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Low temperature FMR in the system of non-interacting magnetic nanodisks

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Abstract. Magnetodynamical properties of systems of magnetic nanodisks at the microwave range and low temperatures were studied experimentally. Several periodic square arrays of Permalloy nanodisks deposited onto a glass substrate have been studied. The interdisk center-to-center distance in each array was equal to double disk diameter . The magnetoresonance studies were performed at 70-80 GHz frequency band and at the temperature of 4.2 K. The static external magnetic field was applied perpendicularly to the disks array. As a result the magnetoresonance absorption spectra have been obtained, containing both fundamental mode and spin wave modes. A comparative analysis of the results is performed with the X-band results obtained at T = 300K.

Introduction

One of the main directions of the development in modern electronics is miniaturization and reduction of energy consumption. Spintronics is a very promising area of study for these purposes [1]. However, the development of spintronics is impossible without usage of novel micro-and nano-scaled magnetic systems [2]. Very promising magnetic nano-systems are the patterned magnetic thin films, namely the periodic arrays of thin nanodiscs. They are not only interesting from the physics point of view, but well-organized patterned medium can serve as effective storage medium, where one nanodisc represents one bit of information. The important characteristic of such memory medium is its writing time (the time of magnetic switching process). This time is determined by the dynamic properties of the memory elements, that is by spin wave excitations in the system of nanodiscs.
This paper is devoted to the experimental study of magnetodynamics in the periodic arrays of Permalloy nanodisks within the 70-80 GHz high frequency range at 4.2 K. So far, ferromagnetic resonance (FMR) studies in these systems were performed either by continuous wave FMR at 10 GHz [3] or by broadband FMR up to 12 GHz [4].

Technique and method of experiment

Several periodic square arrays of Permalloy nanodisks deposited onto a glass substrate have been studied. The typical array size is 6×6 mm^2. The interdisk center-to-center distance in each array is twice the disk diameter. Disks diameters (D) are correspondingly: 4000nm, 2000nm, 1500nm, 1000nm, 500nm, 250nm. The thickness of elements in all arrays was fixed at 40nm. From the ratio of disk diameter to distance between disks it follows that we have ensembles of almost non-interacting disks.

The magnetoresonance experiments were performed at 70-80 GHz frequency band and at temperature T=4.2 K. The static external magnetic field was applied perpendicularly to the disks array [5].
In our experiments we used two-mirror opened resonator, consisting of flat and spherical mirrors as a magnetoresonance cell in millimeter waveband (Fig. 1). Mirrors are connected to the rectangular waveguide with a coupling slot.

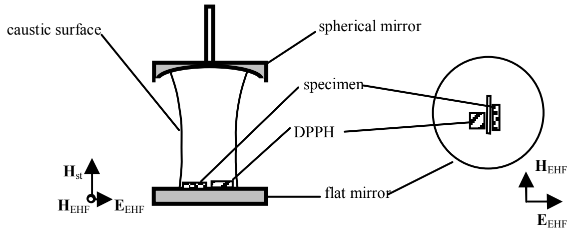

Figure 1 “Parallel” and “normal” orientations of specimen for two-mirror open resonator ESR cell

The diameter of each mirror is 30 mm, and the distance between the mirrors can be varied within 10-20 mm. Two orientations of the sample relatively to the static magnetic field (“parallel” and “normal”) are possible. If the direction of external magnetic field is parallel to the plane of the specimen we have the so-called “parallel” orientation. If the direction of external magnetic field is normal to the specimen plane we have the “normal” orientation (Fig. 1). In experiments described below we used only “normal” orientation. The standard DPPH-marker (DPPH is the organic chemical compound 2,2-diphenyl-1-picrylhydrazyl) was located in the vicinity of the specimen.

Results and discussion

As a result of experiments the magnetoresonance absorption spectra, containing not only the fundamental mode (L1) but also modes, which most likely are spin-wave modes (L2, L3) in nanodot systems have been obtained.

To demonstrate the typical absorption spectrum we selected the specimen with D=500 nm due to its strongest signal.

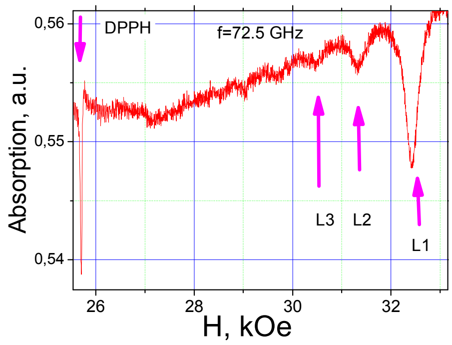

Figure 2 FMR absorption spectra for specimen with D=500 nm (“normal” orientation)

For the rest specimens it is difficult to define the non-uniform (spin wave) modes because the “signal to noise” ratio is quite small (less than 10). The Fig.2 presents the typical FMR absorption spectrum for the sample with D=500 nm. The Fig. 3 shows the resonance frequency-field dependence and Fig. 4 shows the frequency dependence of the magnetic resonance linewidth for the same specimen. The value of “signal to noise” ratio, achieved for specimens with D= 4000 nm, 2000 nm, 1500 nm, 1000 nm, 250 nm allows to identifyconfidently only the basic uniform FMR-mode and the first mode of spin wave. At the same time, the DPPH-response (see, for inst. Fig. 5) can be determined easily.

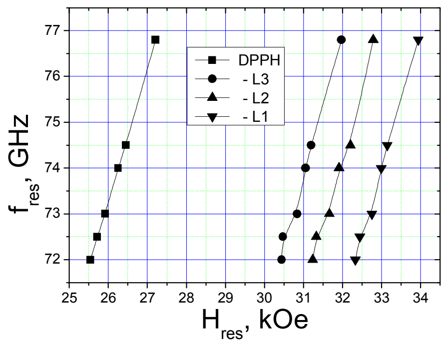

Figure 3 Resonance frequency-field dependence for specimen with D=500 nm

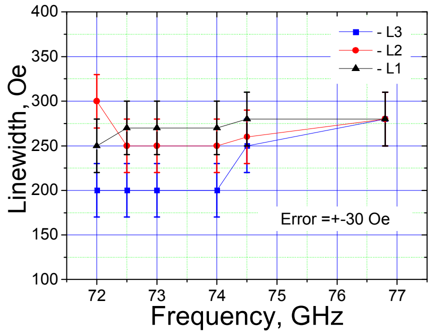

Figure 4 Frequency dependence of the magnetic resonance linewidth (for D=500 nm)

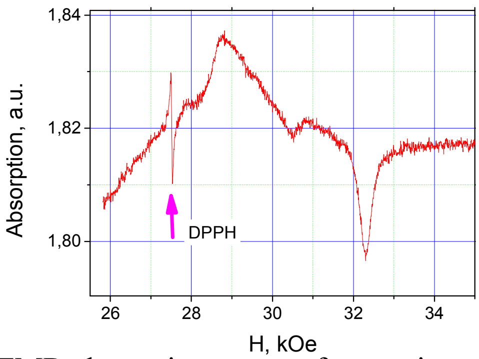

Figure 5 FMR absorption spectra for specimen with D=250 nm

Such decreasing intensity can be explained by 2D character the specimens' topology. In such a case the perturbation of the magnetic order in the thin-film nanodot system when the temperature falls toward liquid helium seems to be very probable. However this suggestion should be verified by detailed experimental study.

Summary

The FMR magnetoresonance absorption spectra in the set of arrays of non-interacting permalloy nanodiscs were detected for T=4.2 K and at high frequency range 65-75 GHz. For the specimen with D=500 nm the magnetic resonance linewidthes of spin waves differ at frequencies 72-74 GHz and tend to be equal at high frequencies (above 77 GHz). The structure of the spectrum is similar to the spectra of the same systems for frequencies of 9-10 GHz at room temperature [3]. We note very high signal/noise ratio for specimens under study, which make it possible to identify confidently only restricted number (two) of spin wave modes. The possible reasons of such behavior need further experimental and theoretical investigations and are the subject of further analysis.

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References

Reference an article:

[1] I. Žutić, J. Fabian, S. Sarma, Spintronics: Fundamentals and applications, Rev. Mod. Phys. 76 (2004) 323-410.

[2] B. Pigeau, et al., A frequency-controlled magnetic vortex memory, Applied Physics Letters. 96 (2010) 132506.

[3] G.N. Kakazei, T. Mewes, P.E. Wigen et al., Probing Arrays of Circular Magnetic Microdots by Ferromagnetic Resonance, J. Nanoscience and Nanotechnology. 8 (2008) 2811-2826.

[4] F.G. Aliev, J.F. Sierra, A.A. Awad, G.N. Kakazei, D.-S. Han, S.-K. Kim, V. Metlushko, B. Ilic, and K.Yu. Guslienko, Spin waves in circular soft magnetic dots at the crossover between vortex and single domain state, Phys. Rev. B. 79 (2009) 174433-1-174433-7.

[5] S. Tarapov, S. Roschenko, S. Nedukh et al., Electron spin resonance properties of magnetic granular GMI-nanostructures in millimetre waveband, International Journal of Infrared and Millimeter Waves, 25 (2004) 1581-1589.

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