Weak measurement of cotunneling time

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Quantum mechanics allows for the existence of virtual states that have no classical analogue. While they are forbidden by energy conservation in classical mechanics, their presence within quantum mechanics as short-lived states is allowed by the time-energy uncertainty principle. Virtual state, being volatile, defy direct observation through strong measurement that would collapse the states itself.

Here we show how a virtual state of an interacting many-body system can be detected via weak measurements. Specifically we employ a composite measurement protocol called Weak Value (WV) [1], consisting of a weak measurement followed by a strong measurement for the determination of the time it takes an electron to tunnel through a virtual state of a quantum dot (QD). Such a cotunneling process [2] is strikingly different from a single particle tunneling under the barrier, since here transport of an electron involves a virtual many-body correlated state on the QD.

We introduce a realistic system-detector setup, which employs a quantum point contact (QPC) as charge detector and is valid both in the sequential and cotunneling regimes. We relate the correlation function of the system-detector currents to the sequential tunneling and cotunneling traversal time. We show that contrary to classical intuition, the cotunneling time is independent of the strength of the dot-lead coupling, and the expectations based on either the uncertainty principle, or on analogy with a single particle tunneling ("imaginary velocity" under the barrier) are unfounded. In fact we find that the cotunneling time depends parametrically on whether the cotunneling is dominated by elastic or inelastic processes.

[1] Y. Aharonov, D. Z. Albert, and L. Vaidman, Phys. Rev. Lett. 60, 1351 (1988).

[2] D. V. Averin and Y. V. Nazarov, Phys. Rev. Lett. 65, 2446 (1990).