operating the device with oscillating gate voltages with frequency *f* allows the generation of quantized currents $I = ef$ from source to drain.