Topological amplification and perfect phase matching in a Josephson junction array with a non-local pump

Tomas Ramos

A. Gómez-León, J.J. García-Ripoll, A. González-Tudela, D. Porras

Institute of Fundamental Physics, IFF-CSIC, Madrid, Serrano 113bis, 28006 Madrid

t.ramos.delrio@gmail.com

We propose a realization of a truly directional and broadband Josephson traveling-wave parametric amplifier (JTWPA) using a homogeneous array of Josephson junctions (JJ) coupled to an auxiliary array of linear superconducting resonators [1]. We send the strong pump on the auxiliary array, which distributes an effective non-local pump on all sites of the JJ array. Tuning the spatial dependence of pump's phase, we can compensate for the momentum mismatch due to the non-linear dispersion of the JJ array and thereby achieve perfect phase matching without dispersion engineering.

Moreover, the phase of the non-local pump breaks time-reserval symmetry, allowing the device to enter a topological amplifying steady-state phase [1,2]. In this regime, microwave signals are unidirectionally amplified along the JJ array with all back-reflections and backward noise exponentially suppressed. Moreover, due to the topological origin of the directional amplification, the gain grows exponentially with system size, and it is robust to large amounts of disorder. We characterize the performance of the topological JTWPA using state-of-the-art superconducting circuit parameters, showing that a device with N~30 sites is enough to surpass 30 dB of near quantum-limited amplification and -30 dB of isolation over a bandwidth of a GHz [1]. Our work opens the door to the scalable integration of the quantum processors with compact, directional, and broadband pre-amplifiers on the same chip.

References

[1] T. Ramos, A. Gómez-León, J.J. García-Ripoll, A. González-Tudela, D. Porras, "Directional Josephson traveling-wave parametric amplifier via non-Hermitian topology", arXiv:2207.13728.

[2] A. Gómez-León, T. Ramos, A. González-Tudela, D. Porras, "Non-Hermitian topological phases in traveling-wave parametric amplifiers", arXiv:2207.13715

Figures

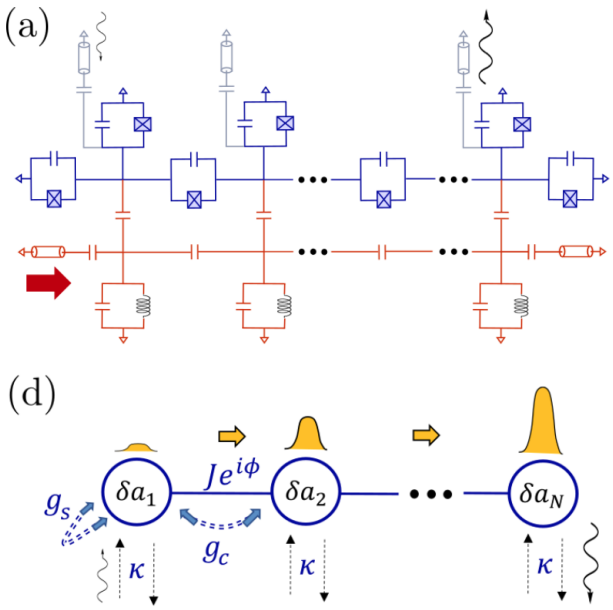

Figure 1: (a) Architecture for the realization of a superconducting topological traveling-wave parametric amplifier. It consists of a Josephson junction array (blue) coupled to a linear array of superconducting resonators (red).
(d) In the topological amplifying phase, the device amplifies unidirectionally and photons accumulate at one extreme of the chain.