Long distance coupling between two YIG spheres

Yutong Zhao

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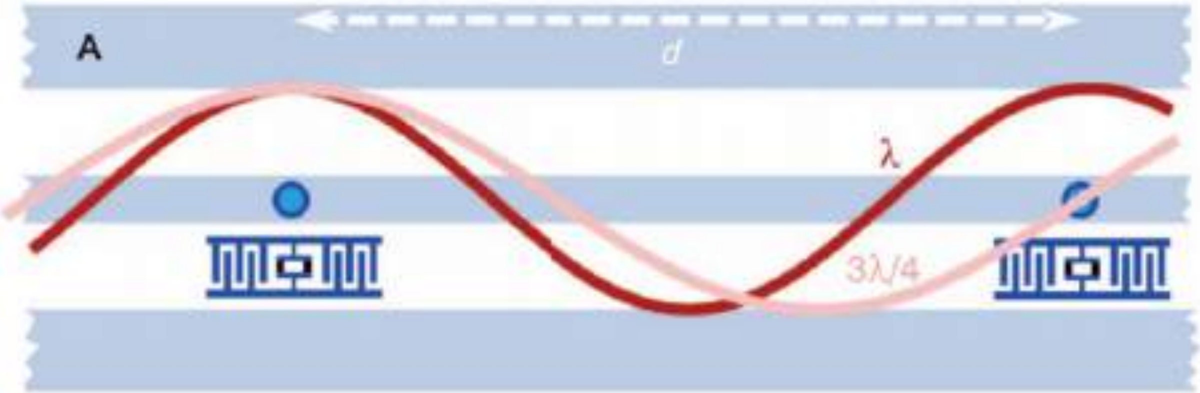
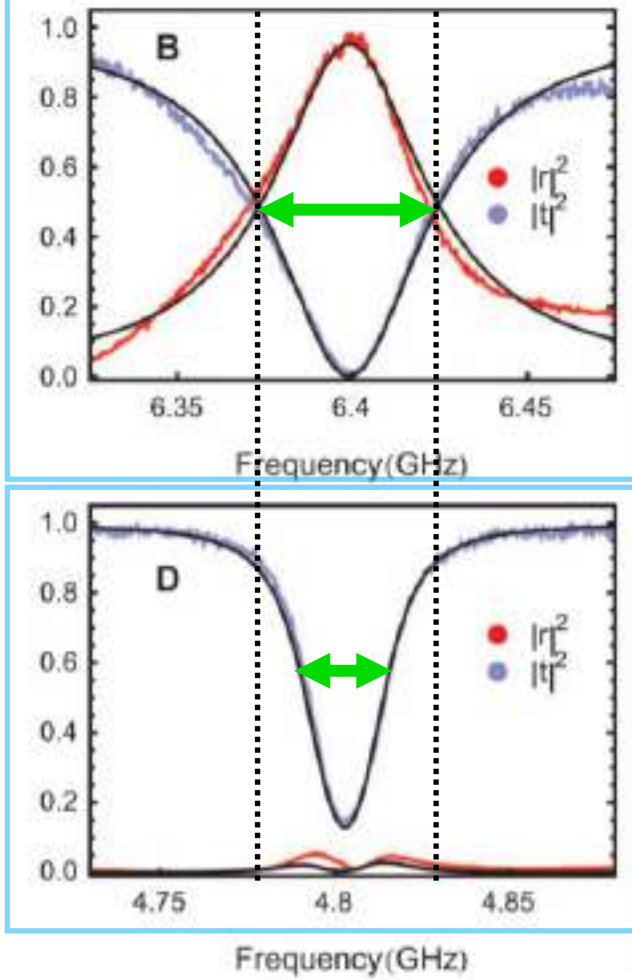
Photon-Mediated Interactions Between Distant Artificial Atoms

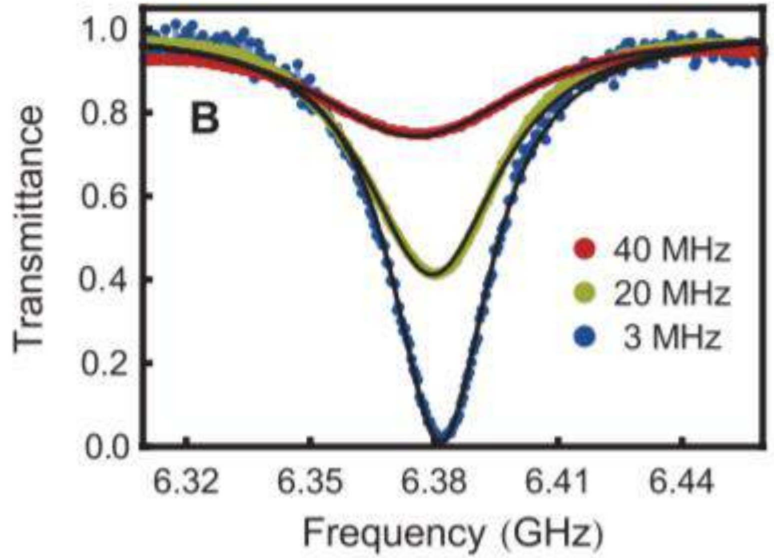
Arjan F. van Loo,[1*] Arkady Fedorov,[1†] Kevin Lalumière,[2] Barry C. Sanders,[3]
Alexandre Blais,[2] Andreas Wallraff[1]





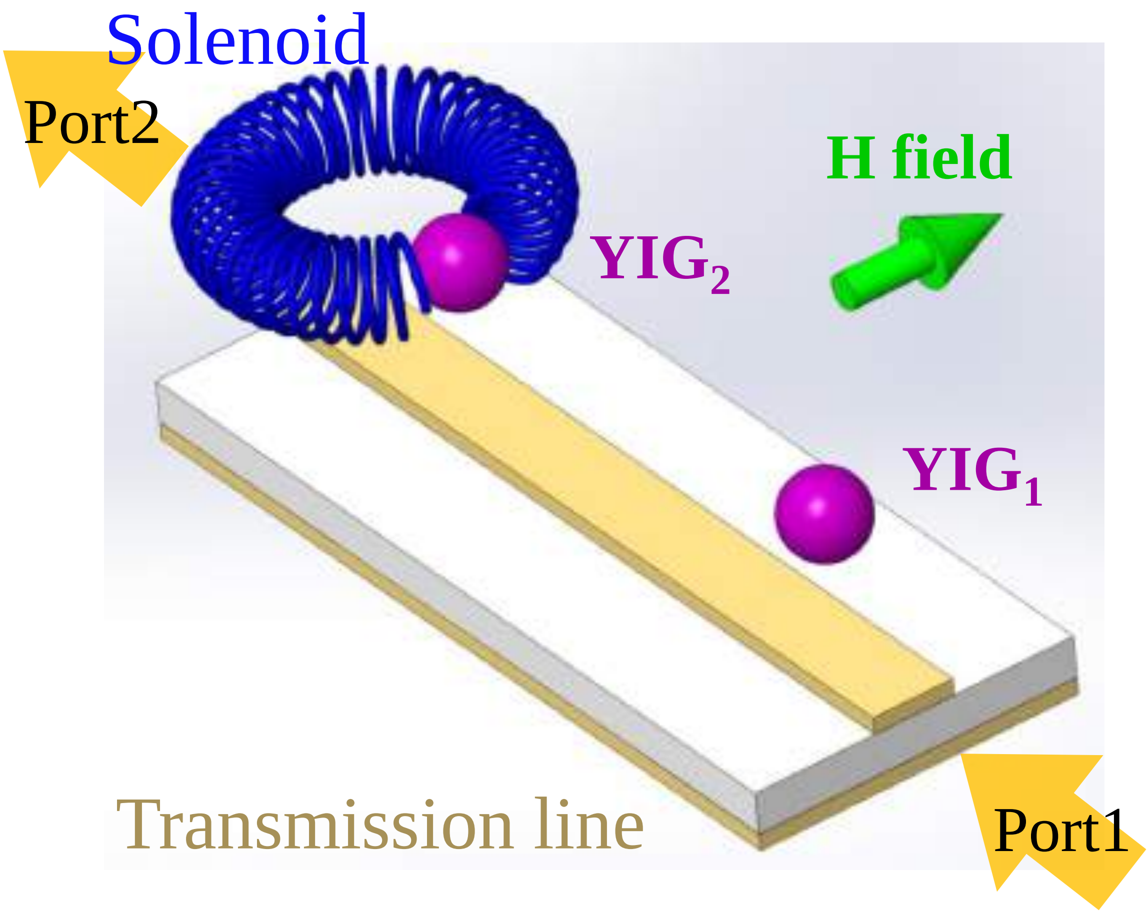
$$d \sim \lambda$$

$$d \sim \frac{3}{4}\lambda$$

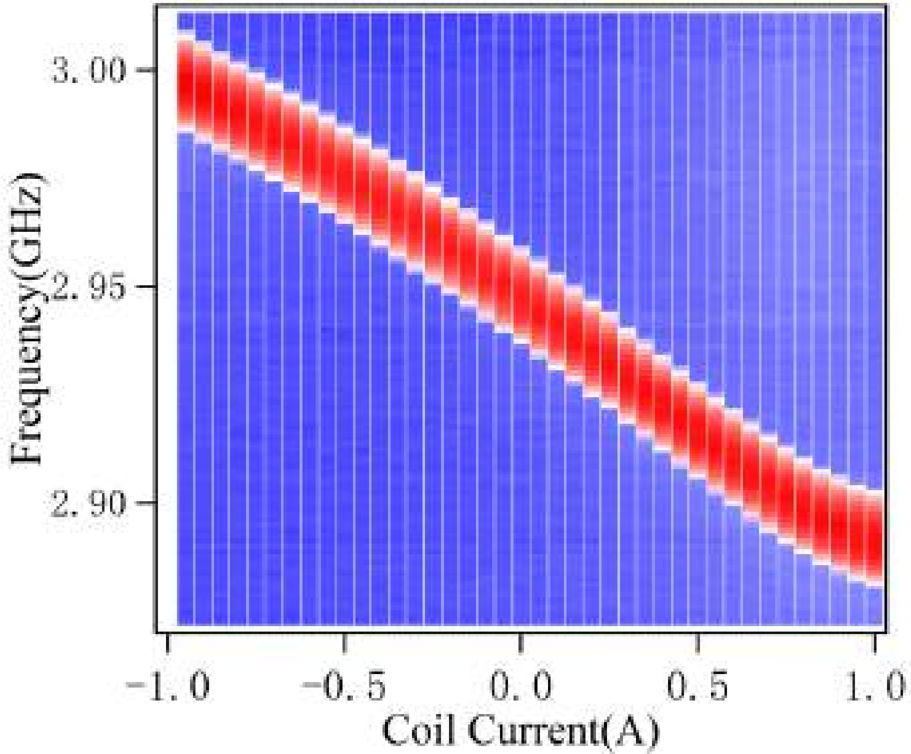


Single qubit Spectrum

Experiment Setup



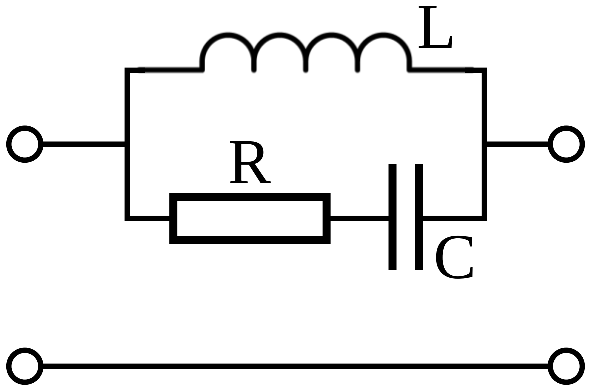
Mapping with only YIG$_2$



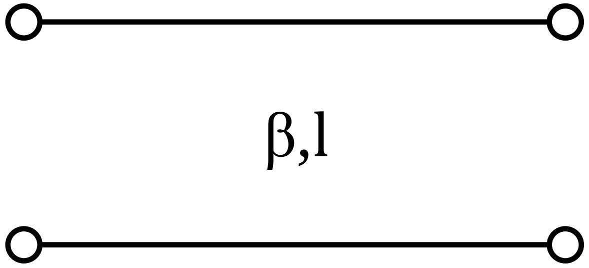
Range:
~120MHz
~ 35Gs

Theory (RLC circuit)

- YIG and transmission line



$$Z_R = R$$
$$Z_L = i\omega L$$
$$Z_R = \frac{1}{i\omega C}$$



$$Z_s = \frac{i\omega L - LCR\omega^2}{1 + iRC\omega - CL\omega}$$

$$Z_s = Z_0$$

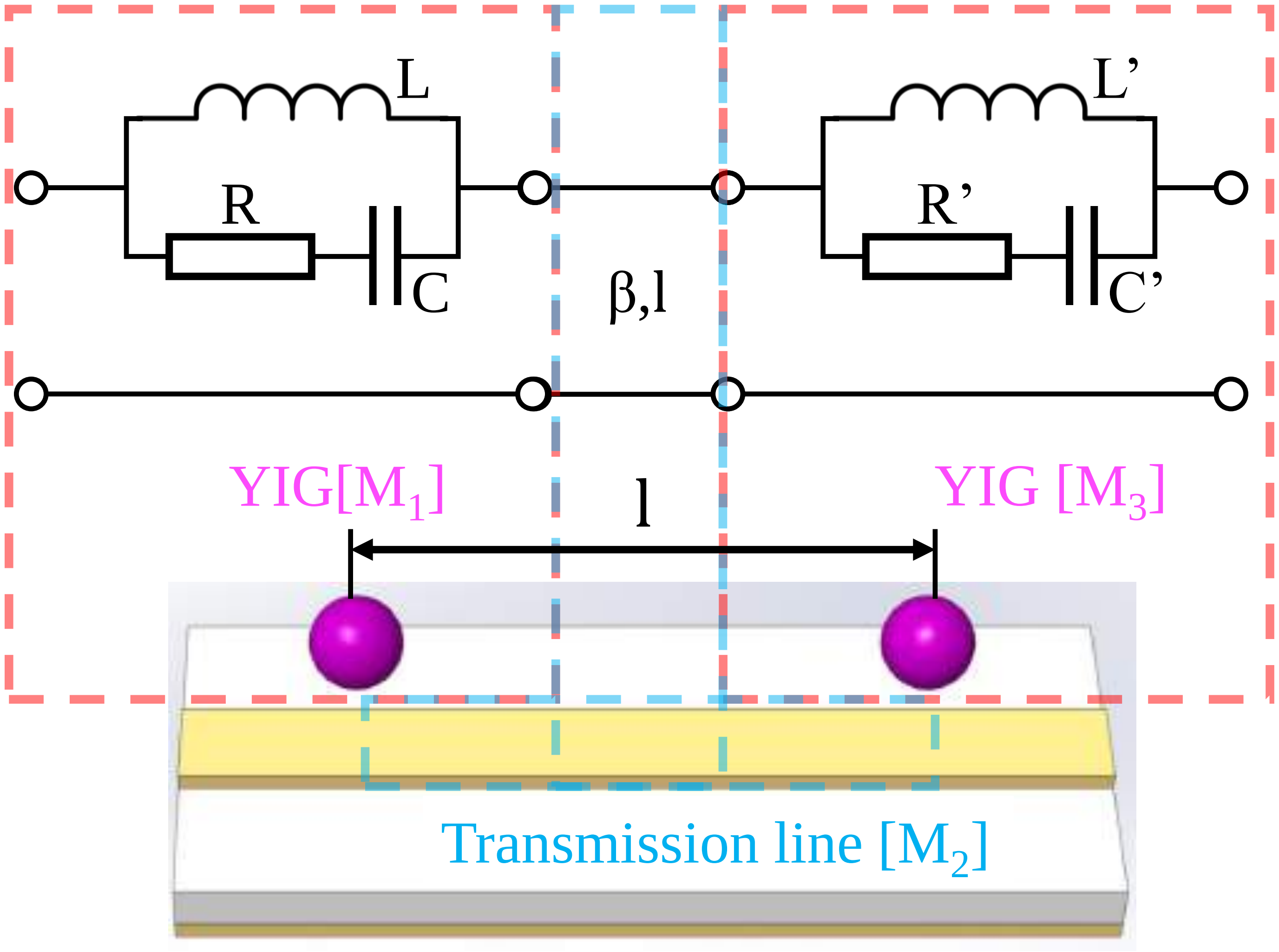
$$\mathrm{M}_1 = \begin{pmatrix} 1 & Z_s \\ 0 & 1 \end{pmatrix}$$

$$M_2 = \begin{pmatrix} \cos(\beta l) & i \cdot \mathrm{Z}_0 \sin(\beta l) \\ i \cdot \mathrm{Z}_0^{-1} \sin(\beta l) & \cos(\beta l) \end{pmatrix}$$

$$S_{21} = \left| 1 - \frac{\frac{g}{2Z_0}}{i(\omega_0 - \omega) + \Delta\omega + \frac{g}{2Z_0}} \right|$$

$$|S_{21}| = |\cos(\beta l) - isin(\beta l)\,| = 1$$

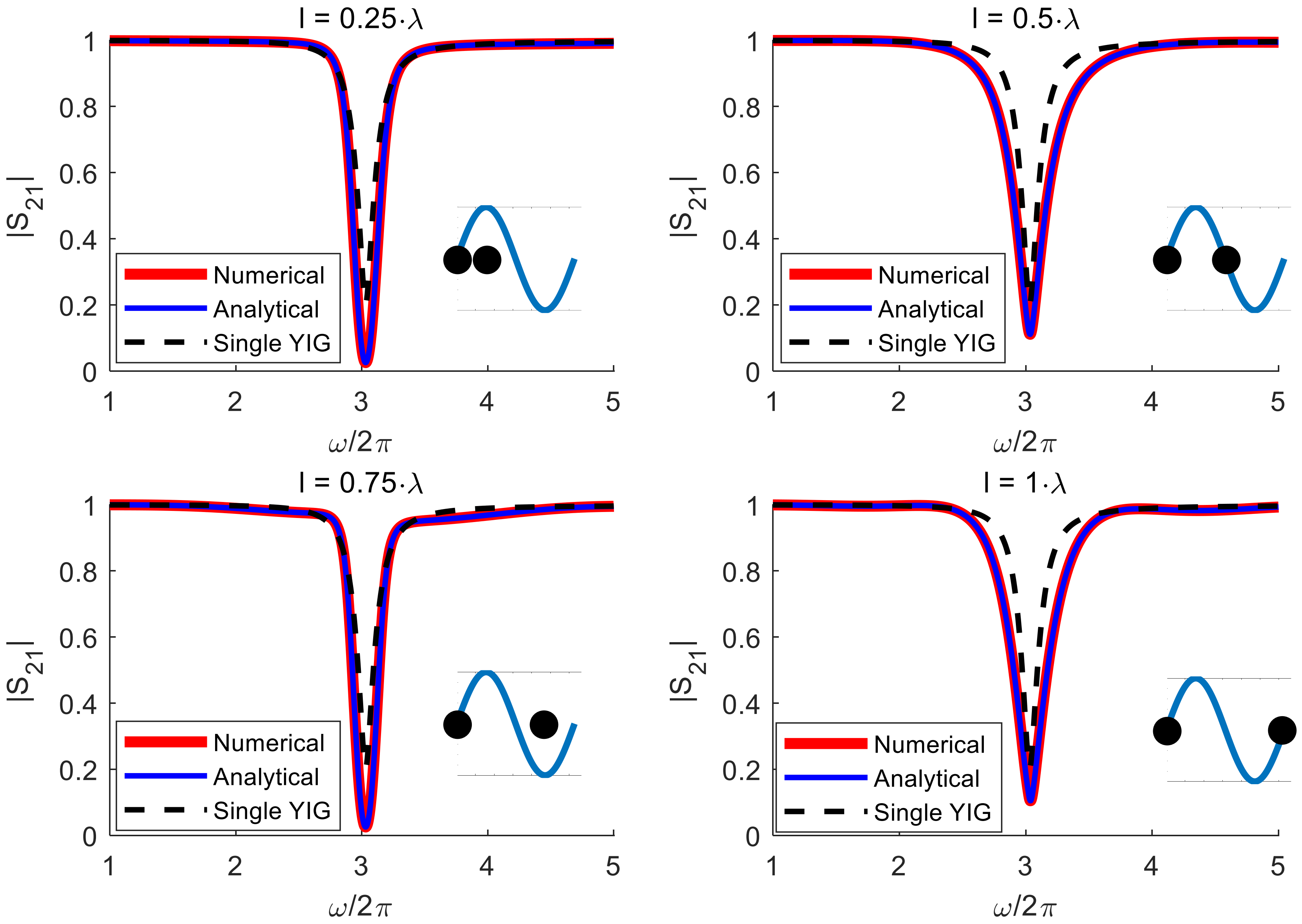
RLC model of two YIG sphere



$$M = M_1 \cdot M_2 \cdot M_3$$

$$S_{21} = \left| \frac{2}{\boxed{\cos(\beta l) \cdot \left(2 + \frac{Z_s}{Z_0} + \frac{Z_s'}{Z_0}\right)} + i\sin(\beta l) \cdot \left(2 + \frac{Z_s}{Z_0} + \frac{Z_s'}{Z_o} + \frac{Z_s Z_s'}{Z_0^2}\right)} \right|$$

RLC Model Calculations



$\cos(\beta l) = 1$
$\sin(\beta l) = 0$

$\cos(\beta l) = 1$
$\sin(\beta l) = 0$

$\cos(\beta l) = 1; \sin(\beta l) = 0$, Pure Lorentzian case

For a single YIG:

$$S_{21} = \left|\frac{1}{\left(1+\frac{Z_s}{2Z_0}\right)}\right| = 1 - \frac{\frac{g}{2Z_0}}{-i(\omega_0-\omega)+\Delta\omega+\frac{g}{2Z_0}}$$

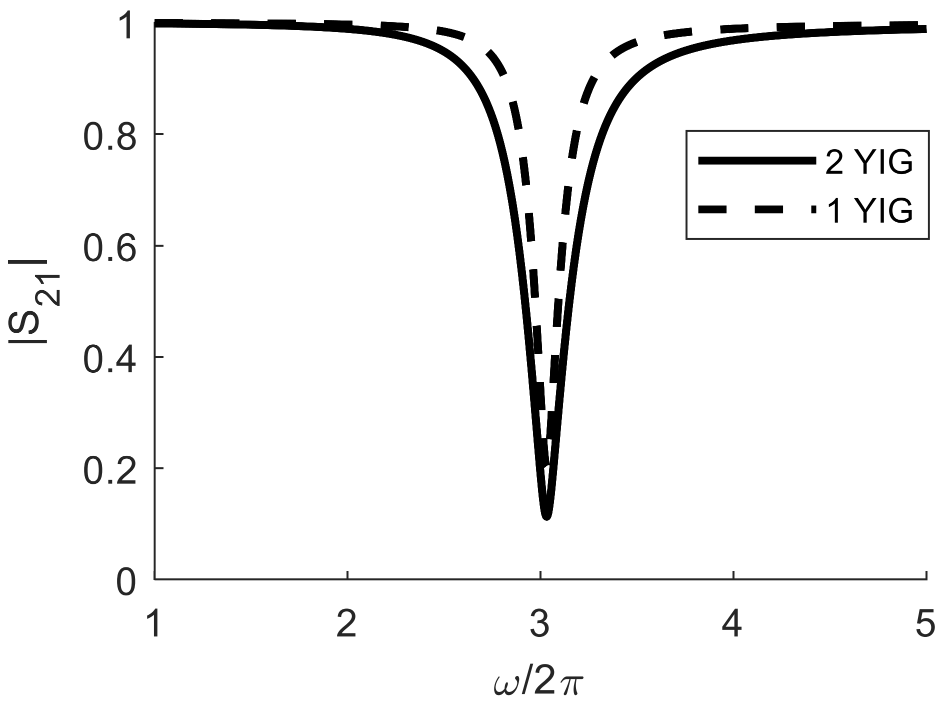
$$g = g_1 + ig_2\omega = \frac{1}{2C} + i\omega\cdot\frac{R}{2}$$

For two identical YIG:

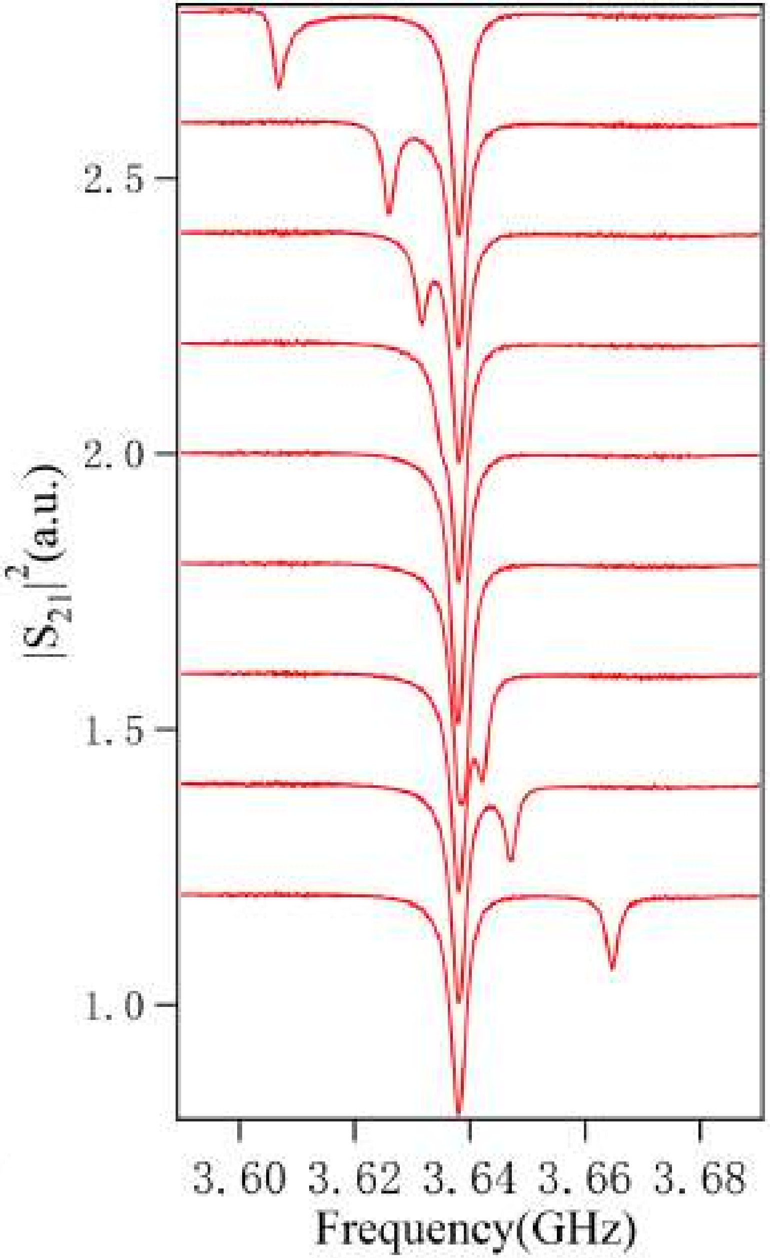
$$S_{21} = \left|\frac{1}{\left(1+\frac{Z_s}{Z_0}\right)}\right| = 1 - \frac{\frac{g}{Z_0}}{-i(\omega_0-\omega)+\Delta\omega+\frac{g}{Z_0}}$$

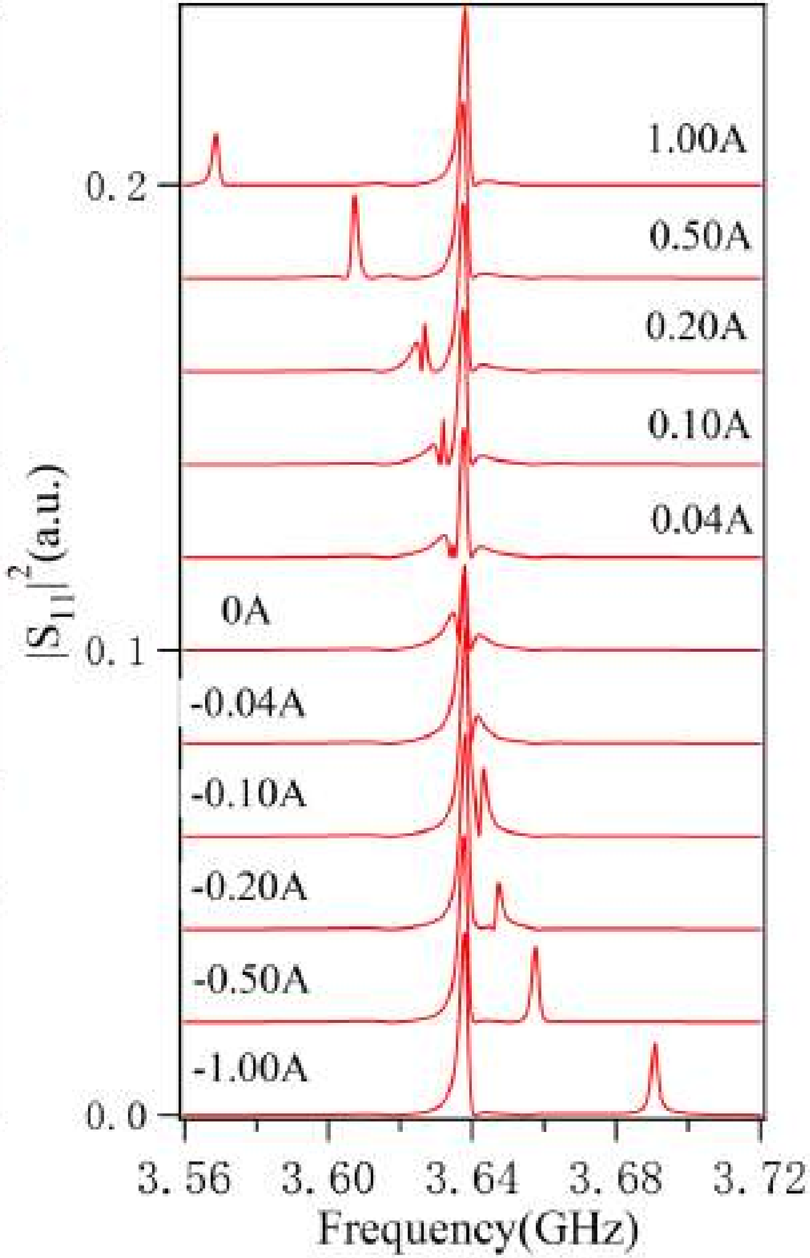
$$\Delta\omega' = \Delta\omega + \frac{g_1}{Z_0} \quad \Rightarrow \quad \text{Linewidth broaden}$$

$$\omega_0' = \frac{\omega_0}{1+\frac{g_2}{Z_0}} \quad \Rightarrow \quad \text{Resonance slightly shift}$$

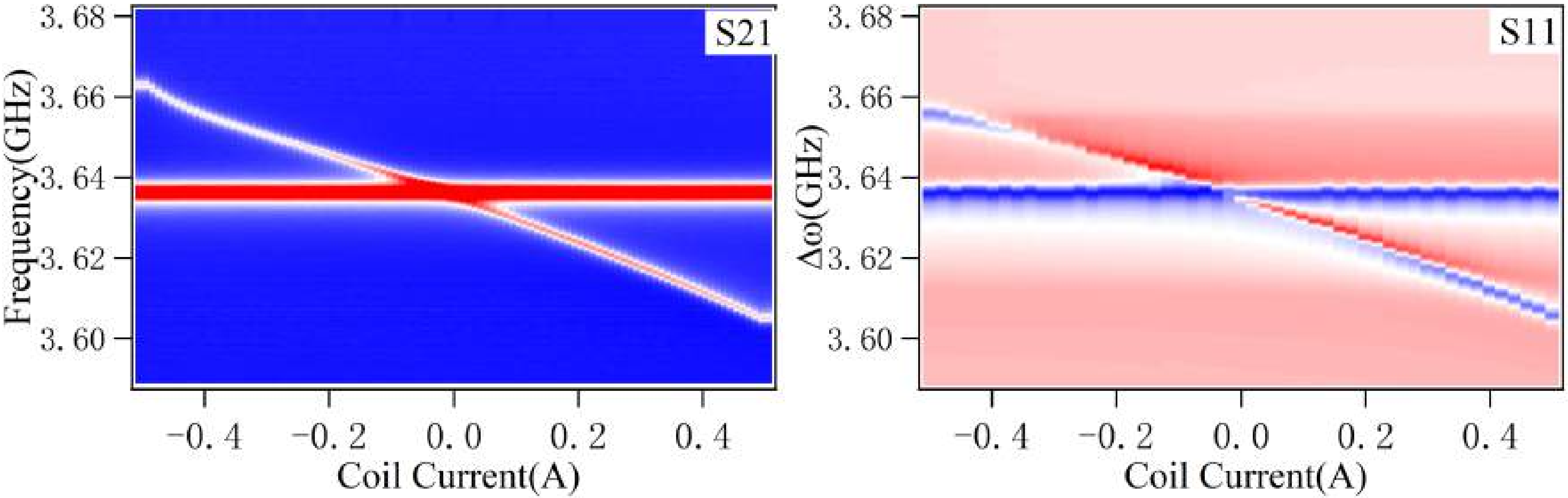


Preliminary Experiment Results





Preliminary Experiment Results (l=35mm~0.77 λ?)



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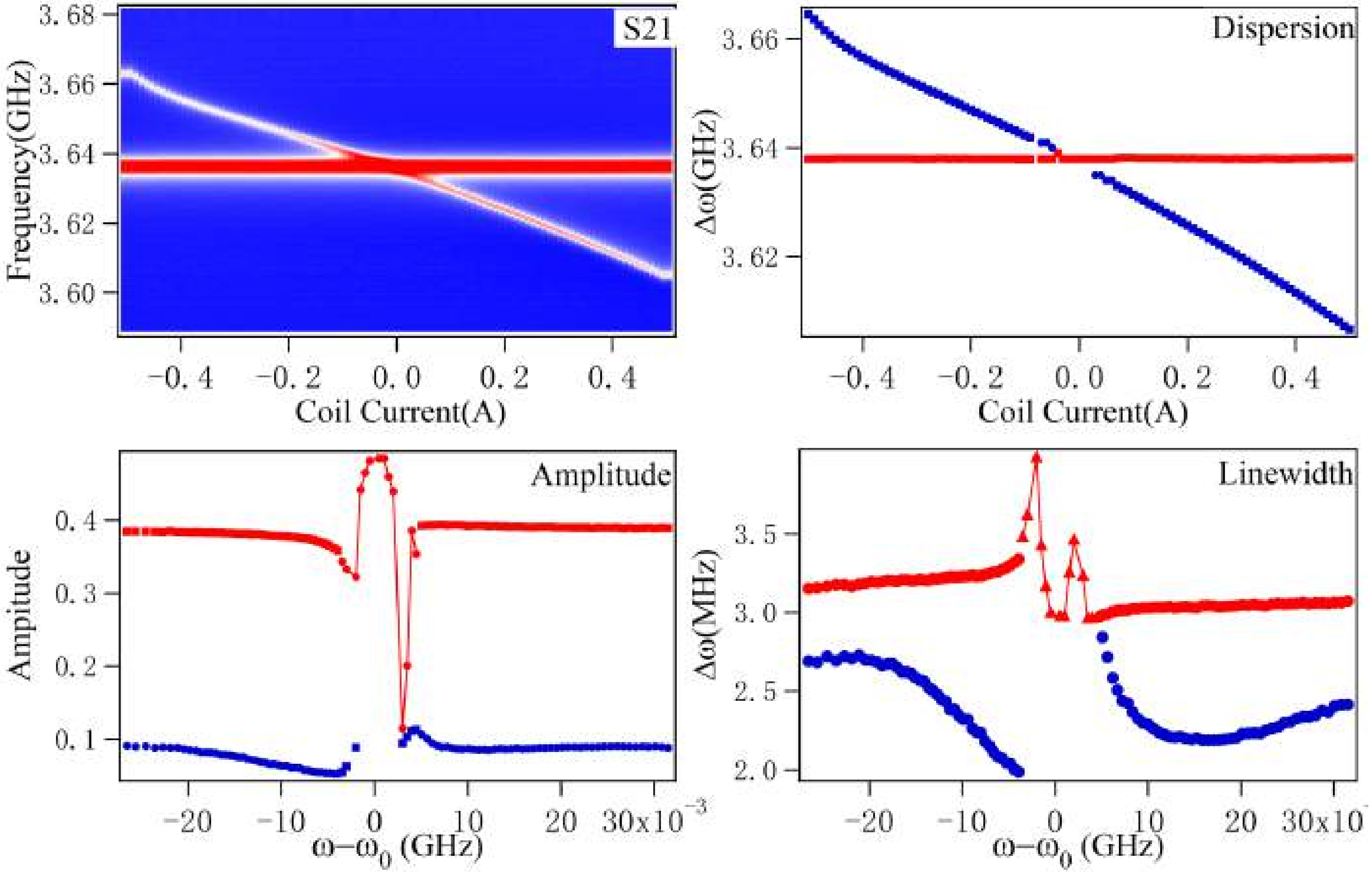
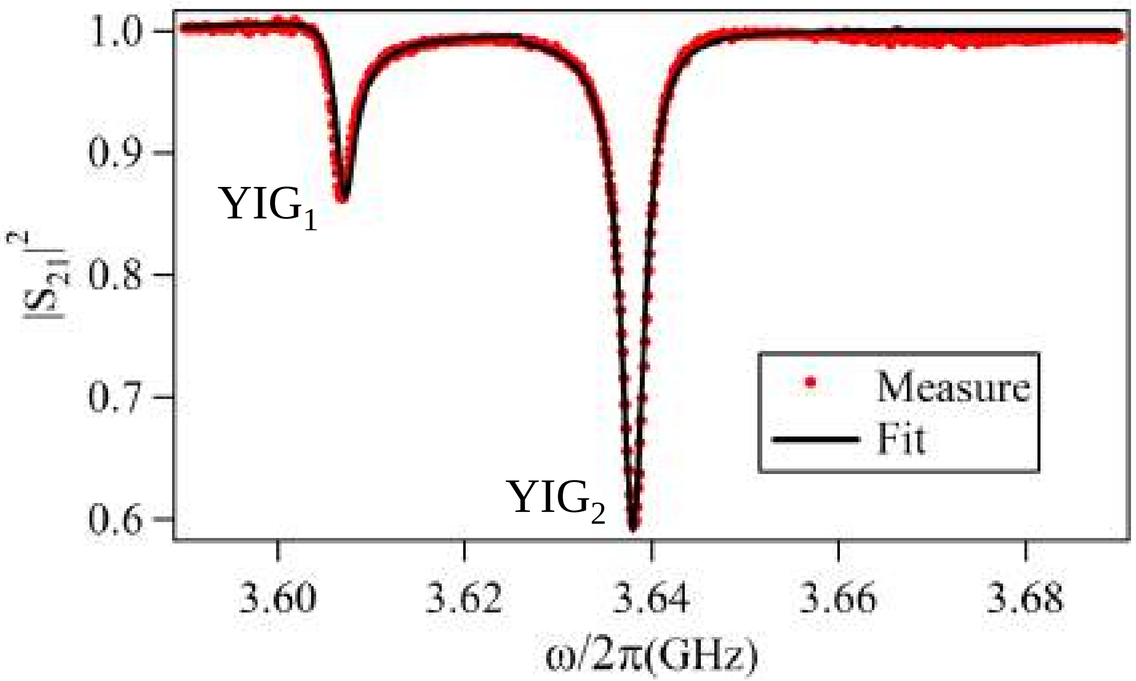


Fitting results



$R_1 = 19.10\ \mu\Omega$
$C_1 = 200.1\ nF$
$L_1 = 7.945$ pH

$R_2 = 9.948\ \mu\Omega$
$C_2 = 180.7\ nF$
$L_2 = 4.138$ pH

Next step

1. More data analysis and theory.
2. Using two identical YIG perform the experiment.
3. Perform more experiments on and A-P cavity.