



# Generation of circulating cavity magnon polaritons in a compact geometry resonator

Maxime Ardisson, Guillaume Bourcin, Jeremy Bourhill, David Spenato, David Dekadjevi, Jean-Philippe Jay, Alain Fessant, Isabella Boventer, Romain Lebrun, Vincent Vlaminck, et al.

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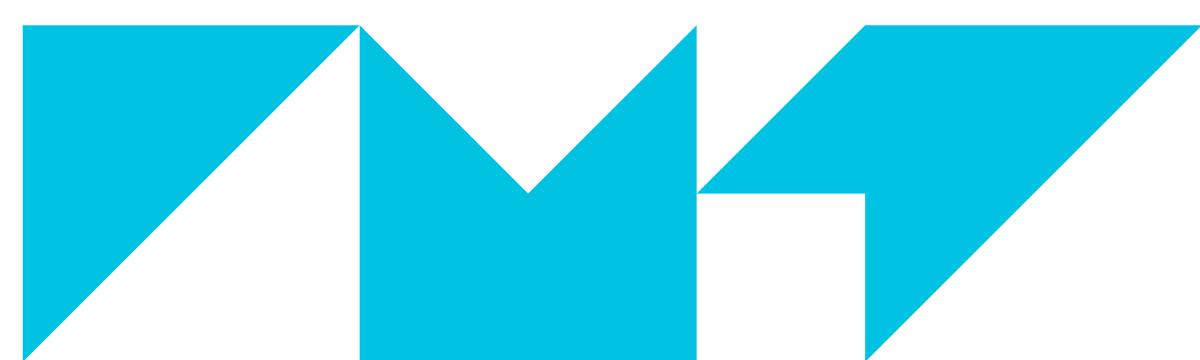
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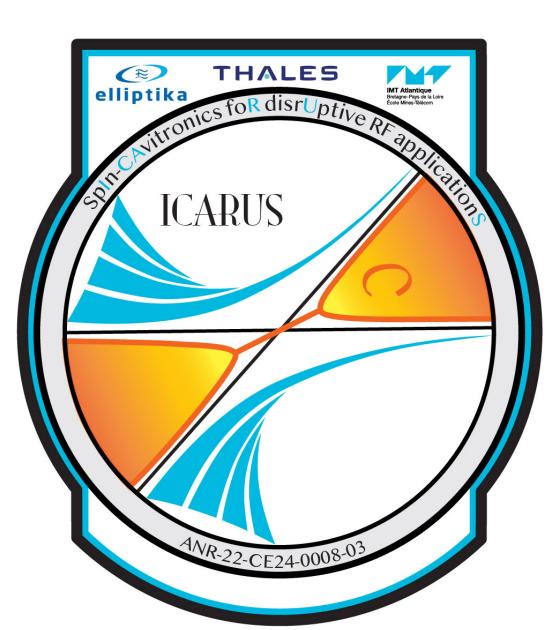
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# GENERATION OF CIRCULATING CAVITY MAGNON POLARITONS IN A COMPACT GEOMETRY RESONATOR

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## INTRODUCTION

PHYSICAL REVIEW APPPLIED

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Editor's Suggestion

Generation of Circulating Cavity Magnon Polaritons

Jeremy Bourhill, Weichao Yu, Vincent Vlaminck, Gerrit E. W. Bauer, Giuseppe Ruoso, and Vincent Castel  
Phys. Rev. Applied 19, 014030 – Published 10 January 2023

► **Generation** of circularly polarised unidirectional cavity magnon polaritons in a torus cavity [1]

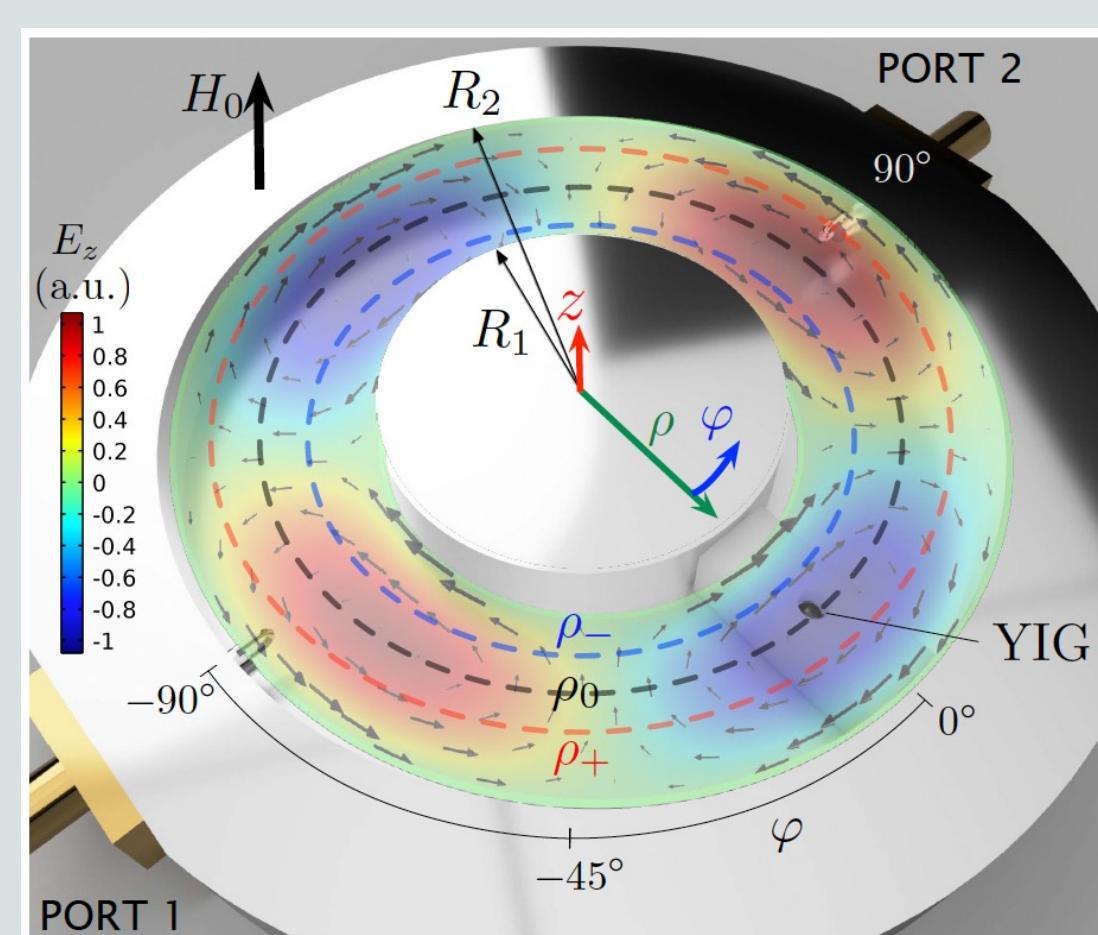
► **Achieved** by the observation of a three-mode interaction picture when the magnetic resonance of a 1.8 mm YIG sphere and a cavity resonance were tuned coincident in frequency and the sphere is positioned at precise radial locations

► **Torus-shaped microwave cavity:**

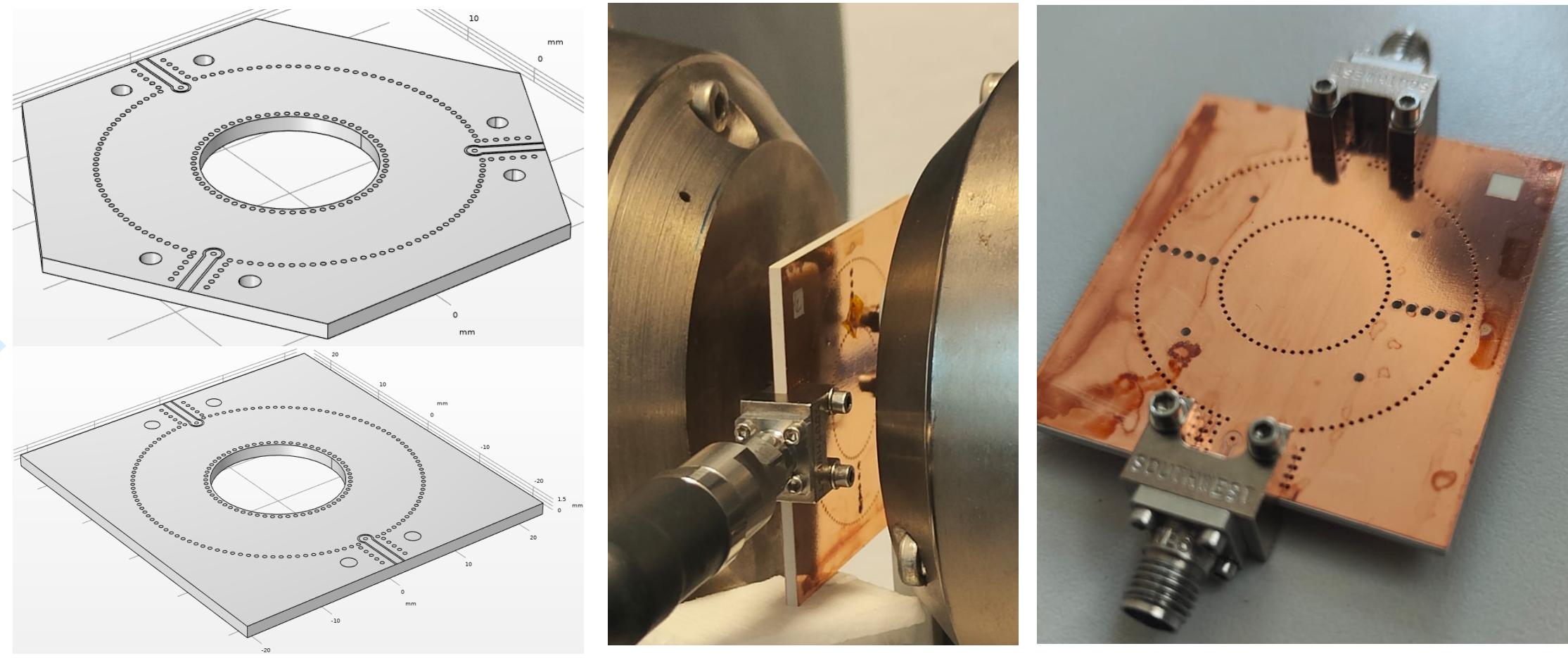
- Machined from high purity aluminium in two parts (lid and base)
- The inner and outer radii  $R_1$  (15 mm) and  $R_2$  (30 mm) and the height  $h$  (6 mm)
- 2 magnetic loops around the radial axis at  $\varphi = \pm 90^\circ$  that couple to  $H_\varphi$
- Pure YIG sphere couples to a clockwise (cm,  $m > 0$ ) or counterclockwise (ccw,  $m < 0$ ) photon

► **Multiple sphere setup:** How to demonstrate the generation of high-power unidirectional photon beam with high coherence and narrow bandwidth [2] in such big device?

## SIW CAVITY



SIW integration:  
Towards multiple YIG sphere setup



- Substrate Integrated Waveguide (SIW)
- Increasing the dielectric permittivity of the medium carrying the electromagnetic waves: reduction the device dimension
- From 60 to 36 mm for the external diameter
- Substrate: RO3003 ( $h=1.52$  mm)

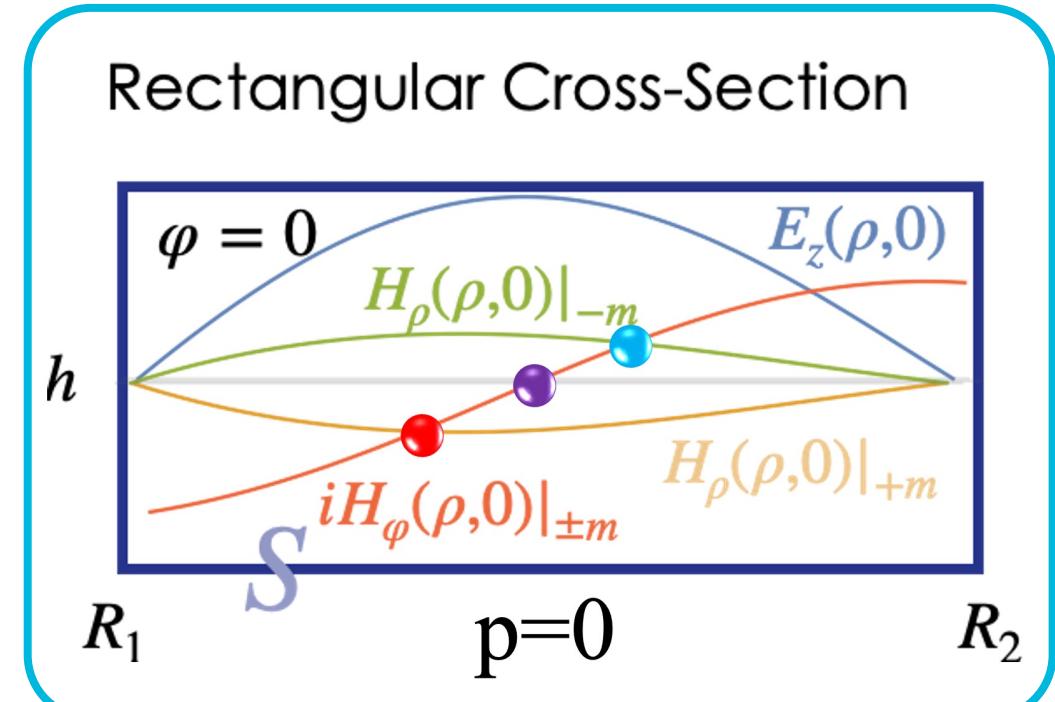
Microwave magnetic field of the TE modes is circularly polarized

$H_z = 0$  and  $\partial_n E_z | s = 0$     **TE mode**

$$E_z = \psi(\rho, \varphi) \cos\left(\frac{p\pi z}{h}\right), \quad p = 0, 1, 2, \dots$$

$$\psi(\rho, \varphi) = R_m(\rho) e^{im\varphi}, \quad m = 0, \pm 1, \pm 2, \dots$$

$$R_m(\rho) = J_m\left(\gamma_{p,m}\rho\right) + C N_m\left(\gamma_{p,m}\rho\right)$$



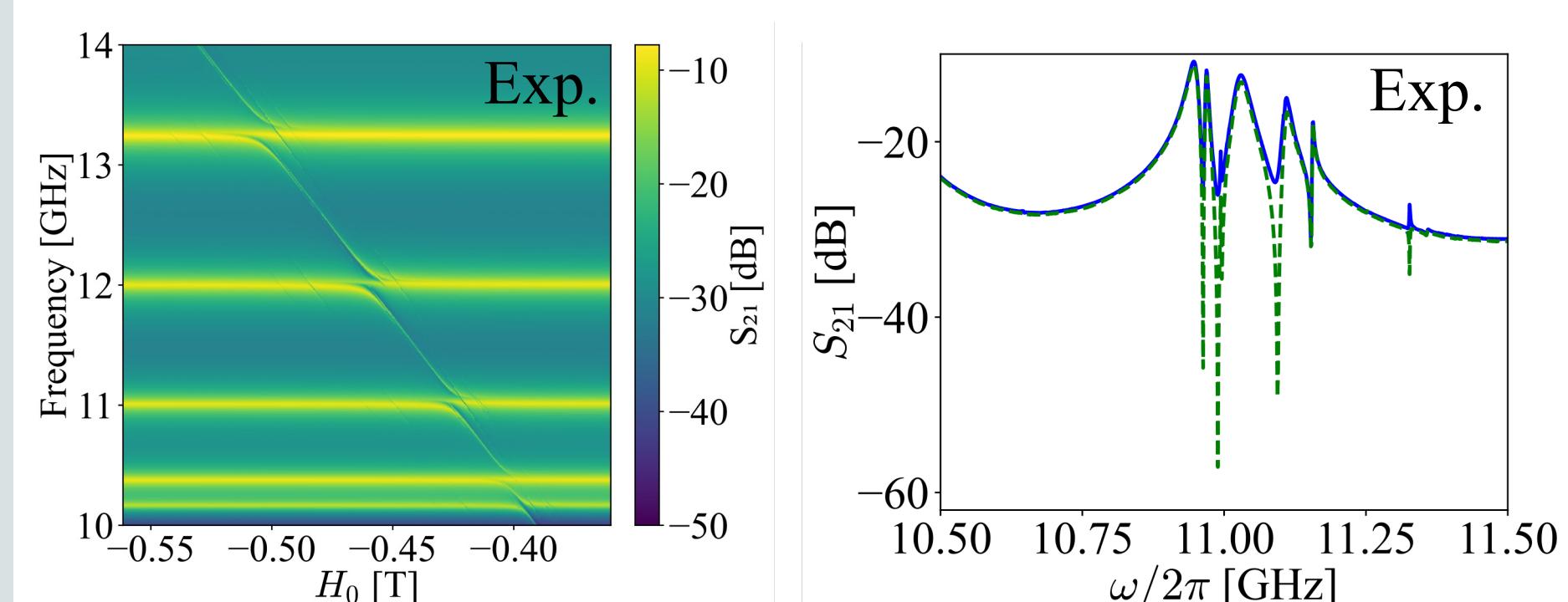
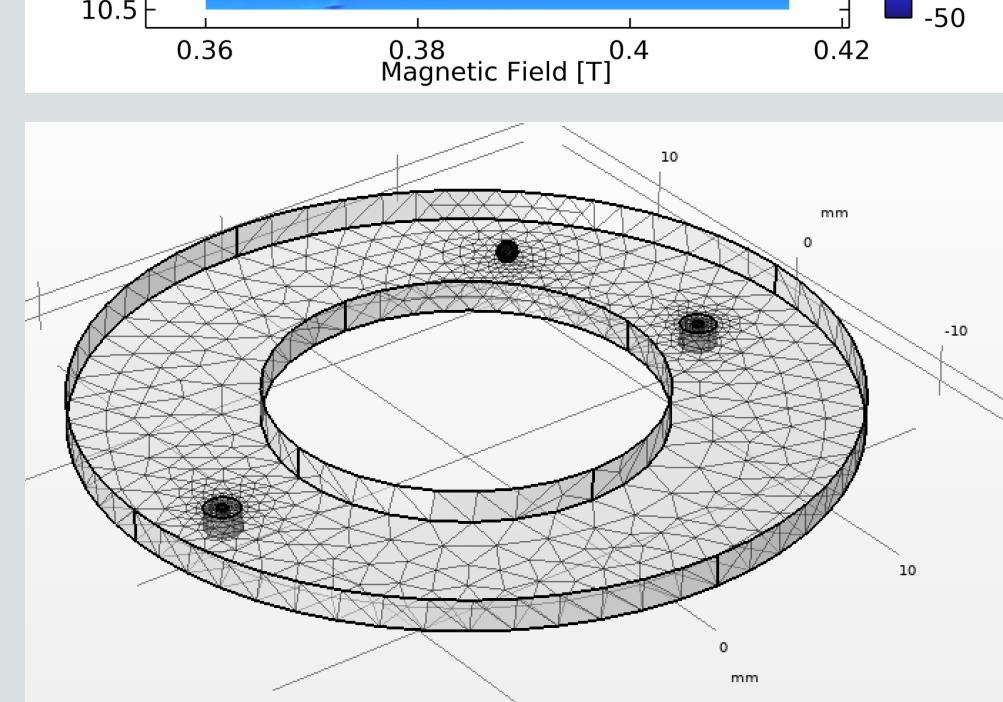
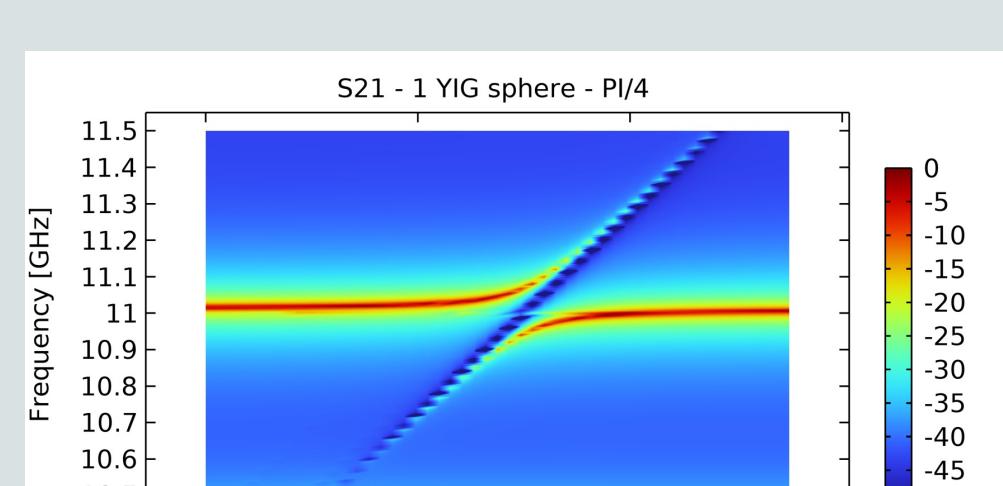
$$E_z(\rho, \phi, z) = \left( J_m\left(\gamma_{p,m}\rho\right) - \frac{J_m\left(\gamma_{p,m}R_1\right)}{N_m\left(\gamma_{p,m}R_1\right)} N_m\left(\gamma_{p,m}\rho\right) \right) e^{im\varphi} \cos\left(\frac{p\pi z}{h}\right) \quad \rho_+$$

$$H_p(\rho, \varphi) = \frac{1}{\mu_0 \gamma_m c} \frac{m}{\rho} E_z$$

$$H_\varphi(\rho, \varphi) = -i \frac{1}{\mu_0 \gamma_m c} \frac{\partial E_z}{\partial \rho}$$

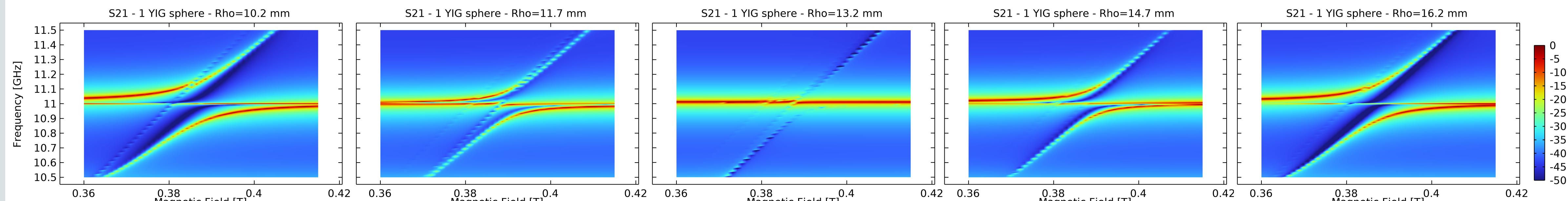
$-m$	$+m$
$H_\varphi = -iH_\rho$	$H_\varphi = iH_\rho$
$H_\varphi = iH_\rho$	$H_\varphi = -iH_\rho$
$H_\varphi = 0$	$H_\varphi = 0$

## SIMULATION & MEASUREMENT



**Simulation:**

- We calculate the microwave-induced dynamics of the Kittel mode by solving the coupled Maxwell and linearized Landau-Lifshitz-Gilbert (LLG) equation in the frequency domain in the macrospin by an electromagnetic FEM
- Simulated microwave transmission amplitudes for  $m = 2$  TE mode of the SIW chiral cavity as a function of the radial sphere position.



## CONCLUSION & PERSPECTIVES

- Simple sphere setup: 2 and 3 ports configuration, frequency and magnetic field dependence as function of the radial position
- The confirmation of predicted results [2] demonstrates the feasibility of a proposed multiple sphere setup, in which the magnets are placed along the same radial line and will coherently couple to one another
- New design configuration: low loss dielectric substrate and working frequency at 20, 30 and 40 GHz

[1] Jeremy Bourhill, Weichao Yu, Vincent Vlaminck, et al. Generation of Circulating Cavity Magnon Polaritons, Phys. Rev. Appl. 19, 014030 (1 2023)

[2] Weichao Yu, Tao Yu, and Gerrit E. W. Bauer. Circulating cavity magnon polaritons. Phys. Rev. B 102, 064416 (6 2020)