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Charge sensing and real-time electron counting in quantum dots

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The charge state of a Coulomb blockaded quantum dot can be sensed at the single-electron level using charge sensors integrated on-chip [1]. Quantum point contacts or quantum dots have proven to work as reliable charge sensors. Coupling between the quantum dot's charge state and the sensor is provided by Coulomb interactions between electrons in the two systems. The technique is therefore independent of the material of quantum dot and sensor, and works for diverse systems such as GaAs [1] and graphene [2]. Different materials, such as InAs and GaAs have even been combined. Time-resolved charge sensing is of fundamental interest for studying the statistical properties of charge flow, like the full counting statistics. Single-shot charge and spin read-out schemes are also needed for the measurement of qubits. Some of our recent work has focused on the exploration and optimization of the read-out bandwidth limits. Towards this goal, we learned how to influence the dot-detector coupling [3], and how to employ high-frequency techniques in the range of a few hundred megahertz [4], or even up to a few gigahertz for improved performance. New experiments using the slower conventional sensing schemes have allowed us to explore non-equilibrium statistics and the fluctuation theorem. In our measurements, rare events can be detected, where electrons flow against the applied source-drain bias direction thereby consuming entropy in agreement with theoretical predictions.

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