TE_{102} Mode Rectangular Cavity Resonator for FMR Measurement

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I. Introduction

In spintronics society, the tool to study the magnetization dynamics, which is the ferromagnetic resonance (FMR) linewidth measurement technique provides a convenient way for measuring damping parameters in magnetic materials [1]. For the measurement, the DUT (device under test) is placed at the center of a cavity at which the magnetic-field component of the microwave mode is maximized while the electric-field component is minimized. In order to obtain accurate damping parameters, we need to get a good performance cavity (highly quality factor).

In this study, we describe FMR measurement utilizing a rectangular cavity (TE_{102} mode) resonator operating at 9.5 GHz.

II. Design and Mechanical Construction of the Cavity Resonator

In theory, the values of a = 22.9 mm and b = 10.2 mm, the two entrance dimensions of the rectangular cavity, correspond to the ones of a WR-90 waveguide. The unloaded quality factor Q_0 and the cavity resonance frequency f_0 can be evaluated by using Eqs.(1)-(2) [2]: the values of 9810 and 9.5GHz are respectively found for the TE102 mode.

$$Q_0 = \frac{\lambda}{\delta} \times \frac{\left(\frac{abd}{4\pi}\right)\left(k_x^2 + k_y^2\right)\left(k_x^2 + k_y^2 + k_z^2\right)^{\frac{3}{2}}}{\left(\frac{ad}{2}\right)\left[k_x^2 k_z^2 + \left(k_x^2 + k_y^2\right)^2\right] + bd\left[k_y^2 k_z^2 + \left(k_x^2 + k_y^2\right)^2\right] + abk_z^2\left(k_x^2 + k_y^2\right)} \qquad (Eq.1)$$

In Eq.(1) kx=mπ/a, ky=nπ/b, and kz=pπ/d; d=43.6 mm represents the length of the rectangular cavity, $\delta = \sqrt{2\rho/\omega\mu}$ the skindepth, λ the free wavelength, and ρ the resistivity of the metal (gold resistivity: 2.4 $\mu\Omega cm$).

$$f_0 = \frac{c}{2n_0} \times \left(\frac{m^2}{a^2} + \frac{n^2}{b^2} + \frac{p^2}{d^2}\right)^{\frac{1}{2}} \qquad (Eq.2)$$

n_0=1.0003 is the air index of refraction (20°C, 1 atm).

III. Testing of the Rectangular cavity and Discussion

For testing of the rectangular cavity resonator, we can measure the reflected microwave voltage as a function of the frequency from a rectangular resonant cavity (Fig. 1). From the result, the reflected microwave voltage shows a sharp absorption peak at f_0=9.40202 GHz, which means the microwave energy is absorbed at the resonance frequency. And the resonance frequency is shifted about 0.1 GHz from the expected value (f_0=9.5

GHz). This difference might be caused by roughness of the cavity wall or mechanical error from the machining work. Then we confirmed that the rectangular cavity is characterized by their Q_0 or unloaded quality factor, which indicates how efficiently the cavity stores microwave energy. The Q_0 factor is expressed as $f_0/\Delta f$. The f_0 is the resonant frequency of the cavity resonator and Δf is the width at half height of the absorption energy peak. In Fig. 1, we obtained that the width at half height of the resonance is approximately Δf=2.1587 MHz. And measured(expected) value of Q_0 factor is 8710 (9810) in homemade rectangular cavity. Our design of rectangular cavity has better than commercial rectangular standard cavity (The unloaded cavity Q is about 6000 [3])

In order to examine, we use the rectangular cavity resonator, which has ferromagnetic resonance (FMR) experiment by using Py sample at different magnetic field. And the modulation frequency is 10 kHz. The Py sample size is 4 mm x 4 mm x 30 nm (Fig. 2). As shown in Fig. 2, the blue line represents absorption peak which happen resonance frequency (9.3825 GHz) and external magnetic field (1.2 kOe). This blue line show that the condition of FMR phenomena fulfilled between RF frequency and precession of magnetization frequency. So the microwave power is absorbed by the resonance condition. The point of black shows first derivative of absorption peak.

IV. Conclusion

In conclusion, we designed and made X-band cavity resonator to measure the ferromagnetic resonance field (H_0) and linewidth, which parameters are essential to investigate the Gilbert damping parameter and saturation magnetization from the ferromagnetic resonance (FMR). Recent mechanical machine tools have capable of high precision manufacturing and home made rectangular cavity resonator shows higher Q values compare with that of the commercial one.

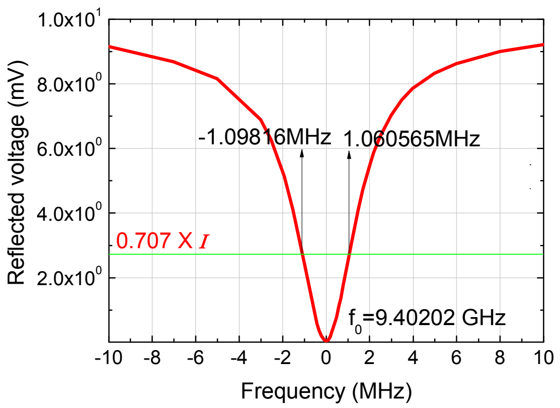

Figure 1. The reflected microwave voltage as a function of the frequency in rectangular cavity.

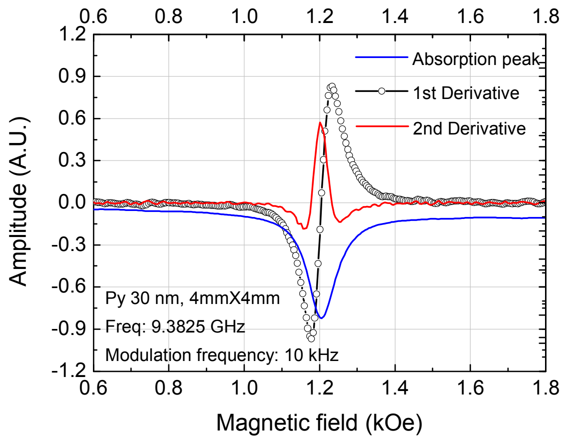

Figure 2. Ferromagnetic resonance (FMR) experiment by using Py sample at different magnetic field.

V. Reference

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