A microwave photomultiplier based on inelastic Cooper pair

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The detection of single photons is a fundamental quantum measurement, complementary to linear amplification. However, in the microwave domain this is a difficult task due to the low energy of the photons. We present here a photo-multiplier using the energy of a Cooper pair tunneling across a voltage-biased Josephson junction to convert one microwave photon into several photons at a different frequency. This process relies on the strong non-linearity provided by the interaction between a Josephson junction and its high-impedance electromagnetic environment. We have fabricated and measured a device composed of a low critical current SQUID galvanically coupled to two high-impedance resonators visible in Figure 1. It showed almost perfect conversion from one to one and two photons as well as a threefold multiplication with 0.75 efficiency in a 125 MHz bandwidth as shown in Figure 2. By cascading two of these multiplication stages and adding a quantum limited amplifier, it should be possible to discriminate itinerant single photon states from vacuum without dead time [1].

References

[1] J. Leppäkangas, M. Marthaler, D. Hazra, S. Jebari, R. Albert, F. Blanchet, G. Johansson, M. Hofheinz, Physical Review A, 97 (2018) 013855

Figures

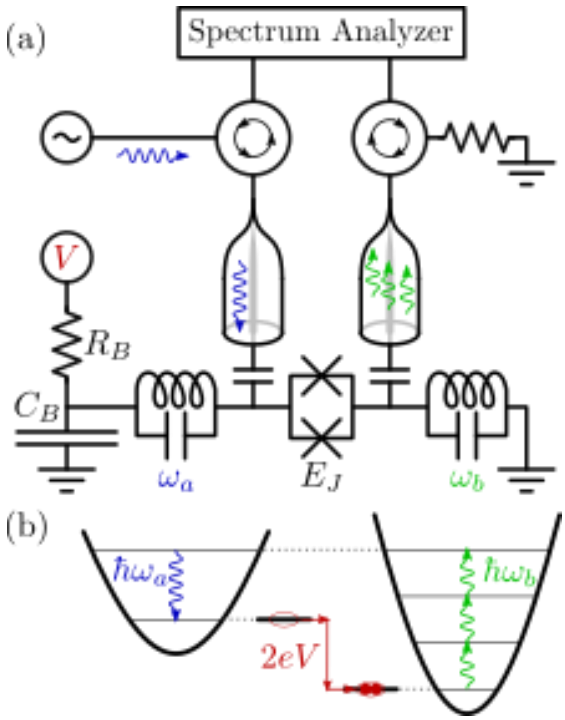

Figure 1: Microwave photon-number amplification. (a) Simplified electrical schematic. The sample consists of two buffer resonators at frequencies ω_a and ω_b. They are non-linearly coupled by a SQUID biased at a voltage V via a heavily filtered bias line. Blue input photons are sent on the left-hand microwave transmission line. They are transformed into green photons in the output line. (b) Voltage V is set such that $2eV+\hbar\omega_a = 3\omega_b$.

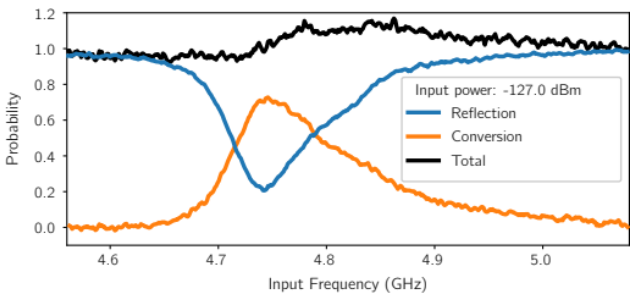

Figure 2: Measured reflection and conversion probabilities as a function of the frequency of the input photons for the 1 to 3 conversion.