Weak quantum measurement schemes of mesoscopic currents

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Measurements in classical and quantum physics are described fundamentally different. E.g. a long-standing problem in quantum mesoscopic physics is which operator order corresponds to noise expressions like $\langle I(-\omega)I(\omega)\rangle$, where $I(\omega)$ is the measured current at frequency ω. Symmetrized order describes a classical measurement while nonsymmetrized order corresponds to a quantum detector, i.e., one sensitive to either emission or absorption of photons.

To investigate the differences of quantum und classical measurement schemes, one can define formally similar measurements procedures with respect to the disturbance they cause. Obviously, strong measurements, both classical and quantum, are invasive – they disturb the measured system. We show that it is possible to define general weak measurements, which are noninvasive: [1] the disturbance becomes negligible as the measurement strength goes to zero. An interesting consequence concerns the question of causality in a time-resolved measurement. Classical intuition suggests that noninvasive measurements should be time-symmetric (if the system dynamics is reversible) and we confirm that correlations are time-reversal symmetric in the classical case. However, quantum weak measurements – defined analogously to their classical counterparts – can be noninvasive but not time-symmetric. We present a simple example of measurements on a two-level system which violates time-reversal symmetry and propose an experiment with quantum dots to measure the time-symmetry violation in a third-order current correlation function.

To access the quantum noise properties, the measurement scheme has to be generalized. We show that both operator orders schemes can be embedded in quantum weak-measurement theory taking into account measurements with memory, characterized by a memory function which is independent of a particular experimental detection scheme. [2] We discuss the resulting quasiprobabilities for different detector temperatures and how their negativity can be tested on the level of second-order correlation functions already. Experimentally, this negativity can be related to the squeezing of the many-body state of the transported electrons in an ac-driven tunnel junction.

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References

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