Comment on "Continuous Quantum Measurement: Inelastic Tunneling and Lack of Current Oscillations"

A recent Letter [1] revisits the problem of continuous weak measurement of quantum coherent oscillations of a qubit with a linear detector, the role of which is played by the quantum point contact (QPC) in the low-transparency regime. Previous studies of this problem [2–5] demonstrated that the qubit oscillations with the frequency Ω should be reflected in the spectral density $S(\omega)$ of the detector output (electron current in the case of the QPC detector) as a peak at frequency $\omega = \Omega$. An interesting feature of such a peak [2] is that its height provides the measure of detector "ideality," i.e., shows how close the detector is to being quantum limited. For the quantum-limited detector the maximum peak height can reach 4 times the noise pedestal: $S(\Omega) - S_0 \leq 4S_0$, where S_0 is the output noise of the detector (current shot noise for the QPC detector). This conclusion of Ref. [2] has been confirmed in [3–5]. Similar results have been also obtained for continuous measurement of a single spin precession [6,7]. An analogous spectral peak associated with the Rabi oscillations of the continuously monitored qubit has been observed experimentally in [8].

In contrast to all these developments, the main claim of the Letter [1] is that there is no peak in the spectral density of current in continuous qubit measurement by the QPC detector. The purpose of this Comment is to emphasize that this claim is incorrect, and to point out the error in the arguments of [1]. The error stems from incorrect use of the "conditional" description of the measurement process. The conditional approach allows one to simulate individual random outcomes of a quantum measurement and has several important advantages, providing, e.g., a simple description of the feedback control of quantum systems. However, it uses an *assumption* that quantum interference between different possible outcomes of measurement is suppressed, and may lead to incorrect conclusions if the basis for which the interference can be neglected is chosen incorrectly. A mistake of this type was made in the Letter [1] which *assumes* that the qubit interaction with the QPC detector suppresses quantum interference between qubit energy eigenstates. While these states indeed decohere on the long time scales of order Γ_d^{-1}, where Γ_d is the qubit decoherence rate due to the backaction noise of the detector, their coherence is preserved on the short time scales of order Ω^{-1} in the relevant case of weak interaction with the detector, $\Gamma_d \ll \Omega$. The short-time quantum coherence between energy eigenstates is constantly being created by the qubit-detector coupling that does not commute with the qubit Hamiltonian. The fact that it is incorrectly *neglected by the assumption* in [1] leads to wrong results for the spectral density $S(\omega)$ at $\omega \simeq \Omega$.

Quantitatively, the assumption of suppressed quantum coherence translates into the form of the current (super) operator [Eq. (9) of [1]] written as a sum of several noninterfering "jump processes" in the energy domain. Since this description is adequate only on the long time scales, it produces the correct expression for the current spectrum $S(\omega)$ at low frequencies $\omega \simeq \Gamma_d$ [see unnumbered equation after Eq. (13) in [1]] that coincides with the previous results [2,5], but does not reproduce current oscillations with frequency Ω.

The correct expression for the current operator reduced to the qubit space can be obtained for the QPC detector if the bias voltage V across the QPC is large, $eV \gg \Omega$, so that the detector and qubit dynamics have different characteristic times (see [2,9]). The corresponding expression [e.g., Eq. (6) in [9]] differs from Eq. (9) of [1] in that the different tunneling processes in the detector are added coherently, implying that proper "unravelling" of the qubit dynamics in conditional approach should be done as in [3,10], according to the values of the detector current, not energy. This effectively assumes that there is no coherence between states with a different number of electrons passed through the detector. For $eV \sim \Omega$, it is impossible to write down the current operator in the qubit space alone, since the qubit and detector dynamics cannot be separated. Perturbative treatment of the coupled qubit-detector dynamics [5] shows that, as expected, the oscillation peak in spectral density exists for sufficiently large bias voltages $eV > \Omega$.

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