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PROBING OF PHOTONIC STATES IN 1D SPACE

V N Antonov[1,3*], T Hönigl Decrinis[1], O V Astafiev[1,2]
R Shaikhaidarov[1,3] and A Yu Dmitriev[2]
[1]University of London, UK
[2]Moscow Institute of Physics and Technology, Russia
[3]University of London, UK

The wave mixing is well revealed and theoretically described phenomenon of a nonlinear optics. It has applications in phase conjugation, generation of squeezed states, parametric frequency conversion, signal regeneration schemes and exploited significantly for spectroscopic study of various systems. The wave mixing was thoroughly investigated in a medium such as fiber, atomic beams and vapors, with various numbers of mixed waves, exploiting two or more levels of a system. However, any medium represents a huge ensemble of atoms, so one needs many photons to drive the medium efficiently. Also, energy levels are broadened in homogeneously and hence what is accessible in wave mixing experiment is collective response of an ensemble of atoms. Quantum Wave Mixing (QWM) reveals itself as an elastic scattering of coherent classical and non-classical photonic states of electromagnetic waves on a single atom. We show a spectrum, corresponding to four-wave mixing of non-classical photonic states with a fingerprint of interacting photon states: the number of frequency peaks due to stimulated emission

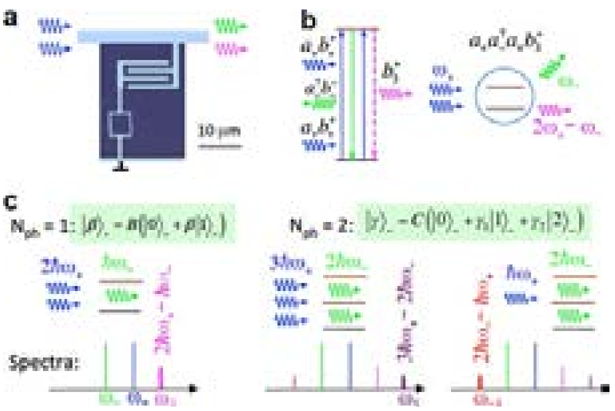

Fig1. a) A false colored SEM image of the device: a superconducting loop with four Josephson junctions, behaving as an artificial atom is embedded into a transmission line and strongly interacts with propagating electromagnetic waves.

b) Four-wave mixing processes resulting in the single-photon field creation at $\omega_3 = 2\omega_+ - \omega_-$. In classical mixing, the process operators $a_+ a_-^\dagger a_+ b_3^\dagger$ comes in pair with the symmetric one $a_- a_+^\dagger a_- b_3^\dagger$. In the mixing with non-classical states, time symmetry is broken resulting in the asymmetric spectrum. c) Schematic representation of QWM with non classical coherent states and sensing of the coherent quantum states. Two sequential pulses ω_- and then ω_+ are appliedbreaking time symmetry and, therefore, spectrum symmetry. Coherent photonic states are created in the atom by the first pulse at ω_- and then mixed with the second pulse of ω_+. Single-photon, N_{ph}=1, state β can only create a peak at $\omega_3 = 2\omega_+ - \omega_-$ because only one photon at ω_- can be emitted from the atom. Two photon, N_{ph}=2, coherent state γ results in creation of an additional peak at $3\omega_+ - 2\omega_-$, because not more than two photons ω_- can be emitted. Also one photon of can be absorbed, N_{ph}-1, creating additional left-hand-side peak at $2\omega_- - \omega_+$. Always exceeds by one the ones due to absorption, see Fig.1. We also study four- and higher-orderwave mixing of classical coherent waves. In this case the time dynamics of the peaks exhibits a series of Bessel-function quantum oscillations with orders determined by the number of interacting photons. In our study we operate in the microwave range of electromagnetic radiation. The two level superconducting circuit, qubit, serves as the artificial atom which scatter the microwave radiation, see Fig. 1. In a wider context these artificial atoms may be a building blocks of novel on-chip quantum electronics, which utilize the quantum nature of electromagnetic waves.

BIOGRAPHY

V N Antonov has his expertise in solid state nanophysics. He is one of scientists who made a breakthrough in experiments on quantum phenomena in low dimensional hybrid nanostructures, like Andreev interferometer, ferromagnetic/superconducting systems. A single photon terahertz detector based on semiconductors quantum dot developed in collaboration with Komiyama and Astafiev keeps a record sensitivity and it is used in a number of applications. A recent activity in superconducting quantum circuitry, superconducting resonators of high quality factors, and nanomagnetics is a subject of a number of publications in high ranked journals. He is also involved in development of the technology of high power diode laser for communications as an expert in nanofabrication.

v.antonov@skoltech.ru