

Abstract

Author: Emil Rizvanov

Title: Superconducting Traveling Waves Parametric Amplifiers

University: Comenius University

Faculty: Faculty of Mathematics, Physics and Informatics

Department: Department of Experimental Physics

Supervisor: prof. RNDr. Miroslav Grajcar, DrSc.

City: Bratislava

Date: 20.2.2025

Type of Thesis: Doctoral Thesis

This doctoral thesis focuses on the design of a traveling-wave parametric amplifier (TWPA) that exploits plasma oscillations in Josephson junctions. The performance of TWPAs is typically limited by issues related to impedance matching and phase matching. Conventional approaches to addressing these challenges—such as periodic impedance modulation or the use of resonators and phase shifters—tend to increase circuit complexity. This added complexity often gives rise to new, difficult-to-identify problems, which can in turn lead to additional unwanted impedance mismatches. This work presents a novel, conceptually simpler solution that enables a higher degree of integration of the amplifier's constituent elements. The proposed approach is based on a Josephson metamaterial with a suitably engineered dispersion profile, implemented by periodically adding a parallel (shunt) capacitor to every n -th Josephson junction. This strategy enables efficient phase matching in the three-wave mixing regime, resulting in high gain while maintaining compatibility with standard fabrication processes. An extension of the standard coupled-mode theory, complemented by numerical simulations, provides insight into the nonlinear dynamics of the proposed amplifier and allows for an analysis of its feasibility as well as the key advantages of the proposed solution compared to existing approaches.