Relaxation time of parametrically excited magnetostatic modes in YIG

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Abstract

Parallel pumping experiments were conducted on a single crystal yttrium iron garnet sphere. Microwave radiation from magnetostatic modes, which were parametrically excited through parallel pumped spin-waves, was studied experimentally at several temperatures. As excitation microwave power is turned off, it will be thought that microwave radiation decreases exponentially. Relaxation time of a magnetostatic mode, which is excited beyond thermal equilibrium level, is estimated by this method.

Key words: YIG ; parametrically excited magnon ; relaxation time ;

1. INTRODUCTION

A nonlinear effect of a ferromagnetic resonance is characterized by the threshold microwave power P_{thr}. In parallel pumping experiments, where a microwave magnetic field is applied parallel to a static field, a magnon (spin-wave) system keeps a thermal equilibrium state at pumping power $P < P_{\mathrm{thr}}$. Just above P_{thr}, the number of magnons in a very narrow region in a wave-number space, i.e., resonant magnon, grows exponentially[1]. We study change of relaxation time at liquid nitrogen and liquid helium temperatures. Temperature dependence of relaxation time in magnetostaic mode is reported.

For a ferromagnetic spherical sample, the dispersion relation is as follow,

$$\omega_k/\gamma = \left[(H_i + H_e a^2 k^2) \times (H_i + H_e a^2 k^2 + 4\pi M_0 \sin^2\theta_k)\right]^{1/2} \quad (1)$$

where γ is gyromagnetic ratio, θ_k is angle between k and the applied field, and $H_i = H_0 - 4\pi N_Z M_0$. Here, H_0, M_0, N_Z, H_e is applied dc magnetic field, saturation magnetization, demagnetizing factor along the applied field, an exchange field, respectively. The result of Eq.(1) is a band of dispersion curves bounded by the $\theta_k = 0$ and $\theta_k = \pi/2$. Equation 1 is applicable until the wave length is perhaps one-tenth the size of the spheroid, beyond which the effect of the boundaries becomes significant[2].The spectrum is completed by the magnetostatic modes, which locate at k=0 limits of Eq.(1). At a nonequilibrium state parametrically excited spin-waves are nonlinearly coupled with magnetostatic modes. An energy flow from spin-wave to magnetostatic modes is observed by detecting microwave radiation from magnetostatic modes.

2. EXPERIMENTS

Experiments were carried out at the X-band with a single crystal sphere of YIG. The microwave was generated by HP 83624A synthesized sweeper and amplified upto 40W by a traveling wave tube. The pulse modulation of microwave power was employed. The measurement section was a short-circuited X-band wave-guide,

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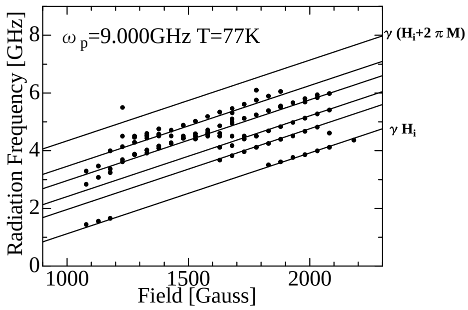

Fig. 1. Radiation frequency as a function of static field at 77K.

in which an open dielectric resonator (ODR) with the sample YIG was installed. Both a microwave and a static magnetic fields are applied along the [111] direction, which is the easy magnetization axis. To study radiation signal from the sample, it was surrounded by a wire loop. This loop was connected with coaxial cable to a spectrum analyzer. The plane of the loop was parallel to the microwave field h , so that the disturbance of the field in the ODR was minimal.

3. RESULTS AND DISCUSSION

A static field dependence of the radiation microwave frequency at 77K is shown in Fig.1. Solid lines are magnetostatic modes calculated by Walker[2]. This result shows that observed radiations were generated from magnetostatic modes. Similar experiments were conducted at 4.2K. Open diamonds in Fig.2 show FMR points of magnetostatic modes. Closed circles are microwave radiation frequencies as a function of a static field. All points locate on magnetostatic modes or $\omega_p/2$ lines. Microwave radiation at half the pumping frequency from parallel pumped spin-waves have been reported elsewhere[3].

In order to investigate relaxation process of magnetostatic mode, we study a time dependence of radiation power. Each radiation modes are measured independently by the spectrum analyzer. Figure 3 shows time

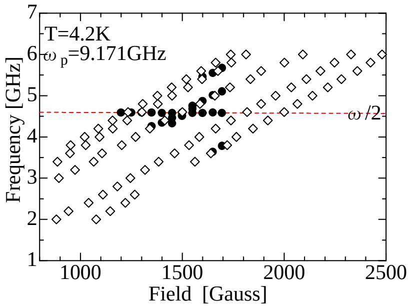

Fig. 2. FMR frequency and microwave radiation frequency as a function of static field at 4.2K.

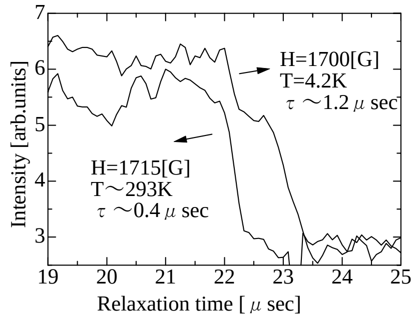

Fig. 3. Time dependence of radiation power at 293K and 4.2K.

dependence of the microwave radiation power from (110) magnetostatic mode at 293K and 4.2K. The excitation microwave, which was modulated as a pulse shape, was stopped at 22 μ sec in Fig.3. The radiation power decreases exponentially from this moment. The relaxation time of magnetostatic mode in a nonequilibrium state is estimated from this method. Observed relaxation times are 0.4 μ sec at 239K and 1.2 μ sec at 4.2K. The relaxation time estimated from a line width of a ferromagnetic resonance is 0.3 μ sec at room temperature. Two relaxation times are consistent with each other. The relaxation time of spin-waves is also obtained from parallel pumping threshold microwave field. A relaxation time of spin-wave at 4.2K is about four times long comparing to a room temperature result. This temperature dependence is consistent with our result also.

In conclusion, relaxation times of excited magnetostatic modes are studied by a time dependence of microwave radiation. Temperature dependence of magnetostatic modes has similar property in comparison to spin-waves even in a nonequilibrium state.

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