Continuous microwave photon counter using superconducting cavity-coupled semiconductor quantum dots

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The growing interest in quantum information has created strong interest and efforts to realize high-fidelity readout of the quantum states with minimal error rates. Many leading approaches in this domain rely on the readout and manipulation of quantum states using microwave photons using superconducting circuits [1]. However, microwave photon detection and counting with superconducting circuits involve additional steps to prepare the qubits before an actual measurement [2]. An alternative avenue lies in superconductor-semiconductor hybrid devices. Recent studies have demonstrated a continuous and high-efficiency microwave photon-to-electron conversion using superconducting cavity coupled semiconductor double quantum dots (DQD) [3]. We here present counting microwave photon absorption events individually and continuously using a hybrid system [4]. Our device utilizes photon-assisted tunneling in a double quantum dot (DQD), where a third dot capacitively coupled to the DQD detects the tunneling events [see Fig. 1(a)]. Figure 1(b) shows the measured time traces of the detector current with the DQD level detuning set to the photon energy (E = 27.3 μeV) and with varying microwave input powers. Our device detects both single and multiple-photon absorption events independently, thanks to the gate voltage-tuneable energy levels of the quantum dots. We find that the photon-assisted tunnel rates in a DQD provide crucial information about the cavity photon state when analyzing the results using the P(E) theory—a theoretical framework delineating the mediation of the cavity photon field via a two-level absorber. Remarkably, the input microwave photons set a tuneable environment for the cavity photon field, which we were able to measure using our photon counter. We further describe single-photon detection using the Jaynes-Cummings input-output theory and show that it agrees with the P(E) theory predictions. In the single-photon detection limit, we show that the theoretical predictions of the P(E) theory align excellently with the Jaynes-Cummings input-output theory [4]. Our study paves the way for continuous photon counting in the microwave domain, holding significant promise for applications in quantum information processing and fundamental studies with microwave photon statistics.

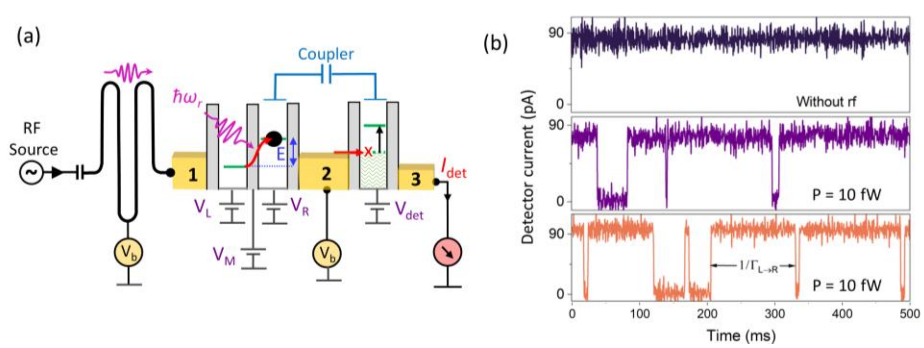

Fig.1. (a) Schematic representation of the cavity coupled DQD-QD microwave photon counter and (b) measured time traces of the detector current with varying microwave input power showing the photon-assisted tunnelling events.

References

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