

NEW MECHANISM of COHERENT PHOTONS EMISSION

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In this paper, we propose an original mechanism for generating coherent radiofrequency photons based on Bose–Einstein condensation of magnons.

Coherent photons used in lasers and masers are caused by the quantum-mechanical phenomenon of stimulated (induced) electromagnetic radiation. Excited atoms emit photons with the same quantum state as the stimulated photons. The density of already existing photon states in the resonator is multiplied. We have discovered and demonstrated another method for obtaining coherent photons. It is based on the electromagnetic radiation emitted by magnon from a Bose-Einstein condensate (mBEC). In the case of usual magnetic resonance with a small concentration of magnons, the latter emit photons corresponding to the local frequency of magnons. The resonance line is broadened by both homogeneous and inhomogeneous broadening. In a large number of investigations, we found that as the magnon density increases above the critical value corresponding to the theory of BEC formation for particles and quasiparticles, the magnetic resonance line narrows. Both homogeneous and inhomogeneous line broadening disappears. A magnon, annihilating, emits a photon in the same quantum state as the existing magnon. Therefore, in the case of the formation of a coherent state of magnons in BEC state, they emit coherent photons.

The existence of the magnon Bose condensate was first discovered in superfluid $^3\text{He-B}$ [1]. At the same time, the related phenomenon of magnon (spin) superfluidity was discovered [2]. Then mBEC was discovered in superfluid $^3\text{He-A}$ [3]. It was then discovered in solid-state antiferromagnets [4]. Finally, magnon Bose condensation was discovered at room temperature in an Yttrium Iron Garnet (YIG) film magnetized perpendicular to its surface. It has been shown theoretically [5] that the mBEC in YIG at room temperature should occur in the conditions when the angles of deflection of magnetization precession exceed of about $\theta=2.5^\circ$. Experimental studies have shown that the phase transition from magnon gas to mBEC occurs in the range of deflection angles about $\theta=3^\circ$ [6,7,8].

In this case, there is no need for a resonator. The role of the resonator is played by magnetic resonance, the frequency of which can be tuned by changing the magnetic field. To achieve the required concentration of magnons, we can use the gain in the feedback line. That is, the emitted photons are amplified by a radio-frequency amplifier. This signal is fed back to the sample. With a sufficient gain, the magnon density is sufficient to form mBEC. That is, the principle of self-generation is realized and at the same time we enter the region of coherent radiation of radio-frequency photons.

We proposed to create a self-generator of coherent radiation based on the following principle. Electromagnetic radiation of the mBEC is picked up by an antenna and fed to the amplification cascade. The signal from this cascade is fed to the emitter, which excites magnons in the same sample. The emitter and antenna are oriented at an angle of 90° to minimize their direct interaction. The presence of feedback with amplification leads to self-generation of radiation.

An important feature of this device is the use of the Bose amplification principle, first proposed by R. Feynman. According to this principle, in the presence of a Bose condensate, new particles can only appear in the quantum state of already existing particles of the ground state. Therefore, even if after the amplification cascade, spectrum of electromagnetic radiation of the emitter broadens due to thermal fluctuations and external noise, these changes will not affect the quantum state of the Bose condensate after the amplification cycle. To accumulate radio frequency photons, one can use a radio engineering resonator and emit this coherent radiation outward using an antenna. Further research into this new method of producing coherent radiation may find many applications in the future.

In this way we have realized the state of a continuously living Bose-Einstein condensate.

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