Amplification of an isolated magnon mode in a rapidly cooling gas of magnons

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It is shown below that microwave magnonic modes having a sufficiently low frequency (near the bottom of a magnonic spectrum) could be coherently amplified in a thermally pumped, and, then, rapidly cooled magnonic gas. This effect, recently observed in [1, 2], is analogous to the action of a MASER, but the pumping here is thermodynamic, created by the action of an incoherent heat pulse. It has been also previously shown experimentally [3, 4], that an application of heat pulse to an ultra-thin ferrite film, followed by a subsequent rapid cooling of the film, can lead to the formation of a room-temperature magnonic Bose-Einstein condensate (BEC) at the bottom of the magnonic spectrum.

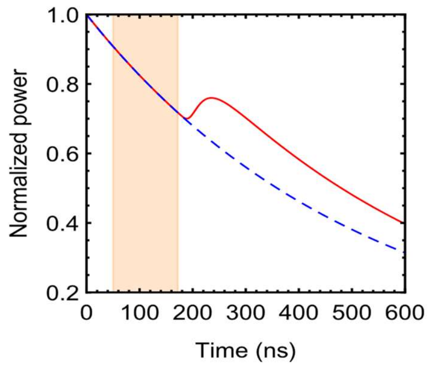

Figure 1: Normalized power of an isolated low-frequency magnon mode versus time with (solid red line) and without (dashed blue line) interaction with a hot magnon gas. Highlighted area shows the duration of the heating pulse.

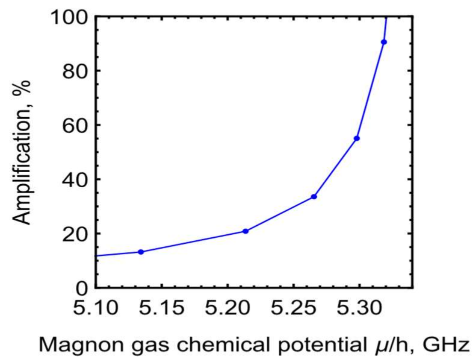

Figure 2: Relative amplification of an ILFM power as a function of the maximum chemical potential of the hot quasi-equilibrium magnon gas interacting with the ILFM.

Now, the experiments [1,2], and our current work, confirm that incoherent thermal pumping of a magnon gas in combination with rapid cooling, can lead to a coherent amplification of different magnonic modes, such as a nonlinear magnonic bullet mode, having frequency below the bottom of the magnonic spectrum [1], or a propagating spin wave mode, having frequency above the bottom of the magnonic spectrum [2].

We developed a model (see [3] for details), based on kinetic equations for magnonic amplitudes, which describes interaction between a rapidly cooling magnon gas and an isolated low-frequency magnonic mode (ILFM), and shows that the main reason for the ILFM amplification is the formation of a non-zero chemical potential in the quasi-equilibrium magnon gas existing near the spectral bottom. The ILFM gain is proportional to $\mu - \hbar\omega_{lf}$, where μ is the chemical potential of the magnon gas, and ω_{lf} is the ILFM frequency.

The results of numerical modeling of the ILFM amplification process are presented in Fig.1, where temporal evolution of a normalized power of an ILFM interacting with rapidly cooling magnon gas is shown by a solid red line. It is clear, that ILFM is substantially amplified in the process of rapid cooling. The dependence of the ILFM amplification on the maximum chemical potential of the magnon gas (Fig. 2) demonstrates a nonlinear behavior, and a large increase of the ILFM amplification is observed at $\mu_0/\hbar \approx \omega_m = 5.3$ GHz, when the magnon gas is close to the formation point of the room-temperature BEC of magnons.

References

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