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Bose-Einstein Magnon Condensation in Laterally Confined Thin Films

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Bose-Einstein Condensation (BEC) is a fundamental physical phenomenon that exhibits fascinating properties such as superconductivity and superfluidity. Its realisations in various physical systems could so far can be divided into two types: either BEC is achieved due to a strong decrease in temperature in ultra-cold atomic gases and cryogenic liquids, or a strong external injection of bosonic quasi-particles is required. In the gas of magnons, BEC can be obtained even at room temperature [1]. The room-temperature magnon BEC observed in magnetic insulators (single-crystal films of yttrium iron garnet, YIG) has a large potential in high-speed and low-power-consuming information processing and data transfer. At the same time, the miniaturization of BEC-based magnonic devices constitutes an extraordinary challenge for their future applications. Futhermore, the decrease in the size of magnetic samples opens the way to new BEC methods and raises questions about the properties of such condensates in systems with higly discrete spectra.

Here, I present a novel and universal approach to enable Bose-Einstein condensation of magnons in confined nanosized systems [2]. The essential feature of this approach is the introduction of a disequilibrium of magnons with the phonon bath. After heating to an elevated temperature, a sudden decrease in the phonon temperature, which is approximately instant on the time scales of the magnon system, results in a large excess of incoherent magnons. The consequent spectral redistribution of these magnons leads to increase in chemical potential of the magnon gas and triggers the Bose-Einstein condensation. We have observed this phenomenon by time-resolved Brillouin light scattering (BLS) spectroscopy in a typical spintronic structure heated by the application of dc electric current pulses (see Fig. 1).

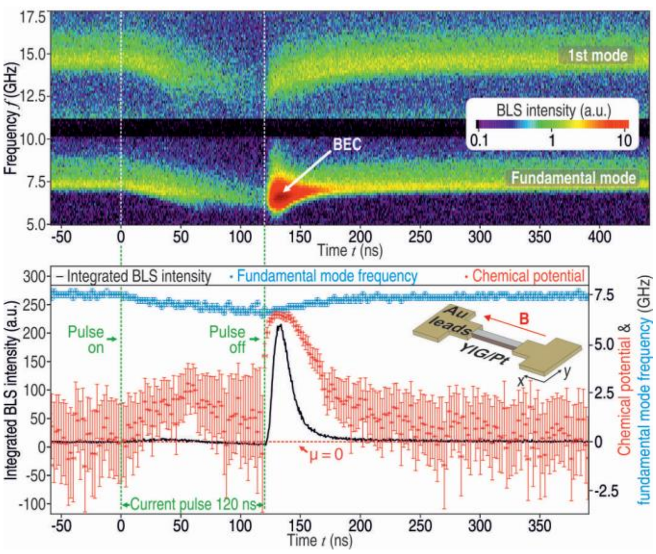

Fig. 1. Brillouin light scattering measurements of magnon Bose-Einstein condensate obtained by rapid cooling of a nanosized magnetic sample.

Moreover, we have studied by numerical simulations the formation of the magnon BEC in parametrically excited nanoscopic systems and proposed a new way to enhance condensate’s lifetime by lateral confinement [3]. We revealed the role of dipolar interactions in the generation of a magnon BEC as a metastable state in YIG ultrathin film structures. We directly map out the nonlinear magnon scattering processes to show how fast quantized thermalization channels allow the BEC formation in confined structures (see Fig. 2).

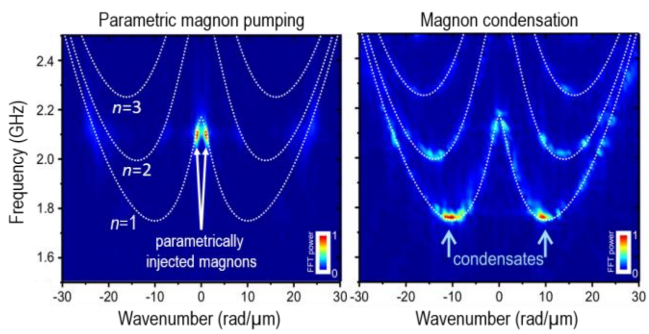

Fig. 2. Micromagnetic simulation of parametric magnon injection followed by thermalization of parametrically pumped magnons and their condensation at the bottom of a discrete spin-wave spectrum.

Both our investigations greatly extends the freedom to study dynamics of magnon BEC in confined systems and to design integrated circuits for magnon BEC-based applications at room temperature.

References

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