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A quantum model for rf-SQUIDs based metamaterials enabling 3WM and 4WM Travelling Wave Parametric Amplification

In superconducting quantum computing a qubit state can be inferred through the measurement of low-power microwave fields. In this context, the large bandwidth and ultralow-noise amplification given by a Travelling Wave Josephson Parametric Amplifier (TWJPA) plays an essential role. In our work we derive a quantum model for an rf-SQUID (rf-Superconducting QUantum Interference Device) based TWJPA, enabling the amplification of the input signal through a three-wave or a four-wave mixing process. These two different working regimes can be properly selected by changing the external bias conditions, represented by a DC current or a magnetic flux. Within the model, we derive an analytical expression for the gain and the squeezing of a given input signal at the single-photon level. Furthermore, we investigate the time evolution inside the device of the probability distribution of the photonic population in the particular cases of two-mode Fock and coherent input states.

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