On-Demand Microwave Generator of Shaped Single Photons

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Single photons will likely form an important element of next-generation communication networks that can carry quantum information, forming part of a quantum internet [1]. This work demonstrates a new type of single-photon generator that can give the photons a desired "shape", which can increase their efficiency when used in a quantum network. We achieve this new functionality through a novel means: we manipulate quantum vacuum fluctuations [2] on nanosecond timescales.

Our generator [3] is a superconducting circuit with two main parts. The first, a superconducting qubit, acts like an artificial atom that emits microwave light. The second is a superconducting transmission line with a tunable electrical "length". The tunability is achieved by terminating the line by a dc-SQUID which acts as a an adjustable boundary condition [4, 5, 6].

When the artificial atom is placed in the transmission line, it will emit single photons into the line after it has been excited by a resonant microwave pulse. This has been demonstrated before [7]. The problem with a typical setup is that the atom sits in the transmission line in a fixed configuration, so that it always emits the photon in the same way, that is, with the same shape. In this work, we were able to control the emission of the atom, and thereby shape the photons, by shuffling around quantum vacuum fluctuations in the transmission line. In this way we mitigate the effects of the intrinsic decoherence of the artificial atom and achieve a significantly higher efficiency of photon emission compared to previous approaches.

Beyond the applications in quantum communication, our setup is also an excellent platform to study fundamental processes in quantum electrodynamics. The control of the qubit emission unavoidably impacts the dispersive effects of the electromagnetic continuum on the single artificial atom, producing visible effects in its frequency.

The result of this work is an important proof-of-principle of an enabling technology for quantum networks, which is easily extensible to other types of superconducting qubits, resonators and other physical systems beyond superconductors.

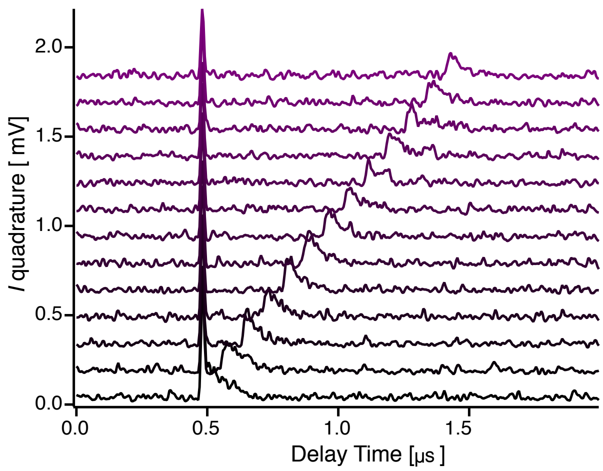

Figure 1: On-demand single-photon generation. The figure shows the emission of a qubit excited by a microwave pulse which arrives at 0.5 μs. Each trace displays an increasing delay of the qubit emission.

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