Design and modelling of practical JTWPA

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Abstract: The current status of development of practical and reliable Josephson junctions-based traveling wave parametric amplifiers (JTWPA) for qubit integration and readout is reported.

Amplifying weak microwave signals is crucial for many applications, including readouts for superconducting qubits and other quantum devices. Leading quantum noise limited amplifiers in the microwave domain are realized by parametric pumping of nonlinear circuits made with elements like Josephson junctions (JJs) or high–kinetic–inductance components [1]. Among the various realizations of superconducting parametric amplifiers, those based on traveling wave (TWPA) are most promising for their wide bandwidth, a key characteristic for the scaling up of quantum processors and for the implementation of large array detectors. Despite the predictions of the commonly proposed JTWPA models [2], practical implementations suffer from unwanted behaviours, such as limited and frequency modulated gain, low dynamic range and unwanted spectral modes. To address these issues, we have developed and extensively explored a numerical model which directly solves the full nonlinear differential equations describing the JTWPA [3-4]. By tuning the driving conditions, we capture the broad spectrum of dynamical regimes accessible to JTWPAs, delineating the conditions under which transitions to chaos occur. Furthermore, we extend our study to JJs characterized by non-sinusoidal current phase relations (CPR) to explore the impact on the amplifier's performance [5]. In Fig.1 some of the obtained results are shown.

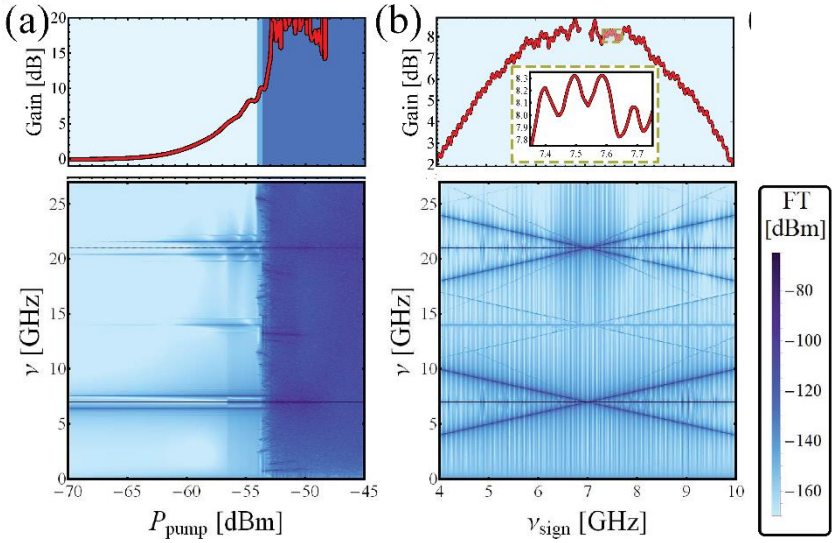

Fig. 1 (a) Gain (top) and Fourier spectrum of the output voltage (bottom) versus pump power level, Ppump, at vsign = 6.42 GHz (panel a) and versus the signal frequency, vsign, at Ppump = −55 dBm (panel b). Other parameters are: vpump = 7 GHz and Psign = −100 dBm. The dark blue region in the power spectrum is the chaotic region.

Through the study of gain characteristics, Poincaré sections, and Fourier spectra, we can understand how the various device parameters, design choices and junction nonlinearities may influence the JTWPAs' performances, thus giving insights into optimizing the design for enhanced performance and robustness in practical applications.

References

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