Supplementary Material for:

Cavity quantum electrodynamics with ferromagnetic magnons in a small yttrium-iron-garnet sphere

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1. Measured transmission spectrum of the cavity without a YIG sphere

Our rectangular three-dimensional (3D) cavity with input/output ports was made of oxygen-free copper and has dimensions $50\times18\times3\ \text{mm}^3$. By adjusting the lengths of the pins inside the input and output ports, the coupling rates of these two ports to the relevant cavity modes are tuned to $\kappa_{\text{i},1}/2\pi=0.19$ MHz and $\kappa_{\text{o},1}/2\pi=0.20$ MHz for the fundamental (first) mode TE_{101} of the cavity, and $\kappa_{\text{i},2}/2\pi=0.85$ MHz and $\kappa_{\text{o},2}/2\pi=0.99$ MHz for the second mode TE_{102} of the cavity. Figure S1(a) shows the transmission spectrum of the 3D cavity without a YIG sphere, as measured at 22 mK. It is found that the frequencies of the cavity modes TE_{101} and TE_{102} are $\omega_{\text{c},1}/2\pi=8.855$ GHz and $\omega_{\text{c},2}/2\pi=10.306$ GHz, respectively. The total cavity decay rates are measured to be $\kappa_{\text{tot},1}/2\pi=1.1$ MHz for the cavity mode TE_{101} and $\kappa_{\text{tot},2}/2\pi=2.4$ MHz for the cavity mode TE_{102}, where the corresponding intrinsic loss rates of the cavity are 0.71 MHz and 0.56 MHz, respectively.

When the transmission spectrum of the 3D cavity without a YIG sphere is measured at room temperature, the resonance frequencies of the cavity shift and the corresponding intrinsic loss rates increase. This is due to the changes of the mechanical and material properties of the 3D cavity, as compared with the cavity at 22 mK. Figure S1(b) shows the measured transmission spectrum of the 3D cavity at room temperature. From the measurement results, it is found that the frequencies of the cavity modes TE_{101} and TE_{102} are $\omega_{\text{c},1}/2\pi=8.822$ GHz and $\omega_{\text{c},2}/2\pi=10.265$ GHz, respectively. The total cavity decay rates are measured to be $\kappa_{\text{tot},1}/2\pi=2.5$ MHz for the cavity mode TE_{101} and $\kappa_{\text{tot},2}/2\pi=5.9$ MHz for the cavity mode TE_{102}, where the corresponding intrinsic loss rates of the cavity are 2.11 MHz and 4.06 MHz, respectively.

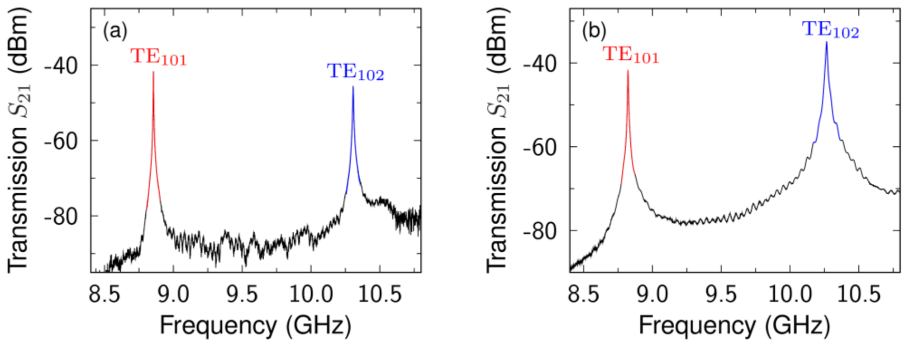

FIG. S1: **Transmission spectrum of the rectangular 3D cavity without a YIG sphere.** (a) Measured transmission spectrum at 22 mK. (b) Measured transmission spectrum at room temperature.

2. Calculated transmission spectrum of the cavity containing a YIG sphere

The transmission of the 3D cavity containing a YIG sphere can be calculated using equation (4) in the main text. Figures S2 and S3 show the calculated transmission spectra, so as to compare with the transmission spectra measured at 22 mK and room temperature, respectively. The parameters used in the simulations are all extracted from the measurement results as provided in the main text and Table 1. Comparing Fig. S2 (S3) with Fig. 2 (3) in the main text, one can see that the calculated transmission spectra agree very well with the measured ones. This indicates the validity of the extracted parameters from the measurement results.

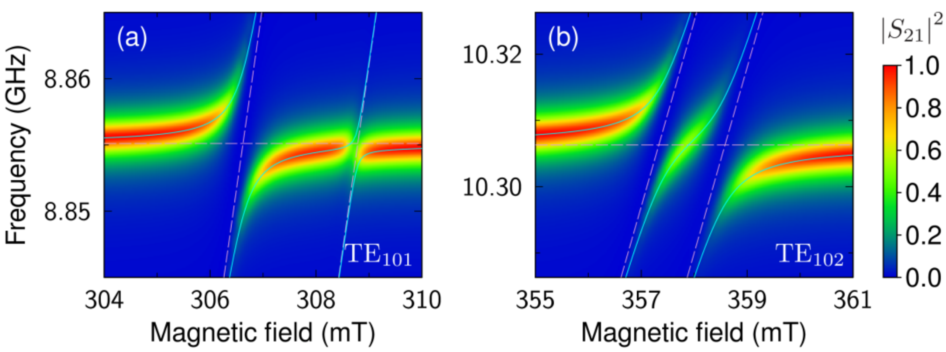

FIG. S2: **Calculated transmission spectra at cryogenic temperature**. Numerical calculations of the transmission spectrum are performed using equation (4) with extracted parameters in the main text and Table 1. The calculated spectra are displayed with different frequencies around (a) the first cavity mode TE_{101} and (b) the second cavity mode TE_{102}.

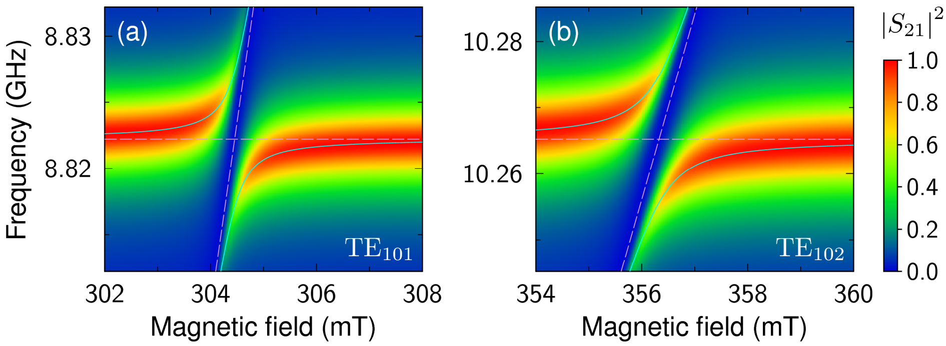

FIG. S3: **Calculated transmission spectra at room temperature.** The calculated spectra are also displayed with different frequencies around (a) the first cavity mode TE_{101} and (b) the second cavity mode TE_{102}.