Bose-Einstein condensation and superfluidity of magnons in ferromagnetic films under pumping.

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Abstract

We discuss theory and experiment on Bose-Einstein condensation and superfluidity of magnons in ferromagnetic films. The Bose-Einstein condensation of magnons in Yttrium Iron Garnet (YIG) film at room temperature under the rf pumping was discovered in 2006 by the Münster experimental team led by S. Demokritov. [1] There are two equal minima of energy in the magnon spectrum of YIG film at non-zero momenta and therefore two condensates. The same experimental group has discovered the interference of the two condensates [2] thereby proving their coherence. Theory [3] stated that strong degeneration of the ground state of non-interacting magnons with respect to distribution of them between two minima is lifted by the magnon interaction. Theory predicts that interaction leads to spontaneous violation of the reflection symmetry and non-equal number of magnons in two condensates for thick films. In thin films the condensate is symmetric at low magnetic field and transits to non-symmetric state at higher field. In non-symmetric phases (thick films) theory predicts and some experiments confirm attractive interaction between magnons. In equilibrium state it would produce collapse of condensate, but at permanent pumping there appears strong repulsion between magnons. Experimental evidence of this repulsion was found in recent experiments performed by Borisenko *et al.* in YIG films with magnetic trap for magnons. [4]

The coherence of condensate gives chance to superfluidity . Though the normal magnon density by 100 times exceeds the condensate density, as we proved in [5,6], velocity of the superfluid magnon liquid is by 4-6 decimal orders larger than the velocity of normal part at typical values of magnetic field and its gradient. Thus, the spin current is mainly superfluid. Non-direct experimental evidences of superfluidity were presented in the works [4] and [7]. We propose to realize magnon superfluidity creating a phase soliton bouncing between two reflecting boundaries.[5] Such solitons may serve as lossless and fast carriers of information and energy.

The reason of repulsion in thick homogeneous films may be slow momentum relaxation. When the momentum relaxation time is comparable or longer than magnon lifetime, free energy is not minimal in stationary state. Stationary state may be still not symmetric, but much less asymmetric than the equilibrium state. This change of stationary state changes sign of interaction.

References.

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