



HAL
open science

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.

► To cite this version:

Maxime Ardisson, Guillaume Bourcin, Jeremy Bourhill, David Spenato, David Dekadjevi, et al.. Generation of circulating cavity magnon polaritons in a compact geometry resonator. 21ème Colloque Louis Néel, Nov 2023, Sète, France. , 2023. hal-04295922

HAL Id: hal-04295922

<https://hal.science/hal-04295922>

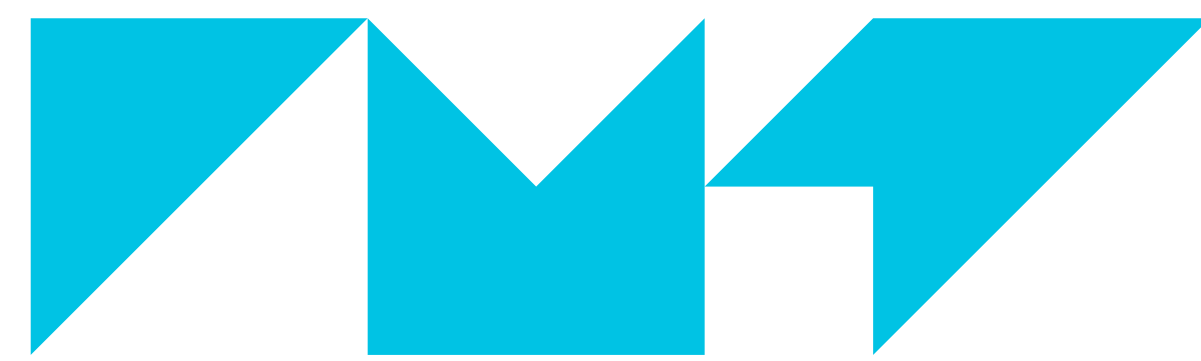
Submitted on 21 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

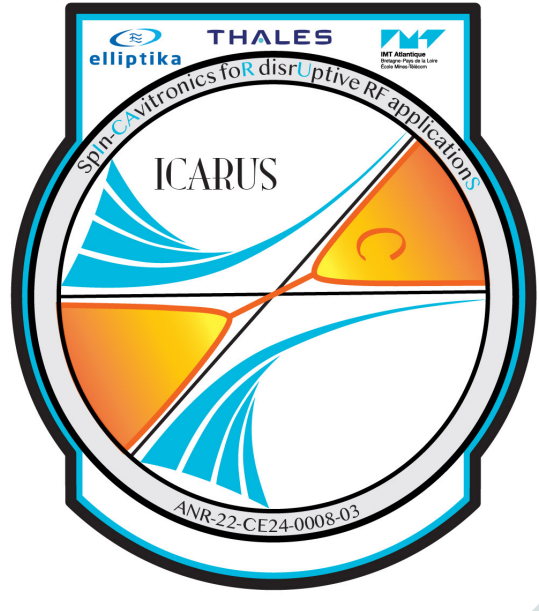
L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

GENERATION OF CIRCULATING CAVITY MAGNON POLARITONS IN A COMPACT GEOMETRY RESONATOR



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom



Maxime Ardisson^{1, 2, 4}, Guillaume Bourcin^{1, 2}, Jeremy Bourhill³, David Spenato⁵,
David Dekadjevi⁵, Jean-Philippe Jay⁵, Alain Fessant⁵, Isabella Boventer⁴, Romain
Lebrun⁴, Vincent Vlaminck^{1, 2}, and Vincent Castel^{1, 2}

¹IMT Atlantique, Technopole Brest-Iroise, CS 83818, Brest Cedex 3 29238, France

²Lab-STICC, NSF (UMR 6285), CNRS, Technopole Brest-Iroise, CS 83818, Brest Cedex 3 29238, France

³Quantum Technologies and Dark Matter Research Lab, Department of Physics, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia

⁴Thales Research and Technologies, Palaiseau, France

⁵Laboratoire d'optique et de magnétisme OPTIMAG, Brest, France

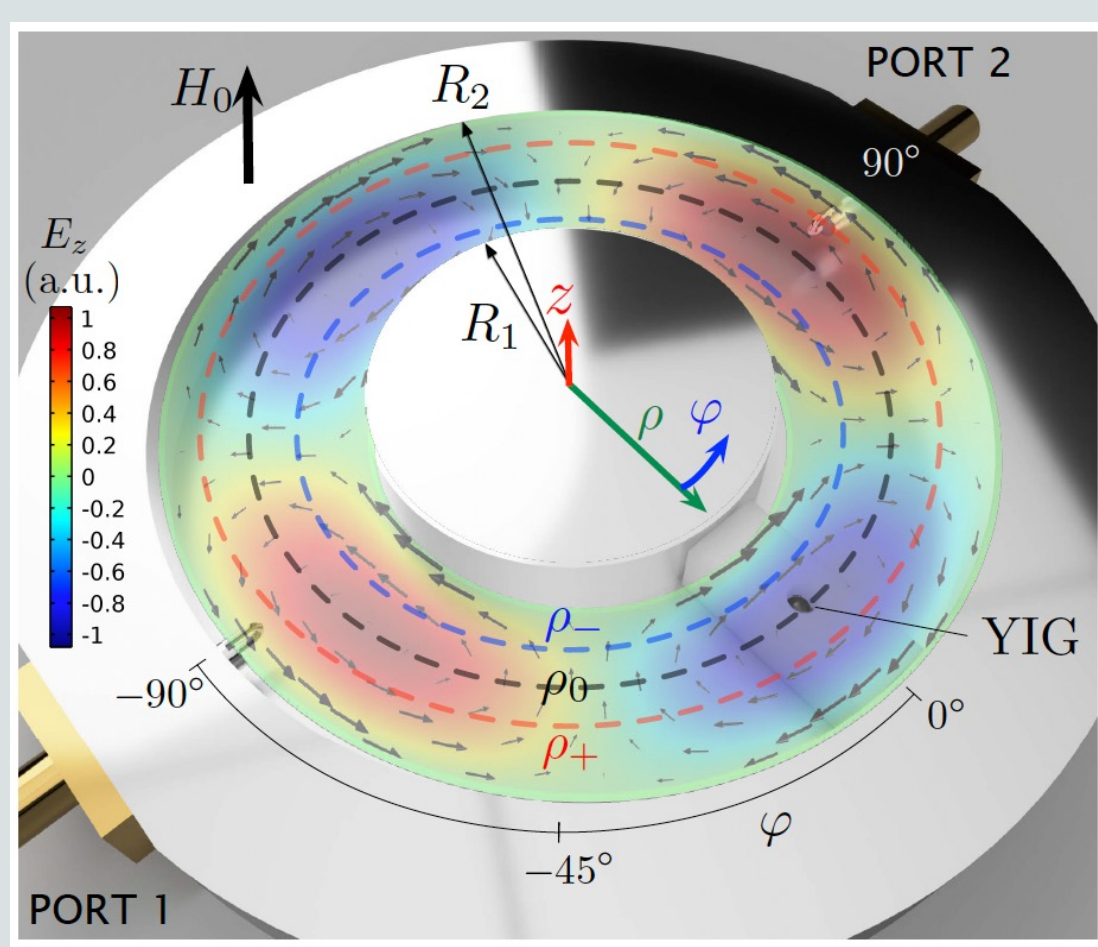
INTRODUCTION

- **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 R1 (15 mm) and R2 (30 mm) and the height h (6 mm)
 - 2 magnetic loops around the radial axis at $\varphi = \pm 90^\circ$ that couple to H_φ
 - Pure YIG sphere couples to a clockwise (cm, $m > 0$) or counterclockwise (cew, $m < 0$) 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?

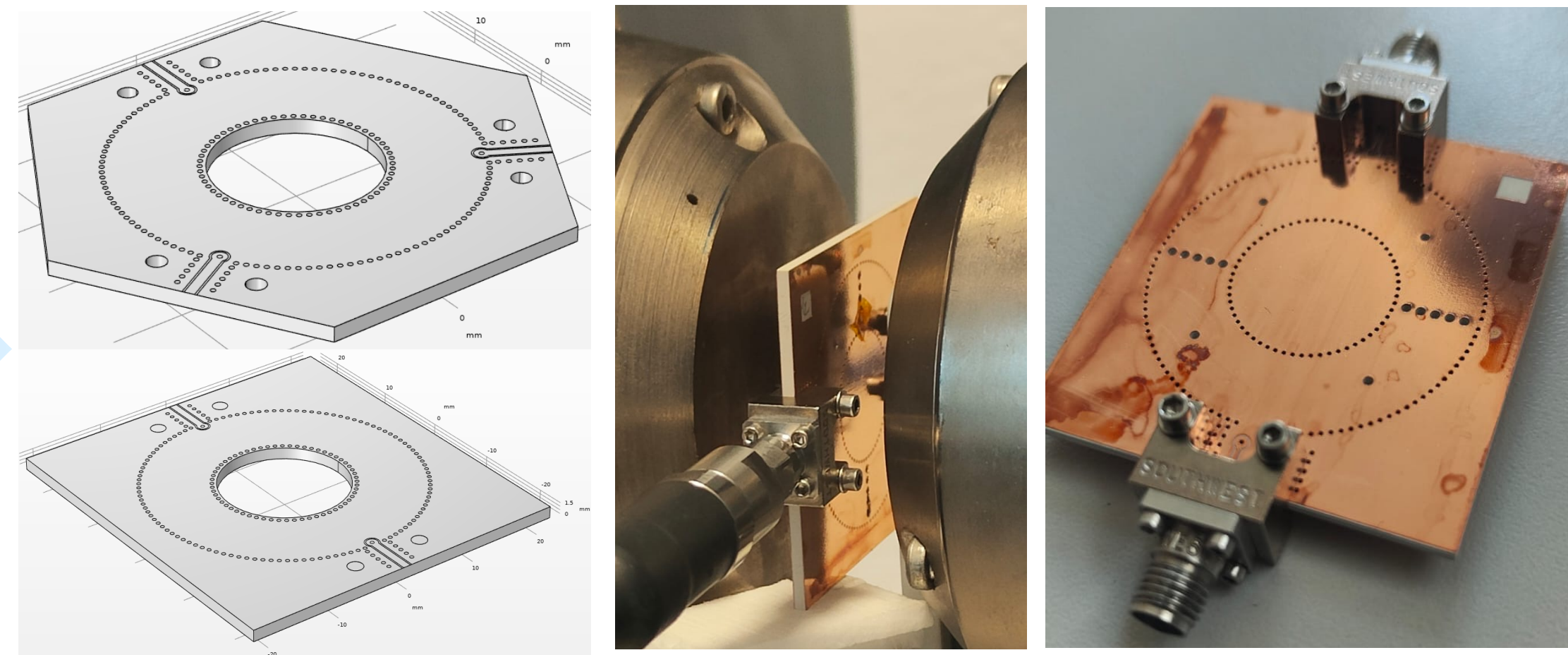
PHYSICAL REVIEW APPLIED



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)

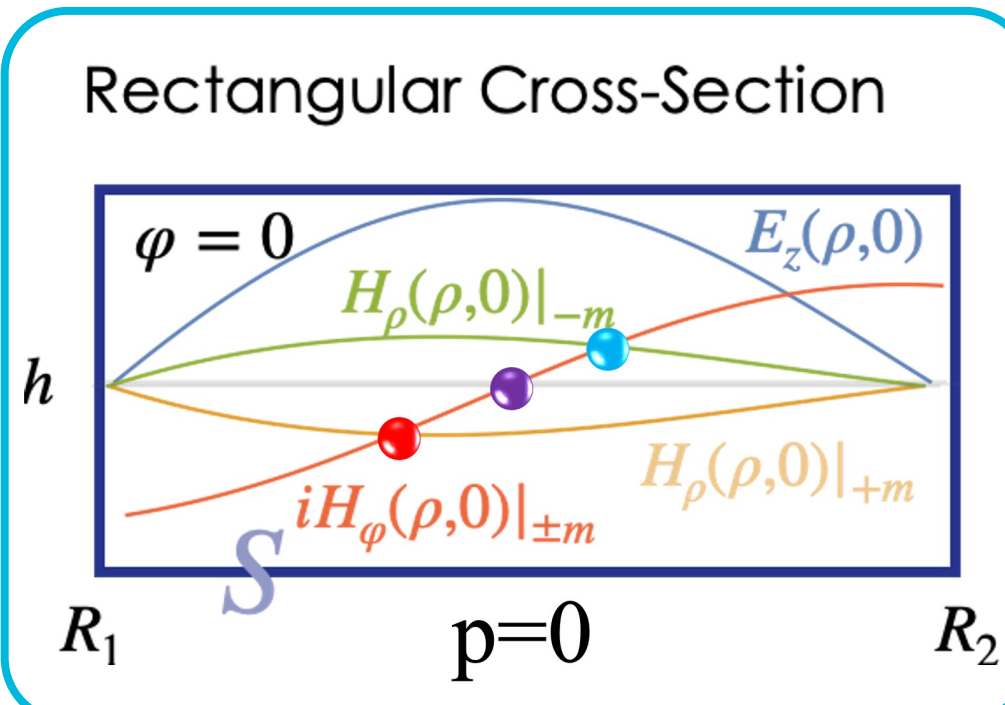
Microwave magnetic field of the TE modes is circularly polarized

$$H_z = 0 \text{ and } \partial_n E_z |_{s=0} = 0 \quad \text{TE mode}$$

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

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

$$R_m(\rho) = J_m(\gamma_{p,m}\rho) + CN_m(\gamma_{p,m}\rho)$$



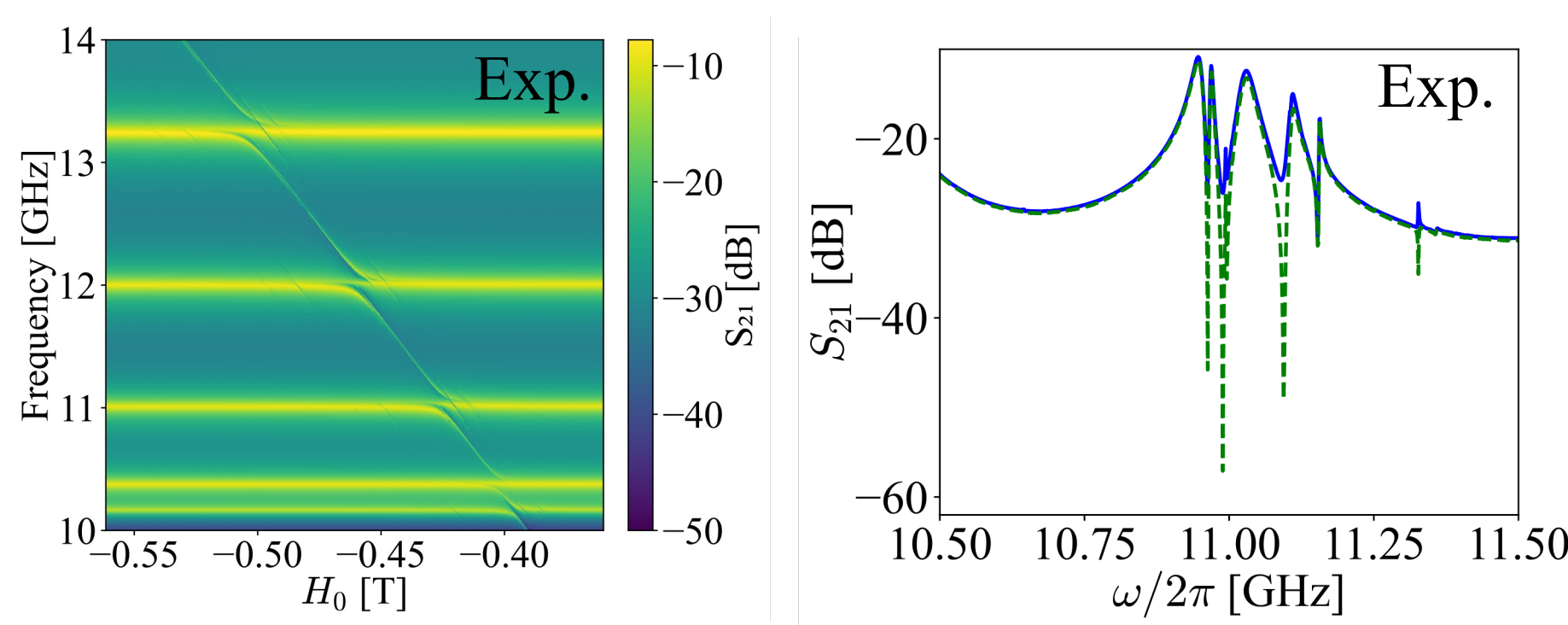
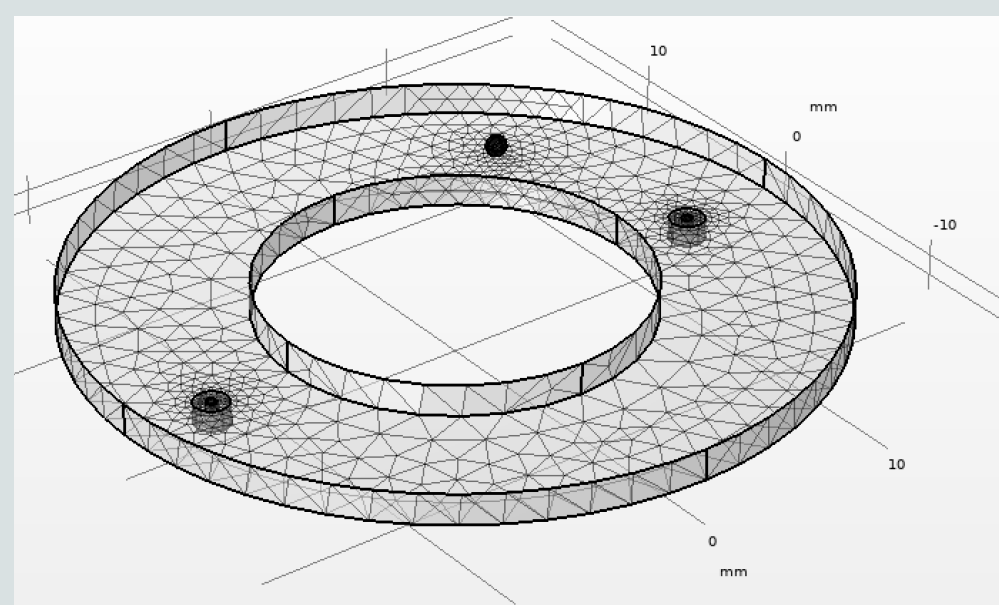
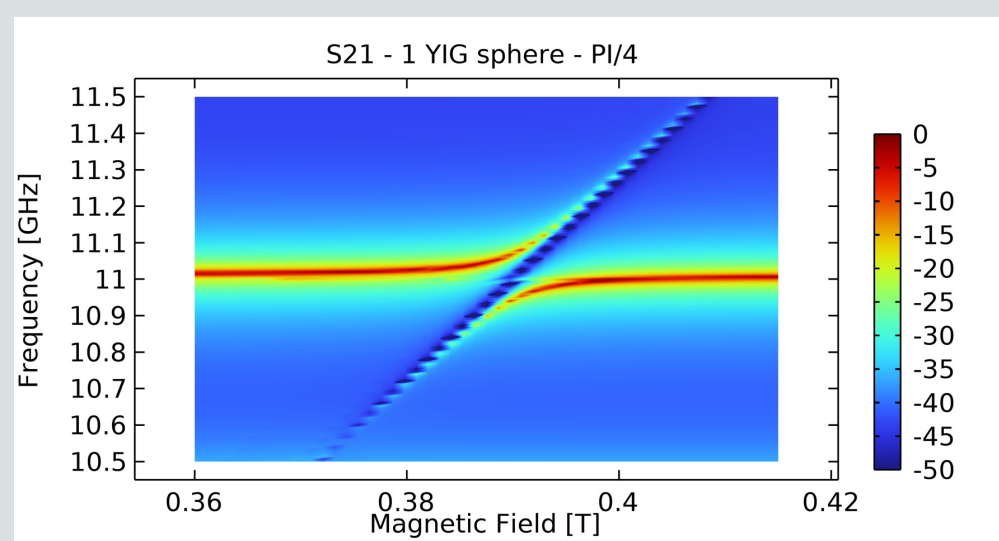
$$E_z(\rho, \varphi, z) = \left(J_m(\gamma_{p,m}\rho) - \frac{J_m(\gamma_{p,m}R_1)}{N_m(\gamma_{p,m}R_1)} N_m(\gamma_{p,m}\rho) \right) e^{im\varphi} \cos\left(\frac{p\pi z}{h}\right)$$

| | ρ_+ | ρ_- | ρ_0 |
|------|------------------------|------------------------|-----------------|
| $-m$ | $H_\varphi = -iH_\rho$ | $H_\varphi = iH_\rho$ | $H_\varphi = 0$ |
| $+m$ | $H_\varphi = iH_\rho$ | $H_\varphi = -iH_\rho$ | $H_\varphi = 0$ |
| | $H_\varphi = 0$ | $H_\varphi = 0$ | $H_\varphi = 0$ |

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

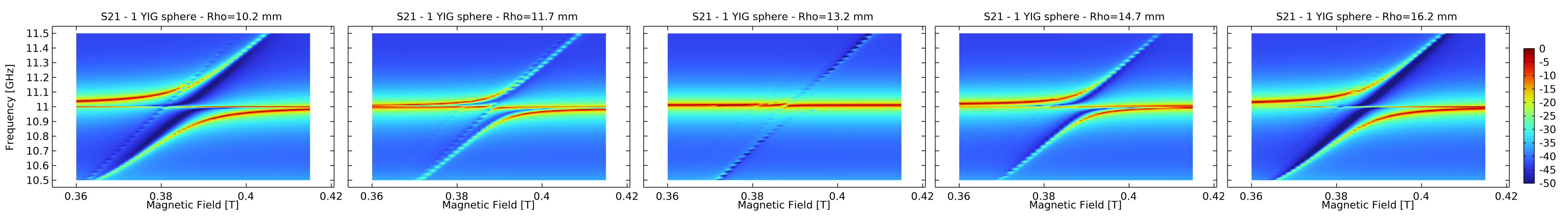
$$H_\varphi(\rho, \varphi) = -i \frac{1}{\mu_0 \gamma_m c} \frac{\partial E_z}{\partial \rho}$$

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

REFERENCES

- [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)

vincent.castel@imt-atlantique.fr
IMT Atlantique
Technopôle Brest-Iroise CS 83818
29238 Brest Cedex 3

