June 29th – July 4th, 2025
Costa Dorada - Spain

3rd International Workshop on Microwave Research and Applications

Book of Abstracts

COMARUGA 2025

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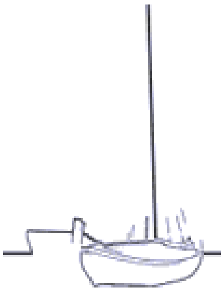
INTERNATIONAL WORKSHOP ON MICROWAVE RESEARCH AND APPLICATIONS

BOOK OF ABSTRACTS



Coma-ruga, Tarragona (Spain)
Juny 29th – July 4th, 2025

Organizing Committee:
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COMA-RUGA 2025 | International Workshop on Microwave Research and Applications

Hotel Balneario Playa de Comarruga | Avinguda Balneari, 4, 6, 43880 Coma-ruga, Tarragona

Schedule

	Sunday, June 29th	Monday, June 30th	Tuesday, July 1st	Wednesday, July 2nd	Thursday, July 3rd	Friday, July 4th	
9:30 - 10:10		O1.1 *KEYNOTE SPEAKER* **Darío Arena** Ferromagnetic Resonance Studies of Magnetic Thin Films and Multilayers	O2.1 *KEYNOTE SPEAKER* **Luis Viña** Josephson-like oscillations of polariton condensates in matter couplers	O3.1 *KEYNOTE SPEAKER* **Dmitry Garanin** Skyrmion Crystal in a Microwave Field	O4.1 *KEYNOTE SPEAKER* **Gloria Platero** Quantum information transfer mediated by topological edge states	O5.1 *KEYNOTE SPEAKER* **Mehmet Emre Tasgin** Overcoming atmospheric noise in quantum radar and key distribution	9:30 - 10:10
10:10 - 10:35		O1.2 **Subhashri Chatterjee** Ultrafast Edge Photocurrent on WTe_2 by On-chip THz Spectroscopy	O2.2 **Alexander Buzdin** Photogalvanic phenomena at GHz range in superconductors supporting intrinsic diode effect	O3.2 **Felipe Caballero-Briones** Multifrequency attenuation in nanostructured multilevel metastructures based on GO/Fe3O4/PPy composites for military detection applications	O4.2 **Jeroen Danon** AC current driving of superconductor-semiconductor-based Josephson junctions	O5.2 **Martí Gich** Ferrites for non-reciprocal devices above 100 GHz	10:00 - 10:35
10:35 - 11:00		O1.3 **Ya Zhang** Novel terahertz bolometric detection using MEMS beam resoantors	O2.3 **Sachin Krishnia** Detection of orbital torques on magnetic layers via microwave techniques	O3.3 **María Guijarro Maortua** Analysis of the Impact of Shaped Metasurfaces on the RCS Reduction	O4.3 **Eran Ginossar** A proposal for charge basis tomography of superconducting qubits	O5.3 **Joffre Gutierrez Royo** Low surface impedance REBCO coatings for microwave applications under high magnetic fields	10:35 - 11:00
11:00 - 11:30		**COFFEE BREAK**					11:00 - 11:30
11:30 - 11:55		O1.4 **Charles Creffield** Microwave driving a trapped ion to simulate the Riemann zeta function	O2.4 **Nathalia Duque-Madrid** Assessment of Machine Learning Models in Characterization of Magnetodielectric Composites	**POSTER SESSION** (extended coffee break)	O4.4 **Sara Ghayeb Zamharir** High Performance Terahertz Quantum Cascade Lasers for Spectroscopic Applications	O5.4 **Antoni García-Santiago** Copper-modified barium-based nanocomposites as random anisotropy magnets for microwave applications	11:30 - 11:55
11:55 - 12:20		O1.5 **Benjamin Martinez** Spin transport in antiferromagnetic materials	O2.5 **Pilar Marín** Tunable Microwave Scattering Signatures of 3D Sensing Platforms Based on Ordered Magnetic Microwire Assemblies	O3.5 **Miguel Bello** Effects of retardation on many-body superradiance in chiral waveguide QED	O4.5 **Álvaro Gómez León** High-quality Poor Man's Majorana bound states from cavity embedding	O5.5 **Jorge Fernandez Soriano** Giant Barnett Effect from Moving Dislocations	11:55 - 12:20
12:20 - 12:45		O1.6 **Nico Dix** On the complexity of materials engineering for high-frequency circulators with hard magnetic ferrites	O2.6 **Jaume Calvo de la Rosa** Novel methods for enhanced radar absorption in multilayer magnetic composites	O3.6 **Marc Vazquez Aige** Development of a specialized free-space EM characterization method for thin samples with an alignment system and angle of incidence control	O4.6 **Christopher Wächtler** Topological Quantum Synchronization	**CLOSING REMARKS**	12:20 - 12:45
12:45 - 16:00		**LUNCH**					12:45 - 16:00
16:00 - 16:40		O1.7 *KEYNOTE SPEAKER* **Paulo Ventura Santos** Generation of GHz helical acoustic drum modes on a chip	O2.7 *KEYNOTE SPEAKER* **Fernando Sols** Temporal Nambu-Goldstone mode and Floquet thermodynamics in spontaneous and driven Floquet states	O3.7 *KEYNOTE SPEAKER* **Peng Zhang** Recent Advances in multipactor physics and mitigation	O4.7 *KEYNOTE SPEAKER* **Clivia M. Sotomayor Torres** Topological phononics: experimental challenges		16:00 - 16:40
16:40 - 17:05		O1.8 **Regina Galceran** Wrinkles for magnonics	O2.8 **Rosa López** Beating Carnot efficiency with periodically driven chiral conductors	O3.8 **Soraya Sangiao** Broadband spin pumping characterization of YIG/W bilayer thin films	O4.8 **Stefano Bosco** Harnessing Large Spin-Orbit Interactions for Next-Gen Hole Spin Qubits		16:40 - 17:05
17:05 - 17:35		**COFFEE BREAK**					17:05 - 17:35
17:35 - 17:50		O1.09 **Anna Castellví-Picanvol** Stroboscopic Kerr Imaging of Magnetoacoustic Waves in Ferromagnetic Thin Films	O2.9 **Viktor Rindert** High Frequency Magnetic Resonance using Terahertz Generalized Spectroscopic Ellipsometry	O3.9 **Sigmund Kohler** Degeneracies, Conical Intersections, and Dissipation in Floquet Systems	O4.9 **Hannes Rotzinger** Experiments with Milimeter-Wave Photons at Milli-Kelvin Temperatures		17:35 - 18:00
17:50 - 18:05		O1.10 **Júlia Odena Bermudo** Orbital currents generated by surface acoustic waves in FM/NM bilayers					
18:05 - 18:20		O1.11 **Darío González Diez** Rayleigh-Jeans condensation of magnons in an optomagnomechanical system	O2.10 *KEYNOTE SPEAKER* **Enrique Del Barco** Adiabatic Spintronics with Topological Magnetic Insulators	O3.10 *KEYNOTE SPEAKER* **Georg Engelhardt** Photon-resolved Floquet theory and its application to microwave sensing	O4.10 *KEYNOTE SPEAKER* **Fernando Luis** Circuit QED with Molecular Spin Qudits		18:00 - 18:40
18:20 - 18:35		O1.12 **Quim Badosa** Electric control of switching fields in FM thin films using surface acoustic waves					
18:35 - 18:50		O1.13 **Pablo Cerrato Serrano** Design of an optomagnomechanical crystal for the investigation of novel quantum states of matter					
	Welcome party (19:30 at *Tarragona* room, Hotel Balneario Playa de Comarruga)			**Conference dinner** (20:30 at Cara al Mar restaurant)			

JUNE, 30th

EVENT SCHEDULE

COMA-RUGA 2025

International Workshop on Microwave Research and Applications

01.1. Darío Arena	*09:30 – 10:10*
Ferromagnetic Resonance Studies of Magnetic Thin Films and Multilayers	
01.2. Subhashri Chatterjee	*10:10 – 10:35*
Ultrafast Edge Photocurrent on WTe_2 by On-chip THz Spectroscopy	
01.3. Ya Zhang	*10:35– 11:00*
Novel terahertz bolometric detection using MEMS beam resonators	
COFFE BREAK (11:00 – 11:30)	
01.4. Charles Creffield	*11:30 – 11:55*
Microwave driving a trapped ion to simulate the Riemann zeta function	
01.5. Benjamin Martinez	*11:55 – 12:20*
Spin transport in antiferromagnetic materials	
01.6. Nico Dix	*12:20 – 12:45*
On the complexity of materials engineering for high frequency circulators with hard magnetic ferrites	
LUNCH (12:45 – 16:00)	
01.7. Paulo Ventura Santos	*16:00 – 16:40*
Generation of GHz helical acoustic drum modes on a chip	
01.8. Regina Galceran	*16:40 – 17:05*
Wrinkles for magnonics	
COFFE BREAK (17:05 – 17:35)	
01.9. Anna Castellví-Picanyol	*17:35 – 17:50*
Stroboscopic Kerr Imaging of Magnetoacoustic Waves in Ferromagnetic Thin Films	
01.10. Júlia Òdena Bermudo	*17:50 – 18:05*
Orbital currents generated by surface acoustic waves in FM/NM bilayers	
01.11. Darío González Diez	*18:05 – 18:20*
Rayleigh-Jeans condensation of magnons in an optomagnomechanical system	
01.12. Quim Badosa	*18:20 – 18:35*
Electric control of switching fields in FM thin films using surface acoustic waves	
01.13. Pablo Cerrato Serrano	*18:35 – 18:50*
Design of an optomagnomechanical crystal for the investigation of novel quantum states of matter	

JULY, 1st

EVENT SCHEDULE

COMA-RUGA 2025

International Workshop on Microwave Research and Applications

02.1. Luis Viña	*09:30 – 10:10*
Josephson-like oscillations of polariton condensates in matter couplers	
02.2. Alexander Buzdin	*10:10 – 10:35*
Photogalvanic phenomena at GHz range in superconductors supporting intrinsic diode effect	
02.3. Sachin Krishnia	*10:35– 11:00*
Detection of orbital torques on magnetic layers via microwave techniques	
COFFE BREAK (11:00 – 11:30)	
02.4. Nathalia Duque-Madrid	*11:30 – 11:55*
Assessment of Machine Learning Models in Characterization of Magnetodielectric Composites	
02.5. Pilar Marín	*11:55 – 12:20*
Tunable Microwave Scattering Signatures of 3D Sensing Platforms Based on Ordered Magnetic Microwire Assemblies	
02.6. Jaume Calvo de la Rosa	*12:20 – 12:45*
Novel methods for enhanced radar absorption in multilayer magnetic composites	
LUNCH (12:45 – 16:00)	
02.7. Fernando Sols	*16:00 – 16:40*
Temporal Nambu-Goldstone mode and Floquet thermodynamics in spontaneous and driven Floquet states	
02.8. Rosa López	*16:40 – 17:05*
Beating Carnot efficiency with periodically driven chiral conductors	
COFFE BREAK (17:05 – 17:35)	
02.9. Viktor Rindert	*17:35 – 18:00*
High Frequency Magnetic Resonance using Terahertz Generalized Spectroscopic Ellipsometry	
02.10. Enrique Del Barco	*18:00 – 18:40*
Adiabatic Spintronics with Topological Magnetic Insulators	

JULY, 2nd

EVENT SCHEDULE

COMA-RUGA 2025

International Workshop on Microwave Research and Applications

03.1. Dmitry Garanin	*09:30 – 10:10*
Skyrmion Crystal in a Microwave Field	
03.2. Felipe Caballero-Briones	*10:10 – 10:35*
Multifrequency attenuation in nanostructured multilevel metastructures based on GO/Fe3O4/PPy composites for military detection applications	
03.3. María Guijarro Maortua	*10:35– 11:00*
Analysis of the Impact of Shaped Metasurfaces on the RCS Reduction	
COFFE BREAK (11:00 – 11:30)	
POSTER SESSION	*11:30 – 11:55*
Extended coffee break	
03.5. Miguel Bello	*11:55 – 12:20*
Effects of retardation on many-body superradiance in chiral waveguide QED	
03.6. Marc Vazquez Aige	*12:20 – 12:45*
Development of a specialized free-space EM characterization method for thin samples with an alignment system and angle of incidence control	
LUNCH (12:45 – 16:00)	
03.7. Peng Zhang	*16:00 – 16:40*
Recent Advances in multipactor physics and mitigation	
03.8. Soraya Sangiao	*16:40 – 17:05*
Broadband spin pumping characterization of YIG/W bilayer thin films	
COFFE BREAK (17:05 – 17:35)	
03.9. Sigmund Kohler	*17:35 – 18:00*
Degeneracies, Conical Intersections, and Dissipation in Floquet Systems	
03.10. Georg Engelhardt	*18:00 – 18:40*
Photon-resolved Floquet theory and its application to microwave sensing	

CONFERENCE DINNER | 20:30 at Cara al Mar restaurant

JULY, 3rd

04.1. Gloria Platero	*09:30 – 10:10*	Quantum information transfer mediated by topological edge states
04.2. Jeroen Danon	*10:10 – 10:35*	AC current driving of superconductor-semiconductor-based Josephson junctions
04.3. Eran Ginossar	*10:35– 11:00*	A proposal for charge basis tomography of superconducting qubits
COFFE BREAK (11:00 – 11:30)		
04.4. Sara Ghayeb Zamharir	*11:30 – 11:55*	High Performance Terahertz Quantum Cascade Lasers for Spectroscopic Applications
04.5. Álvaro Gómez León	*11:55 – 12:20*	High-quality Poor Man's Majorana bound states from cavity embedding
04.6. Christopher Wächtler	*12:20 – 12:45*	Topological Quantum Synchronization
LUNCH (12:45 – 16:00)		
04.7. Clivia M. Sotomayor Torres	*16:00 – 16:40*	Topological phononics: experimental challenges
04.8. Stefano Bosco	*16:40 – 17:05*	Harnessing Large Spin-Orbit Interactions for Next-Gen Hole Spin Qubits
COFFE BREAK (17:05 – 17:35)		
04.9. Hannes Rotzinger	*17:35 – 18:00*	Experiments with Milimeter-Wave Photons at Milli-Kelvin Temperatures
04.10. Fernando Luis	*18:00 – 18:40*	Circuit QED with Molecular Spin Qudits

JULY, 4th

05.1. Mehmet Emre Tasgin *09:30 – 10:10*

Overcoming atmospheric noise in quantum radar and key distribution

05.2. Martí Gich *10:10 – 10:35*

Ferrites for non-reciprocal devices above 100 GHz

05.3. Joffre Gutierrez Royo *10:35– 11:00*

Low surface impedance REBCO coatings for microwave applications under high magnetic fields

COFFE BREAK (11:00 – 11:30)

05.4. Antoni García-Santiago *11:30 – 11:55*

Copper-modified barium-based nanocomposites as random anisotropy magnets for microwave applications

05.5. Jorge Fernandez Soriano *11:55 – 12:20*

Giant Barnett Effect from Moving Dislocations

CLOSING REMARKS (12:20 – 12:30)

Ferromagnetic Resonance Studies of Magnetic Thin Films and Multilayers

Darío A. Arena,[a] Ayomipo Ojo,[a] Vimukthi Deshan Ganepola Arachichige,[a]

[a]*Department of Physics, University of South Florida, Tampa, FL. U.S.A.*

Ferromagnetic resonance (FMR) is a versatile tool for investigating fundamental properties of materials with long-range spin order. In this talk, I will present the use of FMR in investigating three distinct phenomena in magnetic thin films. First, we will examine the enhancement of indirect exchange coupling (IEC) at reduced temperatures in epitaxial Fe / MgO / Fe bilayers. The FMR spectra reveal two distinct eigenmodes: a low-field acoustic mode and a high-field optic mode. The resonance field difference between these modes indicates that the IEC is antiferromagnetic with a coupling field of ~ -4 mT at 300 K, increasing to ~ -15 mT at 180 K while probing the Fe [100] direction. Additionally, the amplitude ratio of the acoustic to optic modes increases with decreasing temperature, signifying an enhancement of the coupling strength [1].

Second, we will use FMR to measure the exchange stiffness in the topological Weyl semimetal Co_2MnGa (CMG) as a function of temperature and film thickness. In the CMG films, the applied magnetic field is perpendicular to the plane of the sample permitting excitation of perpendicular standing spin wave (PSSW) modes, and the difference in effective magnetization between the PSSW and uniform modes is used to quantify the exchange stiffness. Thin CMG films (20 nm) show low exchange stiffness ($\sim$ 1 pJ/m) which is independent of temperature. Thicker CMG films (> 50 nm) exhibit much larger exchange stiffness (> 10 pJ/m), which increases as the temperature is lowered, indicating a competition between exchange interactions and thermal agitation [2].

Lastly, we will show how comparing FMR spectroscopy with x-ray magnetic circular dichroism (XMCD) can be used to quantify spin mixing in ferro- and ferrimagnetic thin films. In the solid state, some degree of mixing of the free space S_z eigenstates is unavoidable, but experimental confirmation of the spin mixing parameter $\langle b^2 \rangle$ is challenging, particularly for polycrystalline and amorphous materials as well as buried magnetic layers. We present studies which compare the orbit to spin moment ratio (μ_ℓ / μ_s) extracted from XMCD spectra to the μ_ℓ / μ_s calculated from the spectroscopic g-factor determined from FMR. The difference between the two measurements can be related to $\langle b^2 \rangle$. We will present FMR / XMCD studies of $\langle b^2 \rangle$ in Ni-based multilayers [3], $Co_{(1-x)}Fe_x$ thin films [4], and amorphous FeGd ferrimagnetic films [5].

[1] Ayomipo Ojo, Anna Ravensburg, V. Kapaklis, D.A. Arena, *et al.*, *in preparation.*
[2] Ayomipo Ojo, A. Markou, C. Felser, D.A. Arena, *et al., in preparation.*
[3] J.M. Shaw, R. Knut, A. Armstrong, D.A. Arena, *et al., Phys. Rev. Lett.,* **127** 207201 (2021).
[4] J.M. Shaw, H. Nembach, D.A. Arena, *et al., in preparation*.
[5] Vimukthi Deshan Ganepola Arachichige, J.M. Shaw, H. Nembach, D.A. Arena, *et al., in preparation*.

Ultrafast Edge Photocurrent on WTe_2 by On-chip THz Spectroscopy

Subhashri Chatterjee,[1,*] Katsumasa Yoshioka, [1] Taro Wakamura, [1] Norio Kumada[1]
NTT Basic Research Laboratories, NTT Corporation, Atsugi, Japan

Layered 2D materials, such as van der Waals (vdW) materials and transition metal dichalcogenides (TMDs), have attracted significant attention for next-generation THz optoelectronic devices due to their potential for ultrafast photocurrent generation.[1] In homogeneous 2D materials, such photocurrent generation can be realized by breaking crystal symmetry inherently along certain edges. Recently, WTe_2 has been studied under continuous wave (CW) laser illumination at room temperature, where nonlinear photocurrents are generated along lower-symmetry directions, while they are absent along higher-symmetry directions due to symmetry constraints.[2] However, another study attributes the observed photocurrent to the photothermoelectric effect (PTE).[3] To resolve this controversy, a temperature-dependent time-domain study of carrier dynamics is essential to disentangle the underlying mechanisms of photocurrent generation.

In this study, we investigate edge photocurrent generation in WTe_2 using on-chip THz spectroscopy.[4] A low temperature grown GaAs photoconductive (PC) switch is connected to a mechanically exfoliated WTe_2 flake through a Goubau-line waveguide with a distance of 440 μm. A femtosecond laser with 517 nm wavelength light was used to illuminate the WTe_2 sample, while the generated photocurrent is extracted by probing with a time delay t from PC switch. (Fig. 1 (a)) shows the canning photocurrent microscopy (SPCM) image. When the laser is directed onto the edges along the <110> symmetry direction, an ultrafast time-domain photocurrent is observed, whereas no such photocurrent is detected along higher-symmetry directions Figure 1(a). Figure 1(b) represents the temperature-dependent edge photocurrent, revealing a transition in waveform shape from cosine-like to sine-like. Additionally, below 100 K, the photocurrent behavior indicates contributions from both electron and hole pockets. We conclude that the change in photocurrent shape results from a shift in the chemical potential of the material at different temperatures. Furthermore, our results suggest that photocurrent generation is primarily driven by the PTE.

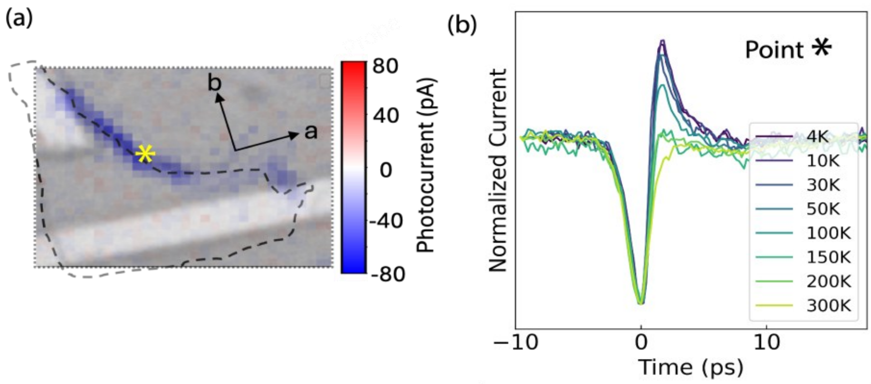

Figure 1. (a) SPCM image of WTe_2 at 4K, (b) TD ultrafast photocurrent extracted from WTe_2 edge at Point *.

1. *Nature Reviews Physics* **3**, 178–192 (2021), 2. *Nat Commun* **10**, (2019), 3. *Nat Phys* **19**, 507–514 (2023), 4. *Nat Photonics* **16**, 718–723 (2022)

Novel terahertz bolometric detection using MEMS beam resoantors

Ya Zhang,[a] Kazuhiko Hirakawa,[a,b] Kazusuke Maenaka[c]

[a] *Tokyo University of Agriculture and Technology*
[b] *University of Tokyo*
[c] *University of Hyogo*

Terahertz (THz) electromagnetic spectrum draws wide attention for nondestructive and/or biocompatible sensing. In order to be widely applicable to the THz sensing, it is of prime importance to develop THz sensors that can be operated at room temperature and have high sensitivity and fast operation speed. However, conventional room-temperature THz thermal sensors fall short of expectations in these characteristics.

Here we report uncooled, sensitive, and fast THz bolometric detectors using microelectromechanical system (MEMS) resonators [1-2]. Doubly clamped MEMS beam resonators are fabricated using III-V (GaAs) semiconductors and silicon materials. The MEMS resonator absorbs THz radiation and induces a temperature rise, leading to a shift in its resonance frequency. This frequency shift, proportional to the amount of THz radiation absorbed by the resonator, allows the THz radiation to be measured. The MEMS bolometer can achieve a NEP of ~ 20 $pW/Hz^{0.5}$ and an operation frequency of ~10 kHz, significantly faster than conventional thermal-type THz sensors such as pyroelectric sensors and Golay cells. The performance of the MEMS bolometer can be further enhanced by using the nonlinear dynamics of the MEMS resonators [3-4], as well as by integrating the MEMS beam with THz metamaterial absorbers [5]. The proposed MEMS bolometer is promising for realizing fast THz spectroscopy and imaging applications.

[1] Ya Zhang, Yasuyuki Watanabe, Suguru Hosono, Naomi Nagai, and Kazuhiko Hirakawa, Appl. Phys. Lett. 108 (16), 163503 (2016).
[2] Ya Zhang, Suguru Hosono, Naomi Nagai, Sang-Hun Song, and Kazuhiko Hirakawa, J. Appl. Phys. 125 (15), 151602 (2019).
[3] Ya Zhang, Ryoka Kondo, Boqi Qiu, Xin Liu, and Kazuhiko Hirakawa, Phys. Rev. Appl. 14, 014019 (2020).
[4] Ya Zhang, Yuri Yoshioka, Mirai Iimori, Boqi Qiu, Xin Liu, and Kazuhiko Hirakawa, Appl. Phys. Lett. 119 (16), 163503 (2021).
[5] Zihao Zhao, Kazuho Harada, Chao Li, Isao Morohashi, and Ya Zhang, Proceeding of 2024 IEEE SENSORS (2024).

Microwave driving a trapped ion to simulate the Riemann zeta function

Charles Creffield,[a] German Sierra,[b] Ran He,[c] , Ming-Zhong Ai,[c] Jin-Ming Cui,[c] Yun-Feng Huang,[c] Yong-Jiang Han,[c] Chuan-Feng Li,[c] and Guang-Cao Guo[c]

[a]*Dpto de Física de Materiales, Universidad Complutense de Madrid, Spain*

[b]*Instituto de Física Teórica, UAM-CSIC, Madrid, Spain*

[c]*University of Science and Technology of China, Hefei, China*

The non-trivial zeros of the Riemann zeta function are central objects in number theory, governing, for example, the distribution of the prime numbers, and are also of great interest in the physics of random matrix theory and quantum chaos. In this talk I will describe how the position of the zeros can be measured by driving an ion held in a Paul trap with a precisely specified microwave signal [1]. The waveform of the signal is selected so that the spin-dynamics of the ion is frozen when the driving parameters coincide with a zero of the zeta function, using a technique known as "Floquet engineering" [2]. Scanning over the driving amplitude thus allows the locations of the Riemann zeros to be experimentally measured to a high degree of accuracy, providing a quantum simulation of these fascinating mathematical objects.

[1] R. He *et al*. npj Quantum Information 7, 109 (2021).

[2] C.E. Creffield and G. Sierra, Physical Review A 91, 063608 (2015).

Spin transport in antiferromagnetic materials

S. Chen[a], Ll. Balcells[a], B. Bozzo[a], C. Frontera[a], Z. Konstantinovic [b], C. Magén [c], N. Mestres[a], A. Pomar[a] and B. Martínez[a]

[a] Instituto de Ciencia de Materiales de Barcelona. ICMAB-CSIC. Bellaterra. Spain
[b] Center for Solid State Physics and New Materials, Institute of Physics Belgrade, Serbia
[c] Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza; Laboratorio de Microscopías Avanzadas (LMA), universidad de Zaragoza, Zaragoza, Spain

Traditionally, spintronics research has focused on ferromagnetic (FM) materials, but recent discoveries highlight the versatility of antiferromagnetic (AFM) materials. AFM insulators, particularly complex oxides, enable efficient spin current transmission while blocking charge flow, with some cases even showing spin current enhancement. [1,2] Additionally, electrical switching has been demonstrated in both metallic and insulating AFMs via spin torque mechanisms.[3] These properties have sparked interest in AFMs as active spintronic components, particularly as insertion barriers in FM/non-magnetic (NM) bilayers. This study investigates how microstructure and crystallographic growth direction affect spin current transmission through epitaxial NiO layers in $La_{2/3}Sr_{1/3}MnO_3$ (LSMO)/NiO/Pt heterostructures. Spin currents are generated via ferromagnetic resonance (FMR) in LSMO, transmitted through NiO, and detected in Pt using the inverse spin Hall effect (ISHE). The influence of interfacial effects and structural symmetry in the transport of spin currents through the heterostructure as a function of temperature and NiO barrier thickness will be discussed.

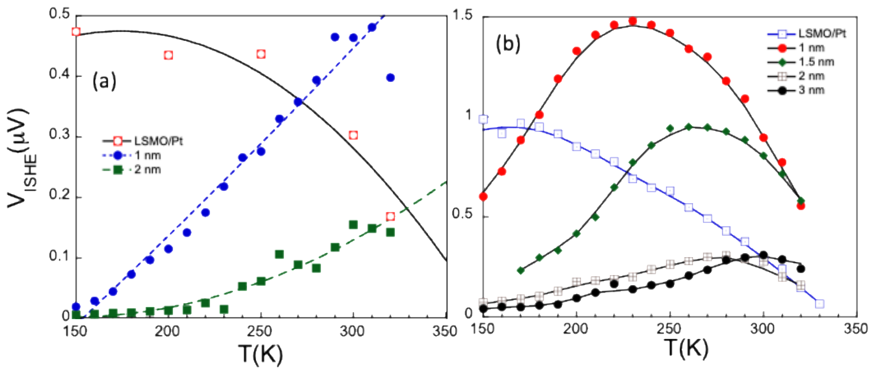

Figure 1. Temperature dependence of the V_{ISHE} voltage signal as a function of the NiO layer thickness for (001) (a) and (111) (b) oriented samples. The V_{ISHE} voltage signal corresponding to a LSMO(15 nm)/Pt(5 nm) reference sample is also included for comparison.

References

[1] H. Wang et al. Antiferromagnonic spin transport from Y3Fe5O12 into NiO, Phys. Rev. Lett. 113 (2014) 097202.
[2] W. Lin et al. Enhancement of Thermally Injected Spin Current through an Antiferromagnetic Insulator, Phys. Rev. Lett. 116 (2016) 186601.
[3] P. Wadley et al. Current Polarity-Dependent Manipulation of Antiferromagnetic Domains. Nat. Nanotechnol. 13, 362 (2018).

On the complexity of materials engineering for high-frequency circulators with hard magnetic ferrites

Ana Vila Costa,[a] Xavier Mir Pérez,[b] Naureen Khanam,[a] Vinod V K Thalakkatukalathil,[a] Nico Dix,[a] Pedro de Paco Sánchez,[b] and Martí Gich Garcia,[a]

[a] *Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Campus UAB, Bellaterra 08193, Spain*

[b] *Department of Telecommunications and Systems Engineering, Universitat Autonoma de Barcelona, Bellaterra 08193, Spain*

Magnetic ferrites are widely implemented in telecommunication and radar systems. Among the passive electronic elements, the well-established isolators and circulators must be adapted to the 95-300 GHz range, desired for the next generation of wireless transmission applications 6G and beyond [1],[2]. However, several challenges [3] must be overcome to allow the higher operation frequency and fabrication cost. On the materials side, suitable hard magnetic ferrite oxides have a limited saturation magnetization due to the substitution of Fe sites with non-magnetic elements and, thus, a reduced permeability at high frequency. The need to implement dense and magnetically oriented ceramics of controlled shapes with sizes below the mm scale pose fabrication challenges.

Here, we report on the fabrication and functional characterization of ferrite circulators in the 90-140 GHz range. The base materials used were Al substituted [Sr,Ca] M-type hexaferrite nanoparticles (fres ≈ 120 GHz), the powders present strong magnetic anisotropy evidenced by a coercive field strength above 1.5 T. MUTs were prepared by sintering ceramic disks and cutting them in suitably sized shapes, which were supported with polystyrene foam and centred inside a machined waveguide circulator. We compare as-prepared and magnetized MUTs (under external field of 7 T) with measurements with applied small external magnetic fields up to 0.3 T. Although a non-reciprocal response is observed for the S12/S21 scattering parameters, the observed difference is 4 dB in remanent state, till far from the desired 25 dB difference for application. A commercial high density and magnetically oriented hexaferrite from TDK with fres ≈ 80 GHz [4] was also characterized for comparison. Also, we will present preliminary data in the 140-220 GHz range using epsilon iron oxide as MUT. The results are discussed together with simulations, assisting and predicting the potential for application as passive devices.

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Generation of GHz helical acoustic drum modes on a chip

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Helical acoustic fields open the way for several advanced functionalities including the generation of optical beams with orbital angular momentum (OAM), the polarization control of magnetic excitations as well as the exploitation of non-reciprocal and topological phenomena [1]. The generation of helical acoustic fields has so far only been achieved at relatively low (i.e., sub-GHz) frequencies. In this contribution, we demonstrate a novel concept for the electrical excitation of laterally confined GHz helical acoustic modes in the form of Lamb waves (plate modes) on a chip [2,3]. The lateral confinement relies on the strong dependence of the frequency spectrum of the Lamb acoustic modes on the thickness of the propagating medium. As a result, Lamb modes generated by a piezoelectric resonator in a thicker (or thinner) region of the substrate remain confined in this region via reflections at the lateral boundaries with thinner (thicker) substrate regions. If the generation region is disk-shaped, the lateral reflections form drum-like modes, which are like the low-frequency (sub-GHz) modes of a thin membrane but now oscillating at GHz frequencies. We experimentally confirm the lateral confinement by radio-frequency spectroscopy as well as by maps of the surface displacements of the surface using optical interferometry with high spatial resolution. Finally, we demonstrate the generation of helical drum modes with tunable helicity by using an array of sector-shaped piezoelectric transducers powered with appropriate radio-frequency phases. The interferometric maps show that the OAM of the acoustic field can be transferred to an optical beam, thus providing a way to produce light with OAM modulated at GHz frequencies. Our finite-element and analytical models confirm that the confined Lamb modes with tunable helicity arise from the intrinsic elastic response of the structured sample and provide useful insights into the acousto-elastic coupling, thus guiding adaptation to other material systems. The acoustic drum modes thus provide a flexible platform for acousto-optical chiral functionalities in the GHz frequency range. Applications for spin chiral control as well as for the efficient generation of optical beams with OAM are discussed.

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Wrinkles for magnonics

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Magnonic crystals are magnetic metamaterials designed to control and manipulate spin waves (magnons). Magnons, collective excitations of electron spins, offer promising avenues for data transmission and processing [1] due to their low power requirements and compatibility with standard CMOS technology. Their propagation can be controlled by engineering artificial periodic structures at the micro-nanoscale in magnetic materials, and are generally fabricated through complex lithographic processes.
In certain systems, periodic structures can emerge naturally when using flexible substrates: these spontaneous surface modulations (wrinkles) appear under deformation in order to accommodate compressive strain. Such wrinkles on thin films may be purposely engineered during the deposition of the thin film on an elastomer substrate under tension [2] (for example to protect the film during future mechanical stress) and in magnetic thin films, they can induce a change in the magnetic properties due to the strain [3]. Notably, the spacing of these wrinkles—ranging from several tens of nanometers to micrometers—aligns well with the typical wavelengths of spin waves in ferromagnetic media.
In our work, we investigate the wrinkles of magnetic thin films grown on flexible polymer substrates, considering them as an ideal platform for magnonic systems – and eliminating the need for costly lithographic fabrication. We demonstrate how these wrinkles impact the magnetic anisotropy, as measured through magneto-optical Kerr microscopy and ferromagnetic resonance techniques. Additionally, we investigate how the wrinkles respond to applied stress, revealing a mechanically bistable behavior in their orientation. This bistability could enable unique forms of tunability in magnonic devices. Finally, micromagnetic simulations allow us to characterize the spin-wave dispersion in these wrinkled films, underscoring their potential for scalable and tunable magnonic applications.

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Stroboscopic Kerr Imaging of Magnetoacoustic Waves in Ferromagnetic Thin Films

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Spin waves play a crucial role in spintronics as they enable low-power information transport without charge currents. Their controlled excitation and propagation are essential for applications in non-volatile memory, magnetic logic, and wave-based computing. However, existing imaging techniques, such as microfocus Brillouin light scattering and scanning transmission X-ray microscopy, face limitations in temporal resolution or require synchrotron radiation. Time-resolved wide-field MOKE microscopy offers a powerful alternative [1], providing direct, real-time visualization of magnetoacoustic interactions with high spatial and temporal resolution. Surface acoustic waves (SAWs) efficiently couple with magnetostrictive ferromagnetic materials, inducing large-angle magnetization precession [2]. This interaction enables the excitation of spin waves, which can be imaged using magneto-optical Kerr effect (MOKE) microscopy.

In this work, we employ a stroboscopic Kerr imaging technique to visualize magnetoacoustic waves in thin ferromagnetic layers with micrometer spatial resolution. The results of our experiments provide time-resolved images of magnetoacoustic waves, allowing the study of their behavior as a function of the applied magnetic field and propagation angle. These waves are generated by SAWs, excited via interdigital transducers (IDTs) on a piezoelectric substrate, and interact with thin ferromagnetic layers such as nickel and cobalt, inducing magnetization oscillations. A picosecond-pulsed laser illuminates the sample, and the reflected signal is captured using a MOKE microscope.

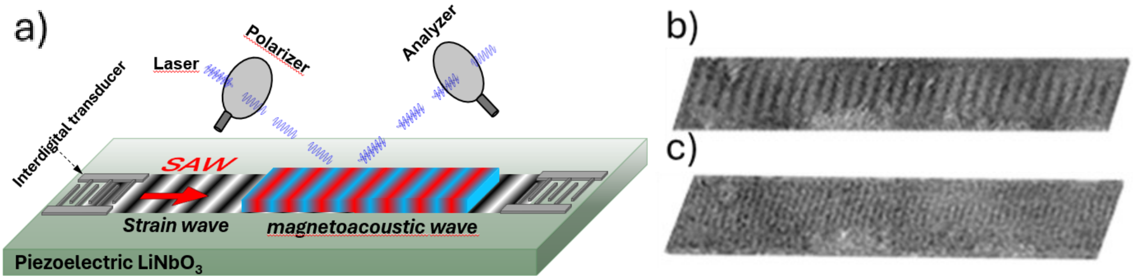

Figure. Set-up showing the generation and propagation of surface acoustic waves (SAWs), the resulting magnetoacoustic wave, and the detection via stroboscopic light. Stroboscopic images of magnetoacoustic waves at **(a)** 124 MHz and **(b)** 248 MHz.

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Orbital currents generated by surface acoustic waves in FM/NM bilayers

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Surface acoustic waves (SAWs) can be coupled efficiently to magnetostrictive ferromagnetic materials (FM) and are known to drive large angle magnetization precession [1,2]. The resulting magnetization oscillation may pump spin and orbital currents into adjacent nonmagnetic (NM) materials, which eventually can be converted into detectable charge currents from inverse spin and orbit Hall effects. However, pumping mechanisms can have diverse origins such as spin or orbital pumping, magnetorotation, and phonon angular momentum transfer—all of them with different symmetries with respect to the angle between SAW and magnetization. Typically, the detection of spin currents is done through inverse spin Hall effect (ISHE) in large spin orbit coupling (SOC) materials such as Pt, Ta and W. Nevertheless, these materials can be toxic, hard to find and are associated with environmentally harmful techniques. More recently, the orbital angular momentum has taken protagonism as it is predicted to have a comparable or even larger effect than its spin counterpart and may occur in cleaner and less expensive materials.
Here, we explore different pumping mechanisms in bilayer systems made of FM/NM through acoustically driven magnetization waves. The studied hybrid devices consist of a piezoelectric substrate where Interdigital Transducers (IDTs) are placed facing each other to generate and detect SAWs transmission. The FM/NM bilayers are deposited in different structures in the acoustic path in between facing IDTs (Figure 1 (d)) and both transversal or longitudinal voltages can be detected in presence of SAW. We compare nickel and cobalt as FM and chromium and aluminium as NM.
We demonstrate that SAW may induce orbital currents that are detected in the NM layer. Figure below shows a large inverse orbital Hall effect in the chromium compared with a tiny effect in aluminium. We study further amplitude asymmetries as a function of the angle between SAW and magnetization to quantify both the orbital pumping from FM and the orbital Hall conductivity in the NM metals.

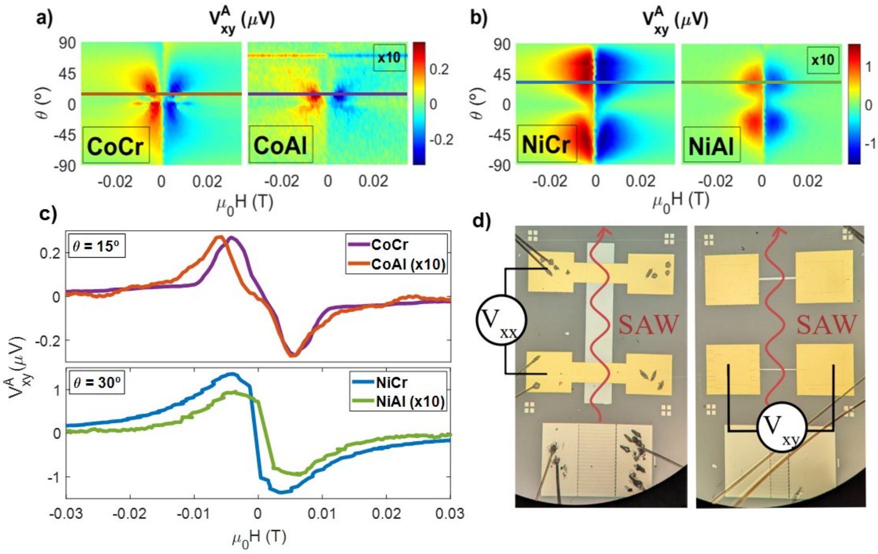

Figure 1. Measures of the angular dependence of the antisymmetric part of the transversal voltage (V^A_{xy}) for **a)** Cobalt/Chromium, Cobalt/ Aluminium and **b)** Nickel/Chromium, Nickel/ Aluminium bilayers in the presence of 1.3 GHz SAWs. **c)** Measures of the field dependence of the V^A_{xy} for the Cobalt bilayers at θ=15° and the Nickel bilayers at θ=30°. **d)** Experimental set-up for longitudinal (V_{xx}) and transversal (V_{xy}) voltage detection.

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Rayleigh-Jeans Condensation of Magnons in an Optomagnomechanical System

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Over the past two decades, the dynamics of parametrically pumped magnons in thin Yttrium-Iron-Garnet (YIG) films have been extensively explored at room temperature [1-3]. Since the discovery of a singularity in the population of the lowest-energy state in 2006 [1], significant efforts have been made to understand the fundamental properties of this unintuitive system. This led to the development of a stochastic Landau-Lifshitz-Gilbert (LLG) equation with non-Markovian damping [4], classifying this effect as a classical phenomenon, Rayleigh-Jeans Condensation (RJC), analogous to the quantum Bose-Einstein Condensation (BEC).
In this study, we investigate RJC within an optomagnomechanical system, characterized by strong couplings between specific magnon, phonon, and photon modes [5]. Initially, we simulate magnon dynamics using the LLG equation within MuMax3 [6], confirming the onset of RJC above a critical oscillating magnetic field. Subsequently, we introduce an additional coupling term to model the strong interaction with a particular mechanical mode, analyzing the dynamics of its population and revealing a rich phase diagram.
Furthermore, we explore the potential applications of this condensate in optomagnomechanical systems for quantum information processing.

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Electric control of switching fields in FM thin films using surface acoustic waves

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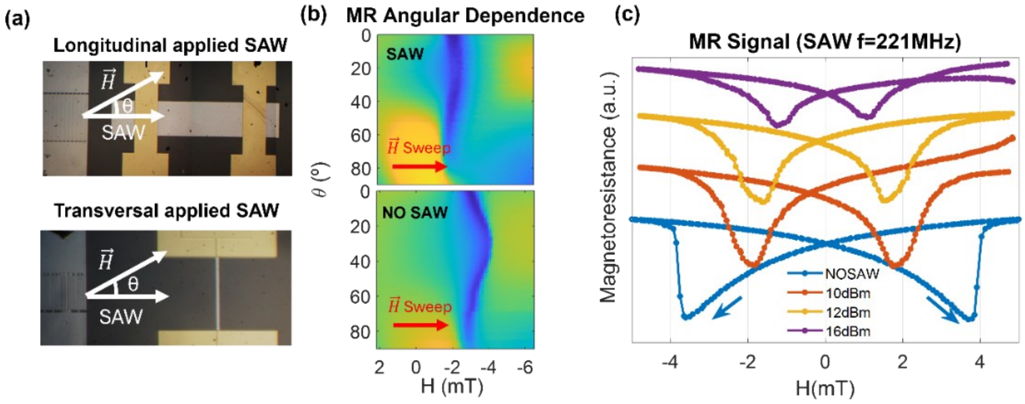
Surface acoustic waves (SAWs) provide a dynamic and energy-efficient means to control magnetization in ferromagnetic thin films through the magnetoelastic effect. By inducing periodic and time varying strain, SAWs can modulate magnetic properties in materials without the need for external magnetic fields. Recent studies have demonstrated SAW-driven magnetization effects in magnetostrictive materials including precessional magnetization switching [1], SAW-activated magnetic domain motion [2] and large angle magnetoacoustic waves [3]. However, a comprehensive understanding of their impact on coercive field reduction remains incomplete.
Here, we explore the influence of SAWs on the switching process of different ferromagnetic systems (Nickel and Cobalt), revealing a significant reduction in the coercive field, reaching up to 75% for certain conditions. This effect was attributed to the strain-induced modulation of magnetic anisotropy, which causes both precessional switching of the magnetic moment and variations in domain wall propagation. To disentangle these effects, we performed experiments on ferromagnetic samples deposited on the acoustic path of a SAW channel (see Figure (a)) and measured simultaneously the magnetoresistance, as a measure of the overall magnetic moment, and the MOKE as an indicator of the magnetic domain configuration. We repeated experiments in samples with different geometries to determine the contribution of both domain wall propagation and magnetic oscillations. In this contribution we present results obtained in Nickel and Cobalt thin films by varying both frequency, angle and amplitude of the applied SAWs. Our findings highlight the potential of SAW-assisted magnetization control for low-power spintronic applications and tunable magnetic devices.



(a) Microscopic image of IDTs, FM material and Au contacts for longitudinal resistance (top) and transversal resistance (bottom) of the sample with respect to the applied SAW. The transversal configuration is made with a FM path smaller than the used SAW wavelength. (b) Angular dependence of the magnetoresistance (MR) signal. Comparison between MR signal when 221MHz-16dBm SAW is applied (top) and without SAW (bottom). (c) MR signal obtained with and without SAW for different amplitudes and same frequency at $\theta \approx 45^{\circ}$. Arrows indicate the direction of the signal over time.

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Design of an optomagnomechanical crystal for the investigation of novel quantum states of matter

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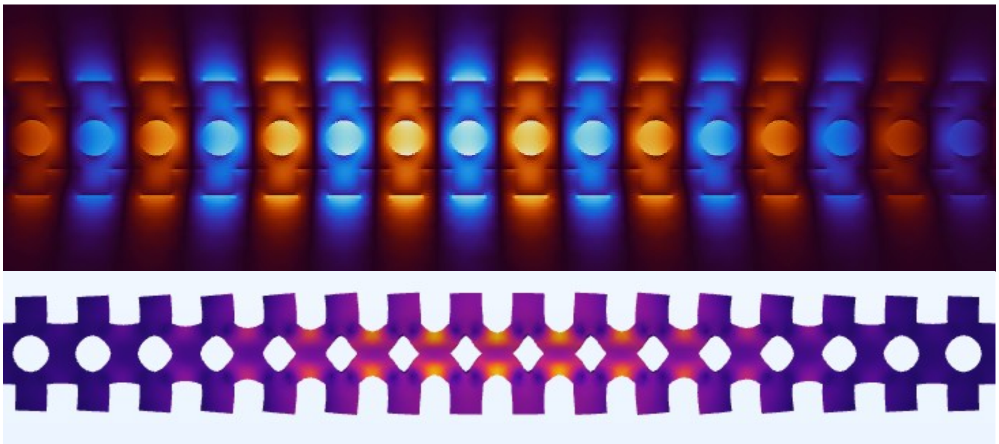
Hybrid systems came up as a way to combine the best aspects of different quantum systems. Spin systems in magnetic materials are a promising way to store and process information as well as a good environment to study magnon quantum states. Photons are known for being good transmitters of quantum information. Therefore, a hybrid system of photons and magnons (collective spin excitations) is of high desirability for applications such as the study of quantum states of matter and information processing and storing.
Optomagnonic systems have been studied in the past with direct coupling between magnons and photons [1]. However, the coupling strength fell short compared to other hybrid systems such as optomechanical (photon and phonon) crystals [2] and magnomechanical (magnon and phonon) systems [3].
We present a design of an optomagnomechanical crystal that takes profit of the large magnon-phonon coupling and the optimized crystal design of optomechanical crystals to achieve a high coupling.
We achieve a high-quality optical cavity, in the range of 10^5, with high optomechanical coupling of $2\pi \times 108$ kHz and high magnomechanical coupling of 2.8 MHz. Moreover, due to the coupling mechanism between magnon-phonon and phonon-photon, our cavity is highly tunable and allows for precise measurement of magnon mode by changing the external magnetic field.



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Josephson-like oscillations of polariton condensates in matter couplers

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In this work we demonstrate the operability of new devices for matter routing, similar to photonic routers, in our case for guiding polariton condensates: microcavity couplers. These devices consist of closely spaced parallel optical waveguides, so that energy can be exchanged between them. The coupled power, limited by the overlap of the modes in the coupler arms, is determined by the separation between the waveguides, the wavelength of the polariton condensates, the evanescence of the modes and the interaction length in the couplers [1].

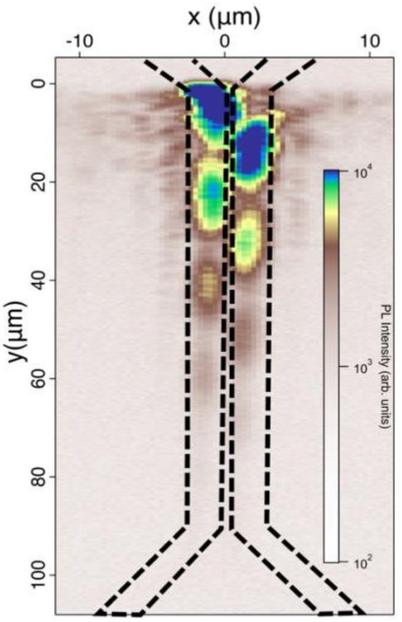

Figure 1 – PL Intensity map obtained after excitation at the top left terminal (not shown). The intensity is coded in a logarithmic false color scale and the dashed lines outline the left and right arms of the coupler.

We investigate the nature of the propagation of the condensates along the coupler arms using a combination of time-resolved (picosecond) microtomography measurements and a theoretical model based on a mean-field approach for the description of the condensates. We pay special attention to the coupling between the two arms for different coupler parameters, excited at the input terminals of the devices, at different power densities, measuring the light emission in the coupling region by blocking the emission from the input and output terminals using spatial filters. The evanescent coupling of the macroscopic wave functions between the waveguides is revealed in real-space oscillations in the condensate. These Josephson-like oscillations had only been observed in coupled polariton traps. We obtain a similar coupling in a controllable waveguide-based design. By making use of these oscillations, controlling the spacing between the coupled waveguides, the length of the coupling zone or the propagation energy, the output port of the polariton fluid can be chosen [2, 3]. Our results are corroborated by numerical simulations using the generalized Gross-Pitaevskii equation, which models coherent polariton dynamics in spatially non-uniform systems.This polariton codirectional device is a scalable, passive coupling element that can serve next-generation compact logic architectures.

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Photogalvanic phenomena at GHz range in superconductors supporting intrinsic diode effect

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We propose a phenomenological theory of photogalvanic effects in superconducting materials and structures exhibiting the diode effect. Using a generalized London model that incorporates quadratic nonlinearity in the relationship between supercurrent and superfluid velocity, we demonstrate that an incident electromagnetic wave can induce a nontrivial superconducting phase difference across the sample [1]. When enclosed within a superconducting loop, this phase battery is expected to generate a circulating dc supercurrent. By increasing the intensity of the electromagnetic wave, one can trigger transitions between loop states with different vorticities. It is important to note that this rectification effect differs from both the inverse Faraday effect in superconductors, which requires circularly polarized radiation, and the photon drag effect in superconducting condensates, recently explored in [2].

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Detection of orbital torques on magnetic layers via microwave techniques

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In recent years, the orbital Hall effect (OHE) and the interfacial orbital Rashba–Edelstein effect (OREE) have been theoretically proposed as orbital analogues to the spin Hall effect (SHE) and Rashba–Edelstein effect (REE) [1,2,3]. These orbital phenomena enable the generation of orbital currents from charge currents and offer higher orbital Hall conductivities over their spin counterparts. Moreover, OHE and OREE do not require materials with strong spin–orbit coupling, thus expanding the range of suitable materials for energy efficient spintronics applications [4].

Here, we investigate orbital torques in nonmagnetic metal (NM)/ferromagnet (FM) bilayers, where NMs include Pt, Ir, and V, and FMs include Ni, CoFeB, and (Co/Ni) multilayers. Using spin-torque ferromagnetic resonance (ST-FMR) in GHZ frequency regime and THz emission spectroscopy, we confirm the presence of current-induced torques originating from OHE in these systems. To enhance orbital-to-spin conversion, we introduce a Pt interlayer in samples with perpendicular magnetic anisotropy (PMA), which is essential for device applications. Low frequency (kHz) harmonic Hall measurements further verify the generation of sizable orbital torques in these heterostructures.

We also examine thulium orthoferrite (TmFeO3), a rare-earth orthoferrite exhibiting a spin reorientation transition (SRT) between 84 K and 92 K. We observe complex resonance behavior under microwave excitation (70–90 GHz) near the SRT, highlighting its potential for dynamic spintronic applications. Lastly, non-reciprocal orbital transport is observed in Ru-based non-local devices, indicating the presence of orbital and interfacial orbital Hall effects [5].

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Assessment of Machine Learning Models in Characterization of Magnetodielectric Composites

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With the current advancements in additive manufacturing and 3D printing, magnetodielectric (MD) composites have become increasingly interesting for developing applications in the microwave range. To characterize these materials, approaches that combine the use of machine learning (ML) models with well-established microwave characterization techniques, such as split ring resonators (SRRs), are increasingly employed for the electromagnetic determination of complex permittivity (ε) and permeability (μ) [1]. In this regard, this study evaluates several well-known ML models and determines their applicability to the simultaneous determination of both permittivity (ε) and permeability (μ). Particularly, this work delves into the methodological considerations affecting the reliability of ML models evaluation, systematically assessing several relevant models for regression problems in the field of microwave characterization [2]: linear regression, support vector machines, random forest, and artificial neural networks. Based on the analysis of performance metrics such as mean squared error (MSE) and the coefficient of determination (R^2), the model with the greatest generalization capability is determined. Furthermore, SHAP (SHapley Additive exPlanations) [3] is applied as an explainability technique to quantify the influence of each input feature on the simultaneous prediction of ε and μ. The results show that the model with the best generalization capability and robustness was the linear regression with second-degree polynomial features. The model explains over 99% of the variance in ε and μ as a function of the frequency response, with an error of 0.0014. SHAP values have indicated that the magnitude of the reflection coefficient and dielectric losses are decisive in predicting ε and μ. These results support the application of the ML-guided approach for characterization of magnetodielectric composites.

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Tunable Microwave Scattering Signatures of 3D Sensing Platforms Based on Ordered Magnetic Microwire Assemblies

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This work explores novel configurations of sensing array platforms composed of Co-based amorphous ferromagnetic microwires (MWs), aiming to enhance the modulation of microwave scattering effects through the application of low-strength DC or AC magnetic fields [1]. Amorphous MWs are ultrasoft ferromagnetic materials (coercivity ~0.2 Oe) characterized by circumferential magnetic anisotropy, which enables high surface sensitivity when exposed to external magnetic fields [2].

Microwave scattering experiments were first conducted by varying the length and number of MWs arranged in parallel to form linear arrays. Based on these results, several array configurations were developed, achieving significant S21 scattering coefficients, with values reaching approximately −50 dB. The influence of DC and AC magnetic fields on the S21 parameter was analyzed in the frequency and time domains, respectively.

Moreover, the sensing capability of the MW arrays to detect mechanical strain was experimentally demonstrated, confirming their potential for multifunctional sensing applications.

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Novel methods for enhanced radar absorption in multilayer magnetic composites

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Progress in radar absorbing materials (RAMs) hinges on solving complex design challenges that involve numerous variables and lie at the intersection of multiple scientific and technological disciplines. This presentation aims to provide a comprehensive overview of the current state of the art in the field, emphasizing the key factors that play a critical role in optimizing radar stealth coatings.

The focus will be on multilayered systems composed of magnetodielectric composites—materials that combine a dielectric matrix with magnetic fillers [1]. Alongside a critical review of recent developments, the presentation will introduce the most relevant theoretical models and frameworks that underpin the design and performance of these materials [2].

We will also present experimental evidence demonstrating the effectiveness of high-absorption and broadband-absorption materials developed by our team according to these design principles [3]. Notably, the magnetic multilayer systems exhibit a high degree of tunability, allowing their absorption characteristics to be tailored through strategic design [4].

Overall, the presentation will examine a wide range of existing designs, elucidate their design criteria, and explore new approaches and future research directions aimed at maximizing microwave absorption capabilities.

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Temporal Nambu-Goldstone mode and Floquet thermodynamics in spontaneous and driven Floquet states

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We study symmetry-breaking in spontaneous Floquet states, focusing on atomic condensates. First, we quantize the Nambu-Goldstone (NG) modes for stationary states spontaneously breaking several symmetries by invoking the generalized Gibbs ensemble. We extend the formalism to Floquet states, where Floquet-NG (FNG) modes emerge with zero quasi-energy. For spontaneous Floquet states [1], there is a genuine temporal FNG mode associated with the broken time-translation symmetry and whose quantum amplitude provides a unique example of time operator in quantum mechanics. Those states conserve energy and a novel charge, the Floquet charge, whose conjugate is the frequency, while driven systems conserve the Floquet enthalpy. This establishes a new thermodynamic paradigm for both spontaneous and externally driven time-periodic systems. We apply our formalism to a flowing quantum gas emitting a continuous train of solitons [1,2] due to the presence of a local attractive potential and thus embodying a time supersolid. We numerically compute its density-density correlations, predicted to be dominated by the temporal FNG mode at long times, and observe a remarkable agreement between simulation and theory [3]. The possible generalization to solid-state systems is discussed.

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Beating Carnot efficiency with periodically driven chiral conductors

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Traditionally, the output of an ideal heat engine is constrained by the Carnot efficiency, a fundamental consequence of the second law of thermodynamics. A key unresolved issue is whether this restriction persists for microscopic engines operating far from equilibrium. In this study, we reveal that a quantum chiral conductor subjected to an alternating current (AC) voltage can achieve efficiencies that significantly exceed the Carnot limit. Remarkably, this system is also capable of extracting work from thermal reservoirs at equal temperatures, thereby contravening the Kelvin-Planck formulation. However, when entropy production is accurately defined, it remains strictly positive, ensuring that the second law is not violated. The essential factors enabling these enhanced efficiencies are: (i) the irreversible generation of entropy via photoassisted excitation processes induced by the AC field, and (ii) the lack of power input due to the system's chiral properties. These findings are particularly relevant in light of recent advances employing nanoscale conductors to explore the ultimate boundaries of thermodynamic engine performance.

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High Frequency Magnetic Resonance using Terahertz Generalized Spectroscopic Ellipsometry

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We present a groundbreaking advancement of magnetic-resonance spectroscopy into the terahertz range using polarization-resolved ellipsometry at high magnetic fields. This method enables precise testing of existing models and uncovers new phenomena, such as the magnetic Lyddane-Sachs-Teller relationship. Furthermore, our approach provides detailed insights into the quantum properties and interaction with the local environment of defects and dopants in semiconductors like SiC,[1] GaN,[2] and Ga2O3,[3] and is applicable to paramagnetic and ferromagnetic resonances. This advancement addresses the limitations of current methods, which often ignore polarization properties and are restricted to fixed frequencies.

Using this method, we discovered a magnetic counterpart to the dielectric Lyddane–Sachs–Teller relation, derived from Bloch's nuclear induction model.[4] The magnetic LST relation links the static magnetic permeability to the product of the longitudinal and transverse optical modes of magnetic excitations, in contrast to the dielectric version, which depends on the squares of resonance frequencies. We experimentally verify this relationship using terahertz electron magnetic resonance spectroscopic ellipsometry on an iron-doped gallium nitride crystal under an external magnetic field, thereby establishing the existence of a magnetic analogue to the LST relation.

Moreover, we used our method to investigate Cr^{3+} impurities in β-gallium oxide.[3] The technique enabled precise mapping of spin-resonance features across magnetic field and frequency, revealing both zero-field and Zeeman splitting. By fitting spin-Hamiltonian parameters, which predict the resonance freuqencies, we determined the magnitudes and signs of the zero-field splitting terms, resolving ambiguities of previously reported values. Spectral analysis confirmed that Cr^{3+} substitutes exclusively only one of the two inequivalent gallium sites.

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Adiabatic Spintronics with Topological Magnetic Insulators

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I will present our recent experimental demonstration of electrically induced antiferromagnetic resonance in the topological antiferromagnetic insulator $MnPS_3$, providing the first direct validation of a revolutionary theoretical framework in spintronics [1,2]. This theory, rooted in the concept of adiabatic spintronics, proposes that the dynamics of magnetic order in certain topological materials can be driven by a pure voltage—completely bypassing the need for electrical currents and, with them, the ubiquitous problem of Joule heating. Such a mechanism has profound implications for the future of information technology, particularly as data manipulation is projected to become the dominant source of global energy consumption. Our results confirm that the Neel spin-orbit torques can be generated electrically within a single insulating magnetic structure, eliminating the need for external spin sources or engineered heterostructures. The experiments were performed at frequencies in the 100 GHz range using a home-made, quasi-optical sub-THz microwave spectrometer. By continuously varying the polarization of the microwave excitation from linear to circular in both the Faraday and Voigh geometries, we were able to controllably switch the driving mechanism of the resonance from magnetic (Zeeman-type) to purely electrical (via the Neel spin-orbit torque). This polarization-tuning approach allowed us to isolate and unambiguously identify the electrically induced component of the resonance—offering direct evidence of adiabatic pumping effects predicted by the theory. This work, supported by the W. M. Keck Foundation, not only confirms the existence of a dissipation less voltage-driven control of magnetism, but also establishes topological magnetic insulators as a promising material platform for next-generation lossless spintronic devices. The implications extend to a wide range of technologies, including AI computation, where power efficiency is rapidly becoming the central challenge. I will conclude by discussing how these results open new directions for materials research, device engineering, and large-scale funding opportunities aimed at solving the energy crisis in modern computing.

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Skyrmion Crystal in a Microwave Field

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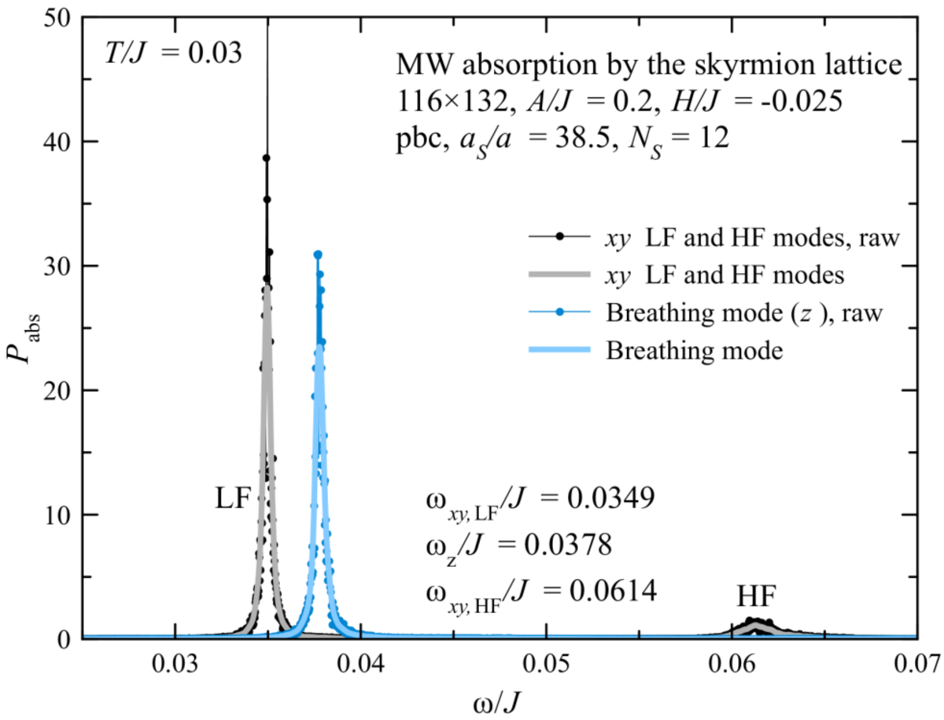
Temperature and field dependences of the frequencies of uniform modes of the skyrmion lattice (SkL) in a 2D ferromagnetic film with Dzyaloshinskii-Moriya interaction, as well as their damping, are computed within the model of classical spins with no phenomenological damping added [1]. The low-frequency (LF), or quasi-bulk, mode, as well as the high-frequency (HF) mode respond to the microwave field (MF) in the *xy* plane, whereas the breathing mode responds to the MF field along *z*. MW-absorption peaks due to all three modes obtained by computing the free evolution of the system at the temperature *T* and using the fluctuation-dissipation theorem are shown in the figure. Resonance MF irradiation of the LF mode is the most interesting as it leads to the SkL destruction. The HF mode is typically weak, while exciting the breathing mode leads to the skyrmion collapse. We show that at the initial stage of the resonance excitation of the LF mode with MW, the magnetization of the film exhibits Rabi-like oscillations with the energy being absorbed and then released. Then the absorbed energy starts to migrate to non-uniform modes and the process becomes chaotic. This finally leads to SkL melting which is investigated in terms of the time dependence of the orientational and translational order parameters. A distinct single-stage melting transition has been observed. The system's spin temperature T_S increases in this process but remains much lower that then the equilibrium SkL-melting temperature [2], so that the SkL destruction we observe is non-thermal. Similar results were obtained with a fixed spin temperature.



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Multifrequency attenuation in nanostructured multilevel metastructures based on GO/Fe_3O_4/PPy composites for military detection applications

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This work highlights the potential of graphene-based composites embedded in resin metastructures for the study and development of architectures with tunable electromagnetic attenuation properties. Magnetic graphene-based composites with the general composition GO/Fe_3O_4/PPy were synthesized and integrated into 3D-printed, three level metastructures varying compositions and filler charges to evaluate their electromagnetic attenuation capabilities. Structural, chemical, morphological, magnetic, and electromagnetic characterizations were performed. The formation of spherical nanoparticles distributed over graphene oxide sheets and polypyrrole nanotubes, which in a 3D printed polymeric resin led to the development of a nanostructured metastructure was demonstrated. The Gated Reflected Line (GRL) free-space electromagnetic characterization which measured the reflection loss response of the metastructures showed several electromagnetic attenuation peaks in the X-band (8-12 GHz). The electromagnetic response was modelled based on the superposition theorem to generate an equivalent electrical circuit of the nanostructured metastructures. The optimum relation of conductive and magnetic material for composites, as well as filler material incorporated into the resin was determined. The results demonstrated the capacity of the structures to attenuate at least 90% of the incident wave in "real life" conditions. The nanostructured metastructures exhibit enhanced broadband attenuation response in the X-band frequency range (8-12 GHz), demonstrating its potential application in electromagnetic protection and detection systems.
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Analysis of the Impact of Shaped Metasurfaces on the RCS Reduction

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Low observability technologies are under constant development as they allow a target to be hidden from a detection system, which translates into a reduction of its radar cross section (RCS). The are several ways to reduce the RCS, that are mainly classified as absorption, scattering and polarization conversion. Specifically, there are designs that manage to scatter the electromagnetic waves impinging on them, so that the reflection is not received by the radar. The works that can be found in the literature analyze flat surfaces, considering them as the worst case. However, the applicability of these solutions to real targets needs to be studied.
In this contribution, the shaping of a dispersive chessboard metasurface on a real target is studied. For this purpose, a model of an Unmanned Aerial Vehicle is used to analyze the critical areas that generate a larger radar cross section. Although the areas that cause the most RCS are the flat areas, the edges between them can also be problematic and that is part of this study, In this aspect, it is verified that their presence is not a problem in terms of RCS reduction. On the other hand, the fuselage of the target under study is curved, so it is also necessary to analyze curved shaped structures. In this line, the original flat metasurface has been adapted to different cylindrical curvatures, achieving for all cases similar results to those obtained with the flat design.

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Effects of retardation on many-body superradiance in chiral waveguide QED

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We study the superradiant decay of a chain of atoms coupled to a chiral waveguide, focusing on the regime of non-negligible photon propagation time. Using an exact master equation description which accounts for delay effects, we obtain evidence to suggest that competition between collective decay and retardation leads to the emergence of an effective maximum number of atoms able to contribute to the superradiant dynamics, resulting in a plateau of the peak emission rate. To develop this analysis further, we investigate the inter-atomic correlations to find features consistent with the formation of individual superradiant domains. Moreover, we find that retardation can also result in persistent oscillatory atomic dynamics accompanied by a periodic sequence of emission bursts.

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Development of a specialized free-space EM characterization method for thin samples with an alignment system and angle of incidence control

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Free-space methods for electromagnetic characterization can be beneficial when developing materials for electromagnetic shielding. We focus on magnetic composites optimized for their wide-band absorption capabilities [1, 2]. Furthermore, these measurements are non-destructive and highly versatile. These advantages are beneficial to many scientific fields, as it allows to characterize the samples under the same environmental conditions as their potential applications [3]. Considering the potential of free-space antenna setups, we developed a methodology aimed at adding further improvements and versatility for our area of study. The setup is meant for electromagnetic characterization of thin films in the X and Ku frequency bands (8-18 GHz) and is implemented inside a compact anechoic chamber (80 MHz-18 GHz). We use different sets of horn antennas to study reflection and transmission in two configurations. In one configuration, the sample is placed on a conductive support to study reflection as a function of the angle of incidence. In the other configuration, both antennas are pointing at the sample, which is positioned between them in a linear arrangement. Moreover, the experimental setup has a laser system for antenna and sample alignment to ensure maximum precision. The design's versatility was accomplished by using 3D-printing personalized supports, anchors, and other accessories. This way, we can study the effect of further variables such as the angle of incidence or temperature. The system was optimized via electromagnetic finite element and ray-tracing simulations for the near field and far field cases respectively. Preliminary results show potential for future usage of the proposed setup when developing absorptive materials. The combination of reflection-loss measurements, characterization using the Nicolson-Ross-Weir method [9, 10], and an alternative confirmation of the dielectric constant via a resonant chamber, makes for a strong case in the characterization of thin materials. This work was made possible thanks to the support of the U.S. Air Force Office of Scientific Research (AFOSR) under grant FA8655-22-1-7049.

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Recent Advances in multipactor physics and mitigation

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Multipactor is a nonlinear phenomenon that occurs when electrons driven by a radio frequency (rf) electric field in a high vacuum environment create an avalanche by impacting one or more metallic or dielectric surfaces. The electron avalanche sustains itself by a rapid charge growth through secondary electron emission from the surfaces and can cause a multitude of problems in space-based rf and microwave systems, such as satellite communication payloads and spacecraft components, travelling wave tubes (TWTs), high power microwave sources [1], and particle accelerators. Mitigation of multipactor has been one of the major challenges for the rf community over the past few decades [2].

In this talk, I will first provide a brief overview of basic concepts of multipactor discharge including secondary electron emission, electron kinetics, multipactor susceptibility, and saturation mechanisms. I will then present recent advances in multipactor mitigation strategies, focusing on engineered device surfaces and engineered non-sinusoidal rf fields [3-5]. In addition to vacuum electron multipaction, recent advances in multipactor-induced ionization breakdown in microwave devices are also highlighted [6].

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Broadband spin pumping characterization of YIG/W bilayer thin films

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Efficient conversion between spin and charge currents is the key ingredient for reducing power consumption in spintronic devices, therefore, identifying materials with high efficiency in spin-to-charge conversion is a relevant and timely technological challenge today. The standard mechanism to produce such conversion is the Inverse Spin Hall Effect (ISHE) [1], in which a spin current is converted into a transverse charge current in a material having a high spin-orbit coupling. The efficiency of this conversion in a material is quantitatively characterized by the spin Hall angle.
Because the highly resistive β-phase of W has the highest spin Hall angle reported for a simple element, while the low-resistive α-phase of W has a small spin Hall angle, we have studied the efficiency of spin-to-charge conversion in W. To this end, broadband spin pumping experiments have been performed, utilizing the phenomenon of ferromagnetic resonance to generate pure spin currents and inject them into the material under study from an adjacent ferromagnetic insulator. Specifically, the ISHE signal has been studied in spin pumping experiments at frequencies up to 20 GHz in YIG/W(t) bilayers in which the W layer thickness has been varied between 2 and 12 nm. The structural properties of the different layers forming the bilayer have also been studied in detail using high-resolution transmission electron microscopy.

Our findings highlight the link between structural and transport properties and the spin Hall angle, paving the way for designing next-generation spintronic devices with precise control over spin current generation and detection [3].

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Degeneracies, Conical Intersections, and Dissipation in Floquet Systems

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A frequent approach towards understanding ac-driven quantum systems is based on an approximate mapping to a static system via a series expansion in the inverse of the driving frequency. Such Floquet approaches may work even for intermediate frequencies, and often the analysis can be performed analytically. Quantum dissipation brings in an additional challenge, because one has to find a suitable approximation not only for the central driven system, but also for the system-bath coupling. For some limits, it is known that the final population of the Floquet states is determined by the quasienergies. In other cases the time-averaged energy expectation value seems crucial [1].

In this context, conical intersections of quasienergies represent interesting points in parameter space at which the stationary state of the driven dissipative system may change qualitatively. Such intersections typically emerge when the system for a determined value of one parameter exhibits a symmetry, while variation of this parameter breaks the symmetry. Then many properties of the steady state can be deduced already from a symmetry analysis. I will present such analysis which reveals the impact of the mean energies. The findings are confirmed by numerical results for the two-level system in the presence of a heat bath [1] and an electron reservoir [2]. The symmetry that allows the degeneracy may not be obvious, but be hidden in a time-dependent invariant [3]. Moreover, I will introduce a strategy to find such hidden invariants and discuss their properties for the example of the driven two-level system.

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Photon-resolved Floquet theory and its application to microwave sensing

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he experimental development of radio- and microwave-sensing devices based on spectroscopy of Rydberg atoms has continuously improved in recent years, reaching an astonishing sensitivity. However, a theoretical framework predicting the sensitivity of such spectroscopic quantum sensing devices for arbitrary parameter regimes is still lacking, in particular, because of the difficulties in predicting the measurement noise beyond the photon-shot noise.

In this talk, I will introduce a theoretical framework of light-matter interaction, dubbed photon-resolved Floquet theory (PRFT), which is capable to track the photon exchange of a driven quantum system with its driving field in the semiclassical regime [1]. Noteworthy, in closed quantum systems, the PRFT predicts a macroscopic light-matter entanglement effect [2]. In open quantum systems, it predicts diverging photonic fluctuations in the weak dissipation regime [3]. The application of the PRFT to spectroscopy demonstrates how the framework can assist in improving spectroscopic quantum sensing methods [4]. For radio-frequency and microwave frequency sensing with Rydberg atoms, the PRFT is a flexible tool to find experimental parameters optimizing the measurement precision.

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Quantum information transfer mediated by topological edge states

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The recent fabrication and control of semiconductor quantum dot arrays open the possibility of using these systems as quantum links for transferring quantum information between distant sites, an indispensable part of large-scale quantum information processing. Recently, it has been shown how to imprint nontrivial topology in a quantum dot array using Floquet engineering[1].
In this talk, I will first review the different protocols to directly transfer particles and quantum states in quantum dot arrays between distant sites. Then I will discuss an alternative way to transfer information with high fidelity using protected topological edge states in systems with non-trivial topology [2,3] and the role of topological domain walls in speeding up the particle transfer [6]. I will consider the simplest topological insulator, the SSH chain, and also the Creutz-Ladder model [4,5], where the domain walls can hold two topological states. It allows the use of one as a quantum memory while the other transfers information through the wall, allowing for complex transfer operations between topological states. It opens efficient avenues for quantum state transfer protocols in low-dimensional topological lattices.

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AC current driving of superconductor-semiconductor-based Josephson junctions

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I will first briefly review a few experimental results on SQUIDs realized in proximitized two-dimensional hole gases in germanium [1]. The current-phase relationship (CPR) of the SQUIDs turned out to be highly tunable, both through the magnetic flux and through gates that control the transparency of the Josephson junctions, which allowed tuning the SQUID to a regime where the second harmonic of its CPR dominates. Adding an AC current drive to the junction yielded additional tunability of the cricitcal currents in the two directions, which could be used to reach a regime where a net supercurrent can only flow in one direction through the SQUID. Motivated by these results, we theoretically explored the dependence of the critical currents of such a junction on the amplitude and frequency of an AC current drive, using a simple RSJ model [2,3]. Both in the slow- and fast-driving limits and for harmonic and biharmonic drives we found simple analytic results, which can help connecting the experimentally measured response to current driving to the underlying CPR of a junction [4].

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A proposal for charge basis tomography of superconducting qubits

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We introduce a general protocol for obtaining the charge basis density matrix of a superconducting quantum circuit, based coherent microwave pulses for control and measurement [1]. Inspired by cavity state tomography, our protocol combines Josephson-energy pulse sequences and projective charge-basis readout to access the off-diagonal elements of the density matrix, a scheme we thus dub charge basis tomography. We simulate the reconstruction of the ground state of a target transmon using the Aharonov-Casher effect in a probe qubit to realise projective readout and show the Hilbert-Schmidt distance can detect deviations from the correct model Hamiltonian. Unlocking this ability to validate models using the ground state sets the stage for using transmons to detect interacting and topological phases [2], particularly in materials where time-domain and spectroscopic probes can be limited by intrinsic noise.

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High Performance Terahertz Quantum Cascade Lasers for Spectroscopic Applications

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Quantum Cascade Lasers (QCLs), first introduced in 1994 in the mid-infrared spectral region [1], are unipolar semiconductor lasers that rely on the intersubband transitions within the conduction band of a planar periodic quantum well/quantum barrier heterostructure.

Terahertz (THz) QCLs, operating in the 1.2–6 THz frequency range, are promising radiation sources in the so-called terahertz gap of the electromagnetic spectrum. Following the first demonstration of THz QCLs in 2002 [2], these devices have opened new avenues in high-resolution spectroscopy of atoms, molecules, and ions. Specifically, the rotational transition of OH at 3.5 THz and the fine structure transition of neutral atomic oxygen (OI) at 4.7 THz are of particular interest in atmospheric science due to their role in Earth's energy balance [3]. Beyond spectroscopy, these devices find applications in non-destructive imaging, biomedical diagnostics, security screening, and ultra-high-speed wireless communications, making them invaluable tools in both scientific research and practical technologies.

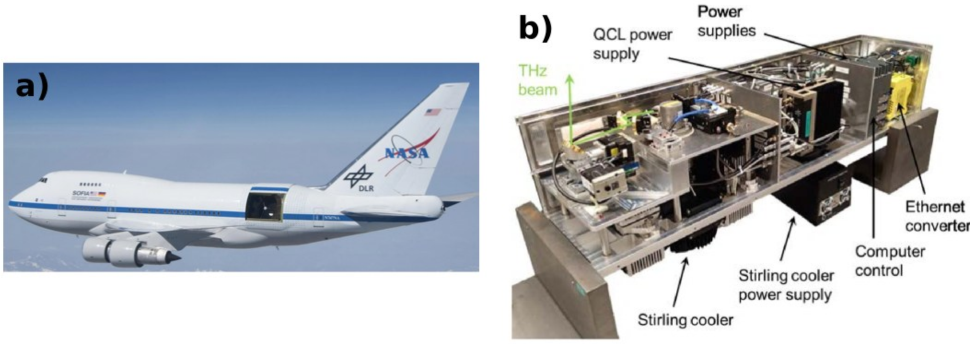

Fig.1 a) Photo of SOFIA during operation. b) Photo of the opened local oscillator box of the upGREAT heterodyne array receivers on the SOFIA [4].

In this contribution, we report on the development of high performance THz QCLs with target frequencies of 3.5 and 4.7 THz, based on $GaAs/Al_xGa_{1-x}As$ heterostructures. Our QCLs have already been implemented as local oscillators onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) (Fig. 1) [4] to detect interstellar atomic oxygen via heterodyne spectroscopy, as well as to perform absorption spectroscopy of ions in plasma.

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High-quality Poor Man's Majorana bound states from cavity embedding

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Poor man's Majorana Bound States (MBS) arise in minimal Kitaev chains when the parameters are fine-tuned to a sweet spot [1]. We consider an interacting two-site Kitaev chain coupled to a single-mode cavity and show that the sweet spot condition can be controlled with the cavity frequency and the hopping between sites. Furthermore, we demonstrate that photon-mediated effective interactions can be used to screen intrinsic particle interactions, improving the quality of the original MBS. Finally, we describe the experimental signatures in the cavity transmission to detect their presence and quality. Our work proposes a new way to tune poor man's MBS in a quantum dot array coupled to a cavity [2].

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Topological Quantum Synchronization

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Synchronization is a particular example of driven-dissipative dynamics, where individual systems adjust their dynamics upon interactions to achieve a unified rhythm. With the recent developments in quantum technology which allow one to exquisitely tailor both the system and environmental properties, synchronization has emerged in the quantum domain with considerable current interest from both basic and applied perspectives. Since the underlying description of the world is quantum, it is natural to ask how synchronization phenomena are modified when the degrees of freedom are quantum, and how the principles of synchronization can be stated in a way compatible with quantum mechanics. In this talk, I will give an overview of different attempts to define and explore quantum aspects of synchronization; in particular, synchronization of quantum limit-cycle oscillators and within the framework of strong dynamical symmetries. Additionally, I will discuss the new frontier of topological quantum synchronization — an interdisciplinary topic which combines topological concepts with synchronization — focusing on two particular examples: First, edge state synchronization in a topological lattice of quantum van der Pol oscillators and second, synchronization of emerging, fractionalized spins in the gapped symmetric phase of the spin-1 Haldane chain. Compared to previous examples of many-body synchronization, this synchronized dynamics does not require any fine tuning and is thus inherently more robust. These examples demonstrate that the strategic use of dissipation can be a powerful tool to generate nontrivial nonequilibrium many-body dynamics.]

Harnessing Large Spin-Orbit Interactions for Next-Gen Hole Spin Qubits

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QuTech, Delft University of Technology, Delft, The Netherlands

Hole nanostructures are leading candidates for large-scale quantum computers due to their pronounced spin-orbit interactions (SOIs) and remarkable tunability. In this presentation, I will discuss various strategies for harnessing this tunability to enhance the performance of current hole spin qubits, with a focus on both silicon and germanium qubits.
Charge noise presents a significant obstacle for shuttling spins[1], a critical requirement to establish long-range connectivity between distant qubits. Here, I will explore how SOIs can induce intricate spin dynamics that effectively filter out low-frequency noise, thereby improving the efficiency of spin shuttling processes.
Furthermore, the influence of SOIs extends to two-qubit gates, where exchange anisotropies[2,3], induced by these interactions, offer avenues for accelerating the execution of two-qubit gates without compromising fidelity. This implies that by leveraging the unique properties of SOIs, novel methods can be devised to expedite gate operations, and to encode more reliably quantum information[4], thus paving the way towards large-scale spin based quantum information processing.

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Experiments with Milimeter-Wave Photons at Milli-Kelvin Temperatures

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Superconducting quantum circuits and many other cryogenic qubit types typically operate at microwave frequencies. Here, the tool set of microwave components is extensive, well-tested and low-noise. Quantum applications in the millimeter regime are still rare, mainly because the components are bulky, costly, and place high demands on the cryogenic system. However, the ten to twenty times higher photon energy at e.g. 100 GHz offers many interesting new possibilities, such as very compact qubits, increased resilience to temperature fluctuations or a faster qubit manipulation.
We have developed a cryogenic setup for single mm-wave photons consisting of dielectric waveguides and tested it with a superconducting Fabry-Pèrot cavity at 10 milli-Kelvin[1]. We show that the quality of the mm-wave signals is sufficient to measure cavity quality factors of over 10 million at 110 GHz in the few photon limit. The results show no evidence of the influence of atomic two-level systems in the cavity.

[1] J. Lenschen, et al. arXiv:2411.15058

Circuit QED with Molecular Spin Qudits

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Molecular complexes combine perfect reproducibility with the ability to encode multiple qubits or, in general, *d*-dimensional qudits in their electronic and nuclear spin states. A molecule can then act as a small-scale quantum processor or even correct errors [1-4]. Exploiting these advantages calls for a solid-state platform able to initialize, control and read-out the molecular spins, and of establishing links between remote spins [5]. I'll discuss recent experiments aimed at achieving this goal by coupling molecular spin ensembles to chips hosting multiple superconducting microwave resonators and transmission lines [6-8]. The results provide proof-of-concept implementations of basic quantum operations. Also, we find that the circuit can mediate effective interactions between distinct spin ensembles located on remote resonators. In the case of spin qudits, high cooperativity coupling to electronic and nuclear spins has been achieved [6], which provide the basis for a full control and detection of the multiple spin states. Finally, I'll discuss different strategies, based on the optimization of either the circuit [9] or the molecular integration [10], for extending this approach to address individual molecular spins.

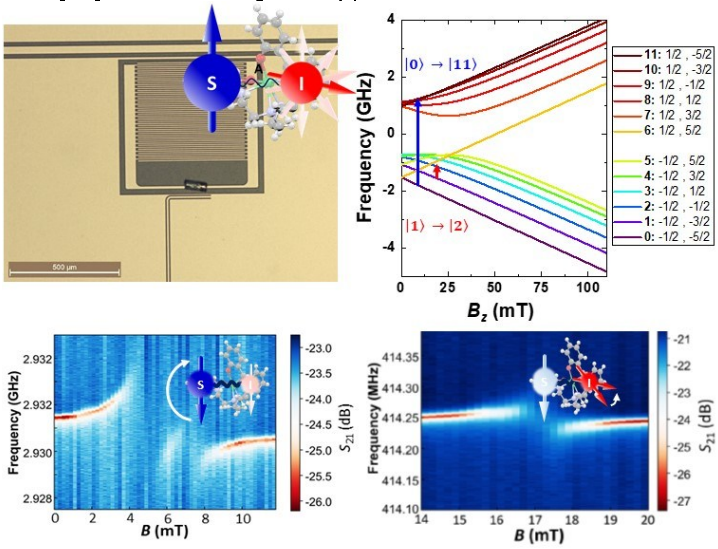

Figure 1. A single crystal of a ^{173}Ybtrensal electronuclear spin qudit is coupled to a superconducting resonator. Microwave transmission experiments show that the spin-photon coupling reaches high cooperativity, which allows reading out the qudit states.

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Ferrites for non-reciprocal devices above 100 GHz

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There are very few magnetic materials suitable to implement non-reciprocal devices such as circulators in the millimeter wave range. This is because a good functional response requires a large magnetization and a large anisotropy field anisotropy field H_a, to have a ferromagnetic resonance FMR at high frequency. However, H_a is proportional to the magnetic anisotropy K and inversely proportional to the saturation magnetization M_s. Since magnetic insulators do not reach magnetic anisotropies in the order of 10^6 J/m^3, it is difficult that a material can simultaneously display a large M_s and a large H_a.

In this contribution, we will illustrate these challenges by presenting the changes in the magnetic properties and the FMR induced by Fe^{3+} substitution by Cr^{3+} and Sc^{3+} in ε-Fe_2O_3 and by Al^{3+} in $Sr_{1-x/12}Ca_{x/12}Al_xFe_{12-x}O_{19}$. In particular, the Cr^{3+} substitution increases the magnetic anisotropy field, and the FMR from 178 GHz to about 200 GHz. In contrast, the Sc^{3+} substitution which has an opposite response, lowering the FMR. Regarding the Sr hexaferrite, the incorporation of Al^{3+}, significantly increases H_a. We will discuss the prospects of using these materials in passive non-reciprocal devices operating above 100 GHz.

Low surface impedance REBCO coatings for microwave applications under high magnetic fields

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[d] *CERN - The European Organization for Nuclear Research, Geneva (Switzerland)*

Emerging high-energy physics technologies require excellent RF response under high-magnetic fields or under high-electric field gradients; like CERN's FCC-hh next generation high-energy accelerator, which operates at 16T and at 50K; Dark Matter axion detection haloscope cavities, where the detection sensitivity scales as the square of the external magnetic field; or high-power linear colliders with an accelerating gradient above 100 MV/m. Therefore, at the operating conditions of these technologies, penetration of magnetic field lines into the superconductor is unavoidable and thus, its RF response is governed by vortex pinning. Under those conditions, NbTi and $NbSn_3$ superconductors offer a very poor, lower-than Cu, RF response and the high-energy physics community turned its attention back to Cu. However, we demonstrated that under the conditions required for such applications, $REBa_2Cu_3O_{7-x}$ (RE = Y, Gd, Eu) (REBCO) offers outstanding, better than-Cu RF response [1, 2]. The reason for this is its higher critical temperature T_c > 90K, larger upper critical field H_{c2} (4K) > 100T and larger pinning forces F_p (4K) = 1000 GN/m3. Unfortunately, its usage in RF applications is impeded by complicated material growth that requires meticulous stoichiometry control and biaxially textured templates, making it virtually impossible to grow REBCO directly on the geometrically complex surfaces required for many applications.

In this talk, we present our recent studies, where we have worked towards understanding the high-field microwave response of REBCO coated conductors (CCs) up to 16T, in a wide cryogenic temperature range, at several RF-frequencies and under different RF-power levels. We will also present our developments on a coating technique using CCs to cover flat and curved surfaces (such as those needed for cavities). Our findings have placed CC's technology as a solid candidate to replace Cu as the low surface-impedance coating in high-energy physics applications, such as accelerators and dark mater detectors.

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Copper-modified barium-based nanocomposites as random anisotropy magnets for microwave applications

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We show experimentally that copper-modified barium-base nanocomposites behave as random anisotropy magnets and prove good as microwave (MW) absorbers in the GHz range. We prepared several ceramic samples by adding divalent copper cations to common barium hexaferrites. We analyzed the variables involved in forming these nanocomposites following a design of experiments (DoE) procedure, which allowed us to quantify the effect of each variable and can, therefore, be an interesting tool for optimizing their properties. We conducted a structural characterization and found that the modified samples consisted of micron-sized clusters of agglomerated nanoparticles. These particles were a random mixture of nanocrystallites derived from the original barium hexaferrite and divalent copper ferrite. After performing magnetic measurements, we verified that the magnetization approaching saturation of the modified materials fits well to random anisotropy magnets in the so-called strong limit, when the samples are formed by independent, non-interacting crystallites [1], in contrast to the original hexaferrite, which did not show any of the characteristics of such state

Recent theoretical models postulated random magnets as broadband MW absorbers [2]. To test these ideas in our samples, we measured the two-port *S* parameters in the GHz range using a vector network analyzer (VNA) with coaxial connectors. Then we deduced the complex dielectric permittivity and magnetic permeability using the Nicolson-Ross-Weir model. We therefore calculated the reflection loss coefficient (R_L), according to the principle of equivalent transmission line, and found a remarkable enhancement of the power absorption in millimeter-thick samples. These findings strongly support the application of our ceramic nanocomposites as MW-absorbing materials [3].

The Air Force Office of Scientific Research supported this work.

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Giant Barnett Effect from Moving Dislocations

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We show that moving dislocations generate giant effective local magnetic fields in a crystal lattice that can flip spins. Since massive creation of fast-moving dislocations is associated with a powerful elastic stress, this suggests a new mechanism of the magnetization reversal generated by laser or microwave beams or by electrically induced shear deformation.

Influence of microwire properties on the performance of multilayer microwave absorbing systems

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The study of microwave absorbing materials constitutes a fundamental line of research in the field of applied electromagnetics, where the need to suppress electromagnetic interference (EMI) and to reduce radar cross-section (RCS) drives the continuous development of novel materials and structures with enhanced absorption capabilities. Accordingly, it becomes crucial to fully understand their behavior through a combination of theoretical modeling and experimental validation. This work presents an in-depth experimental investigation on the integration of metallic and ferromagnetic microwires as functional additives in multilayer paint-based microwave absorbing systems. The study focuses on how the microwire properties, specifically their composition, length, concentration and thermal treatments, affect the electromagnetic absorption performance within the 2–18 GHz range. Layer thicknesses have also been carefully controlled to ensure consistency of experimental results and reliability in the extraction of electromagnetic parameters. The ultimate goal of this study is the preparation and design of paint-based multilayer samples to achieve microwave attenuation by destructive interference mechanisms.

Deep Learning for magnetization Dynamics

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Building block of magnetic memories and sensors are magnetic thin films materials. In order to calculate the magnetization dynamics of thin magnetic film, the Landau-Lifshitz-Gilbert (LLG) equation is solved numerically. The typical way *for solving* LLG *equations* is to first discretize it in space by finite elements or finite differences and than to *solve* numerically the resulting system in time, and requires a considerable computational effort. To ease this process, by reducing the computational load or assisting in characterizing field measurements, machine learning can be of utility also in the field of magnetism [1-3].

In this work, a deep neural network is used to model the ferromagnetic resonance in magnetic thin films. The data for training the model was obtained by time integration of the LLG equation. To obtain an optimal compression ration a convolutional autoencoder was used. Consequently, the magnetic dynamics to an external field can be computed quickly.

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Composite materials for broadband microwave absorbing coatings

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The field of microwave absorption has seen a rise in interest due to its vast applications, ranging from telecommunications and aerospace to electronic devices and defense, particularly in stealth technology. It is no surprise, then, that many publications are dedicated to this topic, ranging from magnetic characterization to novel materials, yet few focus on the manufacturing and characterization of materials ready to use in such applications [1].
In this poster, composite materials with a polymeric matrix and a variety of fillers are studied for broadband microwave absorption. These composite materials have filling factors optimized for broadband absorption and adequate rheological properties, so they can be applied as a sprayed coating. This allows for easy application on a variety of substrates while achieving maximum homogeneity and thickness control. The fillers used include soft magnetic iron particles and ceramic random anisotropy magnets in the form of doped barium hexaferrites [2,3]. Also, this poster is not limited to single-layer systems, but bi-layer and trilayered systems that expand on the previous works [4,5].
Thus, the objective is to prepare and optimize these composite materials and to characterize and assess their performance as wave absorbers in settings that closely resemble the requirements for their applications.

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MAGNETIC INDUCED TRANSPARENCY IN CAVITY-MAGNON POLARITONS

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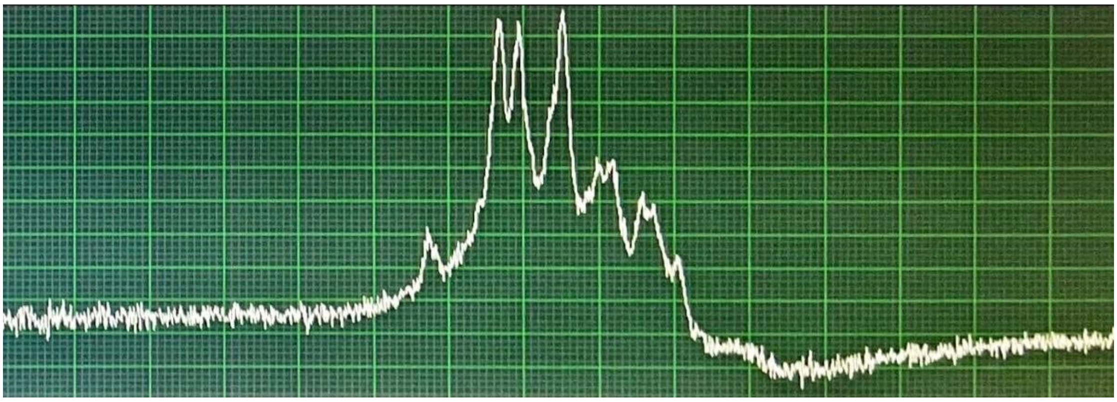
Magnons and phonons are collective excitations of the spin system and the atomic lattice of a material, respectively, interacting via magnetostrictive forces. In high-quality magnets such as Y3Fe5O12 (YIG), strong coupling of these quasiparticles has been observed, revealing phenomena like Magnomechanical Induced Transparency (MMIT). Recently, these effects have garnered significant scientific interest due to their potential applications in low-power information processing and quantum communication technologies.
MMIT is a quantum coherent phenomenon that arises when magnons hybridize with mechanical vibrations (phonons). This interaction leads to destructive interference between excitation pathways, creating a transparency window around the magnon resonant frequency [1].

In this work, we investigate magnon-phonon coupling in a magnetic YIG film grown on a non-magnetic Gd3Ga5O12 (GGG) substrate. Through phonon pumping, magnetization dynamics generate phonon currents that leak into the substrate, which acts as a phonon cavity, carrying away energy and angular momentum from the ferromagnet [2, 3]. Specifically, we report ferromagnetic resonance (FMR) spectra of these bilayers over various power and magnetic field ranges and analyze their associated parameters (phonon and magnon linewidths, magnetoelastic coupling strength, cooperativity, etc.) to detect and characterize magnetic transparency.



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Non-thermal microwave effects on nanoscale structure of bulk water studied with second-harmonic scattering

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Non-thermal effects of microwaves (MWs) have been proposed to play a role in neurostimulation [1] and the enhancement of chemical reactions [2]. However, they remain a topic of continuous debate, primarily due to the scarcity of experimental evidence on a molecular level. Second-harmonic scattering (SHS) [3] (Fig. 1) detects, in bulk liquids, a subset of the sample that presents structural or electronic anisotropy, which makes it a suitable candidate to probe molecular level perturbations due to the MW field. Here, we apply SHS to investigate the effect of continuous 2.4 GHz MW exposure on the nanoscale structuring of liquid water. We observe instantaneous changes to the SHS intensity upon microwave exposure, which cannot be attributed to the induced temperature variations, and hint towards changes in the water intermolecular network. To enhance the interaction between the MW field and the liquid, we design and characterize a cylindrical resonator that supports the TM_{010} mode at 2.4 GHz and is compatible with optical scattering measurements.

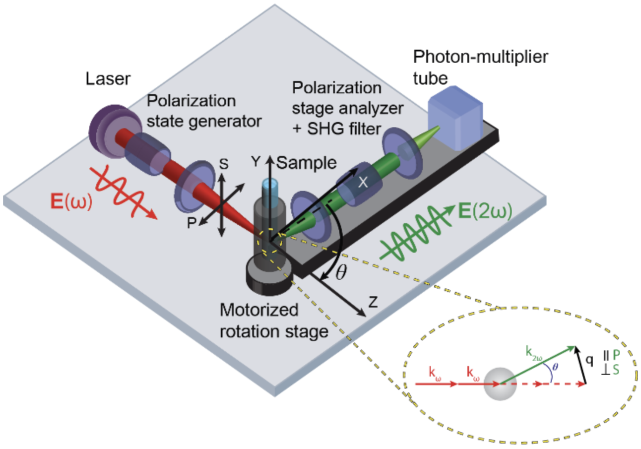

Figure 1: Method: A: schematic of femtosecond elastic second-harmonic scattering with variable detection angle θ, with k-vector interaction geometry.

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