Strong interaction between light and electrons (6)

"Coupling constant and line width"

Product used : Electron spin resonance spectrometer (ESR)

When an ESR spectrum of paramagnetic sample is measured in the state subjected to the Purcell effect, its line width broadens extraordinarily as shown in Application Note ER200006E. It would be a serious problem in which we must reduce the filling factor when a sample which has many spins is measured using a cavity. This is not a problem only with a ferromagnetic sample, but also with a paramagnetic one as well. How much should we reduce the filling factor by? To obtain a rough guide for it, ESR spectral line widths (ΔH_{pp}) and shift widths of cavity frequency (Δf) were simultaneously measured on the respective sample position moved as shown in Fig. 1(a).

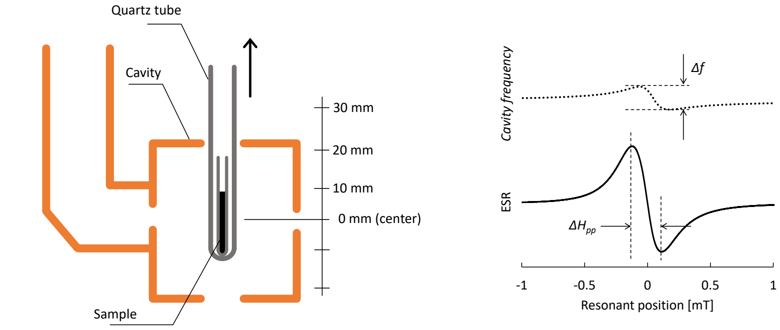

Fig.1 A drawing of the experiment which investigates a relation with sample moving and line width.
(a) Sample location in the cavity. (b) Measurement examples of Δf (upper) and ΔH_{pp} (lower).

Relationship between frequency shift and line width in the state subjected to Purcell effect

As increasing the sample amount, frequency shift width also increases. Thus, it can be considered that there is a correlation between coupling constant g_m and frequency shift Δf in the state subjected to the Purcell effect. Simulation results of frequency shift widths at several g_m values based on S_{11} equation[1][2] show a correlation according to quadratic function related to g_m (*conf.* Fig. 2(a)). In this simulation, we have set Q_u = 18000 and $\gamma_m/2\pi$ (HWHM) = 3.39 MHz. Therefore, it can be considered that the observed line width ΔH_{pp} is proportional to Δf, because ΔH_{pp} is proportional to g_m^2[2]. As a result, by plotting ΔH_{pp} at respective Δf, sample intrinsic line width and optimal filling factor (optimal sample position) can be estimated. As shown in Fig. 2(b), ΔH_{pp} can be fitted by linear function. By moving a sample to the position until the line width is no longer changed (in this case, more than + 30 mm), Normal spectrum and analysis which is not affected by a strong interaction between photon and spins is capable, even if spin density is high. This is a little troublesome experiment. However, this experiment is also effective on ESR/FMR measurements using more concentrated magnetic samples. Using this plot would be useful to study about the effect of the interaction between photon and spins.

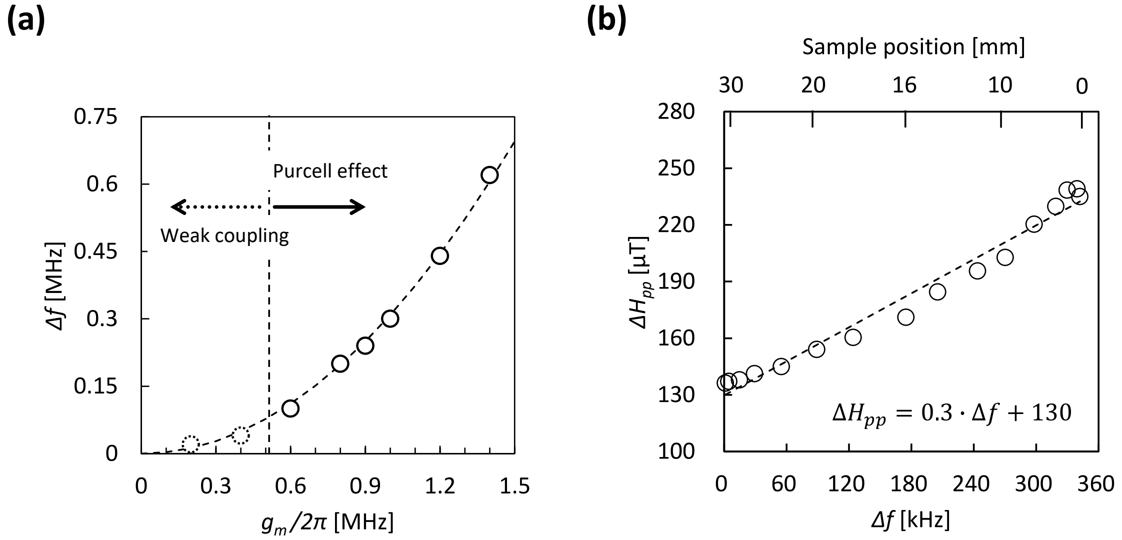

Fig.2 (a) Simulation results about the relation with g_m and Δf. (b) Spectral line width ΔH_{pp} plotted at respective observed Δf.

Reference: [1] E. Abe, H. Wu, A. Ardavan, and J. J. L. Morton, Appl. Phys. Lett. **98**, 251108 (2011).
[2] Patent, US10288707B2 "Relaxation time measuring method and magnetic

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