Noise Characterisation of a Flux-Pumped Lumped-Element Josephson Parametric Amplifier using an SIS Mixer

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Josephson parametric amplifiers (JPAs) are widely used in many ultra-sensitive experiments, due to their potential to achieve high gain and quantum-limited noise performance. They are essential for superconducting quantum information research [1] and recently have been considered for the dark matter axion searches [2]. We have recently developed a flux-pumped lumped-element JPA with a tunable operating frequency in the range of 8–10 GHz, as the first stage amplification for the readout of a superconducting qubit [3]. The layout of our JPA chip is shown in Fig. 1.

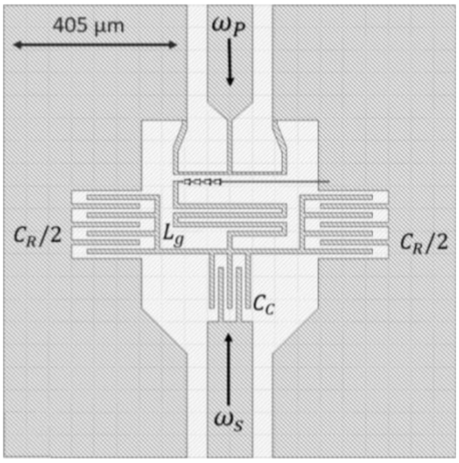

Fig. 1. Design layout of the JPA circuit. The signal is coupled to the *LC* resonator via a coupling capacitor C_c, and is read through a 50Ω CPW line. An array of four SQUIDs is cascaded in series to provide the nonlinear inductance required for parametric amplification. The pump signal is injected into the JPA with a flux line that is 15 μm away from the SQUIDs.

We have previously characterised our JPA at a base temperature of 10mK, and we managed to achieve a maximum gain of 25 dB with a 3dB bandwidth of 15 MHz and a 1dB compression point of –115dBm. Currently, we are in the process of characterising the noise performance of the JPA, using a superconductor-insulator-superconductor (SIS) tunnel junction as a calibrated noise source.

It is well known that the shot noise of an SIS tunnel junction above the gap is given by [4]:

$$T_{shot}(V_0) = \frac{e}{2k_B} I_{dc}^0 R_{dyn} \coth\left(\frac{eV_0}{2k_B T_b}\right)$$

where I_{dc}^0 is the DC tunnelling current, $R_{dyn} = (dI_{dc}^0/dV_0)$ is the dynamic resistance, V_0 is the biased voltage and T_b is the base temperature of the tunnel junction. Therefore, we can use the tunnel junction as a tunable noise source, by simply changing the bias voltage to provide noise power at different levels. In this experiment, we make use of one of the existing 220 GHz SIS mixer chip as the noise source. The SIS mixer block is connected to the input port of the JPA via a coaxial cable. The noise performance of the JPA is then measured by using the standard Y-factor method, with the SIS mixer biased at two separate distinct voltage points. In this conference, we will present a detailed design of the JPA, preliminary measured performance of gain and noise temperature, and analysis of the results.

References

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