Quantum properties of radiation emitted by traveling wave parametric amplifier

Remizov S V[1,2,3,@] **and Elistratov A A**[1]

[1] Dukhov Research Institute of Automatics (VNIIA), Sushchevskaya 22, Moscow 127055, Russia
[2] Kotelnikov Institute of Radioengineering and Electronics of the Russian Academy of Sciences, Mokhovaya 11-7, Moscow 125009, Russia
[3] National Research University Higher School of Economics, Myasnitskaya 20, Moscow 101000, Russia

[@] s.v.remizov@yandex.ru

A superconducting traveling wave parametric amplifier (TWPA) is a set of Josephson junctions, and it is possible to consider such a device as a metamaterial. A classical description of this system is given in [1]. If a coherent drive is applied to the TWPA, quantum effects result in radiation generation in a wide frequency band. It is impossible to describe this process within the framework of the classical approach. Thus, studying the quantum properties of the radiation generated by TWPA under strong coherent driving is challenging. To solve this problem, we use a field-theoretic approach based on the Schwinger–Keldysh technique in Nambu representation in a way similar to [2], where such an approach was used to study the Luttinger liquid. In this way, we managed to create a description of TWPA that considers quantum effects and derive kinetic equations for photon occupation numbers of the modes of the generated radiation. Using the solution of these equations, we calculate the squeezing of the generated radiation and obtain that the squeezing factor is large. It indicates that the radiated photons are strongly entangled. This result may be helpful for various applications in metrology.

[1] Yaakobi O, Friedland L, Macklin C and Siddiqi I 2013 *Phys. Rev. B* **87**(14) 144301
[2] Buchhold M and Diehl S 2015 *Eur. Phys. J. D* **69**(10) 224