

CRETE, GREECE,
11 - 16 SEPTEMBER, 2023



METAMATERIALS

17TH INTERNATIONAL CONGRESS ON ARTIFICIAL MATERIALS
FOR NOVEL WAVE PHENOMENA

PROGRAM BOOK



ORGANIZING INSTITUTIONS

The **Virtual Institute for Artificial Electromagnetic Materials and Metamaterials**, in short the "METAMORPHOSE VI AISBL", is a non-for-profit International Association, whose purposes are the research, the study and the promotion of artificial electromagnetic materials and metamaterials. The Association has been established in 2007 by the partners of the FP-6 Network of Excellence "METAMaterials ORganized for radio, millimeter wave, and PHOTonic Superlattice

Engineering" - METAMORPHOSE NoE - funded by the European Commission in 2004-2008.

The METAMORPHOSE VI is an active network integrating, managing, and coordinating several research and spreading activities in the field of Artificial Electromagnetic Materials and Metamaterials. In order to achieve his purposes, the METAMORPHOSE VI AISBL pursues the following activities:

- Integrate, manage, coordinate, and monitor research projects in the field of Artificial Electromagnetic Materials and Metamaterials
- Spread excellence in this field, in particular, by organizing scientific conferences and creating specialized journals in this field
- Create and manage research programmes in this field
- Activate and manage training programmes (including PhD and training programmes for students and industrial partners)
- Provide information on Artificial Electromagnetic Materials and Metamaterials
- Transfer new technology in this field to the Industry
- Offer advice and services related to Artificial Electromagnetic Materials and Metamaterials to industries, producers, distributors, potential users, service suppliers in Europe and worldwide.

Among the other activities, the Association owns and organizes the Metamaterials Congress Series and the Doctoral Programmes on Metamaterials. (metamorphose-vi.org)



The Foundation for Research and Technology - Hellas (FORTH) was founded in 1983. It is one of the largest research centers in Greece with well-organized facilities, highly qualified personnel, and

a reputation as a top-level research institution worldwide.

FORTH conducts specialized scientific research in strategic high-added value sectors, focusing on interdisciplinary research and development (R&D) activities in areas of major scientific, societal and economic interest, such as: Lasers and Photonics, Microelectronics, Advanced Materials / Nanotechnology, Molecular Biology and Genetics, Biotechnology, Computer Science, Bioinformatics, Precision Medicine, Systems Biology, Robotics, Telecommunications, Applied and Computational Mathematics, Chemical Engineering Sciences, Energy, Environment, Social Sciences & Humanities, Astrophysics and Astronomy. FORTH comprises ten Research Institutes. Its headquarters and central administration are based in Heraklion, Crete. (forth.gr)



ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

Established in 1973, the University of Crete is a young public educational institution sited in a region rich in ancient and modern Mediterranean cultures. Currently around 20,000 undergraduate and graduate students

study in its Schools of Philosophy, Education, Social Sciences, Sciences & Technology, and Medicine, taught by an outward looking academic staff committed to quality in teaching, research, and community partnerships.

The University's 16 Departments offer bachelor's and master's degree programmes with a wide range of core and specialized courses, as well as doctoral research programmes (PhD). The degree programmes run alongside a kaleidoscope of conferences, workshops, short courses, summer schools, public lectures, lifelong learning programmes and other events organized throughout the year.

Research and research training in the University of Crete benefit from an academic and technological environment of international standards, built up also through the interaction with the cluster of the other research-oriented institutions of Crete. These provide a critical mass of expertise in a large variety of disciplines and access to excellent complementary facilities for research and research training in highly competitive fields. (en.uoc.gr)

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Laser & Photonics Reviews (LPR)
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Nanophotonics
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PRESIDENT'S MESSAGE

It is a great honor and pleasure to welcome you to a new edition of our Metamaterials conference as the President of the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (METAMORPHOSE VI). I am happy to serve for a second term as President of this vibrant society, it is a real honor and pleasure to interact with all of you in this role.

It seems we are finally out of the global pandemic, and in-person meetings have resumed to a pre-COVID level. Our community has grown stronger and learned new virtual tools, but in-person interactions remain fundamental to discuss science and grow as a community. In this sense, I am very happy to welcome you again to our flagship conference, and reconnect with the broad metamaterials community.

This year our institute has continued to expand its frontiers, and to bring together worldwide activities and excellence in the thriving and ever evolving field of metamaterials, driving the evolution of our field. We are at the 17th edition of the International Conference on Artificial Materials for Novel Wave Phenomena, an impressive legacy. Yet, we continue to grow, attracting top speakers from all over the world and engaging a thriving community. I am very proud of our Doctoral School program, which has been growing with the new technology tools we have learned through the pandemic, and we look forward to another exciting doctoral School on Metamaterials during this week, focused on energy applications of metamaterials – an important and timely topic for our society at large.

I wish to thank the local organizing team for preparing a wonderful setting to our conference, and I hope that in the coming year we continue in the process of extending the boundaries of Metamorphose within and beyond Europe, engaging the growing metamaterials community across the world. I wish you an exciting conference and a fun week in Crete.

Andrea Alù, President of the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials (METAMORPHOSE VI)

WELCOME MESSAGE

Dear Friends and Colleagues,

It is a great pleasure for us to welcome you in Crete for the 17th International Congress on Artificial Materials for Novel Wave Phenomena – Metamaterials 2023.

The congress takes place near the town of Chania, in a region that combines rich history, picturesque scenes and unique natural environment comprising of beautiful beaches, wild gorges, and green mountains,

The local conference organization has been undertaken by the Foundation for Research and Technology – Hellas (FORTH) and by the University of Crete (UoC), both centered at Heraklion. FORTH is one of the largest and most successful research centers in Greece. Its Institute of Electronic Structure and Laser (IESL), which is the Institute involved in the Metamaterials Research, is an internationally recognized center of excellence in Lasers and Applications, Microelectronics and Devices, Theoretical and Computational Physics, Materials (and Metamaterials) Science. University of Crete is constantly classified among the top 100 young (less than 50 years old) Universities worldwide. It has a strong Science and Engineering School, with emphasis on natural sciences. Its Departments of Physics and of Materials Science have been associated, among others, with important contributions in the Metamaterials research.

Besides FORTH and University Crete, Crete has additional Institutions, with more recognized the Technical University of Crete, located in Chania, and the Hellenic Mediterranean University, located in Heraklion, both with emphasis in Engineering Sciences. All Crete institutions are characterized by high quality research and education, making Crete a place that combines a glorious past with an inspiring present.

We wish and hope that you will enjoy the conference. We have done our best to create a convenient and hospitable conference environment, which will facilitate the attendance of the high-quality presentations and will stimulate fruitful discussions with colleagues and friends. Moreover, we hope that you will enjoy not only the lectures and the conference time, but also the nice surrounding countryside and the unique environment and opportunities offered by West Crete.

Maria Kafesaki, on behalf of the local Organizing Committee.



PREFACE

On behalf of the 2023 technical program committee,

I welcome you to the Metamaterials'2023 – the 17th International Congress on Artificial Materials for Novel Wave Phenomena.

During the years, the metamaterial concept has been experiencing a continuous evolution and transformation, resulting in a new way of thinking with a dramatic impact in many fields of science and technology.

Since the first edition of the Congress, our community has never stopped presenting new scientific findings that have been ever more accompanied by relevant results in technology transfer and industrial exploitation, making metamaterials a recognized key enabling technology in numerous engineering fields.

These trends are reflected by the scientific program that the technical program committee has put together this year, continuing the excellent tradition and the scientific high-quality of the conference series.

The technical program is organized in 5 parallel sessions in 4 full days. We are honoured to have 5 great plenary talks given by world-renowned pioneers (Hatice Altug, Andrea Alù, Geoffroy Lerosey, Albert Polman, Shu Yang) and 1 perspective plenary talk, a novelty of this year, on the emerging topic of time-crystals, given by Nikolay Zheludev. The program also includes 118 invited talks from experts in a diverse set of topics and 4 special sessions on hot topics selected by the technical program committee (i. wave-based signal processing, computing and learning; ii. bio-metamaterials and metamaterials for biosensing; iii. use of artificial intelligence and machine learning in metamaterials; iv. time varying metamaterials). Following the tradition of the previous editions, a special session is also organized and sponsored by the American Physical Society (APS) including talks by the authors whose papers were selected by the APS Editors among the papers appeared in the Physical Review journals in the past year. All the oral and poster sessions include exciting research contributions in various areas of metamaterials and metasurfaces and related topics. Finally, the program also includes a very special event to honour and remember a founder of the METAMORPHOSE VI, a close friend of the Metamaterials Congress, and a pioneer in the field, Prof. Irina Vendik, who passed away this year on May 9th, one week before her 87th birthday.

Last but not least, I would like to thank everyone who has contributed significantly to the formation of the exciting technical program of this conference. These include the authors

who submitted their work for presentation, the reviewers who evaluated the submissions, the organizers of the special sessions, the organizers of the American Physical Society special session, the sponsors for supporting the conference, the steering committee and the scientific advisory board for guiding the conference, the staff of the METAMORPHOSE VI for handling all the administrative aspects, the members of the technical program and the program formation committees for the fantastic program they put together, with a special mention to Mirko Barbuto for his precious everyday help in all the aspects related to the program committee work, the steering committee Chair, Alessio Monti, the General Chair, Maria Kafesaski, and the whole local organizing committee for their dedication, passion, and hard work that I am sure will make this edition of the Metamaterials Congress a memorable and enriching experience for the whole community.

We all look forward to having a wonderful conference in the relaxed atmosphere of Crete, to hearing about the recent developments in the field of metamaterials, and to brainstorming and having scientific discussions in this field we all love.

Enjoy the conference!

Filiberto Bilotti, Chair of the Technical Program Committee

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GENERAL INFORMATION

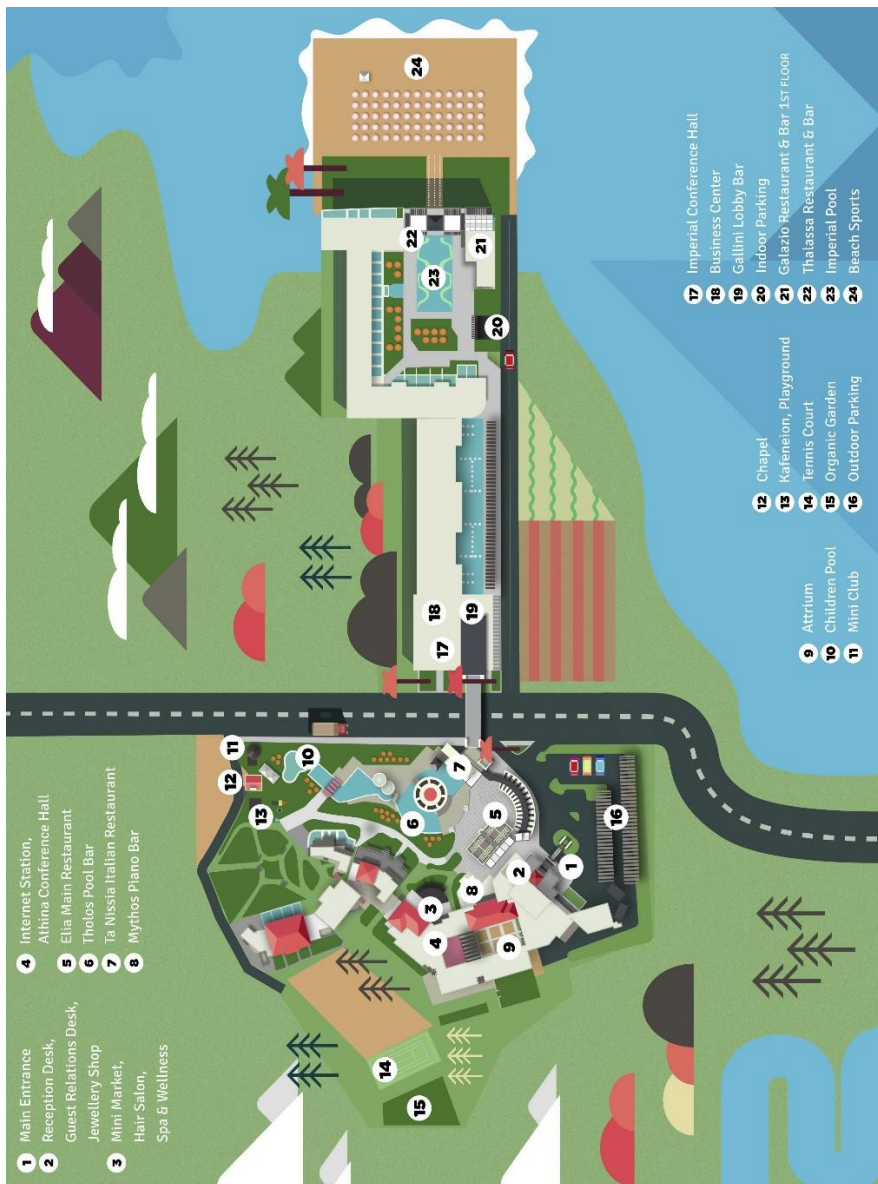
VENUE



The conference will be hosted in **Minoa Palace Resort Hotel**, a luxury 5* beach-side hotel located at the cosmopolitan area of Platanias, 12km west of the picturesque town of Chania and 30min drive from Chania International Airport. Minoa welcomes you to experience the pleasures of indulgence in the most enchanting of settings overlooking the endless azure of the Aegean. The Resort's Congress Hall is a great host for all sorts of corporate events, conferences, workshops & exhibitions, offering flexibility and functionality, as well as state of the art facilities and the latest audiovisual equipment.



VENUE MAP



For more information about the Venue please visit the website: minoapalace.gr



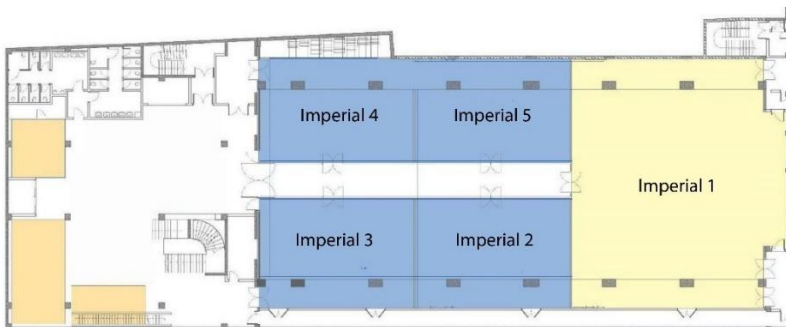
Minoa Palace Resort Hotel

Platanias, Chania, Crete, Greece, 73014 Tel. +30 28210 36500

Email: info@minoapalace.gr

The closest to the conference venue airport is *Chania international airport*. (Please note that Heraklion airport, which is the largest airport in Crete, is more than two hours away from the hotel venue and without any direct and easy or cheap connection with the conference venue.)

MINOA PALACE – IMPERIAL CONGRESS HALL



Imperial Congress Hall

HOW TO GET TO THE VENUE**Arriving by plane**

The **conference venue** is located at **Platanias/Chania, Crete**. During September, Chania is directly connected to several European cities by charter/seasonal flights. Information on destinations can be found in the official website of [Chania Airport](#) . Additionally, regular flights from/to [Athens International Airport](#) exist daily. You are strongly advised to choose a flight to Chania International Airport. Alternatively, one can land to Heraklion International Airport and reach Chania by bus or car. The driving distance between Heraklion and Chania is 142km.

**Arriving by ship**

The city of Chania is connected to Piraeus (Athens) daily. The port is in Souda, 7km away from the city center and 21 km away from the Conference Venue (about 20 min driving). You may consult the timetables or book your boat tickets [here](#) and [here](#). Information regarding the public bus that connects Souda to Chania city center can be found [here](#).

**Bus services**

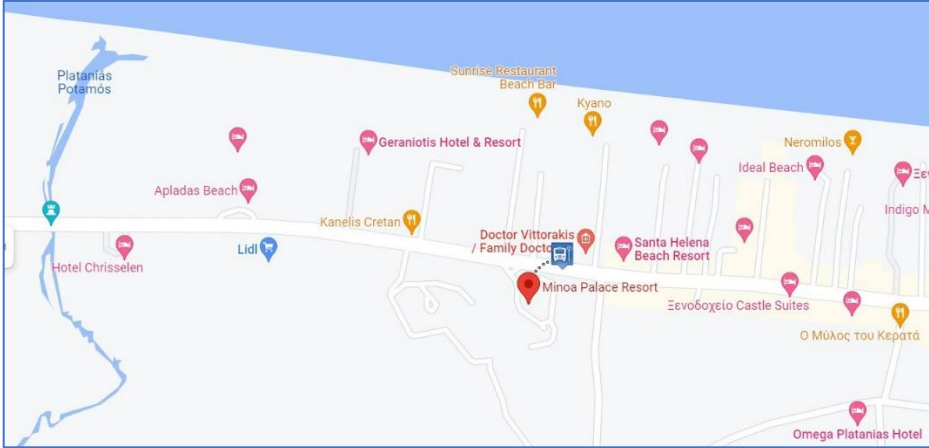
Chania airport → Chania city (Bus station)

Chania airport is located 14km from the city center, and 33.2 km away from the Conference Venue (30-40 min driving). A public bus connects the airport to the city center on a regular basis (line Chania Airport – Chania). The route lasts for 30 minutes approximately, and costs 2.30 €. You may consult the timetables or buy your tickets [here](#)

Chania city (Bus station) → Platanias (bus stop MINOA PALACE)

From Chania Bus station there are enough **routes** you could get to **arrive to the Minoa Palace Resort Hotel**. For your convenience we collected here all those routes:

- | | |
|---------------------------|-----------------------------|
| 1.CHANIA-KASTELI | 7.CHANIA-VOUKOLIES |
| 2.CHANIA-KOLIMPARI | 8.CHANIA-PALAI A ROUMATA |
| 3.CHANIA-PLATANIAS-GERANI | 9.CHANIA-ELAFONISI |
| 4.CHANIA-ZYMRAGOU | 10.CHANIA-KASTELI-FALASARNA |
| 5.CHANIA-DELIANA | 11.CHANIA-PALAI OCHORA |
| 6.CHANIA-RODOPOU | |



Taxi services

Moving by taxi is quite common in Crete and prior booking is not required. You may find relevant information and indicative prices in several websites (taxi4crete.gr/taxi-prices-from-chania-airport.html, www.chaniataxi.gr/en/)

The cost of transfer by taxi is approximately the following:

Chania Airport – Chania City Center	~ 25 €
Chania Airport – Conference Venue	~ 48 €
Chania City Center – Conference Venue	~ 20 €

CRETE

Crete is the largest island in Greece and the fifth largest in the Mediterranean. It is endowed with an exquisite 1,000-kilometer-long coastline dotted with numerous coves, bays and peninsulas, which afford a multitude of soft, sandy beaches along the infinite blue of the Mediterranean Sea. The island is proud for its longstanding history, spanning from the Minoan civilization (3000 B.C.) until today. Crete welcomes you with its smiling Cretan sun, the sounds of the Cretan lyre, the scents of orange blossom and jasmine, a slice of cool red watermelon and a glass of iced “raki”.

Some important archaeological sites of Crete:**The Palace of Knossos**

According to tradition, it was the seat of King Minos and the capital of his state. The palace of Knossos is associated with the exciting myths “the Labyrinth and the



Minotaur” and “Daedalus and Icarus”. References to Knossos, its palace and Minos are made by Homer (the list of ships in Iliad mentions that Crete sent 80 ships under the command of the King of Knossos, Idomeneus, the Odyssey, T 178-9), Thucydides (reference to Minos), Isiodorus and Herodotus, Bacchylides and Pindarus, Plutarchus and Diodorus the Sicilian. The city flourished in the Minoan Times (2000 – 1350 B.C.), when it was the most important and populated centre of Crete. It also played an important role and was particularly prosperous in later periods, like the Hellenistic Times. The city of Knossos was constantly populated from the end of the 7th millennium to the Roman Times. In the Neolithic Times there was a stage of technologically developed agricultural life (stone tools and weaving weights). The residents turned from food-collectors into producers (farmers and shepherds) and there was a trend towards more systematic and permanent settlement. The settlement periods in Knossos succeeded each other and the population of the settlement at the end of the Late Neolithic Period is estimated at 1.000 – 2.000 residents.

The Palace of Phaistos

Phaistos is built on a low hill (altitude of about 100m from sea level), in the south of river Geropotamos (ancient river Lithaios), and dominates the fertile valley of Kato Mesara, which is surrounded by



imposing mountains (Psiloritis, Asterousia, Lasithi Mountains). The Libyan Sea extends in the south. Lithaios surrounds the hill of Phaistos in the east and the north and was a source of water supply for the city. The mild and warm climate of the area made the life of its residents comfortable and pleasant. Phaistos was one of the most important centres of the Minoan civilization, and the most wealthy and powerful city of southern Crete. It is mentioned in the texts of ancient writers (Diodorus, Stravon, Pausanius) and Homer. It is one of the three important cities founded in Crete by Minos. According to mythology, the dynasty of Rodamantus, the son of Zeus and brother of Minos, reigned in it. Homer refers to its participation in the Trojan War and describes it as a “well populated” city. The period of prosperity in Phaistos began with the coming of the Bronze Age in Crete in the middle of the 3rd millennium B.C., when the foundations of the Minoan civilization were laid. Habitation in Phaistos started in the Neolithic period, as revealed by the foundations of Neolithic houses, tools, statuettes and potsherds discovered under the palace during the excavations. The Neolithic settlement is believed to have covered the top of the hill and its southwestern slope. In the middle of the 3rd millennium B.C. the use of metals began, which favoured the development of the city.

The main cities of Crete over the years

The major cities of Crete (Chania, Rethymno, Heraklion, Agios Nikolaos) were once strategically placed on specific coastal locations of the island to defend against invaders. With a history that starts in prehistoric times and harbours that have always connected the island with other ports of the Mediterranean, the Cretan cities today are modern urban centers that have kept the historical identity of the island alive after countless conquerors have called it their own. In the Middle Ages, the island of Crete passed from the Byzantines to the Arabs, back to the Byzantines and then to Venetians; each one introducing different architectural and cultural elements. Every summer, Crete welcomes thousands of visitors that wish to explore the cities, charming harbours and cultural attractions that seem to be present on every corner.

CHANIA

In Chania city center one can enjoy the picturesque old harbour, walk around the old town alleys, and enjoy delicious local food in the numerous small restaurants.

Also, there are plenty of option for excursions to Chania region. You could enjoy exotic beaches, like the beach of Balos, which is ranked 35th among the 100 World’s best beaches. The Falasarna beach and the Elafonisi peninsula also attract millions of sea-lovers each year.



Less than 1 hour driving from Chania is the famous Samaria gorge, which is the second touristic attraction of Crete (after Knossos Minoan Palace). There are busses every day that can take you from Chania to Samaria gorge.

Discover Crete through the following websites:

- incrediblecrete.gr/en/
- cretanbeaches.com/en/
- youtube.com/watch

USEFUL CONTACTS

Minoa Palace (VENUE)	0030-2821036500
Chania Bus Station	0030-2821093052
Taxi Chania	0030-2821098700
General Hospital Chania	0030-2821342000
Medical Center- Vittorakis Polyclinic	0030-2821060606
1st Fire Department of Chania	0030-2821079340, 0030-2821063688
Chania Police Station	0030-2821025854

Local Conference Secretariat (Crete, Greece)

“Diazoma Conferences & Events”

diazoma.net



Tel: 0030-6908 215112

Email: info@diazoma.net, conferences@diazoma.net, meetings@diazoma.net

The proceedings of Metamaterials 2023 are uploaded online. Please visit the link:

<https://congress.metamorphose-vi.org/proceedings2023.zip>

SOCIAL EVENTS**Welcome Reception**

The welcome reception will take place on Monday 11 September at “*Thalassa Restaurant & Bar*” which is in Minoa Palace Hotel. It will start at 18:30 right after the end of the sessions. The Beach Bar of Minoa Palace Resort sets the ideal scenery for welcoming the participants in Crete and sparking the first scientific discussions!

Beverages and tasty finger food will be served!

**Conference dinner**

The conference dinner will take place on Wednesday 13 September at “*Sapel Hall*” at 19:30. The restaurant is close to the Venue (3km distance) and shuttle buses will be used for the transportation of all the participants. During the conference dinner you will have the chance to taste local dishes, combined with traditional music and dancing!



SESSION MATRIX

MONDAY 11 SEPTEMBER 2023

08:30 – 09:00	Opening Ceremony					Imperial 1
09:00 – 10:00	Plenary Talk Andrea Alù (p.28)					Imperial 1
10:00 – 10:30	Coffee Break					
10:30 – 12:30	Imperial 1	Imperial 2	Imperial 3	Imperial 4	Imperial 5	
	Metadevices for wave-matter interactions (p.28)	Time-varying metamaterials and crystals (p.35)	IR and optical metastructure modeling (p.41)	RF, microwave, and millimeter wave metasurfaces-based antennas (p.48)	Nonlinear and reconfigurable photonic metasurfaces (p.54)	
12:30 – 14:00	Lunch break					
14:00 – 15:30	Metamaterials for extreme light matter interactions (p.30)	Wave effects in space/time media (p.37)	Advanced optical metasurfaces (p.43)	RF, microwave, and millimeter wave antennas, scatterers, and lenses I (p.50)	Acoustic metastructures I (p.56)	
15:30 – 16:00	Coffee Break					
16:00 – 17:30	Metadevices for quantum effects and overcoming diffraction limit (p.32)	Time-varying and space-time metastructures (p.39)	Optical metasurfaces and metagratings (p.45)	RF, microwave, and millimeter wave antennas, scatterers, and lenses II (p.52)	Acoustic metastructures II (p.58)	
17:30 – 18:30	Plenary Talk Shu Yang (p.34)					Imperial 1
18:30 – 21:30	Welcome Reception					

TUESDAY 12 SEPTEMBER 2023

09:00 – 10:00	Plenary Talk Hatice Altug (p.60) Imperial 1				
10:00 – 10:30	Coffee Break				
10:30 – 12:30	Imperial 1	Imperial 2	Imperial 3	Imperial 4	Imperial 5
	Complex electromagnetic materials and applications (p.60)	Scattering and wave effects in temporal metamaterials (p.65)	IR and optical metastructures I (p.71)	SS - Use of artificial intelligence and machine learning in metamaterials (p.77)	Metastructures for imaging and sensing I (p.83)
12:30 – 14:00	Lunch break				13.15 - 13.45 Inside Nature Communication (p. 85)
14:00 – 15:30	Fundamental bounds (p.62)	Topological effects and confinement in photonic crystals (p.67)	IR and optical metastructures II (p.73)	RF, Microwave, and Millimeter Wave Antennas, Scatterers, and Lenses III (p.79)	Metastructures for imaging and sensing II (p.86)
15:30 – 16:00	Coffee Break				
16:00 – 17:30	SS - American Physical Society (p.63)	Mechanical and elastic metastructures I (p.69)	Nonlinear and active photonic metasurfaces (p.75)	mm-wave and THz metasurfaces (p.81)	Metastructures for imaging and sensing III (p.87)
17:30 – 18:30	Poster Session (p.90-108)				

WEDNESDAY 13 SEPTEMBER 2023

09:00 – 10:00	<p align="center">Plenary Talk Albert Polman (p.109)</p> <p align="right">Imperial 1</p>				
10:00 – 10:30	<p align="center">Coffee Break</p>				
10:30 – 12:30	Imperial 1	Imperial 2	Imperial 3	Imperial 4	Imperial 5
	SS - Wave-based signal processing, computing and learning (p.110)	Nonlinear and nonreciprocal optical metastructures (p.116)	Nonlinear metaphotonics (p.121)	Reconfigurable intelligent surfaces (p.129)	Reconfigurable and dynamic optical metastructures (p.135)
12:30 – 14:00	<p align="center">Lunch Break</p>				
14:00 – 15:30	2D Materials: new phenomena and applications (p.112)	Mechanical and elastic metastructures II (p.117)	Nonlinear metasurfaces and THz generation (p.123)	Engineered diffraction with metasurfaces and metagratings (p.131)	SS - Bio-metamaterials and metamaterials for biosensing I (p.136)
15:30 – 16:00	<p align="center">Coffee Break</p>				
16:00 – 17:30	Thermal effects in metadevices (p.114)	Mechanical and elastic metastructures III (p.119)	Materials for nanophotonics and metasurfaces (p.126)	Nonreciprocal and topological properties in microwave metastructures (p.132)	SS - Bio-metamaterials and metamaterials for biosensing II (p.137)
17:30 – 18:30	<p align="center">Perspective Talk Nikolay Zheludev (p.115)</p> <p align="right">Imperial 1</p>				
18:30 – 19:00	<p align="center">Special Event in Memory of Prof. Irina Vendik</p> <p align="right">Imperial 1</p>				
19:00 – 19:30	<p align="center">Break</p>				
19:30 – 22:00	<p align="center">Social Dinner</p>				

THURSDAY 14 SEPTEMBER 2023

09:00 – 10:00	Plenary Talk Geoffroy Lerosey (p.139) Imperial 1				
10:00 – 10:30	Coffee Break				
10:30 – 12:30	Imperial 1	Imperial 2	Imperial 3	Imperial 4	Imperial 5
	Nonlocality and bianisotropy (p.140)	SS - Time varying metamaterials I (p.147)	Active optical metastructures (p.153)	Metasurface synthesis and control methodologies (p.159)	Nonlocal, non-Hermitian and tunable metastructures (p.165)
12:30 – 14:00	Lunch Break				
14:00 – 15:30	Chiral materials (p.142)	SS - Time varying metamaterials II (p.148)	Nonlinear and topological effects in optical metastructures (p.154)	Analytical and numerical modeling of metadevices (p.161)	Inhomogeneous, gradient, and reconfigurable metasurfaces (p.167)
15:30 – 16:00	Coffee Break				
16:00 – 18:00	Non-Hermitian structures (p.144)	Space/time engineered metamaterials (p.150)	Plasmonics (p.156)	Nonlinearity and non-Foster elements in microwave metastructures (p.163)	Tunable and reconfigurable metastructures (p.168)
18:00 – 18:30	Closing Ceremony Imperial 1				

MONDAY 11th SEPTEMBER 2023

IMPERIAL 1

08:30 - 09:00 - Opening Ceremony

09:00 - 10:00 - Plenary Session I

Chair: Filiberto Bilotti

09:00 - 10:00 Plenary talk*Extreme Control of Light and Sound with Metasurfaces***Andrea Alù**, CUNY ASRC, USA

In this talk, I discuss our recent research activity in photonics, acoustics and polaritonics, showing how suitably structured surfaces can open exciting avenues to enable extreme wave phenomena for light and sound manipulation at the nanoscale. In particular, I will discuss the role of broken symmetries, geometrical rotations, and of strong wave-matter interactions in polaritonic systems to open new opportunities for classical and quantum wave manipulation. Our findings open opportunities to tailor waves in robust and efficient ways, controlling their propagation, breaking Lorentz reciprocity and enabling topological order and phase transitions. In the talk, I will discuss the fundamentals of these concepts, and their impact on practical technologies, from imaging and sensing to computing.

10:00 - 10:30 – Coffee Break

10:30 - 12:30 - Oral Sessions (Monday Morning)

“Metadevices for wave-matter interaction”

Chairs: Javier García de Abajo, Pavel Ginzburg

10:30 - 11:00 - Nanophotonics in two-dimensional Materials (Invited Talk)**Javier García de Abajo**, ICFO-Institut de Ciències Fòtoniques, Spain

We discuss new approaches to the synthesis, design, and exploitation of two-dimensional materials for nanophotonics, including plasmonics in ultrathin crystalline metals, a disruptive class of quantum-phase materials, recent advances in the solution to the problem of coupling between free-space light and ultra-confined optical excitations, and the application of these developments to the study of ultrafast nonlinear phenomena and quantum optics at the atomic scale.

11:00 - 11:15 - Plasmonic Self-Complementary Spiral Nanoantenna with Constant Input Impedance**Syuzanna Asadulina**, ITMO University, Russia**Juan P. del Risco, Juan D. Baena** Universidad Nacional de Colombia, Colombia

Plasmonic nanoantennas with constant input impedance within a wide range of mid infrared frequencies are designed. However, the scaling up to the infrared is not trivial since metals are not good conductors in such high frequencies. We have found an alternative way to recover the validity of the Babinet's principle and thus the achievement of constant input impedance.

11:15 - 11:30 - *Plasmonic Nanocavities and Propagating Surface Plasmons*

Arsenios Gisdakis, Kalun Bedingfield, Angela Demetriadou, University of Birmingham, United Kingdom

Jeremy Baumberg, University of Cambridge, United Kingdom

Particles assembled on a flat metal surface can achieve light-matter strong coupling at ambient conditions by utilizing plasmonic nanocavities. Such nanocavities launch propagating surface plasmon polaritons along the metal surface. Using different methods, we quantify the fraction of energy coupled into propagating surface plasmon polaritons and into the far-field.

11:30 - 11:45 - *Effect of the Phase Transition on Optical Properties of Individual VO₂ Nanostructures*

Peter Kepič, Brno University of Technology, Czech Republic

By observing the optical resonances of individual VO₂ nanostructures during the phase transition in transmission electron microscopy, we want to understand its phase transition better and explain the gradual tuning of future tunable VO₂ devices.

11:45 - 12:00 - *Driving Chemical Reactions with Polariton Condensates*

Sindhana Pannir-Sivajothi, University of California San Diego, USA

Vibrational polaritons are hybrid light-matter excitations of systems where photon modes and molecular vibrations couple strongly. Along with these hybrid polariton modes, under collective strong light-matter coupling, many dark modes which do not possess any photonic character also co-exist. These dark modes may reduce the effect of polaritons on chemical reactivity. In this work, we propose a way to amplify polaritonic effects on chemical reactivity using a Bose-Einstein condensate of vibrational polaritons. See Nat. Commun. 13, 1645 (2022) for an extended version of this work.

12:00 - 12:15 - Optics Behind Vaterite-based Drug Delivery

Pavel Ginzburg, Hani Barhom, Andrey Machnev, Andrey Ushkov, Hod Gilad, Denis Kolchanov, Tel Aviv University, Israel

Nano-engineered capsules for targeted drug delivery is an essential milestone on pathways to advance precision medicine concepts. As a vast majority of phenomena occur in a liquid environment in vivo, understanding cargo-fluid interaction mechanisms in vitro becomes an important factor, which can control the drug release rates. In this contribution we will introduce the concept of metamaterial drug delivery capsule, “golden vaterite”, and demonstrate its unambiguous advantages in the future paradigm of light-driven theranostics. In particular, optomechanical drug delivery, bioimaging, drug release and thermal therapy with the aid of ‘golden vaterite’ will be shown.

12:15 - 12:30 - Coated Ellipsoidal Model of the Effect of Organic Ligands on the Electromagnetic Absorption of Gold Nanoparticles in Biological Tissue

Brage Svendsen, Olle Hennert, Robert Themptander, Mariana Dalarsson, KTH, Sweden

Radiofrequency heating of gold nanoparticles for cancer treatment has seen intensive interest during the last decade, but the physical heating mechanisms are still debated. Here, we study Joule heating in coated ellipsoidal nanoparticles as a means of modelling the effect organic ligands has on the electromagnetic absorption of biological tissue.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Monday Afternoon 1)
“Metamaterials for extreme light matter interactions”

Chairs: Owen Miller, Radoslaw Kolkowski

14:00 - 14:30 - The Optimal Near-Field Antenna (Invited Talk)

Owen Miller, Yale University, USA

An antenna near an emitting molecule can dramatically enhance its radiation. We derive general fundamental limits to this process, which depend only on the quality factor of the resonant antenna and its separation distance from the molecule. Conventional bowtie-antenna designs fall far short of the limits, due to their inability to access the full near field of the molecule. We show that a surprising complementary-material design can approach

the ultimate limits, offering potentially dramatic enhancements over the current state-of-the-art designs.

14:30 - 14:45 - Boosting Third Harmonic Generation through Bound State in the Continuum in High Contrast Non-Local Metasurfaces

Paolo Franceschini, University of Brescia, Italy

Andrea Tognazzi, University of Palermo, Italy

Giovanni Finco, Department of Electrical and Photonics Engineering, Technical University of Denmark, Denmark

Luca Carletti, University of Brescia, Italy

Ivano Alessandri, University of Brescia, Italy

Costantino De Angelis, University of Brescia, Italy

Alfonso C. Cino, University of Palermo, Italy

Osamu Takayama, Department of Electrical and Photonics Engineering, Technical University of Denmark, Denmark

Radu Malureanu, Department of Electrical and Photonics Engineering, Technical University of Denmark, Denmark

Andrei V. Lavrinenko, Department of Electrical and Photonics Engineering, Technical University of Denmark, Denmark

Domenico de Ceglia, University of Brescia, Italy

We fabricated and characterized the linear response of an high-contrast non-local metasurface sustaining bound states in the continuum and predict asymmetric spectrum of the generated third harmonic radiation.

14:45 - 15:00 - Bound States in the Continuum and Non-Hermitian Engineering of Hybrid TE-TM Resonances in Periodic Metasurfaces

Radoslaw Kolkowski, Andriy Shevchenko, Department of Applied Physics, Aalto University, Finland

We show that hybrid TE-TM collective resonances in periodic metasurfaces can form perfect bound states in the continuum (BICs) despite being strongly coupled to lossy meta-atoms. Furthermore, the non-Hermitian character of the studied system can be used to realize exceptional points and robust degeneracies of the hybrid bright and dark eigenstates.

15:00 - 15:15 - *Merging Bound States in the Continuum at an Exceptional Point***Adria Canos Valero**, University of Graz, Austria**Andrey Bogdanov**, Qingdao Innovation and Development Center of Harbin Engineering University, China**Thomas Weiss**, University of Graz, Austria

We demonstrate that Bound States in the Continuum (BICs) can coalesce at an Exceptional Point (EP). The new singularity does not radiate, but inherits all characteristics of EPs. We validate our theory with a realistic design of a dielectric metamaterial. Remarkably, the Q-factor of such 'EP-BIC' grows with increasing symmetry breaking, unlike all BICs studied up to date.

15:15 - 15:30 - *Inverse Design of Whispering-Gallery Nanolasers with Tailored Beam Shape and Polarization***Iago Diez**, University of Exeter, United Kingdom**Isaac Luxmoore**, University of Exeter, United Kingdom

In this paper, we present the inverse design of monolithic whispering-gallery nanolasers which emit along their axial direction with a tailored laser beam shape and polarization.

15:30 – 16:00 Coffee Break**16:00 - 17:30 - Oral Sessions (Monday Afternoon 2)*****“Metadevices for quantum effects and overcoming diffraction limit”***

Chairs: Christos Argyropoulos, Vladimir Shalaev

16:00 - 16:30 - *Boosting Quantum Optical Effects with Plasmonic Metasurfaces and Metamaterials* (Invited Talk)**Christos Argyropoulos**, Pennsylvania State University, USA

We demonstrate compact plasmonic metasurfaces to efficiently generate entangled and correlated single-photon pairs with unprecedentedly high Spontaneous Parametric Down-Conversion generation rates. We also present epsilon-near-zero optical metamaterials based on plasmonic waveguide designs that promise to realize quantum phase gates and achieve multiqubit entanglement for longer distances and extended time.

16:30 - 17:00 - Scalable Quantum Photonics with Single-Photon Emitters in Silicon Nitride
(Invited Talk)

Vladimir Shalaev, Purdue University, USA

Recently, we discovered intrinsic quantum emitters in silicon nitride (SiN), which provide bright and high-purity single-photon emission at room temperature and the capability of seamless integration with SiN photonic waveguides. We established methods of creation of these quantum emitters and performed foundational photophysical studies at room and cryogenic temperatures. We explore the possibility of generating indistinguishable photons at high repetition rates at cryo-temperatures as well as at room temperature, with the use of plasmonic metamaterials, which may enable broader applications of SiN quantum emitters. Plasmonic speed-up of spontaneous emission rate beyond the rate of quantum decoherence processes may enable the generation of indistinguishable photons that could enable important quantum photonics applications, including quantum communication and quantum computing.

17:00 - 17:15 - Emerging Anomalous In-gap Modes in non-Hermitian System

Sayan Jana, Lea Beilkin-Sirota, Tel Aviv University, Israel

Non-Hermitian systems have emerged recently due to their unique properties, like faster propagation of wave packets in contrast to Hermitian counterparts, non-reciprocal wave guiding, etc. In general, non-reciprocity can be tailored through unequal directional hopping between two different sites and also via onsite gain/loss balancing. The goal of this research is to examine the impact of both non-Hermitian constitutive parameters, i.e. directionality and gain/loss, in a coupled one-dimensional (1D) double-chain network. The directional hopping in a 1D system causes the localization of bulk modes at the boundaries, known as non-Hermitian skin effect (NHSE), whereas the precise tuning of the gain/loss parameters leads to a complete delocalization of zero energy in-gap modes connecting NHSE at the two ends.

17:15 - 17:30 - Label-Free Optical Classification of Objects Too Small to See

Sergei Kurdiymov, Jun-Yu Ou, Nikitas Papisimakis, University of Southampton, United Kingdom

Nikolay I. Zheludev, University of Southampton; Nanyang Technological University, United Kingdom; Singapore

We present an approach to shape classification of nanoscale objects based on deep learning processing of optical scattering patterns. We demonstrate experimentally classification accuracy of 88% for subwavelength objects smaller than 320 nm ($\lambda/2$).

17:30 - 18:30 - Plenary Session II

Chair: Nader Engheta

17:30 - 18:30 Plenary talk***Switching Chirality in Soft Metamaterials*****Shu Yang**, University of Pennsylvania, USA

From DNA, wood cellulose, seashells, chirality plays a critical role to their biological functions, optical or mechanical properties. Liquid crystals (LCs) are intrinsically anisotropic materials with macroscopic ordering where the average direction of orientation is referred as the director. When LC directors rotate in a helix, chiral nematic phase is formed, leading to reflective colors of which the wavelength is determined by the period of the rotation or pitch. In my talk, I will discuss several methods to switch chirality in LC materials and their applications, including broadband and pixelated camouflage by exploiting large Poisson effect in main-chain chiral nematic liquid crystalline elastomers (LCEs), reconfigurable lattice arrays where the chirality of the circularly polarized light in terahertz can be switched, and Janus microdroplets with tunable, self-recoverable and switchable reflective structural colors, which can be patterned for data encryption.

18:30 - 20:00 - Welcome Reception

MONDAY 11th SEPTEMBER 2023**IMPERIAL 2****10:30 - 12:30 - Oral Sessions (Monday Morning)*****“Time-varying metamaterials and crystals”***

Chairs: Yonatan Sivan, Emanuele Riva

10:30 - 10:45 - Exploiting Time-Varying Radiative Coupling Modulation to Boost Second Harmonic Generation**Andrea Tognazzi**, Università degli Studi Di Palermo, Italy**Paolo Franceschini**, National Institute of Optics - national Research Council, Italy**Anna M. Chernyak**, Lomonosov Moscow State University, Russia**Alexander I. Musorin**, Lomonosov Moscow State University, Russia**Alfonso C. Cino**, Università degli Studi di Palermo, Italy**Andrey A. Fedyanin**, Lomonosov Moscow State University, Russia**Costantino De Angelis**, Università degli Studi di Brescia, Italy

Most effective harmonics generation is realised when bandwidth of metasurface resonances correlates with the pulse bandwidth. We propose a theoretical approach to investigate time-varying systems to boost second harmonic generation beyond the time-bandwidth limit. We perform simulations to obtain guidelines by unveiling the role of pulse duration and quality factors.

10:45 - 11:00 - Harnessing Temporal Modulation to Achieve Surface-to-bulk and Frequency Conversion in Elastic Half-planes**Jonatha Santini, Francesco Braghin, Emanuele Riva**, Politecnico di Milano, Italy**Xingbo Pu, Antonio Palermo**, University of Bologna, Italy

In this work, we establish a time-analog of space metagradings, which consists of a half plane equipped with time-varying resonators. We observe that temporal metagradings induce similar yet different phenomena as compared to the space counterpart. Space metagradings exhibit wavenumber conversion. Here, wavenumber conversion is replaced by frequency conversion, while a scattering process at constant wavenumber takes place in a way to convert Rayleigh waves into bulk waves.

11:00 - 11:30 - Dynamic Nanophotonics with Conducting Oxides and Metal Nitrides: From All-optical Switching to Photonic Time Crystals (Invited Talk)**Alexandra Boltasseva**, Purdue University, USA

Transparent conducting oxides (TCOs) are being investigated for tailorable and tunable optical applications spanning reconfigurable metasurfaces, optical switching in the epsilon-near-zero regime, and exploration of novel optical phenomena such as nonlinearity enhancements and possibility of realizing photonic time crystals.

11:30 - 11:45 - *Time-Varying Metamaterials Based on Indium Tin Oxide*

Jeng Wai Un, Subhajit Sarkar, Yonatan Sivan, Ben-Gurion University, Israel

We provide a comprehensive theory of the electronic, thermal and optical response of low electron density Drude materials (including epsilon near zero transparent conducting oxides and plasmonic nitrides), and in particular, indium tin oxide, (ITO) based on the Boltzmann equation for the electron dynamics, a coarse-grained extended Two Temperature Model and an extended Lindhard formula for the permittivity. We uncover that in addition to the non parabolicity of the conduction band, a key feature that was overlooked previously is the importance of momentum conservation in the interactions between electrons and phonons, which makes them much weaker than realized before. This causes the effective electron temperatures reached in these systems to be much higher than predicted previously, exceeding 10,000 K; under these conditions, the chemical potential decreases dramatically, and may even become negative. These findings enable reaching a full match between experimental findings for the permittivity and reflectivity dynamics, which previously defied standard modelling. Finally, we discuss the use of ITO in time varying metamaterials, such as instantaneously switchable mirrors, photon acceleration devices etc.

11:45 - 12:00 - *Global Synchronization via Non-Reciprocal Coupling: A Route to Photonic Time Crystals*

Venugopal Raskatla, Tongjun Liu, Jun-Yu Ou, Kevin MacDonald, Nikolay Zheludev, University of Southampton, United Kingdom

We report on a new mechanism for the synchronization of noise-driven, linear oscillators based upon non-reciprocal coupling. Under such conditions – which may be achieved, by design, in a photonic metamaterial ensemble of nano-opto-mechanical oscillators – spontaneous synchronization can emerge through a first-order phase transition as a function of coupling strength, providing a route to the realization of keenly-sought continuous photonic time crystals.

12:00 - 12:30 - *Nonlinear Modal Excitation in Coherent Metamaterials* (Invited Talk)

Luca Stefanini, University of Rome RomaTre, Italy

Davide Ramaccia, Filiberto Bilotti, University of Rome RomaTre, Italy

Shima Fardad, Alessandro Salandrino, University of Kansas, United States

Space and time-varying electromagnetic structures give access to regimes of operation that do not occur in their time-invariant counterparts due to modal orthogonality constraints. Using a perturbative approach, we analyze the intermodal energy transfer between a directly excited dipolar mode and a higher order subradiant mode and suggest a coherent control strategy to enhance the conversion efficiency to higher order modes.

12:30 – 14:00 Lunch Break**14:00 - 15:30 - Oral Sessions (Monday Afternoon 1)****“Wave effects in space/time media”**

Chairs: Benjamin Appfel , Simon Horsley

14:00 - 14:30 - *Gain and Non-reciprocity in Space-time Metamaterials* (Invited Talk)

Paloma A Huidobro, Universidad Autonoma de Madrid, Spain

Mario G. Silveirinha, Instituto de Telecomunicacoes-Lisbon, Instituto Superior Tecnico-
Universidade de Lisboa, Portugal

Emanuele Galiffi, City University of New York, Advanced Science Research Center, USA

John Pendry, Imperial College London, UK

I will discuss how space-time metamaterials enable gain and non-reciprocity even in the long wavelength limit, and discuss dipole emission in these media.

14:30 - 14:45 - *Temporal Topological Phase Transition of Parametric Oscillators due to Time Defects*

Benjamin Appfel, Romain Fleury, LWE, EPFL, Switzerland

We consider the effect of time defects in the excitation of a parametric oscillator (PO). We show theoretically and experimentally that the locked phase of the PO, that can be 0 or π , can switch from one to another through a temporal topological phase transition due to the defects.

14:45 - 15:00 - *Temporal Parity-Time-Symmetric Metasurfaces***Xuchen Wang**, Karlsruhe Institute of Technology, Germany**Alex Song**, The University of Sydney, Australia**Mohammad Mirmoosa**, Aalto University, Finland**Viktar Asadchy**, Aalto University, Finland**Carsten Rockstuhl**, Karlsruhe Institute of Technology, Germany

In this talk, we present the concept of temporal parity-time-symmetric metasurfaces. In contrast to spatial parity-time symmetric structure, here, the metasurface exhibits gain and loss in the temporal domain, and the gain and loss are virtually created by time-varying lossless reactive components. It is found that the alternation of gain and loss in the temporal domain results in the closing of the momentum bandgap. At the exceptional point where the size of the momentum bandgap becomes zero, the metasurface exhibits an exotic response for pulse illuminations, expressed in the localization and linear growing of the pulse energy.

15:00 - 15:30 - *The Operator Theory of Dispersive Time-varying Media* (Invited Talk)**Simon Horsley**, University of Exeter, United Kingdom

We develop a compact theory that can be applied to a variety of time-varying dispersive materials. The continuous wave reflection and transmission coefficients are replaced with equivalent operator expressions. In addition to comparing this approach to existing numerical and analytical techniques, we find that the eigenfunctions of these operators represent pulses that do not change their spectra after interaction with the time-varying, dispersive material. In addition, the poles of these operators represent the non-time harmonic bound states of the system.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Monday Afternoon 2)***“Time-varying and space-time metastructures”***

Chairs: Hiroki Wakatsuchi, Xuchen Wang

16:00 - 16:15 - Unleashing Infinitely Wide Momentum Bandgaps in Photonic Time Crystals**Xuchen Wang, Puneet Garg, Aris Lamprianidis, Carsten Rockstuhl**, Karlsruhe Institute of Technology, Germany**Mohammad Mirmoosa, Viktor Asadchy**, Aalto University, Finland

The emergence of photonic time crystals has engendered considerable scientific curiosity, owing to their unique features, including the momentum bandgaps. However, the generation of experimentally detectable momentum bandgaps poses a formidable challenge, particularly at high frequencies, necessitating the use of high-power pumping that may lead to deleterious material overheating. To tackle this problem, we propose two routes toward theoretically unlimited enhancement of the momentum bandgap size.

16:15 - 16:30 - Space-time Metasurface for Self-adaptive Retro-reflective Doppler Cloaks**Xinyu Fang, Mengmeng Li, Minghui Chen, Dazhi Ding**, Nanjing University of Science and Technology, China**Daive Ramaccia, Alessandro Toscano, Filiberto Bilotti**, RomaTre University, Italy

Doppler cloaks are engineered electromagnetic covers, based on (space-)time modulated metamaterials and metasurfaces, able to compensate the Doppler effect induced by the motion of a scattered, making it appears as if it were at rest to a detecting radar system. Here, we propose the design of retro-reflective planar Doppler cloak composed by a pair of (space-) time modulated metasurfaces: the first metasurface focuses the incident field in a specific location on the second metasurface that is designed for enabling retro-reflection and Doppler frequency shift compensation. The proposed Doppler cloak is applied to a metallic planar reflector, moving towards its normal direction, and illuminated by an oblique plane wave, maintaining the radar cross-section of the reflector as much stable as possible within the designed angular range.

16:30 - 16:45 - Design of Non-uniform Frequency Time Modulated Metasurface for False Targets Jamming**Xinyu Fang, Mengmeng Li, Minghui Chen, Dazhi Ding**, Nanjing University of Science and Technology, China**Daive Ramaccia, Alessandro Toscano, Filiberto Bilotti**, RomaTre University, Italy**Dazhi Ding**, Nanjing University of Science and Technology, China

A design of non-uniform frequency time-modulated metasurface (NF-MTS) is proposed for false target jamming of linear frequency modulated (LFM) radar. The NF-MTS is composed by a number of independent elements, each of them temporally modulated by a different modulation frequency. This system allows realizing desired false targets in the range profile of the radar system. Thanks to the control of the modulation scheme in each element of the metasurface and the combined non-uniform frequency response of the overall surface, NF-MTS has enhanced performance on control of false targets at different observation angles, having more flexible capacity of scattered field manipulation comparing to metasurface based false target jamming only through uniform frequency time modulation.

16:45 - 17:00 - A Combined Substrate-integrated Cavity with Time-modulated Graphene Aperture for the Effective Frequency Generation at the THz Regime

Stamatios Amanatiadis, Vasileios Salonikios, Nikolaos Kantartzis, Traianos Yioultsis, Aristotle University of Thessaloniki, Greece
Theodosios Karamanos, Université PSL, CNRS, France

The analysis of a substrate-integrated rectangular cavity with a time-modulated graphene layer located at its aperture is realized in the present work focusing on the frequency up-conversion characteristics. The time-varying characteristics are induced through the appropriate adjustment of graphene's electric bias field.

17:00 - 17:30 - Additional Selectivity at the Same Frequencies with Waveform-Selective Metasurfaces and their Applications (Invited Talk)

Hiroki Wakatsuchi, Nagoya Institute of Technology, Japan

In this invited talk we introduce the concept of recently developed circuit-based metasurfaces referred to as waveform-selective metasurfaces as well as their application scenarios. Unlike ordinary metasurfaces, waveform-selective metasurfaces have an additional selectivity even at the same frequency in accordance with the incoming waveform, specifically the pulse width. This additional selectivity is exploited to expand the conventional framework to control electromagnetic phenomena and address a range of issues including electromagnetic compatibility, wireless communications, antenna design, and sensing.

MONDAY 11th SEPTEMBER 2023**IMPERIAL 3**

10:30 - 12:30 - Oral Sessions (Monday Morning)

"IR and optical metastructure modeling"

Chairs: Carsten Rockstuhl, Thomas Christopoulos

10:30 - 10:45 - *Metamaterial Properties of Layered Babinet Complementary Patterns***Emese Tóth, Olivér Fekete, Balázs Bánhelyi, Mária Csete**, University of Szeged, Hungary

A multilayer constructed with convex-concave-convex Babinet complementary patterns supports coupled modes in addition to the single layer plasmonic resonances. The resulted transmittance modulation is accompanied by a perturbation in the orientation and ellipticity of the polarization ellipses, in the spectral interval of the negative index material phenomenon. The coexistent magnetic dipoles dynamics correlates with the strength of NIM.

10:45 - 11:00 - *Optimisation of Lasing Dielectric Metasurfaces with Symmetry Constraints on the Modes***Matthew Parry, Andrey Sukhorukov, Dragomir Neshev**, Australian National University, Australia

Metasurface lasers require the optimisation of modes at both the absorption and lasing wavelengths. We demonstrate a novel technique to optimise these bands through symmetry analyses of the eigenmodes that allows us to optimise mode volume into the active media, as well as the directionality of the lasing emission.

11:00 - 11:15 - *Hyperuniform versus Poisson Distributions in Random Metasurfaces at Infrared Wavelengths***Eric Lheurette, Roman Buisine, Olivier Vanbesien**, IEMN - Université de Lille, France**David Dereudre**, Painlevé - Université de Lille, France**Ludovic Burgnies**, IEMN - Université de Lille - ULCO, France**Thibault Deletang, Benoît Cluzel**, ICB - Université de Bourgogne, France

In this communication, we compare the relevance of two kinds of random distributions of Metal Insulator Metal (MIM) resonators describing a metasurface for extinction of an impinging incident signal at infrared wavelengths. The patterns are generated by home-made codes prior to numerical simulations by means of commercial finite element

software. Experimental characterizations are conducted by means of reflection dark-field pump-probe spectroscopy.

11:15 - 11:30 - Analysis and Design of Reflective Nonlinear Metasurfaces Incorporating 2D Materials Utilizing a Multimode Quasi-Normal Mode Framework for Non-Hermitian Systems

Thomas Christopoulos, Emmanouil E. Kriezis, Aristotle University of Thessaloniki, Greece
Odysseas Tsilipakos, National Hellenic Research Foundation, Greece

A nonlinear graphene reflective metasurface for third-harmonic generation in the THz band is presented. The proposed metasurface is analyzed and designed using a multimode framework for non-Hermitian systems incorporating 2D materials that is based on the concept of quasi-normal modes (QNMs) and can correctly estimate both linear and nonlinear responses of the metasurface. The conducted analysis using the QNMs framework allows for the correct encapsulation of the involved physics and the multimode interactions that mediate the complex frequency response of the metasurface and the process of the nonlinear frequency generation.

11:30 - 12:00 - Current Developments in Describing Photonic Materials using a T-matrix Approach: From a General Data Format and Public Repository to the Solution of Inverse Problems (Invited Talk)

Carsten Rockstuhl, Dominik Beutel, Nanda Perdana, Benedikt Zerulla, Nigar Asadova, Puneet Garg, Aristeidis Lamprianidis, Ramakrishna Venkitakrishnan, Lukas Rebholz, Markus Nyman, Christof Holzer, Marjan Krstic, Ivan Fernandez-Corbaton, Karlsruhe Institute of Technology, Germany

We outline a computational framework to study all kinds of photonic materials using a T-matrix-based approach. We outline extensions of that framework to enable the multi-scale modelling of photonic molecular materials, for the inverse design, and suggest a common data format for T-matrices and a repository for them.

12:00 - 12:15 - Chiral Sensing with Metasurface-Mirror Cavities: a Digital Twin

Markus Nyman, Xavier Garcia-Santiago, Marjan Krstić, Lukas Materne, Ivan Fernandez-Corbaton, Philip Scott, Martin Wegener, Carsten Rockstuhl, Karlsruhe Institute of Technology, Germany

We create a comprehensive virtual model, a digital twin, of a cavity-enhanced chiral sensing experiment. Using our digital twin, we design metasurface-mirror cavities that promote light-matter interaction between chiral molecules and the light used to measure

their circular dichroism. We then computationally reconstruct the spectrum of the measured molecule.

12:15 - 12:30 - Maxwell Garnett Effective Medium Model for Dielectric Materials with High Filling Fraction of Cylindrical Pores

Julia Brandt, Manfred Eich, Alexander Petrov, Hamburg University of Technology, Institute of Optical and Electronic Materials, Germany

Guido Dittrich, Patrick Huber, Hamburg University of Technology, Institute for Materials and X-Ray Physics, Germany

The optical properties of dielectric materials with subwavelength cylindrical pores are commonly described by effective medium models. We compare the Maxwell Garnett and the Bruggeman effective medium model for porous silicon with simulations to study their applicability. We found that the Maxwell Garnett model matches the results of the simulations even up to high porosities and discuss the reasons for this. We advocate using this model for membranes with cylindrical pores in the future.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Monday Afternoon 1)

“Advanced optical metasurfaces”

Chairs: Anatoly Zayats, Giuseppe Strangi

14:00 - 14:30 - Optofluidic Control of Colours with Metasurfaces (Invited Talk)

Anatoly Zayats, Diane Roth, King's College London, United Kingdom

Izzatjon Allayarov, Andrey Evlyukhin, Boris Chichkov, Antonio Calà Lesina, Leibniz University Hannover, Germany

We demonstrate theoretically and experimentally dynamic tuning of optical response of dielectric metasurfaces based on the high-sensitivity of surface lattice resonances to their surroundings. Optofluidic platform combining a silicon metasurface on a glass substrate and a variable water level as a superstrate is used to demonstrate dynamic colouring effects.

14:30 - 15:00 - *Harnessing Chirality and Hyperbolicity of Optical Metasurfaces* (Invited Talk)

Giuseppe Strangi, Case Western Reserve University, USA

This talk will review how we inverse design and engineer metasurfaces that support hyperbolic dispersion and chiral polarizability. The fundamental focus of this work remains the control of extreme light-matter interaction stemming from these physical properties, by harnessing excitonic physics, strongly correlated phenomena and light-induced forces in optomechanics.

15:00 - 15:15 - *Nonlocal Metasurfaces with Giant Tunability Enabled by Kirigami*

Freek van Gorp, Corentin Coulais, Jorik van de Groep, University of Amsterdam, Netherlands

Tunable metasurfaces enable active and on-demand control over optical wave fronts using reconfigurable scattering of resonant nanostructures. However, the tunability of the metasurface's resonant response is typically small. Here, we leverage novel insights from mechanical metamaterials to demonstrate optical metasurfaces with a giant tunability enabled by kirigami substrates. By introducing judiciously engineered cuts in a flexible substrate, we can stretch and compress the metasurface to unprecedented extent and thereby tune a high quality-factor resonance supported by a silicon nanoparticle array over a very large spectral range. Our results highlight a promising pathway towards flexible metasurfaces that offer unusually large tunability with applications in dynamic nanophotonic devices.

15:15 - 15:30 - *Opto-Thermal Tuning of Quasi-Bound States in The Continuum in GST Based Metasurfaces*

Marco Gandolfi, Maria Eugenia Serrano Flores, Costantino De Angelis, Maria Antonietta Vincenti, University of Brescia, Italy

Jesse Frantz, Jason D. Myers, Robel Y. Bekele, Jas S. Sanghera, US Naval Research Laboratory, USA

Anthony Clabeau, University Research Foundation, USA

Natalia M. Litchinitser, Department of Electrical and Computer Engineering, Duke University, USA

We design an asymmetric metasurface made of GST blocks and endowed with quasi-bound states in the continuum modes. Our theoretical modelling proves that, upon illumination with a short intense laser pulse, a partial transient crystallization of the

structure can be triggered and bound states in the continuum can be dynamically quenched.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Monday Afternoon 2)

“Optical metasurfaces and metagratings”

Chairs: Natalia Litchinitser, Andrei Lavrinenko

16:00 - 16:30 - *Hyperstructures for Light Manipulation on the Subwavelength Scale*

(Invited Talk)

Wenhao Li, Duke University, United States

Jacob LaMountain, University of Massachusetts, Lowell, United States

Viktor Podolskiy, University of Massachusetts, Lowell, United States

Jesse Frantz, US Naval Research Laboratory, United States

Anthony Clabeau, University Research Foundation, United States

Takashige Omatsu, Chiba University, Japan

Natalia Litchinitser, Duke University, United States

The emergence of optical metamaterials opens new opportunities for optical beam compression and decompression between the micro- to the nanoscales. By exploiting the strongly anisotropic optical properties of engineered nanostructures, we experimentally demonstrate magnifying and de-magnifying hyperstructures – a hybrid hyperlens and a hyper-grating, respectively, enabling optical imaging and probing on the scales below the diffraction limit. In the first part of this talk, we discuss our studies of structured light decompression to the subwavelength scale using a metamaterial structure consisting of a combination of a Fresnel grating and a hyperbolic metamaterials (HMM) slab composed of alternating TiO₂ and Ag layers, aiming at modifying the optical transition selection rules. In the second part of this talk, we experimentally demonstrate a hybrid hyperlens consisting of two anisotropic metamaterial components, a flat hyperbolic metamaterial and a spherical hyperlens. This structure is capable of transferring and magnifying the high spatial-frequency components of the wavevector corresponding to the subwavelength features of the sample near the flat surface of the lens to the far field. The demonstrated planar-shaped hybrid hyperlens opens new opportunities for practical applications in the field of ultra-compact planar, integrated optical devices and circuits.

16:30 - 16:45 - *Incomplete Phase Metagrating for High Order Diffraction Efficiency Redistribution*

Qiyao Liu, Qian Wang, IMRE, ASTAR, Singapore
Zhengdong Liu, Peng Cheng Laboratory, China

Controllable diffraction efficiency grating is important for a wide range of applications, including all-optical diffractive deep neural networks, microwave photonics, optical communication, and photonic quantum computing. The normal gratings have fixed diffraction directions and efficiency. In this work, we propose an unusual metagrating, which breaks the traditional 2π phase constraint in the supercell of metasurface and allows the high order diffraction with controllable efficiency redistribution. The property of polarization independence is verified both theoretically and experimentally. Besides, further tuning on the intensity distribution can be realized by tilting the incidence beams and varying the incident wavelength. This work shines light on various multifunctional diffraction components design in optics and microwave, such as metalens and holograms.

16:45 - 17:00 - *Multifunctional Metacrystals for Advanced Wave Engineering*

Mohammadmahdi Asgari, Viktor Asadchy, Aalto University, Finland
Peter B. Catrysse, Haiwen Wang, Shanhui Fan, Stanford University, USA

Combining several non-trivial functionalities in a single electromagnetic device requires a large number of degrees of freedom in its design. While metasurfaces provide a viable platform for achieving a multifunctional response, it is typically limited to the control of a single light property, such as polarization, propagation direction, or frequency. Here, we show that inversely-designed volumetric dielectric composites (metacrystals) can immensely extend the design space of multifunctional structures and incorporate nearly arbitrary complex operations on various characteristics of different light illuminations simultaneously.

17:00 - 17:30 - *High-contrast Gratings as Optical Biosensors* (Invited Talk)

Leonid Beliaev, Peter Stounbjerg, Sungyeong Kim, Bjørn Nielsen, Mads Evensen, Ada-Ioana Bunea, Radu Malureanu, Lars Lindvold, Osamu Takayama, Peter Andersen, Andrei Lavrinenko, Technical University of Denmark, Denmark
Giovanni Finco, ETH Zurich, Switzerland
Mehri Bideskan, Tarbiat Modares University, Iran
Larissa Vertchenko, Sparrow Quantum Ltd., Denmark

In this report, we give an overview of applications of high-index subwavelength gratings in biosensing. Following the classical design we proposed two novel modifications of high-contrast gratings (HCGs) with optimized characteristics. Numerical analysis reveals the improvement of sensing performance for these new designs compared to conventional ones. The sensors were fabricated and characterized. In the talk, we will report on the full cycle of activities with the high-contrast gratings including their functionalization, measuring the bulk and surface sensitivity, and studies of dummy and genuine analytes. The optical measurements revealed that different designs of HCG are best for exhibiting the higher bulk refractive index (BRIS) sensitivity or for the best performance in terms of surface sensitivity to detect nanometer-size proteins, for example, myoglobin.

MONDAY 11th SEPTEMBER 2023**IMPERIAL 4****10:30 - 12:30 - Oral Sessions (Monday Morning)****“RF, Microwave, and Millimeter Wave metasurfaces-based antennas”**

Chairs: Stefano Vellucci, David González Ovejero

10:30 - 11:00 - *Design of Phase-Gradient Metasurfaces for Antenna Applications* (Invited Talk)**Alessio Monti, Zahra Hamzavi-Zarghani, Davide Ramaccia, Luca Stefanini, Alessandro Toscano, Filiberto Bilotti**, Roma Tre University, Italy
Stefano Vellucci, Michela Longhi, Mirko Barbuto, Niccolò Cusano University, Italy

In this contribution, we review our recent research efforts about the design of phasegradient metasurfaces and their applications for antennas. Specifically, it is shown how such structures can be engineered for improving the performance or enhancing the functionalities of both individual antennas and antenna arrays. Three different examples, including a cylindrical cover for dipole antennas, a non-planar dome for phased arrays and a spatially-dispersive metasurface for phased arrays are discussed.

11:00 - 11:15 - *Metasurface Coatings Enabling Antenna Reconfigurability for Next-generation Communications Smart Repeaters***Alessio Monti, Zahra Hamzavi-Zarghani, Davide Ramaccia, Luca Stefanini, Alessandro Toscano, Filiberto Bilotti**, Roma Tre University, Italy
Stefano Vellucci, Mirko Barbuto, Michela Longhi, Niccolò Cusano University, Italy

In future smart electromagnetic environments, smart repeaters will be used to enhance the coverage capability of the network and introduce reconfigurable re-transmission capabilities, adaptability of the radiating elements, and maximizing data transmission performance. In this context, we show that conformal reconfigurable metasurfaces surrounding an antenna element enable full control over its electrical and radiating characteristics, allowing to set, and changing in real-time, operation frequency, radiation pattern, and polarization state.

11:15 - 11:30 - *Design of a Dual Polarized Metasurface Antenna in Ka-Band*

Ravikanth Thanikonda, Marco Faenzi, Alberto Toccafondi, Enrica Martini, Stefano Maci, University of Siena, Italy

This contribution proposes the complete design for a dual-polarized metasurface (MTS) antenna based on the idea of duplexing an inward and an outward surface waves (SWs) that share the same radiating aperture. The outward SW is launched from the center of the aperture, while the inward SW is excited from the edge, through a two-layer feeding structure featuring a circular corner reflector at the aperture boundary. These SWs produce two circularly polarized broadside beams with opposite circular polarizations after interacting with the modulated impedance boundary condition (IBC) imposed by the MTS. By properly defining the impedance modulation, similar performances are achieved for the two polarizations in terms of beamwidth and efficiency. A practical feeding structure has been designed that employs a concentric triaxial cable, with a transition to coplanar waveguide for one of the two polarizations. This solution represents a promising approach for achieving dual-polarization in MTS antennas, offering high-performance with a simple and low-profile structure.

11:30 - 12:00 - *Dual-Polarized Aperture Antennas Based on Modulated Metasurfaces*
(Invited Talk)

David González Ovejero, IETR UMR CNRS 6164, France
Christos Bilitos, IETR UMR CNRS 6164, France
Stefano Maci, University of Siena, Italy

This contribution presents a new structure that enables dual-polarized radiation with aperture antennas based on modulated metasurfaces. The desired dual-polarized radiation is achieved by exciting in a dielectric substrate two orthogonally polarized modes that are phase matched. To that end, we tailor dispersion characteristics of the first two higher order transverse magnetic (TM) and transverse electric (TE) modes in the dielectric slab. The radiation characteristics are presented for reactance planes modulated along one direction and for two-dimensional concentric modulations. Fabrication aspects are also succinctly discussed.

12:00 - 12:15 - *Design and Experimental Implementation of Inverse-designed Metamaterial-inspired Antenna Systems for Biomedical and Biosensing Applications*

Dimitrios Tzarouchis, Maria Koutsoupidou, Dionysios Rompolas, Ioannis Sotiriou, Efthymios Kallos, Panagiotis Kosmas, Meta Materials Europe, Greece

This work will introduce and discuss an inverse-designed metamaterial-inspired antenna system specifically designed for biomedical/biosensing applications. We showcase two examples one antenna system at 40 GHz for biosensing and one at 1GHz for bioimaging applications.

12:15 - 12:30 - *Matching an Open Coaxial Probe with a Metasurface for Enhanced Sensitivity Dielectric Measurement*

Yarden Mazor, Rotem Gal-Katzir, Tel-Aviv University, Israel
Emily Porter, The University of Texas at Austin, USA

In this work, we propose using an impedance metasurface to improve the matching of a standard coaxial probe to biological tissue and following that, the dielectric measurement sensitivity to perturbations in the background medium. We utilize a simplified transmission line model to show that the sensitivity can be significantly improved using a thin inductive sheet between the aperture and the sample. We verify the analytical model with full-wave simulations and show that enhanced sensing depth is obtained. [ct here](#)

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Monday Afternoon 1)

“RF, Microwave, and Millimeter wave antennas, scatterers, and lenses I”

Chairs: Arthur Yaghjian, Samel Arslanagic

14:00 - 14:30 - *Circularly Polarized Helical Antennas Revisited* (Invited Talk)

Arthur Yaghjian , Electromagnetics Research, USA

The surface-wave and periodic leaky wave models of the multi-turn helix antenna operating in the axial mode are reviewed to try to shed some light on the seeming inconsistency of these two different models. One-turn helices are also considered to show under what conditions monofilar and bifilar helices can radiate axial circularly polarized fields that approximate Huygens sources, which have recently gained the attention of the metamaterials community.

14:30 - 14:45 - *Genetically Designed Superdirective Compact Antenna*

Dmytro Vovchuk, Gilad Uziel, Andrey Machnev, Pavel Ginzburg, Tel Aviv University, Israel
Vjačeslavs Bobrovs, Riga Technical University, Latvia

High-gain antennas are essential hardware devices, powering numerous daily applications, including distant point-to-point communications, safety radars, and many others. High gain is typically achieved at an expense of enlarging an antenna aperture in units of operational wavelength and remains a typical engineering guideline. However, a high gain can be achieved with careful overlapping of multiple interfering resonances within a subwavelength structure. Chu-Harrington limit is rather a standard criterion to assess performance and structures upon their gain characteristics. Compact antennas, surpassing this limit, are called superdirective. Here we design and demonstrate an architecture, based on near field coupled wires. Applied genetic optimization promises 8.81 dBi of realized gain within a compact subwavelength size structure at the C frequency band.

14:45 - 15:00 - *Genetically Designed Superscatterers – One Among a Trillion*

Pavel Ginzburg, Dmytro Vovchuk, Anna Mikhailovskaya, Konstantin Grotov, Andrey Machnev, Denis Kolchanov, Dmitry Dobrykh, Tel Aviv University, Israel

Experimental demonstration of superdirectivity and superscattering is among the long-standing challenges in electromagnetic theory. An appealing approach to increase a scattering cross-section is accommodating several spectrally overlapping resonances within a subwavelength structure. In this contribution, we will present several strategies to design superscatterers with the aid of generic optimization and demonstrate their state-of-the-art performances experimentally. We will formulate a new tight superradiant criterion of superscattering and demonstrate that only 1 among a trillion random structures can approach it.

15:00 - 15:30 - *Tailoring of Electromagnetic Radiation and Scattering by Simple Water-Based Devices* (Invited Talk)

Samel Arslanagic, Technical University of Denmark, Denmark

In this work, we will first review our activities in the exciting new research direction of water-based functional material platforms. Subsequently, we elaborate in detail on our recent results on an interesting realization of a water-based Huygens antenna, for efficient tailoring of radiation, as well as on a realization of a simple, reconfigurable, water-based resonator with an integrated impedance surface, for efficient tailoring of scattering. In

contrast to many other efforts, our attention is devoted to simple and easily made water-based designs. Extensive numerical and experimental results will be shown at the presentation. Our promising results, combined with the said advantages of water, cements its role as an interesting material for use in a wide range of functional material platforms.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Monday Afternoon 2)

“RF, Microwave, and Millimeter wave antennas, scatterers, and lenses II”

Chairs: Oscar Quevedo-Teruel, Pavel Belov

16:00 - 16:15 - Algorithm-based Encoding Metasurface for Beam Steering at 60 GHz

Ali Mourad, Ludovic Burgnies, Eric Lheurette, Univ. Lille, CNRS, France
Guy Salingue, Valery Guillet, Richard Razafferson, Orange Innovation, France

A metasurface for a beam steering at high angle is designed, fabricated, and characterized. Based on an optimization algorithm called “Pattern Search”, an optimal configuration is quickly obtained. The simulation of the complete metasurface using CST Microwave Studio software and measurements demonstrate a beam steering up to 44° with low loss of about 3 dB and over the frequency range 58 - 61 GHz.

16:15 - 16:30 - Liquid Crystal Meta-Reflectarray for D-band

Dayan Perez-Quintana, Miguel Beruete, Universidad Pública de Navarra, Spain
Erik Aguirre, Eduardo Olariaga, Jose A. Marcotegui, TAFCO METAWIRELESS, Spain
Sergei A. Kuznetsov, Novosibirsk State University, Russia
Valeri Lapanik, Shevchenko Institute of Applied Physical Problems, Belarus

A numerical demonstration shows a liquid-crystal-based reflectarray (LC-RA) that can be reconfigured and operates in the D-band frequency range of 105 to 125 GHz. The device has a high-impedance surface with a metasurface patterned with patches on a 2-mm-thick quartz substrate separated from the ground plane by a 40 μm-thick LC layer. The LC-loaded RA unit cells are electrically biased using narrow inductive strips that connect neighboring patches in one direction. The simulated prototype has a reflection phase tunability of up to 266 deg with insertion losses of around 2.5 dB. To achieve a reflected beam at 25 deg, the beam-steering scenario considers using a single row of the RA with 1 × 33-unit cells illuminated by a horizontally polarized plane wave at an incidence angle of $\theta_i = 10\text{deg}$.

16:30 - 17:00 - *Geodesic Lenses: The use of a Third Dimension as an Extra Degree of Freedom* (Invited Talk)

Oscar Quevedo-Teruel, KTH Royal Institute of Technology, Sweden

In this paper, we describe the operation of geodesic lenses, and their potential use for the design of lens antennas. The main advantage of these lenses is their low losses when implemented in parallel plate configurations, as well as their low cost when mass produced given their smooth shapes, specially in millimetre and sub-millimetre applications.

17:00 - 17:30 - *Volumetric Resonator Based on Split Loops for Wireless Power Transfer* (Invited Talk)

Aigerim Jandaliyeva, Andrey Vdovenko, Mikhail Sigantov, Leila Suleiman, Pavel Seregin, Mikhail Udov, Alena Shchelokova, Pavel Belov, ITMO University, Russia

Traditional wireless power transfer (WPT) methods are limited to 2-D configurations and involve putting the electronic device next to the charging pad. However, this approach limits the mobility of the device during charging. In this work, we have developed and investigated a novel solution that uses a volumetric resonator consisting of a pair of split loops. This resonator can transmit power wirelessly on a room-scale, making charging more convenient and less restrictive. One remarkable feature of this resonator is the magnetic field distributed in the volume with 96% uniformity. This allows us to transfer energy to a receiver anywhere within the resonator's internal volume with fixed efficiency. In other words, the receiver's location inside the resonator has almost no effect on the efficiency of the power transfer. The proposed resonator can be represented as a room, and low-power devices can be charged inside of it.

MONDAY 11th SEPTEMBER 2023**IMPERIAL 5****10:30 - 12:30 - Oral Sessions (Monday Morning)**
“Nonlinear and reconfigurable photonic metasurfaces”

Chairs: Wenshan Cai, Igal Brener

10:30 - 10:45 - *Third-Harmonic Circular Dichroism in a Chiral All-Dielectric Metasurface***Marco Gandolfi, Davide Rocco, Paolo Franceschini, Luca Carletti, Costantino De Angelis,** Università degli Studi di Brescia and CNR-INO, Italy**Yigong Luan, Luca Fagiani, Attilio Zilli, Michele Celebrano, Marco Finazzi,** Politecnico di Milano, Italy**Matteo Galli, Lucio Andreani,** Università di Pavia, Italy**Monica Bollani,** CNR -IFN, Italy**Andrea Tognazzi,** University of Palermo, Italy**Johann Osmond,** Institute of Photonics Sciences, Spain

We engineer, fabricate, and experimentally characterize chiral metasurfaces, empowered with quasi-bound state in the continuum, exhibiting nonlinear circular dichroism ($> 90\%$), and high conversion efficiency (10^{-3} W^{-2}).

10:45 - 11:00 - *High Q Factor Third Harmonic Generation in Resonant Silicon Metasurfaces***Omar A. M. Abdelraouf, Aravind P. Anthur, Xiao Renshaw Wang, Qi Jie Wang,** Nanyang Technological University, Singapore**Hong Liu,** Institute of Materials Research and Engineering, Singapore

Low loss dielectric metasurfaces have emerged as a promising approach to enhancing near field confinement due to the high optical nonlinearity of dielectric materials. In addition, novel structures and optical resonant modes have been introduced to the design, which leads to high Q factor dielectric metasurfaces to enhance the third harmonic generation. We have demonstrated hybrid dielectric metasurfaces constituted with phase change material and amorphous silicon meta-atoms to realize tunable third harmonic generation (THG) via Fano resonance in the visible regime, and crystalline silicon metasurfaces supporting bound states in the continuum resonance in the DUV regime, respectively. Both approaches have been experimentally validated to generate high THG power with high Q factors, superior to the performance of the dielectric metasurfaces in the same regime.

11:00 - 11:30 - *Ultrafast Phenomena in Plasmonic Metamaterials with Hot-Carrier Transport* (Invited Talk)

Wenshan Cai, Georgia Institute of Technology, USA

Leveraging the ultrafast dynamics of plasmonically induced hot electrons allows us to achieve ultrafast all-optical control of light, realize externally triggered second-order optical nonlinearity, and obtain light-induced optical chirality in hybrid plasmonic metamaterials.

11:30 - 11:45 - *Polarization-Dependent Tunable Hybrid Resonant Gold-Silicon Nanoantenna*

Pavel Kustov, Vitaly Yaroshenko, Elena Petrova, Martin Sandomirskii, Eduard Ageev, Yali Sun, Dmitry Zuev, ITMO University, Russia

Here we experimentally demonstrate the control of the optical response in different polarizations through irreversible laser-tuning of individual components of the hybrid nanoantennas. Such nanoantennas consist of a gold nanodisc placed on the top of a truncated silicon nanocone. It is shown that laser action on resonant nanoantennas leads to a change of initial structural color upon the illumination with TM polarized light and no changing upon TE polarization. In turn, the proposed operation method of hybrid nanoantenna geometric parameters and optical phenomenon find its application as a modern design in the security label and data storage development.

11:45 - 12:00 - *Asymmetric Transmission and Variable Beam Splitting using Coherently Coupled All-dielectric Grating-insulator-grating (GIG) Metamaterials*

Abbas Sheikh Ansari, Ashwin K. Iyer, Behrad Gholipour, University of Alberta, Canada
Jun-Yu Ou, University of Southampton, United Kingdom

Asymmetric transmission (AT) and reconfigurability in the direction of transmission using metamaterials and metasurfaces are demanded in various applications in optics and photonics. Here we show that coherent coupling between two dielectric nanogratings in a three-layer grating-insulator-grating (GIG) structure enables AT and variable beam splitting (VBS)

12:00 - 12:30 - *Entangled Photon Pair Generation and Beam Steering of Incoherent Emission Using Semiconductor Metasurfaces* (Invited Talk)

Igal Brener, Sandia National Laboratories, USA

Metasurfaces made from III-V semiconductors offer unique opportunities for quantum light generation and dynamic beam steering of incoherent light.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Monday Afternoon 1)

“Acoustic Metastructures I”

Chairs: Romain Fleury, Yakir Hadad

14:00 - 14:15 - Continuously Tunable Chiral Sound Field in a Non-Hermitian Ring Cavity

Tuo Liu, Institute of Acoustics, Chinese Academy of Sciences, China

Chiral exceptional points (CEPs) in travelling-wave resonators provide promising ways to generate and control chiral modes. This paper presents a possible means of continuously tuning the chirality of excited sound field in a loss-biased non-Hermitian ring cavity by exploiting chirality-reversal radiation and varying between two CEPs with opposite chirality.

14:15 - 14:30 - Cubic-symmetry Acoustic Metamaterials with Roton-like Dispersion Relations

Ke Wang, Yi Chen, Martin Wegener, Karlsruhe Institute of Technology, Germany

Muamer Kadic, Université de Franche-Comté, France

Changguo Wang, Harbin Institute of Technology, China

We design a cubic-symmetric acoustic metamaterial that exhibits highly unusual roton-like dispersion relations along the three principal cubic directions. The behavior is achieved by introducing nonlocal interactions into an airborne-sound metamaterial consisting of compartments and channels. The design principle is verified by numerical finite-element calculations and theoretical analysis.

14:30 - 15:00 - Design of Anomalous Dispersion Cones in Nonlocally-Resonant Metamaterials (Invited Talk)

Romain Fleury, Aleks Bossart, EPFL, Switzerland

Here, we show how to leverage nonlocal resonances -delocalized zero-energy modes with nontrivial wavevectors- to induce anomalous dispersion cones in architected media. The presence of such cones induces many hallmark properties of metamaterials, such as negative refraction, band gaps, slow sound and subwavelength character, albeit without

suffering from the same bandwidth limitations. We use examples across various dimensions and physical settings to explain how to control and even inversely design key properties of anomalous cones, namely their shapes, positions and overall number.

15:00 - 15:15 - *One-way Acoustic Guiding by Longitudinal and Transverse Flow*

Yakir Hadad, Tel-Aviv University, Israel
Ohad Silbiger, Tel-Aviv University, Israel

In this work, we explore one-way acoustic guiding on a sub-diffraction-acoustic waveguide that is immersed or adjacent to longitudinal or transverse flow.

15:15 - 15:30 - *Subwavelength Broadband Perfect Absorption for Unidimensional Open-duct Problems*

Yang Meng, G. Gabard, J.-P. Groby, Laboratoire d'Acoustique de l'Université du Mans, France
C. Bricault, S. Goudé, Valeo Thermal Systems, France
V. Romero-García, Universitat Politècnica de València, Spain

This work presents a general design methodology of metamaterial absorbers made of arrays of Helmholtz resonators for open-duct problems, which is encountered in broad practical applications. By using a single point scatterer, it is insufficient to attenuate both the reflected and radiated waves; a frequency-dependent maximum absorption exists and is derived analytically. To go beyond this absorption bound and achieve perfect absorption, at least two point scatterers are necessary. Specific designs are provided and validated both numerically and experimentally.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Monday Afternoon 2)**“Acoustic Metastructures II”**

Chairs: Min Yang, Sebastian Rieß

16:00 - 16:15 - *Bistable Origami-inspired 1-bit Coding Acoustic Metasurfaces for Reconfigurable Beam Scanning***Dinh Hai Le**, The University of New South Wales, Australia

This paper proposes a novel approach to acoustic metasurfaces that incorporates bistable origami-inspired folding structure and digital coding to enable dynamic reconfiguration of beam scanning. The unit cell of the metasurface is optimized to realize two equilibrium states with 180-degree phase difference that can be coded as binary 0 and 1. By programming each element of the metasurface with different coding sequences, two symmetric reflected acoustic beams can be manipulated at different angles. The proposed design represents a significant advancement in the field of acoustic metasurfaces, offering a flexible and versatile solution for applications such as acoustic imaging, communication, and sensing.

16:15 – 16:45 - *Acoustic Metamaterial Absorbers: The Path to Commercialization* (Invited Talk)**Min Yang**, Acoustic Metamaterials Group Ltd., Hong Kong**Ping Sheng**, Hong Kong University of Science and Technology, Hong Kong

Acoustic metamaterial represents the synergism between wave physics and designed geometric structures, aimed at novel acoustic properties. For the important functionality of acoustic absorption, metamaterials face the challenges posed by a mature, existing group of absorbing materials that has proven their effectiveness. Can the metamaterials do better? If so, at what price? This talk aims to answer these important questions. In particular, we will show that the critical advantage offered by metamaterial absorbers lies in the tunability of the absorption spectrum to fit the needs of the client, in conjunction with a minimum absorber thickness set by the causal constraint. By overcoming the obstacles set by the mass production cost, acoustic metamaterial absorbers have now entered the commercialization stage. We give three examples of the commercialized applications together with their underlying working principles and conclude with some observations.

16:45 - 17:00 - Vibroacoustic Metamaterials for Noise and Vibration Reduction on the Cover of Power Electronics of an electric Vehicle

Sebastian Rieß, Marvin Droste, Heiko Atzrodt, Emad Alasadi, Fraunhofer LBF, Germany
Jose Cándor López, Karsten Finger, Mercedes-Benz AG, Germany
Armin Erraji, Institute for Automotive Engineering (ika), RWTH Aachen University, Germany

In the presented work the potentials of vibroacoustic metamaterials for noise and vibration reduction for the use in electric vehicles are shown. Vibroacoustic metamaterials are applied to a cover of power electronics of an electric powertrain. The work involves the numerical stop band prediction, the elaboration of resonator designs, their manufacturing, and the experimental validation of the vibroacoustic metamaterial applied to the target structure. Validation measurements of the cover configurations are carried out in terms of structural dynamics. Three cover configurations with integrated vibroacoustic metamaterials, differing in terms of damping are compared to a reference cover, a cover with an added bitumen damping layer and an add-on vibroacoustic metamaterial.

17:00 - 17:15 - A Power-Based Approach based on Active Structural Intensity: Stop Band Prediction of Vibroacoustic Metamaterial Plate

Heiko Atzrodt, Arun Maniam, Marvin Droste, Sebastian Rieß, Fraunhofer LBF, Germany

The paper proposes a power-based approach using the active structural intensity for predicting the stop band behaviour of finite Vibroacoustic Metamaterials (VAMM) structures. The proposed method quantifies the vibrational energy flow and energy transmission pathways within a local resonance-based finite VAMM structure, allowing for a quantitative analysis of the vibration attenuation capabilities of a VAMM structure.

TUESDAY 12th SEPTEMBER 2023

IMPERIAL 1**09:00 - 10:00 - Plenary Session III**

Chair: Mirko Barbuto

09:00 - 10:00 Plenary talk*Integrated Metasurfaces for Life Science and Biomedical Applications***Hatice Altug, EPFL, Switzerland**

This talk will introduce our effort on the development of next-generation optical bioanalytical tools enabled by unique combination of nanophotonics with microfluidics, surface chemistry, data science and nanofabrication. One example will describe an AI-aided and immunoassay coupled optofluidic mid-infrared sensor capable of differentiating different misfolded forms of proteins linked to neurodegenerative diseases using their unique IR absorption signatures. The other example will describe a nanoplasmonic single-cell microarray that can spatially and temporally map extracellular secretions while simultaneously capture individual cell morphology at high-resolution and throughput.

10:00 - 10:30 – Coffee Break**10:30 - 12:30 - Oral Sessions (Tuesday Morning)*****“Complex electromagnetic materials and applications”***

Chairs: Vincenzo Galdi, Marcello Ferrera

10:30 - 10:45 - *The Effective Permittivity of an Isotropic Composite Material***Evgeniy Narimanov, Purdue University, USA**

We present the solution to the long-standing problem of calculating the universal contribution to the effective dielectric permittivity of an arbitrary isotropic composite material.

10:45 - 11:00 - *Exploiting Waveguide Networks to Calculate Solutions of Partial Differential Equations***Ross Glyn MacDonald, Alex Yakovlev, Victor Pacheco-Peña, Newcastle University, United Kingdom**

In this communication, we present a method to calculate the solution of partial differential equations (PDE) by exploiting metatronic elements within arrays of parallel plate waveguides connected at series junctions. A full physical and mathematical description

will be discussed with several examples such as the solution of the equation $\nabla^2 f + 7.2f = 0$ using an array of 3×3 waveguide junctions arranged in a square lattice.

11:00 - 11:30 - *Nonlinear Optics in Low-index Materials* (Invited Talk)

Wallace Jaffray, Marcello Ferrera, Heriot-Watt University, United Kingdom
Alexandra Boltasseva, Vladimir Shalaev, Purdue University, United States of America

Transparent conductive oxide (TCO) thin films have been used for photovoltaic systems and touch-screen technologies. Recently, TCOs have shown potential for all-optical applications due to their near-zero-index properties, with high nonlinear figure of merit and broad bandwidth. Research now focuses on designing and realizing nanophotonic devices and systems to leverage the slow-light properties of these materials.

11:30 - 12:00 - *Microwave Applications of Vortex and Composite Vortex Patterns* (Invited Talk)

Mirko Barbuto, Michela Longhi, Stefano Vellucci, Niccolò Cusano University, Italy

Zahra Hamzavi-Zarghani, Alessio Monti, Davide Ramaccia, Luca Stefanini, Filiberto Bilotti, Alessandro Toscano, Roma Tre University, Italy
Andrea Alù, City University of New York, USA

Vortex and composite vortex patterns can occur in a wide variety of physical systems, including plasmas, fluids, and electromagnetic waves. In addition to their spontaneous formation, several approaches for their generation and a diverse range of promising applications in both science and technology have been proposed. In particular, vortex and composite vortices have been efficiently generated at microwave frequencies, where their topological properties have been exploited in communications, imaging, and sensing systems. In this context, the aim of this talk is to provide a summary of our recent results achieved by applying the composite vortex theory to design different microwave structures with reconfigurable capabilities. The proposed devices are optimal candidates for implementing a smart electromagnetic environment, where the electromagnetic response of both communication nodes and environmental objects need to be adapted in real-time.

12:00 - 12:30 - *Exploring Interface Effects in Flatland Optics* (Invited Talk)

Massimo Moccia, Giuseppe Castaldi, Vincenzo Galdi, University of Sannio, Italy
Andrea Alù, City University of New York, USA

This study explores the possibilities of manipulating and controlling the propagation of surface waves in low-dimensional materials or metasurfaces by designing planar discontinuities in the surface impedance. Specifically, two examples are presented, namely “flat leaky waves” and “ghost line waves.” These innovative concepts have the potential to offer new avenues for controlling light at the nanoscale and could find practical applications in various fields ranging from integrated waveguides to optical sensing.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Tuesday Afternoon 1)
“Fundamental bounds”

Chairs: Mats Gustafsson, Eugene Kamenetskii

14:00 - 14:30 - *Tight Scattering and Antenna Bounds* (Invited Talk)

Mats Gustafsson, Lund University, Sweden

Fundamental limits set bounds on the performance of systems and devices by determining the theoretical maximum or minimum performance that can be achieved. They provide understand of the trade-offs and limitations of different design choices and can help to make more informed decisions about how to improve a device. Tight limits are even more useful as they provide a more precise bound on the performance of a design. When the limit is tight, it means that the difference between the theoretical maximum or minimum performance and the actual performance can be made small and that it is possible to design optimal devices. In such cases, it is easier to identify areas for improvement and make changes that will result in significant gains. Tight limits also provide a way to compare different designs, as they allow for a more precise assessment of their relative strengths and weaknesses. Physical bounds (fundamental limitation) have recently been investigated for many radiation and scattering scenarios based on duality and convex optimization. The procedure is based on optimization over sources constrained by power relations. Radiation (antenna) problems are most often naturally posed as optimization over the current distribution, with a feed only constrained by its supplied power. The resulting bounds are hence valid for all antenna structure and feed locations restricted to the design region. In this presentation, we discuss tightness of these type of limits and show that some of them are tight.

14:30 - 14:45 - *Overcoming the Upper Bound on the Bandwidth-to-Thickness Ratio of Ultrathin Absorbers*

Pardha Sourya Nayani, Syracuse University , USA
Younes Ra'di, Syracuse University , United States

We proposed a new concept for designing ultrathin absorbers that can provide several-fold higher absorption bandwidth compared to same-thickness absorbers designed based on conventional approaches.

14:45 - 15:00 - *On the Search for Fundamental Limitations for Harmonic Generation Processes*

Theodoros Koutserimpas, Francesco Monticone, Cornell University, USA

In this talk, we will discuss our recent efforts in the search for fundamental bounds to the second-order electric susceptibility of natural materials and engineered metamaterials at optical frequencies. Specifically, we will present a general approach that utilizes the causality principle to establish susceptibility upper bounds in relation to an allowed dispersion threshold.

15:00 - 15:30 - *Do Point Magnetolectric Scatterers Actually Exist?* (Invited Talk)

Eugene Kamenetskii, Ben Gurion University of the Negev, Israel

In the dipole approximation, bianisotropic meta-atoms are considered as subwavelength resonators without intrinsic magnetolectricity in a sense that no effects of the near-field ME energy are observed. We show that ferrite structures with electric and magnetic dipole-carrying excitations can behave as point scatterers with intrinsic magnetolectricity. This constitutes a new field of research, which we call magnetolectric electromagnetism.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Tuesday Afternoon 2)

“SS - American Physical Society”

Chair: Thomas Pattard

16:00 - 16:30 - *Generation, Distribution and Multiplex of Multiple Polarization States via Optical Metasurfaces: From Classical to Quantum* (Invited Talk)

Ruwen Peng, Ya-Jun Gao, Bo Xiong, Yue Jiang, Yu Liu, Mu Wang, Nanjing University, China

We present here our recent studies on the generation, distribution, and multiplexing of multiple polarization states via optical metasurfaces. One is multichannel distribution and transformation of polarization-entangled photon pairs with dielectric metasurfaces. The other is to break the limitation of polarization multiplexing in optical metasurfaces with engineered noise.

16:30 - 17:00 - Rest-Frame Quasistatic Theory for Rotating Circuit Systems (Invited Talk)

Ben Z. Steinberg, Tel-Aviv University, Israel
Nader Engheta, University of Pennsylvania, USA

We develop static and quasi-static theories for slowly rotating electromagnetic circuits and systems in their rest frame of reference. Rotation induced effects such as fictitious electric and magnetic charges, gain and instabilities, voltage-excited magnetic fields, and more, are exposed. They suggest new circuit functionalities such as rotation-induced memristors of positive or negative memristance, energy-harvesting circuits, and non-local interactions carried by rotation. They are essentially independent of the distance from the rotation axis, thus providing a robust ground for applications. As many EM materials consist of meta-atoms whose internal dynamics is quasi-static, the study potentially paves the way for new types of metamaterials.

17:00 - 17:30 - Multipolar Approach for All-Dielectric Resonators and Metasurfaces (Invited Talk)

K. Frizyuk, S. Gladyshev, M. Poleva, Z. Sadrieva, A. Shalaev, K. Ladutenko, K. Baryshnikova, A. Evlyukhin, M. Petrov, ITMO University, Russia
A. Bogdanov, ITMO University and Qingdao Innovation and Development Base of Harbin Engineering University, Russia and China

Electromagnetic multipoles combined with group theory and symmetry analysis give a powerful tool for describing the spectra of solitary resonators and metasurfaces and their electromagnetic response. In this talk, we show how the multipolar approach can be used for (i) the classification of eigenmodes in the resonators of various shapes; (ii) the description and engineering of bound states in the continuum in metasurfaces; (iii) the generalization of the bianisotropy beyond the dipole approach to the case of arbitrary high-order multipole resonances.

TUESDAY 12th SEPTEMBER 2023**IMPERIAL 2****10:30 - 12:30 - Oral Sessions (Tuesday Morning)**
“Scattering and wave effects in temporal metamaterials”

Chairs: Filippo Capolino, Iñigo Liberal

10:30 - 10:45 - *Rainbow-like Scattering in Temporal Metamaterials Induced By Switched Boundary Conditions*

Luca Stefanini, Davide Ramaccia, Zahra Hamzavi-Zarghani, Alessio Monti, Alessandro Toscano, Filiberto Bilotti, Roma Tre University, Italy
Mirko Barbuto, Michela Longhi, Stefano Vellucci, Niccolò Cusano University, Italy

In this contribution, an anomalous scattering process at a temporal interface is investigated for the first time. The monochromatic electromagnetic field propagating within a parallel plate waveguide (PPWG) is scattered in the free space when a temporal interface is induced by switching one of the two metallic plates to zero conductivity. The coupling process between the single guided mode and the infinite radiating modes in the free-space allows to scatter a continuous spectrum of plane-waves at different frequencies in different directions, realizing a rainbow-like scattering. The contribution provides closed-form solutions for the relationship between the guided mode and the scattered spectrum, along with design guidelines for controlling the frequency components and propagation directions of the rainbow. Full-wave numerical simulations were used to validate the model and verify the prism-like wave phenomenon.

10:45 - 11:15 - *Quantum Light Generation From Time-Varying Media* (Invited Talk)

Iñigo Liberal, Universidad Publica de Navarra, Spain

Time-varying media and/or temporal metamaterials offers unique degrees of freedom in engineering light-matter interactions. Among other aspects, time-varying media enable new forms of quantum light emission and amplification. In our talk, we will review several aspects of quantum light emission from time-varying media, including the generation of squeezed states of light with controlled properties, optical amplification with enhanced noise performance, and thermal emission overcoming the black-body spectrum.

11:15 - 11:30 - *Time-switched Metasurfaces as Frequency Multipliers for Radiated Modes*

Luca Stefanini, Davide Ramaccia, Alessio Monti, Zaha Hamzavi-Zarghani, Alessandro Toscano, Filiberto Bilotti, Roma Tre university, Italy
Mirko Barbuto, Michela Longhi, Stefano Vellucci, Niccolò Cusano university, Italy

Vincenzo Galdi, University of Sannio, Italy

This contribution introduces an optical compressor based on a temporal metasurface that utilizes surface waves to upshift a low-frequency source to ultra-high-frequency free-space radiation. This is achieved by employing a metasurface that can switch from supporting surface waves to being transparent, resulting in a temporal interface. Analytical formulations and numerical simulations are provided to predict and verify the upshift and scattering parameters for the transmitted and reflected fields.

11:30 - 11:45 - *Space-Time Fresnel Prism for Practical Dynamic Systems*

Zhiyu Li, Xikui Ma, Xi'an Jiaotong University, China

Christophe Caloz, KU Leuven, Belgium

This paper presents the concept of a space-time Fresnel prism, a space-time version of the conventional Fresnel prism. This prism emulates the operation of a space-time interface, the building brick of any modulation-based space-time metamaterial, while exhibiting a finite size and being capable to operate in the continuous-wave regime, unlike previously reported space-time and time systems. The main characteristics of the prism are established and its validity is demonstrated by full-wave simulation. This prism may play an instrumental role in the practical development of space-time metamaterial systems, such nonreciprocal, matching beyond the Bode-Fan bound, temporal cloaking, etc.

11:45 - 12:00 - *Range and Direction-of-Arrival Deception with Time-Modulated Scatterer*

Dmytro Vovchuk, Tel Aviv University, Israel

Modern radar systems are capable to determine a target location with high accuracy and, at the same time, have high Doppler tolerance to detect its moving characteristics. This means range and Doppler estimations are inevitably coupled, opening pathways to concealing objects by imprinting artificial signatures on the reflected echoes. Proper temporal control of the backscattered phase can cause the investigating radar to estimate wrong range and velocity, as well as direction-of-arrival (DoA). A method for achieving this by controlling the reflected phase from a time-modulated scatterer is presented both theoretically and experimentally, showing suitability for implementation via time-dependent metasurfaces supporting a semi-passive (battery-assisted) mode of operation. We demonstrate control over the perceived angular location of the concealed target, with proven ability to steer the direction of arrival on demand by over 5 degrees away from its true angular position and show that temporally concealed objects could even be made to appear closer than they truly are without violating the laws of relativity.

12:00 - 12:30 - *Exceptional Points of Degeneracy Induced by Time-Periodic Modulation*
(Invited Talk)

Kasra Rouhi, Alireza Nikzamir, Filippo Capolino, Department of Electrical Engineering and Computer Science, University of California, Irvine, USA
Alexander Figtin, Department of Mathematics, University of California, Irvine, USA

An exceptional point of degeneracy (EPD) is a point in parameter space where at least two eigenvalues and eigenvectors of a system coalesce. We explore the occurrence of EPD in electronic, electromagnetic and mechanical time-varying systems. Remarkably, when using time variation of a system component, EPDs exist in a single resonator and they can be found by just tuning the modulation frequency. We demonstrate EPDs of the second order in linear-time-periodic (LTP) systems and offer examples of their applications, such as sensing and power harvesting.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Tuesday Afternoon 1)
“Topological effects and confinement in photonic crystals”
Chairs: Hrvoje Buljan, Masaya Notomi

14:00 - 14:30 - *Sub-symmetry Protected Topological States* (Invited Talk)

Ziteng Wang, Xiangdong Wang, Zhichan Hu, Liqin Tang, Zhigang Chen, Domenico Bongiovanni, Daohong Song, Nankai University, China
Dario Jukić, Hrvoje Buljan, University of Zagreb, Croatia
Roberto Morandotti, INRS-EMT, Canada

A hallmark of symmetry-protected topological phases are topological boundary states, which are immune to perturbations that respect the protecting symmetry. It is commonly believed that any perturbation that destroys such a topological phase simultaneously destroys the boundary states. However, by introducing and exploring a weaker sub-symmetry requirement on perturbations, we find that the nature of boundary state protection is in fact more complex. We demonstrate that the boundary states are protected by only the sub-symmetry, using Su-Schrieffer-Heeger and breathing Kagome lattice models, even though the overall topological invariant and the associated topological phase can be destroyed by sub-symmetry preserving perturbations. By precisely controlling symmetry-breaking in photonic lattices, we experimentally demonstrate such sub-symmetry protection of topological states. Furthermore, we

introduce a long-range hopping symmetry in breathing Kagome lattices, which resolves a debate on the higher-order topological nature of their corner states. Our results apply beyond photonics and could be used to explore the properties of symmetry-protected topological phases in the absence of full symmetry in different physical contexts.

14:30 - 15:00 - *Non-Hermitian Skin Effect and Topological Singular Points Manipulated by Symmetry Breaking* (Invited Talk)

Masaya Notomi, NTT Basic Research Laboratories, Japan

Symmetry plays a key role in topological and non-Hermitian photonics. Here, we investigate two issues where interesting topological properties are generated by symmetry breaking. First, we show asymmetric absorption/gain in uniform dielectric media leads to novel non-Hermitian skin effect. Second, we show some examples that intriguing chiral topological singular points are generated from exceptional points by breaking symmetry of photonic crystals.

15:00 - 15:15 - *Hybrid Photonic-Plasmonic Cavities Based on the Nanoparticle-on-a-Mirror Configuration for Large Purcell Factors at Visible Wavelengths*

Angela I. Barreda, Carlos III university of Madrid, Spain

Mario Zapata-Herrera, Javier Aizpurua, Materials Physics Center CSIC-UPV/EHU, Spain

Isabelle M. Palstra, Femius Koenderink, Center for Nanophotonics, AMOLF, The Netherlands

Laura Mercadé, Alejandro Martínez, Universitat Politècnica de València, Nanophotonics Technology Center, Spain

We investigate a novel hybrid structure with a nanoparticle-on-a-mirror configuration coupled to a dielectric photonic crystal to obtain Purcell factors larger than 10^5 in the visible range. The proposed design is experimentally feasible with current technology.

15:15 - 15:30 - *Strong Coupling And Entanglement In Extreme Nanophotonic Cavities*

Angus Crookes, Ben Yuen, Stephen Hanham, Angela Demetriadou, University of Birmingham, United Kingdom

We design photonic crystal waveguides that are both high-finesse and achieve sub-wavelength mode volumes. Our designs operate at 780 nm, exist deep into the strong coupling regime, and generate robust multipartite entanglement. Such photonic cavities are easily scaled up to construct large quantum networks realising both local and global entanglement.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Tuesday Afternoon 2)

“Mechanical and elastic metastructures I”

Chairs: Lea Sirota, Bryn Davies

*16:00 - 16:15 - Multi-resonant Piezoelectric Metamaterials based on Digital Circuits for Broadband Wave Isolation***Zhiyuan Liu**, Beijing Institute of Technology, China**Kaijun Yi**, Beijing Institute of Technology, China

We propose a general method to design multi-resonant piezoelectric metamaterials in any type of structures, like beams, plates and shells. The characteristics of multi-resonant bandgaps are investigated. The experiment results confirm the realization of broadband elastic wave transmission isolation within multiple bandgaps.

*16:15 - 16:30 - Elastic Topological Edge States in Non-Hermitian Perturbative Metamaterials***Haiyan Fan, Zhongqing Su**, The Hong Kong Polytechnic University, Hong Kong**Tuo Liu**, Chinese Academy of Sciences, China**Jie Zhu**, Tongji University, China

Non-Hermiticity (material damping) intrinsically exists and can possibly drive the topological phase transition. Here, we utilize the perturbative elastic metamaterials to prove that appropriately tailored non-Hermitian modulation can induce topological edge states to appear not only in the topological bandgap but also in the continuous bulk spectrum.

*16:30 - 16:45 - Tunneling Phenomenon in non-Hermitian Classic Systems***John Benisty, Sayan Jana, Lea Sirota**, Tel Aviv university, Israel

Our research explores non-Hermitian elastic lattices with non-local feedback interactions. Proportional feedback in one-dimensional lattices creates complex dispersion relations that exhibit non-reciprocity with gain and loss in opposite directions. This behavior persists across multiple frequency bands. In classical systems, we observed peculiar tunneling phenomena in one-dimensional chains with non-reciprocity. Our findings highlight the fundamental properties of non-Hermitian elastic lattices and suggest opportunities for

designing meta materials with unique functionalities such as wave filtering, amplification, and localization.

16:45 - 17:00 - Real-Time Creation of Curved Space-Time for Gravitational Lensing in Phononic Crystals

Sayan Jana, Lea Sirota, Tel Aviv University, Israel

We propose a method to mimic the gravitational lensing phenomenon, which describes the deflection of light around a black hole. Our model is based on Weyl semimetals with inhomogeneous potential. We numerically realize a classical analogue of this quantum system by inducing active feedback interactions in a 2D phononic crystal.

17:00 - 17:15 - Mathematical Theory for Supercell Approximations of Fibonacci Quasicrystals

Bryn Davies, Imperial College London, United Kingdom
Lorenzo Morini, Cardiff University, United Kingdom

We present mathematical theory showing that supercell approximations accurately predict the main spectral gaps of Fibonacci quasicrystals. This theory is based on characterising the growth of the underlying recursion relation and corroborates the existence of previously observed "super band gaps". We demonstrate our general theory through application to a one-dimensional metamaterial, composed of a system of structured rods.

17:15 - 17:30 - Multi-polarization Elastic Bound States In the Continuum of Lamb Waveguide

Shuwei An, The Hong Kong Polytechnic University, Hong Kong

Bound states in the continuum (BIC) promote wave-matter interaction and contribute to high-sensitivity devices. Here, we report the elastic BICs with multi polarizations and multi orders in the pillared Lamb waveguide. Our study reveals the rich properties of BICs arising from wave dynamic in elastic media.

TUESDAY 12th SEPTEMBER 2023**IMPERIAL 3****10:30 - 12:30 - Oral Sessions (Tuesday Morning)****“IR and optical metastructures I”**

Chairs: Lei Zhou, Dorota Pawlak

10:30 - 11:00 - *Tailoring the Optical Lineshapes of Metasurfaces* (Invited Talk)**Lei Zhou**, Fudan University, China

In this presentation, we will experimentally demonstrate how to tailor the optical lineshapes of arbitrarily coupled photonic systems based on our rigorous theoretical framework from first principles, with all parameters directly computable via wave function integrations.

11:00 - 11:30 - *Novel Photonic Materials Enabled By Crystal Growth* (Invited Talk)

Dorota Anna Pawlak, Piotr Paszke, Piotr Piotrowski, Monika Tomczyk, Katarzyna Sadecka, Kingshuk Bandopadhyay, Krzysztof Markus, Hańcza Barbara Surma, Andrzej Materna, ENSEMBLE3, Poland
Johann Toudert, ENSEMBLE3, France

We will demonstrate how to utilize the crystal growth methods for manufacturing of novel composite materials for various applications, especially photonics (metamaterials, plasmonic materials), topological insulators, energy conversion. We will focus on two novel bottom-up manufacturing methods: (i) method based on directionally-grown self-organized eutectic structures; and (ii) NanoParticles Direct Doping method (NPDD) based on directional solidification of dielectric matrices doped with various nanoparticles.

11:30 - 12:00 - *Beyond Bulk Optics* (Invited Talk)**Dame Xiang Jiang**, University of Huddersfield, United Kingdom

The evolution of high value manufacturing is being driven by a technological move to smart and autonomous manufacturing processes. Central to this transition are the combination of two technologies: digital twins which are used to virtualise underlying physical processes; and machine learning which can enhance process control and decision-making. A fundamental requirement of these technologies is real-time data, acquired during each stage of a manufacturing process chain. The need for high data-acquisition rates, sensitivity and non-contact operation are broadly satisfied by modern optical sensors, but sensor integration and cost remain persistent challenges that difficult

to address using conventional (bulk) optical systems. This is primarily due to fundamental limitations on size/weight reduction due to a reliance on bulk material properties, coupled with the assemblies of multiple optical elements each of which must be manufactured and aligned to exacting tolerances. Optical metasurfaces are now well-established as flexible approach to the manipulation of light that can implement multiple optical functions with a single lightweight planar optical element. This approach allows for the design of optical systems which are much more compact than those based on conventional optics. Manufacturing optical metasurfaces relies on lithography-based methods which are fundamentally a low-cost once scale-up has been achieved. This talk will report on our approaches to implementing optical sensors for high value manufacturing based on metasurface implementations of: confocal microscopy, chromatic confocal probing, line-scanning spectral interferometry. We show how optical metasurfaces have the potential to revolutionise optical sensor technology, by supporting sensor integration through miniaturisation and consider how the new-found design freedom can enhance functionality at the same time. Finally, we discuss some of the challenges for harnessing optical metasurface as engineered components in real-world systems and articulate the current research opportunities in this area.

12:00 - 12:15 - *Performance Factor Evaluation of Multifunctional Metasurface for Chip Scale Atomic Clock (CSAC)*

Katsuma Aoki, Ponrapee Prutphongs, Satoshi Ikezawa, Kentaro Iwami,

Tokyo University of Agriculture and Technology, Japan

Motoaki Hara, National Institute of Information and Communication Technology (NICT), Japan

In this study, a metasurface with integrated deflecting and quarter-wave plate function was fabricated. By correcting the meta-atom shape by several methods, the phase gradient uniformity and electron beam rendering shape were found to be dominant factors in improving the deflection efficiency.

12:15 - 12:30 - *Epsilon-Near-Zero Cavities for Strong Light-Matter Coupling and Emission Tuning*

Roman Krahne, Aniket Patra, Italian Institute of Technology, Italy

Vincenzo Caligiuri, Antonio De Luca, Dipartimento di Fisica, Università della Calabria, Italy

Bruno Zappone, CNR-Nanotec, Italy

We demonstrate polaritons with Epsilon-Near-Zero (ENZ) effective permittivity in dye-doped metal-dielectric-metal (MDM) cavities. We map both the in-plane and the out-of-plane wave vector dispersions of the anti-crossing of the cavity resonances with the

exciton modes. We find a large Rabi splitting well exceeding 100 meV, and by varying k in cross-plane direction with a surface-forces apparatus we can evaluate the influence of the number of involved photons on the polariton splitting.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Tuesday Afternoon 1)

“IR and optical metastructures II”

Chairs: Joel Yuen-Zhou, Mária Csete

14:00 - 14:30 - Polariton Chemistry: Prospects and Challenges (Invited Talk)

Joel Yuen-Zhou, UC San Diego, USA

I will discuss the prospects and challenges of polariton chemistry, namely, the effort of controlling physicochemical processes and properties using strong light-matter coupling. The main challenge is the large N problem, where in the collective strong coupling regime, a macroscopic number N of molecules couple to each photon mode in a microcavity, rendering the equilibrium effects negligible on a per-molecule basis. Way to ameliorate this problem include polariton condensation, molecular optomechanics, and non-equilibrium effects. I will outline our theoretical efforts along these lines, together with experimental works done with experimental collaborators.

14:30 - 14:45 - Nonreciprocal Huygens' Metasurfaces Based On Bound States In The Continuum

Luis Manuel Máñez-Espina, **Ana Díaz-Rubio**, Universitat Politècnica de València, Spain

Ihar Faniayeu, University of Gothenburg, Sweden

Viktar Asadchy, Aalto University, Finland

Magneto-optical effects are typically very weak in the optical spectrum, and therefore, nonreciprocal devices based on them are very bulky. We demonstrate that optical metasurfaces supporting quasi-bound states in the continuum provide a powerful way for achieving strong nonreciprocal responses. Using the multi-mode temporal coupled-mode theory, we synthesize and analyze a nonreciprocal metasurface with Huygens' meta-atoms.

14:45 - 15:00 - Polarization-Dependent Enhancement Of Magnetic Dipolar Emission With Silicon Nanodimers

Marijn Rikers, Ayesheh Bashiri, Aleksandr Vaskin, Angela Barreda, Michael Steinert, Thomas Pertsch, Isabelle Staude, Friedrich Schiller University Jena, Germany
Duk-Yong Choi, Australia National University, Australia

A silicon dimer with polarization-dependent electric and magnetic field enhancement is designed to modify the emission properties of Eu³⁺ emitters. Fabrication is done using a two-layer electron beam lithography process.

15:00 - 15:15 - Difference Frequency Generation from a Single AlGaAs Nanoresonator

Marco Gandolfi, Luca Carletti, Costantino De Angelis, Università degli Studi di Brescia and CNR-INO, Italy

Massimiliano Guasoni, Optoelectronics Research Centre, University of Southampton, UK
Andrea Tognazzi, University of Palermo and CNR-INO, Italy

We study near to mid-infrared difference frequency generation in AlGaAs isolated nanoresonators. Conversion efficiency is considerably enhanced when the resonator supports optical resonances with good spatial field overlap at the mixing frequencies

15:15 - 15:30 - Metamaterials for Enhancing Reflection and Transmission

Dávid Vass, András Szenes, Balázs Bánhelyi, Mária Csete, University of Szeged, Hungary

Different metamaterial compositions constructed with high density core-shell nanoresonators were studied to enhance the optical response and near-field confinement of the system. The reflectance was enhanced by doping the core of the core-shell or the additional gain shell embedding the passive plasmonic nanoresonator with a laser dye. By varying the metamaterial properties either enhanced reflection or enhanced transmission was achievable.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Tuesday Afternoon 2)**“Nonlinear and active photonic metasurfaces”**

Chairs: Harald Giessen, Costantino De Angelis

16:00 - 16:30 - *Electrically Switchable Plasmonic Polymer Metasurfaces for Video-rate Beam Switching and Multi-focal Metaobjectives* (Invited Talk)

Harald Giessen, University of Stuttgart, Germany

We introduce nanoantennas and metasurfaces from metallic polymers which can be electrically switched in the infrared spectral range via CMOS-compatible voltages of $\pm 1V$ at frequencies of 30 Hz. We demonstrate, on the one hand, an electrically switchable metallic polymer metasurface for ultra-high-contrast active beam switching in transmission. On the other hand, we realize an electro-active metaobjective comprising two metalenses-on-demand.

16:30 - 16:45 - *Nonlinear Wavefront Shaping with Nonlocal Metasurfaces*

Luca Carletti, Università degli Studi di Brescia, Italy

Michele Cotrufo, Adam Overvig, Andrea Alù, City University of New York, USA

We demonstrate wavefront shaping of third-harmonic light generated in nonlocal silicon metasurfaces. The nonlinear geometric phase principle is applied to locally control the phase response of the diffracted third-harmonic light.

16:45 - 17:00 - *Improving Optical Sensing with Noise, Loss, Nonlinearity and Shorter Measurements*

Said Rodriguez, AMOLF, Netherlands

The performance of a sensor is usually improved by suppressing noise and loss, avoiding nonlinearities, and increasing the measurement time. Here I challenge this paradigm by demonstrating resonant optical sensors that benefit from noise, loss, nonlinearity, and short measurement times. I will show that while these ingredients are detrimental in isolation, their combination can improve sensing performance in unexpected ways. A combination of loosing strategies becomes a winning strategy, according to Parrondo's paradox.

Media link(s):

Phys. Rev. Appl. 13, 024032 (2020)

Phys. Rev. Lett. 126, 213901 (2021)

Phys. Rev. Lett. 129, 013901 (2022)

17:00 - 17:30 - *Nonlinear Flat-optics for Analog Image Processing* (Invited Talk)

Costantino De Angelis, Domenico de Ceglia, University of Brescia, Italy

Andrea Alù, City University of New York, USA

Dragomir Neshev, The Australian National University, Canberra, Australia

We demonstrate that nonlinear phenomena combined with engineered nonlocality in flat-optics devices can be leveraged to synthesize Volterra kernels able to perform complex operations on incoming images in real-time. As an illustrative example, we demonstrate edge detection with nonlinear nonlocal flat optics. The advantages over edge-detection through linear flat optics include broadband operation, very large contrast, and better performance in the presence of noise.

TUESDAY 12th SEPTEMBER 2023**IMPERIAL 4****10:30 - 12:30 - Oral Sessions (Tuesday Morning)****“SS - Use of artificial intelligence and machine learning in metamaterials”**

Chairs: Andrea Massa, Corentin Coulais

10:30 - 11:00 - *Machine Learning Based Metafoundation Design and Optimization* (Invited Talk)**Tugberk Guner, Marco Broccardo, Oreste S. Bursi**, University of Trento, Italy

Seismic events such as the Fukushima disaster of 2011 and the more recent Maras incident have brought attention to the vulnerability of conventional construction and protection methods in the face of extreme events. Despite years of research and advancements in the field, there remains a need for unconventional and innovative methods to improve infrastructure resilience while meeting sustainability and efficiency requirements. Metastructures, which leverage the properties of metamaterials to control wave propagation, have emerged as a promising area of research for controlling seismic waves and their impact on structures. In particular, metafoundations based on locally resonant metastructures have shown potential as a simple and effective solution for seismic protection of critical infrastructure, industrial plants, and nuclear power plant components. Compared to traditional solutions, metafoundations offer modular, adaptable, and flexible multidirectional seismic protection that is potentially effective in reducing seismic demand. Recent research has highlighted the design flexibility of metafoundations as a key advantage. In fact, multiple design variables can be standardized for diverse construction locations, leading to the construction of more sustainable and safer structures. However, the flexibility and adaptability of such systems, with their multiple design variables, come with a price. The interaction of most design variables creates bicriteria/multicriteria optimization problems that necessitate complex and multiobjective optimization of resonator parameters with recursive and computationally (very) expensive computations. To address these challenges, this talk presents the most recent developments in Gaussian process-based surrogate models equipped with an active learning scheme for the performance-based design of metafoundations. Starting with simple 1D coupled structures, the proposed method advances to 3D complex coupled structures under multiple conditions. A success rate based on numerical comparisons and quantitative assessments with designs of an expert engineer has been considered to evaluate the proposed method's performance. The proposed procedure is expected to improve the design and feasibility of metafoundations significantly.

11:00 - 11:30 - *Inverse Design of Combinatorial Metamaterials with AI* (Invited Talk)**Corentin Coulais, Ryan van Mastrigt**, University of Amsterdam, Netherlands**Marjolein Dijkstra**, Utrecht University, Netherlands**Martin van Hecke**, AMOLF/Leiden, Netherlands

We use convolutional neural networks in combination with genetic algorithms to design combinatorial metamaterials with superior shock absorption performances.

11:30 - 12:00 - *Metamaterial-Based Devices for Smart EM Environments - ML-Based Synthesis Methods* (Invited Talk)**Andrea Massa**, ELEDIA Research Center and University of Electronic Science and Technology of China, China**Arianna Benoni, Pietro Da Rù, Giacomo Oliveri, Marco Salucci**, ELEDIA Research Center and University of Trento, Italy

The Smart ElectroMagnetic Environment (SEME) vision is expected to foster a deep revision of the fundamental concepts employed since decades in the design of wireless mobile communication systems [1][2]. Unfortunately, the synthesis of SEME metamaterial-based devices involves the optimization of a huge number of micro-scale descriptors and the use of time-costly EM simulations to accurately predict (i) the macro-scale radiating features of each trial design as well as (ii) its complex interactions with the surrounding large-scale environment. Therefore, substantial efforts are required to effectively deal with the arising high computational complexity. Towards this end, innovative synthesis methodologies developed within the so-called System-by-Design (SbD) paradigm have been introduced leveraging properly-customized machine learning (ML) strategies to enable computationally-affordable solutions [11]. This invited talk will survey the recent advances in the exploitation of the SbD for the expedite and reliable design of metamaterial-based SEME devices, envisaging on-going and future trends as well.

12:00 - 12:30 - *Recent Advances in Artificial Intelligence in Passive Static Electromagnetic Skins Design* (Invited Talk)**Giacomo Oliveri, Marco Salucci**, ELEDIA Research Center and University of Trento, Italy**Andrea Massa**, ELEDIA Research Center and University of Electronic Science and Technology of China, China

The recent introduction of the Smart EM Environment concept in mobile communications planning and optimization [1][2] has spurred the interest in the design and

implementation of several new classes of passive static metasurfaces, also labeled as Electromagnetic Skins (EMSs) [3]-[6]. These planar devices are capable of performing advanced wave manipulation functionalities by properly adjusting their quasi-periodic meta-atomic structure [3]-[6]. Owing to their principle of operation, the EMS synthesis problem turns out an intrinsic multi-scale one in which (i) the EMS descriptors are the micro-scale geometric properties of each meta-atom in the skin, while (ii) the design goal usually requires to achieve a desired macro-scale spatial distribution of the scattered wave energy. Consequently, the solution of such a design problem requires the availability of efficient and accurate models for the prediction of the EM wave local scattering from each meta-atom starting from its micro-scale descriptors. Artificial intelligence (AI) techniques have been recently adopted and customized in this framework [5][7][8]. More in detail, AI methodologies have been demonstrated to enable the creation of “EMS Meta-Atom Digital Twins” starting from a (limited) number of full-wave simulations of their response, hence also enabling to account for complex mutual coupling interactions beyond the local periodicity approximation [5][7][8]. The objective of this invited talk is to provide a review on the recent advances and envisaged trends in the applications of AI in meta-atom modeling and passive static EMS synthesis for SEME.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Tuesday Afternoon 1)

“RF, Microwave, and Millimeter wave antennas, scatterers, and lenses III”

Chairs: Ping Sheng, Sawyer Campbell

14:00 - 14:15 - *Wide-angle Broadband Metamaterial Lens Based on Double Wire Medium*

Ivan Matchenya, Grigoriy Karsakov, Eugene Koreshin, ITMO University, Russia

The double wire medium (DWM) is a 3d metamaterial consisting of two orthogonal sets of metallic wires. These media support two propagating modes in a wide frequency region below the plasma frequency. First mode has hyperbolic isofrequency contour in wires plane, second one has hyperbolic isofrequency contour in the diagonal plane which is orthogonal to wires plane. Both modes can be used to create a planar gathering lens but only the first has been studied before. Our full-wave numerical simulations, ray-tracing simulations and experimental measurements have shown that the lens works efficiently over a wide frequency range with bandwidth of about 60% and for angles of incidence up to 30 degree. The proposed lens is easy to produce as it has flat interfaces and straight metallic wires hosted in dielectric matrix.

14:15 - 14:30 - *Circular Array Synthesis of Huygens Coatings Beamforming Metasurfaces*

Michela Longhi, Stefano Vellucci, Mirko Barbuto, University of Rome Niccolò Cusano, Italy

Alessio Monti, Zahra Hamzavi Zarghani, Luca Stefanini, Davide Ramaccia, Filiberto Bilotti, Alessandro Toscano, Roma Tre University, Italy

In this contribution, the design of a cylindrical Huygens metasurface, coating an antenna for beam shaping applications, is performed by exploiting a circular array synthesis method. In particular, we present the possibility to improve the functionality of metasurface coats, acting on the mathematical model of a circular array, which is able to take into account the electromagnetic response of both the overall metasurface gradient and of the single unit-cell.

14:30 - 15:00 - *Ultra-broadband Microwave Absorber with Thickness Approaching the Causality Limit* (Invited Talk)

Ping Sheng, IAS, HKUST, Hong Kong

Sichao Qu, Yuxiao Hou, Dept. of Physics, HKUST, Hong Kong

We present the conceptual design strategy and the implementation of an ultra-broadband microwave absorber, attaining 99% absorption from 3 to 40 GHz, with a sample thickness of 1.42 cm, only 5% over the causality limit.

15:00 - 15:15 - *Reflection Paradox in the Hyperbolic Metamaterials*

Andrey Bogdanov, Harbin Engineering University, China

Electromagnetic waves incident at arbitrary angles on the interface of a lossless hyperbolic medium can completely disappear if the interface has a specific orientation with respect to the optical axis. We resolve this paradox and show that the reflected wave exists, but became extremely decaying as the loss parameter tends to zero. We support our analysis with analytical calculations and experimental verification in the microwave region.

15:15 - 15:30 - *Performance Tradeoffs Between 2D and 3D Coding Metasurface Unit Cells for Broadband and Wide Field of View RCS Reduction*

Sawyer D Campbell, Ryan J Chaky, Pingjuan L Werner, Douglas H Werner, The Pennsylvania State University, USA

Coding metasurfaces have shown tremendous potential for tailoring electromagnetic scattering from objects. While conventional coding metasurfaces have been realized with planar metasurface structures, we demonstrate how extending these geometries to 3D

can lead to increased bandwidths, wider fields of view, and improved polarization responses. To realize this, a custom multiobjective optimization framework was developed to optimize and study the performance tradeoffs between 2D and 3D coding metasurface unit cells.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Tuesday Afternoon 2)

“mm-wave and THz metasurfaces”

Chairs: Miguel Beruete, Stanislav Glybovski

16:00 - 16:30 - *Holographic Metasurfaces for Millimeter-wave Wireless Communication Systems* (Invited Talk)

Miguel Beruete, Public University of Navarre, Spain

This paper presents advancements in millimeter-wave and terahertz frequency metasurfaces, particularly those based on holographic principles. These devices offer significant potential for applications such as compact holographic metalenses and full-space metasurfaces. The paper showcases a range of novel devices and discusses work on vortex beam and hologram generators and metalens antenna systems for future wireless millimeter-wave communications systems.

16:30 - 17:00 - *Designing Huygens' Metasurfaces for Anomalous Refraction of THz Beams* (Invited Talk)

Maksim Tumashov, Stanislav Glybovski, ITMO University, Russia

Sergei Kuznetsov, Novosibirsk State University, Russia

Vinay Killamsetty, Ariel Epstein, Technion - Israel Institute of Technology, Israel

Huygens' metasurfaces (HMSs) can serve as compact and efficient quasi-optical components for the terahertz (THz) range. Here, we apply a precise semi-analytical approach to synthesize an HMS anomalously refracting a normally incident beam in the THz range. The structure is composed of five spatially-modulated impedance sheets deposited on four polypropylene films using contact photolithography. The sheets comprise parallel Al strips with periodic capacitive and inductive loads. Numerical simulations predict the refraction power efficiency of 78%, spuriously scattered power fraction of 8%, and absorbed power fraction of 14%.

17:00 - 17:15 - *Performance of a 220/293 GHz Dual-Band Anomalous Reflector for 6G Applications*

Yuto Kato, National Institute of Advanced Industrial Science and Technology, Japan
Atsushi Sanada, Osaka University, Japan

We propose a dual-band anomalous reflector operating at 220 GHz and 293.3 GHz for the 6G applications. The anomalous reflector consists of paired patch elements on a single-layer and via-free substrate to control higher-order diffraction modes simultaneously at the two frequencies. The proposed reflector achieves highly efficient anomalous reflections in the same direction at multiple frequencies with a numerical optimization. An anomalous reflector operating at 220 GHz and 293 GHz is designed and the reflection performance is numerically investigated. The reflection efficiencies including the material losses are calculated to be 87.6 % and 70.2 % at 220 GHz and 293.3 GHz, respectively.

17:15 - 17:30 - *Performance Analysis of a Novel Metamaterial-inspired Substrate-integrated Cavity for 5G Applications*

Stamatios Amanatiadis, Vasileios Salonikios, Nikolaos Kantartzis, Traianos Yioultsis, Aristotle University of Thessaloniki, Greece

The functionality of a fully planar metamaterial-inspired substrate-integrated cavity is thoroughly investigated in the present work. The power confinement in the cavity is achieved via broadside-coupled complementary split ring resonators that operate as a virtual electric wall. The numerical results highlight the fundamental resonances with a noteworthy quality factor.

TUESDAY 12th SEPTEMBER 2023**IMPERIAL 5****10:30 - 12:30 - Oral Sessions (Tuesday Morning)****“Metastructures for Imaging and Sensing I”**

Chairs: Willie Padilla, Stamatios Amanatiadis

10:30 - 11:00 - *Metamaterial Physics Discovery with Informed Deep Learning* (Invited Talk)**Willie Padilla, Omar Khatib, Yang Deng, Simiao Ren, Duke University, USA****Jordan Malof, University of Montana, USA**

Deep learning has shown marked success in applied arenas including in metamaterials and metasurface research. Neural networks are often the architecture chosen for deep learning and it has been shown that a NN with a single hidden layer is a universal solver. However, NNs are black box models, and it is unknown how or why they work. Thus, any physics they may discover remains hidden. The incorporation of prior knowledge – including physics – into NNs permits a glimpse into the black box. [1-3] More importantly, informed deep learning enables deep NNs to predict physical properties of systems, including metamaterials. Here we overview the field of informed deep learning, demonstrate several results and give an outlook of this exciting direction in deep learning.

11:00 - 11:15 - *Dielectric Sensing by Babinet's Principle in Plasmonics***Joseph A. Riley, Victor Pacheco-Peña, Newcastle University, United Kingdom****Michal Horák, Vlastimil Křápek, Brno University of Technology, Czech Republic**

In this communication, complementary metal-dielectric plasmonic structures designed by exploiting Babinet's principle are studied and designed to act as plasmonic sensors of thin film dielectrics. We make use of metallic plasmonic dimers and their complementary holes on a thin metallic screen to provide an in-depth study of their performance.

11:15 - 11:30 - *Paper Recoil and Quantum Effects in Electron-light-matter Interactions using Low-energy Electrons*

Adamantios P. Synanidis, P. André D. Gonçalves, Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Spain

F. Javier García de Abajo, Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Institutió Catalana de Recerca i Estudis Avançats, Spain

Claus Ropers, Max Planck Institute for Multidisciplinary Sciences, Germany

We present a theoretical framework including both quantum and recoil effects that rigorously describes the interaction between light and low-energy electrons, which we apply to surface-scattered electrons and the prediction of electron-light interaction phenomena.

11:30 - 11:45 - *Single-step Printing for Deep UV Meta-hologram*

Wonjoong Kim, Chanwoong Park, Hyoin Song, Sucheol Ju, Hansang Sung, Heon Lee, Korea University, Korea (South)

By dispersing zirconium dioxide (ZrO₂) nanoparticles in a UV-curable resin, ZrO₂ nanoparticle-embedded-resin (nano-PER) is developed as a printable material that has a high refractive index and low extinction coefficient from near-UV to deep-UV. UV metaholograms operating in near-UV and deep-UV are experimentally demonstrated with vivid and clear holographic images.

11:45 - 12:00 - *Multifunctional Metasurface-Based Sensors Operating at a Single Frequency*

Masaya Tashiro, Ashif Aminulloh Fathnan, Hiroki Wakatsuchi, Nagoya Institute of Technology, Japan

Yuta Sugiura, Keio University, Japan

Akira Uchiyama, Osaka University, Japan

We present the concept of metasurface-based sensors that are capable of sensing more than one physical quantity from a scattering parameter without relying on more than one frequency. Our metasurface sensors exploit time-varying electromagnetic characteristics that are associated with multiple physical quantities. The proposed concept is expected to work even under limited frequency resources.

12:00 - 12:15 - *Metamaterials for Characterisation of Conductive Objects using Time-Domain Reflectometry of Magnetoinductive Waves*

Callum Long, Anya Radkovskaya, Georgiana Dima, Ekaterina Shamonina, University of Oxford, United Kingdom

Laszlo Solymar, Imperial College London, United Kingdom

We utilise a 1D magnetoinductive waveguide comprising of split ring resonators to successfully determine the proximity and location of a conductive object. We combine localisation with characterisation to make vital first steps from defect sensing and towards imaging of inhomogeneous conductive media using magnetoinductive waves.

12:15 - 12:30 - *Contactless Mapping of Conductive 3D Printed Metamaterials*

Georgiana Dima, Ekaterina Shamonina, Christopher J. Stevens, University of Oxford, United Kingdom

Additive manufacturing of conductive materials is an area of high interest in the metamaterials and electronics communities as it has the potential of creating diverse structures faster and cheaper than alternative methods. However, there are still concerns associated with this technology such as the lack of homogeneity or defect presence. This paper presents a method of quality control which can be implemented within or after the printing stage. A small split ring resonator sensor is used to scan the surface and distinguish between regions with or without conductive material. This method will be supported by numerical simulations and experimental results. The resolution of the probe is below 2 mm and it will be shown that invisible defects can be detected.

13.15 - 13.45 - *Inside Nature Communication*

Dr Cristiano Matricardi, Senior Editor at Nature Communications

Understanding the role of the editorial evaluation is of primary importance, especially in a changing landscape where diversity is flourishing but at the same time the importance of differences seems to be flattened. Since its launch in 1869, Nature has seen its mission as two-fold: facilitating the prompt communication of the most important scientific developments to the relevant research communities, while at the same time fostering a greater appreciation of these works amongst the wider public. Although the publishing landscape for scientific research is currently undergoing a period of rapid change, these core principles remain largely unchanged. This talk will endeavour to explain how Nature Portfolio editors navigate the complex landscape of science publishing and at the same time remain firmly bound to the core principles of the Journal.

14:00 - 15:30 - Oral Sessions (Tuesday Afternoon 1)**“Metastructures for Imaging and Sensing II”**

Chairs: Ekmel Ozbay, Jinliang Ren

14:00 - 14:30 - Centimeter Scale Nanostructures: Lithography-free Metamaterials for Photoconversion, Photodetection, Light Emission, Sensing, and Filtering (Invited Talk)

Ekmel Ozbay, Bilkent University, Turkey

Metamaterial-based perfect light absorbers are of particular interest in many applications. We report lithography-free techniques in many applications including photoconversion, photodetection, light emission, sensing, filtering and thermal camouflage. This presentation will summarize our recent accomplishments in this field.

14:30 - 14:45 - Gaussian to Top-hat Beam Shaping Metasurface for Visible Light

Ryota Yamada, Satoshi Ikezawa, Kentaro Iwami, Tokyo university of agriculture and technology, Japan

We propose a metasurface optical element made of silicon nitride that converts a Gaussian beam into a top-hat-shaped line beam in the visible light region. This allows optical cut-off ranging sensors to achieve higher performance without size enlargement.

14:45 - 15:00 - Near-field Enhancement by Guided Bloch Modes at the Second Stop Band of a Nonlocal Optical Metasurface

Xiaorun Zang, Andriy Shevchenko, Aalto University, Finland

We show gap hotspots of plasmonic dimers can be further enhanced by combining the surface lattice resonances with Bloch modes at the second stop band of a nonlocal optical metasurface. This approach can be used to create efficient and reusable substrates for surface-enhanced Raman spectroscopy and other plasmonic sensors.

15:00 - 15:15 - Quantum Imaging using Entangled Photon Pairs from Nonlinear Metasurfaces

Jinliang Ren, Jinyong Ma, Jihua Zhang, Andrey Sukhorukov, Australian National University, Australia

We present a novel imaging technique that combines quantum ghost and scanning imaging protocol to capture two-dimensional images using only a one-dimensional

detector array, enabled by strong spatial correlations and tunable emission angle of entangled photon pairs emitted from an ultrathin nonlinear metasurface.

15:15 - 15:30 - *Two-Dimensional Metal-Organic Frameworks As A Key Material For Planar Optical Sensing Applications*

Pavel Alekseevskii, Anastasiya Efimova, Maria Timofeeva, Yulia Kenzhebayeva, Irina Koryakina, Sergej Shipilovskikh, Valentin Milichko, ITMO University, Russia

We present a new 2D MOF for optical sensing applications. Nanoscale MOFs are prepared by freeze-thaw technique. Exfoliated frameworks demonstrate optical sensitivity to solvents of a varied polarity. In turn, this opens the way to fabricate scalable, freestanding 2D MOF layers for planar chemical optical sensors by industrially oriented approaches.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Tuesday Afternoon 2)

“Metastructures for Imaging and Sensing III”

Chairs: Qiaoqiang Gan, Philipp del Hougne

16:00 - 16:30 - *Plasmonic “Rainbow” Structures for Smart on-chip Spectrometers* (Invited Talk)

Qiaoqiang Gan, King Abdullah University of Sci Tech, Saudi Arabia

A plasmonic “rainbow” trapping metasurface was developed for on-chip spectrometers and sensors. By analyzing the spatial position of the trapped surface plasmon waves, a miniaturized imager-based platform was demonstrated for super-resolution displacement spectroscopic sensing. Furthermore, by analyzing a single image using deep neural networks, we demonstrated an intelligent plasmonic “rainbow” chip for spectroscopic sensing. This image-based system can precisely determine the spectroscopic and polarimetric information of the incident spectral information with no need of conventional benchtop systems.

16:30 - 16:45 - *Design Method for Large-Scale Wide Field-of-View Monochromatic Metalenses*

Hiroyuki Tahara, Toshifumi Yasui, Sony Semiconductor Solutions Corporation, Japan

We propose a novel design method for monochromatic metalenses. The proposed technique divides the metalens periphery into supercells and uses metagrating

optimization to account for the inter-pillar interaction and incident angle bandwidth at a reasonable computational cost, significantly improving metalens performance over the unit-cell based method.

16:45 - 17:00 - *On the Role of Noise in Integrated Wave-Based Sensing and Computing with Dynamic Metasurface Antennas*

Chenqi Qian, Imperial College London, China
Philipp del Hougne, CNRS - IETR (Univ Rennes), France

Metamaterial-based information extraction (sensing and imaging using dynamic metasurface antennas, DMAs, and reconfigurable intelligent surfaces, RISs) and information processing (metamaterial wave computers) are to date rarely combined, and the essential role of noise in information theory is mostly neglected. To combine wave-based sensing with wave-based signal processing, we interpret the sensor's measurement process as an over-the-air analog computation performed on the information contained within the scene. The plurality of programmable meta-atoms in DMAs and RISs allows us to tailor the realized over-the-air analog operation to a specific sensing task. Thereby, the sensor's measurement process simultaneously becomes a task-specific processing step. This allows our measurement to preferentially extract task-relevant information, such that the sensor's latency improves remarkably. Using a discrete-dipole approximation of the programmable meta-atoms, we optimize the metamaterial configurations using deep-learning tools for a prototypical object recognition task under different noise conditions. We show that we can understand "macroscopic" properties of the optimized task-specific metamaterial configurations, for instance, how the overlap and intensity of the resulting scene illuminations evolve with the noise level. Our results are directly relevant to 6G wireless networks that require low-latency sensing capabilities under realistic, hence noisy, conditions.

17:00 - 17:15 - *Scanning Lidar with Optical Metasurfaces*

Emil Marinov, CNRS CRHEA, France

The development of LiDARs is essential to systems such as autonomous vehicles. However, current LiDARs exhibit limited Field of View (FoV) and slow scanning speed. We demonstrated a highly performant LiDAR system by cascading an optical metasurface and an acousto-optical deflector reaching a scanning speed of 6MHz in a 150°-by-150° FoV.

17:15 - 17:30 - High-Q Fano Resonances in Diamond Nanopillars

Vittorio Bonino, Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Italy

Angelo Angelini, Advanced Materials and Life Sciences, Istituto Nazionale di Ricerca Metrologica, Italy

We report on the optical behaviour of a nanostructured diamond surface on a glass substrate. The numerical model reveals that a simple geometrical pattern sustains Fano-like resonances with Q-factor as high as $3.5 \cdot 10^5$ that can be excited by plane waves impinging normally on the surface. We show that the geometrical parameters of the nanopillars affect both the resonant frequency and the line shape. The nanostructured surface can be straightforwardly used as a refractive index sensor with high sensitivity and linearity. Our findings show that diamond-based meta-surfaces are a valuable nanophotonic platform to control light propagation at the nanoscale, enabling large field enhancement within the nanoresonators that can foster both linear and nonlinear effects.

TUESDAY 12th SEPTEMBER 2023**POSTER SESSIONS****17:30 - 18:30 - Poster Sessions (Tuesday Afternoon)*****1 - Absorption Cross-section Analysis for Human Tissue with Embedded Gold Nanoparticles*****Balwan Rana, Mariana Dalarsson, KTH Royal Institute of Technology, Sweden**

We present a parametric analysis of the absorption cross-section of small ellipsoidal composite structures with GNPs embedded in lossy human tissue. New results for realistic tissue material parameters are obtained, that are useful to assess the feasibility of radiotherapeutic hyperthermia-based methods to treat cancer, based on electrophoretic heating of GNPs.

2 - Transmission Reduction on noise Barriers with locally resonant Vibroacoustic Metamaterials**Sebastian Rieß, Saeed Shariatinia, William Kaal, Heiko Atzrodt, Marvin Droste, Fraunhofer LBF, Germany
Peter Rath, ASFINAG, Austria**

In the presented work an acrylic noise barrier demonstrator with vibroacoustic metamaterial is numerically designed, prototypically built and experimentally investigated in terms of noise transmission. To enlarge the stop band region, alternately differently tuned resonators are used. Within the stop band frequency-range from about 500 to 3000 Hz, a maximum reduction in noise transmission of 16 dB can be achieved. In comparison to the doubling of the wall thickness of the noise barrier, a reduction of up to 12 dB is observable.

3 - Investigation of a Plate with Vibroacoustic Metamaterials tuned to the coincidence Frequency of the Plate**Saeed Shariatinia, Sebastian Rieß, Marvin Droste, William Kaal, Heiko Atzrodt, Fraunhofer LBF, Germany**

The present work addresses the investigation of an aluminum plate with vibroacoustic metamaterial, where the natural frequency of the attached resonators is tuned to the coincidence frequency of the base plate. The work involves numerical prediction of the stop band, manufacturing of the prototype and validation measurements in terms of

structural dynamics and acoustic emission. In the frequency ranges of 1480 - 2040 Hz and 2310 - 2995 Hz, two significant stop bands can be observed. In the stop band regions, a vibration reduction of up to 36 dB and a reduction of the sound power level of up to 38 dB can be achieved compared to doubling the thickness of the base plate.

4 - Low-frequency Vibration Absorber - Elastic Metamaterials

Chun-Yu Lu, Xiaofei Xiao, Fatima AlZaabi, Tazio Levato, Vincenzo Giannini, Technology Innovation Institute, United Arab Emirates

Additive manufacturing has made remarkable advancements in recent years, enabling the creation of intricate periodic structures known as phononic metamaterials. Our research utilized a soft material as a foundation to develop low-frequency vibration absorbers that possess phononic bandgaps, preventing elastic waves from propagating within the structure. By leveraging the material's low Young's modulus, we achieved a wide bandgap at 1350 Hz, significantly reducing more than 100 dB in vibration velocity amplitude. Our design has the potential for various applications, including aerospace and transportation components and precision engineering components such as vibration-suppressing platforms, machine tool mounts, and antivibration drone frames.

5 - Investigation of a 1-D Novel Isosceles Trapezoidal Resonator Inclusion Printed on Polytetrafluoroethylene (PTFE) with Woven Fiberglass Substrate

José Everardo Julião Ferreira, IEEE and OSA, Brazil

This paper presents a 1-D novel isosceles trapezoidal resonator inclusion printed on PTFE with woven fiberglass substrate, we have investigated the electromagnetic responses by numerical simulations using Feko and CST Microwave Studio Simulators.

6 - Metasurface Piezoelectric Ring Element-based Planar Acoustic Ultrasonic Transducer with Subwavelength Focusing Beam

Shin Hur, Korea Institute of Machinery & Materials, Korea (South)
YongTae Kim, Korea Research Institute of Standards and Science, Korea (south)

In this study, a new ultrasonic transducer with improved focusing performance was developed using a metasurface piezoelectric ring element optimized through finite element analysis. The metasurface piezoelectric ring element was fabricated by laser processing and packaged with a backing layer, matching layer and housing. The developed planar ultrasonic transducer was tested to generate a subwavelength focusing beam in water. The characteristics of the resonance frequency and frequency bandwidth of the

planar ultrasonic transducer were tested. It also measures the 3D shape of the needle-like subwavelength focusing beam of planar ultrasonic transducer in water. This technology is expected to be useful for high-resolution imaging or medical ultrasonic focusing devices in the future. tract here

7 - Light-Matter Interaction In Transition Metal Dichalcogenide Nanoresonators

Avishek Sarbajna, Dorte Danielsen, Peter Bøggild, Søren Raza, Technical University of Denmark, Denmark

Nicolas Stenger, DTU, Denmark

In this work, we structure thin flakes of tungsten diselenide (WSe₂) into nanoscale bridges and measure their optical response through dark-field spectroscopy. We observe a coupling between the exciton and the lowest-order Mie supported by the nanobridge. Our findings suggests that Mie-exciton interaction is prominent in TMDC nanostructures with feature sizes at the sub-10 nanometer scale.

8 - 2D Metamaterial for Passive Radiative Cooling

Jérémy Werlé, LENS, Italy

Giuseppe Lio, European Laboratory for Non-linear Spectroscopy, Italy

Lorenzo Pattelli, Istituto Nazionale di Ricerca Metrologica, Italy

In this study, we numerically investigate patterning geometries of SiO₂ substrates to maximize the emissivity in the sky transparency window up to values >0.95, while keeping into account fabrication feasibility by lowering the aspect ratio of the envisioned structures below that of previously proposed structures.

9 - Far-Field Photonic Spin Texture of Thermal Radiation From A Non-isothermal Nano-antenna

Parry Chen, Sravya Rao, Yonatan Sivan, Ben-Gurion University, Israel

Chinmay Khandekar, Zubin Jacob, Purdue University, USA

We apply advanced permittivity mode expansion (aka generalized normal mode expansion, GENOME) to study thermal emission. We show that non isothermal systems may emit far field transverse spin, an effect which was so far associated strictly with near field axial waves.

10 - Minimizing the Back-Scattering by a Relativistically-Moving Sphere

Mitchell Whittam, Aristeidis Lamprianidis, Yannick Augenstein, Carsten Rockstuhl,
Karlsruhe Institute of Technology, Germany

The back-scattered energy from a relativistically-moving sphere is minimized. The minimization is carried out using automatic differentiation which locates an optimal case where the back-scattered energy contributes a negligible 0.016% to the average scattered energy, thus providing evidence for the first Kerker condition in this regime.

11 - Photonic Nanojet Enhanced Photoluminescence

Gour Mohan Das, Piotr Paszke, Govindan Vadivel, Rafał Nowaczyński, Jakub Cajzl, Dorota Anna Pawlak,
Ensemble3, Poland

This study proposes a novel technique for enhancing photoluminescence (PL) signal using a combination of a single dielectric microsphere attached to a stem and confocal micro-PL spectroscopy. The technique involves directing a laser through the glass microsphere to generate a photonic nanojet (PNJ), a narrow-focused, non-evanescent, and highly intense electromagnetic beam with subwavelength lateral sizes, and obtaining PL spectra. The PNJ enhanced PL method was tested on NBP glass doped with CdZnSeS quantum dot (QD), 0.1 wt% of Praseodymium ion (Pr³⁺) ions, and 5 times enhancement was observed for the PL signal from Pr³⁺ ion

12 - Electro-optical Effects in MOS Metamaterial Modulator

Alexander Korneluk, Julia Szymczak, Tomasz Stefaniuk, University of Warsaw, Faculty of Physics, Poland

In this work we present our experimental results on electro-optical effects in the multilayer metamaterial. Described effect relies on the free electrons accumulation and depletion at the semiconductor-dielectric planar interface via external voltage. This phenomenon leads to the change in optical properties of a structure that consist of Ag-SiO₂-ITO-Ag stack.

13 - All-Optical Data Processing on a Single Crystal of Coordination Polymer with Dimensional Modulation

Yuliya Kenzhebayeva, Valentin Milichko, School of Physics and Engineering, ITMO University, Russia

Over the past few years a family of 2D materials, based on dynamic structural elements, have been an interesting area of research and application in modern developing processes such as catalysis, data processing or optical computers. However, the problem of high speed and repeatability in ambient conditions of such structural transformations in “smart” materials is still not resolved. Here, we present 2D coordination polymer (CP) based on flexible ligand, which demonstrate fast and reversible structural transformations under the external stimuli such as femtosecond laser irradiation. The nature of structural transformation was confirmed by several independent analysis, which allows to attribute CP to the group of “smart” materials, while the endurance of reversible structural transformations up to 102 cycles makes the CP to be a competitive material in terms of practical commercial applications.

14 - Modeling Electron Energy-loss Spectra of Thermally Tunable Vanadium Dioxide Nanostructures for the Design of Novel-type Nanophotonic Structures

Jiří Kabát, Andrea Konečná, Institute of Physical Engineering, Brno University of Technology, Czech Republic

Michal Horák, Central European Institute of Technology, Brno University of Technology, Czech Republic

Vlastimil Křápek, Central European Institute of Technology, Brno University of Technology, Institute of Physical Engineering, Czech Republic

Vanadium dioxide is a material that exhibits an insulator-to-metal transition. The VO₂ nanostructures can thus support both dielectric (Mie-type) and plasmonic modes depending on its temperature. Here, we demonstrate through numerical simulations that electron energy-loss spectroscopy could be an excellent technique for understanding the thermally switchable modes in VO₂ nanostructures.

15 - Multimodal Interference Semi-analytical Model for Unidirectional Guided Resonances in a Photonic Crystal

Thomas Delplace, Bjorn Maes, University of Mons, Belgium

This work presents a semi-analytical model to study unidirectional guided resonances (UGRs) in photonic crystal slabs based on a multimodal interference method used for bound states in the continuum (BICs).

16 - Subwavelength Superlattices Supporting Optical Mie Resonances**Pavel Tonkaev, Sergey Makarov**, ITMO University, Russia

Self-assembled into superlattice nanocrystals open new opportunities to control of unique optical properties. Employing Mie resonances for superlattices contributes to additional enhancement of emission properties. Here, we theoretically study superlattices from CsPbBr₃ nanocrystals. We show that emission in resonant perovskite superlattices accelerates by 3 times due to Mie resonances. We believe our results are promising for the observation of superfluorescence enhanced by Mie resonances.

17 - Parametric Image Quality Study of Metamaterial Based Satellite Image Sensors**Kamil B. Alici**, TUBITAK Space Technologies Research Institute, Turkey

Image chain simulation studies of a hypothetical earth observation satellite (GOKAY-1) in the presence of metamaterial based image sensors is performed. A number of metamaterial super cell configurations are compared and tradeoff between the modulation transfer function (MTF) and signal to noise ratio (SNR) figures of merit was investigated. The SNR values of 2x2, 4x4 and 6x6 super cell configurations with 64 time delay integration (TDI) steps yielded, SNR = 5, 22 and 49 values, respectively. As the size of the metapixel supercell increase from 0.66 μ m to 1.32 μ m and 1.96 μ m the MTF results got lower performance as indicated by the corresponding MTF curves. Metamaterial based satellite image sensors could lead to better performing earth observation satellites (EOS), satellite image sensors, and thereby satellite imaging cameras.

18 - Spin Wave Amplification with Space-Varying Spin-Transfer Torque Poster**Kazuyuki Nakayama, Kenji Kasahara**, Fukuoka University, Japan**Toshiaki Inada**, University of Tokyo, Japan**Satoshi Tomita**, Tohoku University, Japan

Spin wave amplification utilizing the spin-transfer torques induced by spin polarized current was numerically investigated. A resonant amplification of reflection and transmission signal of spin waves with a bottleneck magnetic structure was observed.

19 - Modified Multipoles in Metamaterials**Alexey Basharin, Maria Cojocari, Anar Ospanova**, University of Eastern Finland, Finland

Multipole expansion is a promising tool for investigation of electromagnetic response of meta-atoms. It works even in the case of relatively complicated and compound scatterers

like multilayer particles, clusters or asymmetrical systems. Commonly, the radiation fields of point electric or magnetic sources are decomposed only into electric or magnetic dipole moments, while real sources can be described by series of multipoles, including higher multipoles and toroidal moments. In this paper, we introduce the modified multipoles describing real sources of electric, magnetic and toroidal types. Using the analytical expressions of first-order multipoles, we discuss how they depend on the position of the center of radiation, as well as on the shift of the source, relative to the center of coordinates. We present multipole moments for the meta-atoms with defects and asymmetry. We discuss how to distinguish the radiation pattern of electric and toroidal dipole moments in far-field zone. Moreover, we present novel modified anapoles. Our modified dipole approach can be useful for multipole analysis of complex systems in photonics such as nanoparticle clusters, metamaterials and nanoantennas, as well as for better understanding issues of toroidal electrodynamics.

20 - Realization of Illusion with a Smaller Device

Zhenzhi Liu, Fu Liu, Xi'an Jiaotong University, P. R. China

Usually, the illusion device is larger than the illusion object. In this presentation, we discuss the possibility of realizing a smaller illusion device. This is achieved by obtaining the desired fields in a smaller region and constructing the device with surface impedance metasurfaces. Simulation results successfully verified the proposed scheme.

21 - Naked-eye Observable Animation with 3D Metasurface Holograms

Masakazu Yamaguchi, Shunsuke Takahashi, Satoshi Ikezawa, Kentaro Iwami, Tokyo University of Agriculture and Technology, Japan

In this study, we have achieved a 3D holographic animation observable with the naked eye using silicon nitride metasurface. The large size of the metasurface hologram and the prism phase allow for naked-eye observation. By irradiating a laser with a wavelength of 532 nm, holographic animation was successfully projected.

22 - Superconducting Quantum Metamaterials for Sensing and Information Processing

Alexandre Zagoskin, Loughborough University, United Kingdom

Superconducting quantum metamaterials can find numerous applications in the field of quantum technologies. In particular, these artificial media can be used for quantum-limited detection of microwave radiation and, in combination with classical neural

networks, further processing the information contained in the detected signal. Here I will review the recent results and planned research in this field.

23 - High Directivity Engineering with Low Index Polymer Quasicrystalline Structures

Vladislav Chistyakov, ITMO University, Russia

Reciprocal space engineering allows generating photonic structures with the desired transport properties. This study demonstrates the high directivity radiation regime of a dipole placed inside a spherical polymer quasicrystalline structure. We set a special distribution of maxima in the reciprocal space on the sphere and find a quasicrystalline structure in real space using the Fourier transform.

24 - AI-Driven Inverse Design of Amorphous Metamaterial with Narrow Band Perfect Reflection

Amir Ghasemi, Dagou Zeze, Mehdi Keshavarz-Hedayati, Durham University, United Kingdom

Amorphous metamaterials are artificially engineered materials with unique properties achieved through manipulating nanostructures. Designing a narrow-band perfect reflector is challenging due to computational costs and complexity, but a machine learning-assisted technique has been developed to create a six-layer perfect reflector made of alternating layers of two materials. This allows for the swift manufacture of custom-made metamaterials, reducing the cost of producing photonic devices such as optical filters, lasers, and spectrometers.

25 - Change of the Magnetic Helicity of a Hopfion in an Applied External Magnetic Field

Ivanina Ilieva, Ivan Fernandez-Corbaton, Karlsruhe Institute of Technology, Germany

We study numerically the change of magnetic helicity of a Hopfion unwinding in a constant magnetic field. The helicity relaxes towards zero, suggesting the possibility of being transferred to the electromagnetic field radiated during the unwinding process. This is theoretically underpinned by the recent unification of magnetic and electromagnetic helicity.

26 - A Scalar Product for Computing Fundamental Quantities in Matter

Ivan Fernandez-Corbaton, Maxim Vavilin, Karlsruhe Institute of Technology, Germany

We introduce a systematic way to obtain expressions for computing the amount of fundamental quantities such as helicity and angular momentum contained in static matter, given its charge and magnetization densities.

27 - Adaptive Mesh Refinement Strategies for Nanophotonics using a Posteriori Error Estimation

Albin Jonasson Svärdsby, Philippe Tassin, Chalmers University of Technology, Sweden

We report on our work developing adaptive mesh refinement for nanophotonic simulations in COMSOL. We compare three adaptive mesh refinement strategies and find that a method based on a posteriori error estimation leads to a lower memory footprint and a decrease in wall-clock time for complex three-dimensional nanophotonic structures.

28 - Non-Destructive Testing of CFRP with Multi-Nested CSRR

Rongqing Kang, Zhaoxuan Zhu, University of Electronic Science and Technology of China, China

Carbon fibre reinforced polymer (CFRP) composites have been widely used in aviation industry. Evaluation of the structural integrity of the CFRP is a significant issue. This paper proposes an electromagnetic sensor for non-destructive testing (NDT) of CFRP. The sensor is designed by etching multi-nested CSRR on the ground of microstrip transmission line to form a two-port sensor network. The multi-nested CSRR introduces a transmission notch which will shift by the disturbance of defects to the electromagnetic field near the surface of the sensor. The performance of the improved multi-nested CSRR sensor and the traditional CSRR sensor in Non-Destructive Testing of CFRP is compared by simulation. The results show that the improved sensor has higher sensitivity than the traditional CSRR sensor and the developed sensor has good performance in detecting internal air-hole and surface crack of CFRP composites.

29 - Metamaterial Based on Up-Conversion Nanoparticles for Photovoltaic Applications

Pablo Reina, Angela I. Barreda, Alicia Gonzalo, Beatriz Galiana, Braulio Garcia-Camara, Carlos III University of Madrid, Spain

The growing interest on photonic devices based on perovskites, such as solar cells, is demanding a larger research to improve their optical response. This work is aimed to numerically simulate up-conversion nanoparticles that can manage the light inside perovskite solar cells within its absorption range. An analysis about ordered arrangements

and their integration with resonant nanoparticles to generate optimum metamaterials has been done.

30 - Fully Automated Inverse Design of Reflective Metalens Optical System

Chenglin Xu, Rob Scarmozzino, Evan Heller, Mayank Bahl, Jan Bos, Synopsys, The Netherlands

In addition to transmissive metalenses, MetaOptic Designer has been extended to reflective metalenses/metasurfaces. Based on specified targets, designers can design optical systems using reflective metalenses/metasurfaces or evaluate the reflection from a designed transmissive system.

31 - Metal-Insulator Transition in Vanadium Dioxide Inspected by Analytical Electron Microscopy

Jan Krpenský, Michal Horák, Jakub Planer, Peter Kepič, Jiří Kabát, Tomáš Šikola, Andrea Konečná, Vlastimil Křápek, Brno University of Technology, Czech Republic

Vanadium dioxide is an emerging plasmonic material with metal-insulator transition, relevant for active plasmonics and switchable optical metasurfaces. We study the metal-insulator transition with analytical electron microscopy, locally correlating signatures of the transition in chemical, crystallographic, and optical properties.

32 - Transient Amplification in Periodic Harmonically Modulated Media

Ioannis Kiropelidis, University of Athens/University of Le Mans, Greece
Fotis Diakonou, University of Athens, Greece
Georgios Theocharis, Vincent Pagneux, University of Le Mans, France

We study the possible amplification of a wave that travels in a periodic time-dependent medium, when we are in the stable regime with no parametric instability. It is shown that, even with asymptotic stability, the non-normality of the propagator (monodromy) matrix implies transient amplification that depends on the parameters of the periodic time modulation and on the initial start of the process.

33 - Laser-induced Surface Nano-structuring for Photonic Applications

Anna Tasolamprou, Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology (FORTH), Greece
Antonis Papadopoulos, Alexandros Mimidis, Andreas Lemonis, Emmanuel Stratakis, Evangelos Skoulas, Biomimetic P.C., Greece

This work showcases various methods for producing laser-induced nanostructures with controllable spatial features, scale, and shape. These structures can be directly fabricated on dielectric surfaces and thin metallic films to enable light manipulation, polarization control, and perfect absorption.

34 - Exploring Polaritons in Optically-Anisotropic Media

Christos Tserkezis, P. Elli Stamatopoulou, N. Asger Mortensen, University of Southern Denmark, Denmark

Sotiris Droulias, University of Piraeus, Greece

Guillermo P. Acuna, University of Fribourg, Switzerland

Vasilios Yannopoulos, National Technical University of Athens, Greece

We explore the properties and functionalities of polaritons that emerge by the coupling of systems characterised by a collective excitonic response, such as J aggregates of organic molecules or excitons in transition-metal dichalcogenides, with optically anisotropic open cavities, typically in the form of individual nanoparticles or aggregates thereof. We examine examples where the optical anisotropy is due to either the structural chirality of the cavity or to an applied magnetic field, and discuss the flexibility and advanced engineering possibilities provided by this additional degree of freedom.

35 - Manipulating the Quasi-Normal Modes of Radially Symmetric Resonators

James Capers, Dean Patient, Alastair Hibbins, Simon Horsley, University of Exeter, United Kingdom

Steve Boyes, DSTL, United Kingdom

The frequency response of a resonator is governed by the locations of its quasi-normal modes in the complex frequency plane. The real part of the QNM determines the resonance frequency and the imaginary part determines the width of the resonance. For applications such as energy harvesting and sensing, the ability to manipulate the frequency, linewidth and multipolar nature of resonances is key. Here, we present a simple analytical tool to control the location and polarity of radially symmetric resonators.

36 - Plasmonic Lightning-rod Effect

Rostislav Řepa, Michael Foltýn, Brno University of Technology, Institute of Physical Engineering, Czech Republic

Michal Horák, Brno University of Technology, Central European Institute of Technology, Czech Republic

Tomáš Šíkola, Vlastimil Křápek, Brno University of Technology, Institute of Physical Engineering; Brno University of Technology, Central European Institute of Technology, Czech Republic

Our study deals with experimental and theoretical research on the plasmonic lightning-rod effect. Electron energy loss spectroscopy has been used to investigate the electromagnetic response of plasmonic antennas and to study the impact of the curvature of their surfaces on the local enhancement of an electromagnetic field.

37 - Bullseye Passive Metasurface for Improved Penetration Rate and Exotic Beam Shape through Opaque Materials via Complex Wavevectors

Sinuhe Perea, King's College London, United Kingdom

Our investigation into the latest spin-momentum locking phenomena, utilizing complex wave-vector, has prompted us to develop an innovative technique for enhancing light transmission through optically opaque materials. By leveraging the Helmholtz equation and introducing a passive metasurface with simultaneous variation in transmission phase and amplitude, we have uncovered potential for significant advancements in various fields, including acoustics structures, telecommunications bandwidth transmission, and biophotonics. This technique offers the opportunity for exotic beam shaping, which could prove useful in subcutaneous analysis and treatment of malignant cells without causing damage to our body.

38 - Broad-band Absorptive Metasurface for Ku- & K-band Frequency Channels

Ahsaan Gul Hassan, Adnan Nadeem, Muhammad Sumaid, Noshewan Shoaib, National University of Sciences and Technology (NUST), Pakistan,

Photos Vryonides, Symeon Nikolaou, Frederick Research Center, Nicosia, Cyprus, Electrical Engineering Department, Frederick University, Nicosia, Cyprus

Harun İldes, Hacettepe University, Ankara, Turkey

In this paper, a square ring resonator based, wide-band absorptive metasurface is presented, capable of absorbing incident waves in frequencies that cover sections of the Ku and the K bands. The proposed metasurface is implemented with an array of cells which consist of a combination of two rhomboid ring resonators with four ohmic resistors integrated in the inner square in order to enhance absorption of the reflected wave. The designed structure can support scalability of absorption in both transverse electric (TE) and transverse magnetic (TM) modes by changing the value of the ohmic resistors. The

reported the percentage of absorption varies between 80 and 100% in 5 GHz frequency range, from 16.1 to 21.1 GHz.

39 - A Compact Single Layer Dual-Bandstop Frequency Selective Surface for WLAN Applications

Juin Acharjee, Oindrila Chaki, Chirasree Roy, Srijani Bhattacharya, Dipayan Ghosh, St. Thomas' College of Engineering and Technology, India
Gouri Shankar Paul, Global Institute of Science and Technology, Haldia, India

In this paper, the design of a new single layer compact frequency-selective surface (FSS) structure is proposed. The proposed unit cell FSS structure comprises of four-corner, modified, interconnected, open square headed dumbbell-shaped (OSHD) structure to provide dual-bandstop behaviour. This provides stopband behaviour over 230 MHz and 300 MHz bandwidths with resonating frequencies of 2.4 and 5.0 GHz, respectively. Surface current distribution and electric field variations are illustrated to explain the bandstop nature of the proposed FSS, having unit-cell size of $0.12\lambda_0$, where λ_0 , is the free-space wavelength at the lower resonating frequency. Additionally, the proposed FSS is polarization independent and shows stable performance for both TE and TM polarisations. The design and analysis have been carried out using the ANSYS HFSS software.

40 - FEKO/GRASP Simulations of Super-Resolution with a Reflective Metal-Mesh Toraldo Pupil on the 32m Medicina Radio Telescope

Luca Olmi, INAF - OAA, Italy
Giampaolo Pisano, Univerisita' La Sapienza, Roma, Italy

We are currently carrying out a project devoted to the implementation of super-resolution on single-dish radio telescopes, aimed to obtain an angular resolution better than the classical diffraction limit. A feasible method to achieve this goal consists of using variable transmittance pupils, and specifically the simplest version of these pupils which consists of a binary phase shift mask, also known as Toraldo pupil (TP). An attractive method to design and fabricate TPs is to use the metal mesh-filter technology, which allows to fabricate both transmissive and reflective TPs. In this work we show, through EM numerical simulations, that super-resolution can indeed be achieved on a Cassegrain radio telescope using a previously designed and tested reflective mesh-filter TP.

41 - Ultra-wideband mmWave Absorber Based on Fractal Metasurface

Hee-Jo Lee, Daegu University, Korea (South)

This study proposes the ultra-wideband millimeter wave (mmWave) absorber based on fractal metasurface. The mmWave absorber with the 1st iteration Minkowski fractal structure shows an average reflection coefficient (S_{11}) of -18.6 dB in the frequency range from 18 GHz to 50 GHz. This average level corresponds to the absorption rate of 97.6 % in the frequency region. Furthermore, the average S_{11} in the Ka-band (26.5-40 GHz) indicates a -21.6 dB level, and the corresponding absorption rate is about 99 %. As a result, we numerically show that the proposed fractal metasurface can realize an excellent absorption rate in the mmWave region.

42 - Analysis of Nonlinear Mesh Grid Screens for High-Power Electromagnetic Field Shielding

Hyun Ho Park, The University of Suwon, Korea (South)

In this paper, a high-power electromagnetic field shielding of a mesh grid screen with PIN diode array as a nonlinear device is analyzed using three-dimensional numerical simulation. The shielding characteristic of the mesh grid screen without a PIN diode is first examined and it is confirmed that the shielding performance is constant regardless of the strength of the incident field. However, the shielding characteristic of the mesh grid screen with PIN diode depends on the strength of incident electric-field, which represents a nonlinear shielding property.

43 - Topological Wireless Power Transfer with Relay Edge States

Joshua Feis, Laszlo Solymar, Ekaterina Shamonina, University of Oxford, United Kingdom

Using topological edge states of diatomic magnetoinductive waveguides, efficient wireless power transfer in the stopband with superior robustness against disorder is possible. A drawback of this approach is that the evanescent nature of the coupling to the edge states imposes a limit in transfer range. Here, we show that by adding additional interfaces to the waveguides we are able to engineer edge states acting as relays thus overcoming this range limitation.

44 - Multiband Polarization Insensitive Metamaterial Absorber for X, Ku, and K band Applications

Nipun Kumar Mishra, Guru Ghasidas Vishwavidyalaya, Central University, Bilaspur, India

Laxmikant Dewangan, School of Studies in Engineering and Technology, GGV Bilaspur, India

In this paper, a strictly polarization-insensitive, metamaterial absorber for three distinct absorption bands X, Ku, and K is investigated numerically and experimentally. The unit cell structure of the absorber comprises a symmetrically arranged defective L-shaped patch imprinted on a metal-backed FR-4 dielectric substrate. The proposed absorber yields multiband response at frequencies 11.1 GHz (Peak absorptivity 96.8%) in the X band, 15.5 GHz, and 16.3 GHz (Peak absorptivity 94.9% and 95.7%) in the Ku band along with broadband response 4.8 GHz with more than 91% absorptivity from 18.6 to 23.4 GHz in the K band. The physical absorption phenomenon is explained by investigating the induced electric field, top and bottom surface current distribution, and various retrieved constitutive electromagnetic parameters. Under normal incidences of electromagnetic waves, the proposed metamaterial structure absorbs TE (Transverse Electric) and TM (Transverse Magnetic) waves effectively for more than 91% from any direction in a given band. A prototype of the absorber has been fabricated and simulated results are validated with measured results. The thickness of the proposed absorber is $\lambda_0/8$ at a center frequency of broadband response making it compact and suitable for radar cross section reduction at X, Ku, and K bands.

45 - Evaluation of Mutual Coupling between Slots in a Metasurface Enhanced SIW Slotted Antenna

Javier Chocarro, Iñigo Ederra, Univesidad Publica de Navarra, Spain

In this paper, we explore the conductance properties of a longitudinal slot on a substrate integrated waveguide (SIW) with three different models. These models allow us to evaluate the impact on the slot conductance of covering it with a metasurface to improve the radiation performance. In particular, the influence of the MTS on the coupling between slots will be analyzed. Our results show that the presence of the MTS reduces the slot conductance and slot resonance length, but has limited impact on the coupling.

46 - Asymmetric Pillars Ring Resonators for Electromagnetically Induced Transparency in a Terahertz Metamaterial using Multi-photon Lithography

Odysseas Tsilipakos, National Hellenic Research Foundation, Greece
Anastasios Koulouklidis, Maria Manousidaki, Gordon Zyla, Stelios Tzortzakis, Maria Farsari, Maria Kafesaki, Savvas Papamakarios, IESL/FORTH, Greece

A novel electromagnetic metamaterial design for low THz applications is reported. The metallic fabricated, using multi-photon lithography, structure was characterised and exhibited promising results for Electromagnetically Induced Transparency in a metasurface for specific operating wavelengths.

47 - Passive Reconfigurable Intelligent Surfaces with Varying Electromagnetic Response in Accordance with the Pulse Width at the Same Frequency

Kairi Takimoto, Ashif Fathnan, Hiroki Wakatsuchi, Nagoya Institute of Technology, Japan
Shinya Sugiura, The University of Tokyo, Japan

In recent years, metasurfaces have been broadly and rapidly studied as intelligent reflecting surfaces (IRSs) or reconfigurable intelligent surfaces (RISs) to artificially control electromagnetic waves and signals and facilitate the design of wireless communication environments. These metasurfaces achieve advanced time-varying control through the introduction of active circuit systems including nonlinear circuit components and an external direct-current (DC) source, although such an external energy source is not always available, thereby limiting the applicability of metasurfaces in wireless communications. For this reason, we present a new concept of RISs that are passive configurations but still exhibit variable electromagnetic characteristics in the time domain. Our RISs can change the reflection angle of incident waves depending on the pulse duration of the incident wave. This is achieved by introducing lumped circuit components, including diode bridges, that convert most of the incoming energy to the zero-frequency component to exploit the transient phenomena well known in DC circuits. The proposed concept is numerically tested, in which the reflection angle is changed depending on the incident pulse width. Our study contributes to providing an additional degree of freedom to design wireless communication environments in accordance with the pulse width.

48 - THz Multiple-Beam Manipulation by Reconfigurable Intelligent Surface with Independent Phase/Amplitude Control

Javad Shabanpour, Aalto University, Finland
Sina Beyraghi, Telefonica Research Barcelona, Spain
Constantin Simovski, Aalto University, Finland

Our paper presents a real-time design using a digital metasurface that can control both the amplitude and phase of reflected waves. Our suggested $VO_{\{2\}}$ -based metasurface effectively manipulates both transverse electric (TE) and transverse magnetic (TM) reflected waves independently with angular stability up to 40° in the range (1.45-

1.55) THz. We anticipate that such metasurfaces may be a good candidate for indoor wireless communication.

49 - Bound States in the Continuum in a Wire Medium

Andrey Bogdanov, Harbin Engineering University, China

We show theoretically and experimentally that a slab of metamaterial composed of thin parallel metallic wires naturally hosts accidental and symmetry-protected bound states in the continuum (BICs). Symmetry-protected BICs represent a longitudinal plasma wave propagating along the wires and completely decoupled from the transversal waves of the environment while accidental BIC appears as a result of Fridrich-Wintgen's destructive interference of plasma waves and waveguide modes. The experiment is performed in the GHz frequency range.

50 - Homogenization of Densely Packed Wire Media Using Transfer Matrix Methods

Ana C. Escobar, Juan D. Baena, Universidad Nacional de Colombia, Colombia

Francisco Mesa, Universidad de Sevilla, Spain

Óscar Quevedo-Teruel, KTH Royal Institute of Technology, Sweden

Multimodal Transfer Matrix Method is a powerful technique that can be used in the study of periodical structures. It allows for accurate calculation of the dispersion relation and effective constitutive parameters even for very densely packed structures. In this work, we calculate effective constitutive parameters of artificial plasmas and compare them with a theoretical model based on a cascade of surface admittances.

51 - Temperature-Controlled Topological Zigzag Arrays of Resonators

Georgii Kurganov, Ekaterina Puhtina, Ildar Yusupov, Alexey Slobozhanyuk,

Dmitry Zhirihin, School of Physics and Engineering, ITMO University, Russia

Yuri Kivshar, Nonlinear Physics Center, Research School of Physics, Australian National University, Australia

Dmitry Dobrykh, School of Electrical Engineering, Tel Aviv University, Israel

We study topological zigzag arrays of dielectric resonators and demonstrate a novel method to control their topological edge states by applying local heating. Numerical and experimental studies confirm that the properties of the topological edge states in such systems can be tuned and controlled by temperature.

52 - Millimeter Wave Metamaterial for High-Order Orbital Angular Momentum Generation

Alexander Schossmann, Michael Töffler, Alexander Bergmann, Graz University of Technology, Austria

We propose a millimeter wave metamaterial for high-order OAM generation. The concept uses a reflecting metasurface irradiated by a small antenna (e.g., on-chip antenna) that emits linearly polarized millimeter waves at an operating frequency of 61 GHz. We present the numerical proof of principle using finite element simulations. Results show that OAM generation of the order of ten is feasible by varying one geometrical parameter of the metamaterial unit cell. Subsequent work is to further optimize the OAM generation by combining variations of multiple parameters to minimize the amplitude response variation and experimentally analyze the concept.

53 - Modelling of Interconnected Electromagnetic Waveguide Junctions Using Petri-Nets

Alessandro Ventisei, Alex Yakovlev, Victor Pacheco-Peña, Newcastle University, United Kingdom

Petri-Nets (PNs) as a graphical model has been previously been applied in diverse research and industrial fields. We show our ongoing efforts in exploiting PNs to represent TEM pulse propagation within junctions of parallel plate waveguides. Focusing our attention on the representation of multiple reflections of TEM pulses occurring in interconnected junctions (each junction having several interconnected waveguides) or waveguides ended on perfect electric conductor (PEC).

54 - Topological Classification Of Weyl Points In Dispersive Continuous Media

Guilherme R. Fonseca, Mário G. Silveirinha, Instituto de Telecomunicações, Universidade de Lisboa - Instituto Superior Técnico, Portugal

Filipa R. Prudêncio, Instituto de Telecomunicações, Instituto Universitário de Lisboa (ISCTE-IUL), Portugal

Paloma A. Huidobro, Instituto de Telecomunicações, (IFIMAC) Universidade Autónoma de Madrid, Spain

In recent years there has been a great interest in topological materials and in their intriguing properties. Here, we present a first principles method to compute topological invariants of three-dimensional gapless phases. Our approach allows to calculate the topological charges of Weyl points through the efficient numerical computation of gap

Chern numbers, which relies solely on the photonic Green's function of the system. We particularize the framework to the Weyl points that are found to emerge in a magnetized plasma due to the breaking of time reversal symmetry. We discuss the relevance of modelling nonlocality when considering the topological properties of continuous media such as the magnetized plasma.

55 - The Shocks in Josephson Transmission Line

Eugene Kogan, Bar-Ilan University, Israel

We consider the series-connected Josephson transmission line (JTL), constructed from Josephson junctions, capacitors and resistors. We calculate the velocity of shocks in the discrete lossy JTL. We propose the simple wave approximation, which decouples the continuum JTL equations into two separate equations for the right- and left-going waves. The approximation, in particular, allows to easily consider the formation of shocks.

56 - Generally Incident Fresnel Coefficients for Simple to Biaxial Media Interfaces

Jeffrey Massman, Air Force Research Laboratory, Sensors Directorate, USA

Michael Havrilla, Air Force Institute of Technology, USA

Generalized closed form expressions of the Fresnel coefficients for an arbitrarily incident plane wave upon a simple to biaxial media interface is introduced. The analysis enforces boundary conditions through eigenwave expansions of both the simple media and anisotropic permittivity and permeability biaxial media. This generalized eigenwave approach results in explicit formulations accounting for the co- and cross-polarized scattering components from the simple to biaxial media interface. The solutions in this paper can be used to analyze scattering phenomena of general biaxial media as well as address theoretical scattering parameter formulations for material measurement techniques.

WEDNESDAY 13th SEPTEMBER 2023

IMPERIAL 1

09:00 - 10:00 - Plenary Session IV

Chair: Kafesaki Maria

09:00 - 10:00 Plenary talk*Optical Metasurfaces Saving Energy in Optical Computing and Photovoltaics***Albert Polman**, Center for Nanophotonics, NWO Institute AMOLF, Netherlands

I will present our recent collaborative work on the design, fabrication and operation of silicon-based optical metasurfaces that perform mathematical operations in an analog way, using light fields as input and output signals. We show how the interplay between scattering components in silicon metasurfaces creates a mathematical derivative on an input image. We then design and fabricate a silicon metasurface that solves an integral equation by using visible light in which we use grating orders as input and output ports on a periodic metasurface with a specially tailored unit cell. The new analog optical computing concepts operate with very low energy consumption, at the speed of light, and can form the basis of more complex geometries solving multiple equations and can be applied in optical neural networks, control systems, and more.

We then apply optical metasurfaces to control and enhance the interaction of free electrons and highly-localized optical near fields in scanning electron microscopy (SEM). Using angle-resolved cathodoluminescence spectroscopy we analyse the spatial modulation of Smith-Purcell radiation that results from the coherent interplay of free-electron driven optical excitations in a chirped metagrating. We embed cylindrically-shaped metagrating patterns onto the input facet of a multi-mode optical fiber to experimentally demonstrate the coupling of free electrons and guided fiber-optic modes via the Smith-Purcell effect.

In the last part of the talk I will introduce an integrated near field/far-field multiple scattering formalism to control the absorption of light in solar cells. We design and fabricate a metallodielectric metasurface back contact for an ultra-high efficiency InGaAs/InGaAsP/Si multi-junction solar cell and enhance the light trapping inside the silicon bottom cell by multiple scattering, creating a record photovoltaic energy conversion efficiency for silicon-based tandem solar cells of 36.1%.

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10:00 - 10:30 – Coffee Break

10:30 - 12:30 - Oral Sessions (Wednesday Morning)
“SS - Wave-based signal processing, computing and learning”
Chairs: Francesco Monticone, David Miller

10:30 - 11:00 - *Programmable Artificial-Intelligence Computing and Information Processing in Electromagnetic-wave Space* (Invited Talk)

Tie Jun Cui, Qian Ma, Southeast University, Institute of Electromagnetic Space, Nanjing, China

With the rapid development and wide application of artificial intelligence technology, it is imminent to find new high-speed and energy-saving computing forms. As an important candidate, all-optical diffractive neural network and photon-integrated neural network have attracted extensive attention due to their excellent computational speed and energy efficiency. Here, we report the recent advances in programmable artificial-intelligence (AI) computing based on information metamaterials, which can not only perform the AI computing at light speed, but also process the digital information directly in the electromagnetic-wave space. By designing programmable transmission structures using information metasurfaces and spoof surface plasmon polariton (SPP) structures, we show that the weights in the electromagnetic-wave neural networks can be independently controlled for multiple tasks, which can also solve the matrix equations at the speed of light. A designable nonlinear function form can be achieved using the programmable periodic structures and detecting feedback loops. We have shown that these programmable AI machines can undertake a series of tasks such as image recognition, target detection, and wireless communications with high accuracy. Our concept may pave a new way for programmable computing and information processing in the electromagnetic space, potentially stimulating the optical computing, sensing, and communication systems.

11:00 - 11:30 - Scalable and Hardware-efficient Optical Neural Network (ONN) for High-Performance Computing (Invited Talk)

Fei Xia, Sylvain Gigan, The Kastler–Brossel Laboratory, ENS, CNRS, Sorbonne Universite, France

Ziao Wang, Jianqi Hu, The Kastler–Brossel Laboratory, ENS, France

Logan Wright, Tatsuhiro Onodera, Martin Stein, Peter McMahon, Cornell University, USA

We developed and implemented a deep optical neural network (ONN) design capable of performing large-scale training and inference in situ. For each elementary building block in the ONN, we introduce trainable parameters in a programmable device, weight mixing with a diffuser, and nonlinear detection on the camera for activation and optical readout. With automated reconfigurable neural architecture search, we optimized the architecture of deep ONNs that can perform multiple tasks at high speed and at large scale. The task accuracies achieved by our experiments are close to state-of-the-art benchmarks with conventional multilayer neural networks.

11:30 - 12:00 - Why Optics Needs Thickness And How Much It Needs (Invited Talk)

David Miller, Stanford University, USA

Based just on the mathematical function some optics is to perform, we deduce a minimum thickness of any optical approach, including metasurfaces. This thickness arises if the input regions for different output “pixels” overlap, leading to a “overlapping nonlocality” number C that, combined with diffraction heuristics, gives this limit.

12:00 - 12:30 - Nonlocal Metasurfaces: Toward Ultra-Thin Imaging and Processing Systems (Invited Talk)

Francesco Monticone, Cornell University, USA

In electromagnetics and photonics, ‘nonlocality’ refers to the phenomenon by which the response/output of a material or system at a certain point in space depends on the input field across an extended region of space. Strong effective nonlocality, and the associated wavevector/momentum dependence, are now being increasingly exploited to enrich and enhance the response of metamaterial and metasurface structures. This talk discusses some of our recent efforts to harness the opportunities of nonlocal platforms, with a focus on nonlocal metasurfaces for ultra-thin imaging and processing systems, as well as their fundamental limitations in terms of thickness and bandwidth.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Wednesday Afternoon 1)**“2D Materials: new phenomena and applications”**

Chairs: Nahid Talebi, Sylvain Lannebère

14:00 - 14:30 - *Probing the Dynamics of Exciton-Polaritons in Two-Dimensional Materials with Electron Beams* (Invited Talk)**Nahid Talebi**, Christian Albrechts Universität zu Kiel, Germany

Recently ultrafast electron microscopy has emerged as a robust tool to investigate the dynamics at the nanoscale spatial and femtosecond time resolution. Here, we demonstrate an ultrafast electron microscopy technique that is based on internal electron-driven photon sources and apply this to investigate the dynamics of exciton-polaritons in free-standing WSe₂ flakes.

14:30 - 14:45 - *Excitonic Light Scattering In Atomically-Thin Optical Elements.***Ludovica Guarneri, Thomas Bauer, Jorik van de Groep**, University of Amsterdam, Netherlands**Qitong Li, Jung-Hwan Song, Mark Brongersma**, Stanford University, United States

Monolayer transition metal dichalcogenides such as WS₂ exhibit exciton resonances that can be leveraged to achieve strong light scattering in atomically-thin optical elements. Here, we show how the quantum mechanical exciton properties of the material dictate the optical efficiency of metasurfaces that are carved directly out of monolayer WS₂.

14:45 - 15:00 - *Impact of Substrates and Quantum Effects on Exciton Line Shapes of 2D Semiconductors at Room Temperature***Jorik van de Groep**, University of Amsterdam, Netherlands**Qitong Li, Mark L. Brongersma, Jung-Hwan Song**, Stanford University, USA**Pieter G. Kik**, University of Central Florida, USA

Exciton resonances in monolayer transition-metal dichalcogenides exhibit strong light-matter interaction. Their spectral line shape is critical in the design of nanophotonic devices. Here, we highlight that the interference with the substrate reflection strongly influences the line shape and that quantum mechanical exciton dynamics can be retrieved, even at room temperature.

15:00 - 15:15 - *Nonlinear All-Optical Coherent Generation and Read-Out of Valleys in Atomically Thin Semiconductors*

Paul Herrmann, Sebastian Klimmer, Thomas Lettau, Mohammad Monfared, Isabelle Staude, Ulf Peschel, Giancarlo Soavi, Friedrich Schiller University Jena, Germany
Ioannis Paradisanos, Institute of Electronic Structure and Laser, Foundation for Research and Technology, Greece

We report the coherent ultrafast generation and detection of valleys in atomically thin semiconductors, based on optical Stark shift and second harmonic generation. Our results are supported by simulations based on time-dependent density functional theory.

15:15 - 15:30 - *Transistor-like Optical Gain in Two-Dimensional Materials with Berry Curvature Dipoles*

Tatiana Rappoport, Instituto de Telecomunicações – Lisboa and Instituto de Física, Universidade Federal do Rio de Janeiro, Portugal
Tiago Morgado, Sylvain Lannebère, Instituto de Telecomunicações and Department of Electrical Engineering, University of Coimbra, Portugal
Mário Silveirinha, University of Lisbon – Instituto Superior Técnico and Instituto de Telecomunicações, Portugal

Here, we demonstrate that low-symmetry two-dimensional metallic systems with large Berry curvature dipoles biased with a static electric field may behave as “distributed transistors” and provide polarization-tunable non-Hermitian and non-reciprocal responses. It is shown that an incident electromagnetic wave passing through the biased two-dimensional material may experience optical gain, depending on the wave polarization, direction of wave propagation, and orientation of the electric bias.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Wednesday Afternoon 2)**“Thermal effects in metadevices”**

Chairs: Georgia Theano Papadakis, Zubin Jacob

16:00 - 16:30 - *Mid-IR and Thermal Photonics with Emerging Low-dimensional Materials*
(Invited Talk)**Georgia Theano Papadakis**, ICFO, Spain

In this talk I will discuss the properties of several emerging low-dimensional materials that are typically exfoliated in the laboratory, rather than grown in large scale. First, I will introduce a method for retrieving the mid-IR dielectric properties of exfoliated flakes, which are typically too small to be characterized via the standard spectroscopic ellipsometry. Second, several low-dimensional materials exhibit significant anisotropy in the mid-IR range. I will discuss approaches to leverage this property for deep-subwavelength control of optical chirality and polarization control of a mid-IR beam. Finally, I will present simple design rules that can be applied in lithography-free mid-IR absorbers and emitters for active tunability via temperature-controlled phase-change materials.

16:30 - 17:00 - *HADAR: Fundamental limits to thermal perception* (Invited Talk)**Zubin Jacob**, Purdue University, USA

We review recent progress in the field of infrared thermal metasurfaces from controlling the spin degree of freedom to long-wave spectro-polarimetric imaging.

17:00 - 17:15 - *Thermal Emission in Temporal Metamaterials: Fundamentals and Novel Phenomena***J. Enrique Vázquez-Lozano, Iñigo Liberal**, Universidad Pública de Navarra (UPNA), Spain

We sketch out an original theoretical formulation for rigorously addressing thermal emission in time-modulated media, highlighting the emergence of non-local correlations, the possibility to overcome the black-body spectrum, the role of ENZ bodies as genuine platforms to enhance thermal emission, and the conception of innovative thermal emitters.

17:15 - 17:30 - Nanoparticle Derived Suppressed-Scattering Bands for Radiative Cooling

Carlos Lezaun Capdevila, José M. Pérez-Escudero, Alicia E. Torres-García, Miguel Beruete, Iñigo Liberal, Public University of Navarra, Spain
Antonio Caggiano, University of Genova, Italy
Ignacio Peralta, Technische Universität Darmstadt, Germany
Jorge S. Dolado, Donostia International Physics Center (DIPC), Spain

Suppressed scattering bands are detected when embedding dispersive nanoparticles in a medium, allowing fine tuning of reflectance properties in one band while keeping emission in another. This effect has potential applications in the design of radiative coolers based on random nanoparticle mixtures.

17:30 - 18:30 - Perspective Talk on Time Crystals

Chair: Filiberto Bilotti

17:30 - 18:30 - Perspective Talk on Time Crystals***Wilczek's Time Crystals and Metamaterials***

Nikolay Zheludev, University of Southampton and NTU Singapore, United Kingdom

I review the Frank Wilczek's (2012) original concept of Time Crystals - a new state of matter with broken time translation symmetry. I also report on recent experimental result demonstrating that a classical metamaterial nanostructure, a two-dimensional array of plasmonic metamolecules supported on nanowires, exhibit the continuous time crystal behaviour in presence of light¹. I argue that the continuous time crystal state is of interest to applications in all-optical modulation, frequency conversion, timing and all-optical computing.

18:30 - 19:00 - Special Event in Memory of Prof. Irina Vendik

WEDNESDAY 13th SEPTEMBER 2023**IMPERIAL 2****10:30 - 12:30 - Oral Sessions (Wednesday Morning)****“Nonlinear and nonreciprocal optical metastructures”**

Chairs: Mario Silveirinha, Constantinos Valagiannopoulos

10:30 - 11:00 - *Nonlinear Tuning of Topological States in Photonic Structures* (Invited Talk)**Zhigang Chen**, Nankai University, China

The Su-Schrieffer-Heeger (SSH) lattice represents a paradigmatic one-dimensional topological model, which has been widely employed in topological photonics and realized with versatile platforms including nanophotonics, plasmonics, metamaterials, and quantum optics. In this talk, I will briefly discuss its topological nature and symmetry protection, and then focus on two examples. One is in the fundamental side – about nonlinear control of topological edge states and tuning of parity-time symmetry; the other is more towards application - about topologically tuned terahertz confinement in a nonlinear photonic chip. Nonlinear control of topological states in higher-order topological insulators (HOTIs) will also be discussed.

11:00 - 11:30 - *Spontaneous Symmetry Breaking and Time-Crystal States in Quantum Optics Platforms* (Invited Talk)**Mario Silveirinha**, University of Lisbon - Instituto Telecomunicacoes, Portugal

It is shown that the coupling between a qubit and a gyroelectric nanoparticle may generate spontaneous symmetry breaking and time-crystal type states in atomic systems with a non-trivial spin-orbit-coupling. The lifetime of the time-crystal state is finite and is characterized by two “attractor” states in the Bloch sphere with a topological origin.

11:30 - 12:00 - *Optical Tellegen Metamaterial without External Bias Fields* (Invited Talk)**Viktar Asadchy, Shadi Jazi, Mohammad Asgari**, Aalto University, Finland**Dimitrios Tzarouchis**, Meta Metamaterials Europe, Greece**Ihar Faniayeu, Rafael Cicheler, Alexandre Dmitriev**, University of Gothenburg, Sweden**Shanhui Fan**, Stanford University, USA

The nonreciprocal magnetoelectric (Tellegen) effect promises a multitude of exciting applications in connection to fundamental (e.g., axion electrodynamics) and applied physics (e.g., magnetless isolators). Notably, in the optical spectrum, there are no materials with noticeable and controllable magnetoelectric effects. In this talk, we will

propose a three-dimensional metamaterial with an isotropic and resonant Tellegen response in the visible frequency range. The proposed metamaterial does not need external magnetization or temporal modulation and can be fabricated using readily available nanofabrication techniques and materials.

12:00 - 12:30 - *Giant Enhancement of Nonreciprocity in Gyrotropic Media with Plasmonic Multilayers* (Invited Talk)

Constantinos Valagiannopoulos, National Technical University of Athens , Greece

This work examines a scheme for extensively enhancing the weak response of natural magneto-optical materials. We use gyrotropic multilayers which are characterized by poor nonreciprocity as indicated by the small magnitude of the off-diagonal elements of their permittivity tensor. However, if we incorporate them together with a plasmonic background host to form an average effective medium, the diagonal elements of the effective permittivity tensor of the latter can be designed to become close to zero while maintaining the magnitude of the off-diagonal elements; thereby, the gyrotropic response of the equivalent structure is expected to get hugely amplified.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Wednesday Afternoon 1)

“Mechanical and elastic metastructures II”

Chairs: Stephane Brule, Kwanghyun Kim

14:00 - 14:15 - *Designing Absolute Bandgaps in Network of Beams using Spectral Element Method combined with a Genetic Optimization algorithm*

Théo Bonneval, Léonardo Sanches, Guilhem Michon, Université de Toulouse, France

Maxime Lanoy, Laboratoire d’Acoustique de l’Université du Mans, France

Caroline Lyszyk, Rémy Tanays, Institut de Recherche Technologique Saint Exupéry, France

Adrien Pelat, Laboratoire d’Acoustique de l’Université du Mans, France

We propose the design of a 3D lattice (assembly of beams) to generate forbidden frequency bands for all types of mechanical waves through an optimization routine. The optimization step is performed using the Spectral Element Method (SEM) together with a genetic algorithm. The evolution of the unit cell structure over successive generations is presented for a specific example, resulting to the opening of a complete (relative to all

wave polarizations) band gap. To verify the bandgap efficiency of the optimized 3D lattice structure, the wave propagation in a periodic network of 8 unit cells is computed.

14:15 - 14:30 - *Hard-Magnetic Soft Mechanical Metamaterials for Tunable Elastic Wave Manipulation*

Quan Zhang, University of Galway, Ireland

Stephan Rudykh, University of Wisconsin – Madison, United States

The remote and reversible principle of actuation of hard-magnetic active elastomers (hMAEs) holds great potential for the design of robotics, actuators and sensors, and biomedical devices. Here, I propose to exploit the unique transformative ability of hMAEs integrated into the metamaterial design to develop novel tunable hard-magnetic soft mechanical metamaterials with superior elastic wave properties.

14:30 - 15:00 - *Interaction of Pile Foundations with Rayleigh Waves and Seismic Metamaterial Based on a 1D Mass-in-mass Model* (Invited Talk)

Stephane Brule, Stefan Enoch, Fresnel Institute, France

Sebastien Guenneau, The Blackett Laboratory, Imperial College London, UK

Usually for the design of deep foundations, the kinematics of Rayleigh waves are not specifically used. However, these waves, which can be generated in sedimentary basins with shorter wavelengths, offer remarkable polarization properties. This polarization depends a lot on the stratification of the subsurface soils. For a semi-infinite and homogeneous medium, the polarization in the vertical plane can make it possible to consider a 1D model made of an alternation of masses and springs, or even a seismic metamaterial with a mass-in-mass device.

15:00 - 15:15 - *Nano-optomechanical Phase Change Chalcogenide Metasurfaces*

Behrad Gholipour, Kwanghyun Kim, University of Alberta, Canada

Jun-Yu Ou, University of Southampton, UK

We introduce a new class of programmable nano-optomechanical metasurfaces that take advantage of the non-volatile and reversible optical and mechanical phase transitions exhibited by phase change chalcogenide semiconductors by utilizing the significant volume change of 6%–9% seen in the widely used alloy germanium antimony telluride.

15:15 - 15:30 - Controllable Lorentz Force via Mutual Inductance in Split Ring Resonators

Kailun Xu, Christopher Stevens, Laszlo Solymar, Ekaterina Shamonina, University of Oxford, United Kingdom

Magnetic interactions in metamaterial structures have led to plenty of applications. Here, we show that in split ring resonators, the direction of the induced Lorentz force can be reversed by varying the frequency of the applied AC voltage. These findings have the potential to enable the reconfiguration of programmable structures for new functionalities.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Wednesday Afternoon 2)**“Mechanical and elastic metastructures III”**

Chairs: Martin Wegener, Rui Fang

16:00 - 16:30 - Rotons in Chiral and Monomode Mechanical Metamaterials (Invited Talk)

Martin Wegener, Karlsruhe Institute of Technology (KIT), Germany

We review our recent work on achieving roton-like dispersion relations in three-dimensional microstructured mechanical metamaterials. This includes chiral micropolar metamaterials following Eringen elasticity and Cauchy elastic monomode metamaterials.

16:30 - 16:45 - Machine Learning Assisted Inverse Design On Mechanically Tunable Lateral Hybrid Metasurface

Rui Fang, Durham University, United Kingdom

AI has driven an increase in metasurface design, including our new lateral hybrid system, where two different material resonators form a lattice. Our AI-assisted design optimized the lateral hybrid metasurface for structural color applications, enhancing performance and optical tuning in semiconductors and high-dielectric materials, such as TiO₂ and Si₃N₄. This method could unlock new opportunities in high-precision sensors and marks a major advance in the field.

16:45 - 17:00 - *Transformable Extremal Metamaterial For Reprogrammable Elastic Waves Control*

Zhou Hu, Rui Zhu, Gengkai Hu, Beijing institute of technology, China
Zhibo Wei, Yan Chen, Tianjin university, China
Guoliang Huang, University of Missouri, USA

We propose a methodology for the 2D and 3D transformable extremal metamaterials with the ability of transforming elasticity tensor. Reconfigurability is experimentally validated. Reprogrammable elastic wave manipulations are also demonstrated. This work sheds lights on real-time manipulations of broadband low-frequency elastic waves and the design of smart metamaterials.

17:00 - 17:15 - *Roton-like Dispersion via Polarization Change for Elastic Wave Control*

Luca Iorio, Jacopo Maria De Ponti, Federico Maspero, Raffaele Ardito, Politecnico di Milano, Italy

Roton dispersion relations have been restricted to correlated quantum systems, recent works show the possibility of obtaining this dispersion in elastic metamaterials. In this paper, we demonstrate both numerically and experimentally that beyond-nearest-neighbor connections are not a necessary condition to obtain this dispersion relation in elasticity. Moreover, we show the result of combining the roton dispersion and rainbow physics.

17:15 - 17:30 - *Tetramode Metamaterial as Phonon Polarizer*

Michael Fidelis Groß, Jonathan Ludwig Günter Schneider, Sebastian Kalt, Martin Wegener, Karlsruhe Institute of Technology, Germany
Muamer Kadic, Université de Franche-Comté, France
Yu Wei, Xiaoning Liu, Genkai Hu, Beijing Institute of Technology, China

We design, manufacture, and characterize three-dimensional microstructured elastic tetramode metamaterials, which exhibit four easy modes of deformation within Cauchy elasticity. Applications as a compact broadband polarizer for acoustical phonons at ultrasound frequencies are demonstrated.

WEDNESDAY 13th SEPTEMBER 2023**IMPERIAL 3****10:30 - 12:30 - Oral Sessions (Wednesday Morning)****“Nonlinear metaphotonics”**

Chairs: Maria Antonietta Vincenti, Michael Scalora

10:30 - 10:45 - *Transient Nanostructure Formation in GaAs Film Under Femtosecond Laser Action***Olesia Pashina, Mihail Petrov**, ITMO University, Russia**Olga Sergaeva**, University of Brescia, Italy**Marco Gandolfi, Davide Rocco, Costantino De Angelis**, University of Brescia, CNR-INO, Italy**Giulia Crotti**, Politecnico di Milano, Istituto Italiano di Tecnologia, Italy**Giuseppe Della Valle**, Politecnico di Milano, Italy

We present a self-consistent model computing the electron concentration, the electron and lattice temperatures of GaAs film on substrate during the action of femtosecond laser pulse. Upon illumination with a high-power tightly focused laser pulse the transient modulation of GaAs properties can produce a “transient metallic nanoparticle”.

10:45 - 11:00 - *One-way Complete Polarization Conversion Enabled by Gain at a Chiral Exceptional Point***Donghak Oh, Soojeong Baek, Sangha Lee, Kyungmin Lee, Bumki Min**, Korea Advanced Institute of Science and Technology, Korea (South)**Jagang Park**, University of California, Berkeley, USA**Teun-Teun Kim**, University of Ulsan, Korea (South)

We propose a non-Hermitian metasurface that enables one-way complete polarization conversion at a null-eigenvalued EP through the incorporation of gain. We demonstrate the validity of this concept through numerical verification, by designing a metasurface that converts right circular polarization to left circular polarization while blocking the opposite conversion and eliminating co-polarized transmission.

11:00 - 11:15 - *Photonic Modelling of Two-Photon Purcell Effect Near Plasmonic Nanostructures*

Steve Smeets, Bjorn Maes, Gilles Rosolen, University of Mons, Belgium

Our new photonic model efficiently computes the two-photon Purcell effect of a quantum emitter near any photonic structure beyond the dipolar approximation, which is relevant for plasmonic nanocavities and is applied to a silver nanodisk. The computation of Purcell factors through classical electromagnetic simulations determines the impact of the environment.

11:15 - 11:45 - *Harmonic Generation in Transparent Conducting Oxides: from Nanolayers to Multilayer and Photonic Crystals Arrangements* (Invited Talk)

Maria Antonietta Vincenti, Domenico de Ceglia, University of Brescia, Italy
Michael Scalora, 2Aviation and Missile Center, US Army CCDC, Redstone Arsenal, USA

Transparent conducting oxides have emerged as important players for nonlinear interactions at the nanoscale thanks to the presence of plasma resonances in the infrared range. Here we focus our attention on second and third harmonic generation from transparent conducting oxides in simple arrangements, like freestanding and Kretschmann configurations, and in more complex planar settings, such as multilayer structures or one-dimensional photonic crystals.

11:45 - 12:15 - *Harmonic Generation from Metal/vacuum Interfaces: Free Electron Spill-out Layer as an Epsilon-near-zero Boundary Layer* (Invited Talk)

Michael Scalora, FCDD-AMT-MGI, DEVCOM AvMC, USA

Shroddha Mukhopadhyay, Laura Rodríguez-Suné², Jose Trull, Crina Cojocaru,

Department of Physics, Universitat Politècnica de Catalunya, Spain

Kent Hallman, Peopletec, USA

Maria Antonietta Vincenti, Domenico de Ceglia, Department of Information Engineering – University of Brescia, Italy

Neset Akozbek, US Army Space & Missile Defense Command, USA

We use a detailed microscopic model to explore harmonic generation from metal/vacuum interfaces, where a patina of free electrons extends out into free space and vanishes within an atomic diameter. We discuss the possibility and consequences of such a free electron layer acting as an epsilon-near-zero layer. Just as classical macroscopic electrodynamics cannot discern field fluctuations between atoms, it is also equally unable

of discriminating the rapid decay of the free electron spill-out density within a distance equivalent to an atomic diameter. The best one can do is then to treat the boundary as a layer of free charge density having thickness equal to a single spatial discretization step of unknown average density, equivalent to a delta-function. Under these conditions we predict that if this boundary layer exists it will display an epsilon-near-zero condition that can enhance the local field by several orders of magnitude, depending on linear and nonlinear dispersion (which includes absorption), alongside with a dramatic decrease of nonlinear thresholds. These dynamics could help redefine, and thus reevaluate, both the linear and nonlinear optical properties of metals and other materials deep in the UV range.

12:15 - 12:30 - Polarizing Anisotropic Three-Dimensional Dirac Semimetal Metamaterial Antennas for Terahertz Telecommunication Applications

Kelvin Ooi, S. S. Ng, D. W. J. Chang, Xiamen University Malaysia, Malaysia

Three-dimensional Dirac semimetals have shown interesting optical properties, such as excellent response to the Terahertz frequencies, optical anisotropy, and large nonlinear optical coefficients. In this work, the unique optical properties of three-dimensional Dirac semimetals have been exploited in the design and construction of Terahertz polarizing metamaterial antennas. Antenna arrays consisting of elements of different shapes and sizes were designed, and it is found that the square-shaped element gives the best polarizing performance across a wide bandwidth. The nonlinear polarization switching property of a circular-shaped three-dimensional Dirac semimetal antenna array is also briefly studied, with results that show good sensitivity at moderate pump intensities.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Wednesday Afternoon 1)

“Nonlinear metasurfaces and THz generation”

Chairs: Tal Ellenbogen, Luca Carletti

14:00 - 14:15 - Modeling Optical Rectification in Doubly-Resonant Dielectric Nanostructures: Effective Nonlinear Response and THz Emission Control

Unai Arregui Leon, Giuseppe Della Valle, Department of Physics, Politecnico di Milano, Italy

We numerically study the difference-frequency generation process between two NIR fields in Mie-resonant nanoscatterers, yielding a THz-signal. The key features for boosting the conversion-efficiency are identified and the performance of AlGaAs and LiNbO₃

nanopillars is compared. We present an effective nonlinear reduced model and an analysis of the THz-emission tunability.

14:15 - 14:30 - *Observation of Phonon-Driven Enhanced THz Generation in Thin-Film Lithium Niobate*

Luca Carletti, Davide Rocco, Costantino De Angelis, University of Brescia, Italy
Cormac McDonnell, Tal Ellenbogen, Tel-Aviv University, Israel
Unai Arregui-Leon, Marco Finazzi, Giuseppe Della Valle, Michele Celebrano, Politecnico di Milano, Italy
Andrea Toma, Istituto Italiano di Tecnologia, Italy

We investigated the THz generation from a 500 nm lithium niobate film by optical rectification. We reveal an enhancement of the nonlinear response due to the phonon-driven ionic contributions. Our results encourage the development of new THz emitters and detectors based on nanophotonic structures in the thin-film lithium niobate platform.

14:30 - 14:45 - *Nonlinear Dielectric Metasurfaces for Terahertz Generation*

Davide Rocco, Luca Carletti, Costantino De Angelis, University of Brescia, Italy
Giuseppe Della Valle, Unai Arregui Leon, Politecnico di Milano, Italy
Luke Peters, Marco Peccianti, Alessia Pasquazi, Vittorio Cecconi, Juan S. Totero Gongora, Luana Olivieri, University of Sussex, United Kingdom
Giuseppe Leo, University of Paris, France

Metasurfaces have been demonstrated to be an essential part of the future of thin optics, with applications ranging from cameras to telecoms. Here, we prove that ultrathin aluminium gallium arsenide metasurfaces can nonlinearly generate sizable terahertz signal and demonstrate that the THz emission is strongly affected by the geometry of the dielectric metasurface.

14:45 - 15:00 - *High Volumetric Resonant Nanostructure for Enhancement of Quantum Dot Emission in Colour Conversion Technology*

Son Tung Ha, Emmanuel Lassalle, Thi Thu Ha Do, Institute of Materials Research and Engineering, Singapore
Liang Xiao, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore
Sushant Shendre, Emek Goksu Durmusoglu, Hilmi Volkan Demir, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore
Vytautas Valuckas, Sourav Adhikary, Ramon Jose Paniagua Dominguez, Arseniy Kuznetsov, Institute of Materials Research and Engineering, Singapore

We present a volumetric resonance nanostructure made of TiO₂ formed by the hybridisation of grating and slab resonances to enhance the colour down-conversion of CdSe/ZnS quantum dots. An emission enhancement of 40 times within 0.55 NA is achieved, comprising absorption enhancement, Purcell enhancement and directionality enhancement (i.e., outcoupling). This design has potential in practical applications such as down colour conversion in microLED displays or photovoltaics.

15:00 - 15:30 - *Active, Nonlinear and Anomalous Optical Dynamics in Nanoresonator Arrays* (Invited Talk)

Tal Ellenbogen, Tel Aviv University, Israel

We show how to switch the nonlocal nonlinearity in a hybrid metasurface-liquid-crystal platform. We also unveil new types of volume collective modes in 3D plasmonic nanoresonator arrays that exhibit interesting optical anomalies, and demonstrate the manifestation of collective-like effects in a system constructed from a single nano resonator in a cavity.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Wednesday Afternoon 2)

“Materials for nanophotonics and metasurfaces”

Chairs: Jacob Khurgin, Angelos Xomalis

16:00 - 16:15 - Silicon-Based Dual Linear Polarizer Exploiting Quasi-Bound States in the Continuum

Luca Fagiani, Department of Physics, Politecnico di Milano, Italy

Luca Bolzonello, Johann Osmond, Niek van Hulst, ICFO - Institut de Ciències Fòtiques, The Barcelona Institute of Science and Technology, Spain

Domenico de Ceglia, Department of Information Engineering, Maria Antonietta Vincenti, Department of Information Engineering - University of Brescia, Italy

Monica Bollani, Istituto di Fotonica e Nanotecnologie-Consiglio Nazionale delle Ricerche (IFN-CNR), LNESS, Italy

We present a theoretical and experimental demonstration of a single layer siliconbased metasurface able to convert any arbitrarily polarized incoming light into linearly polarized light. Our metasurface leverages the topological features of symmetry protected quasi-bound states in the continuum and shows an extinction ratio of ~ 40 dB for two linear crosspolarization excitations, paving the way for a novel class of ultra-compact multi-frequency linear polarizers.

16:15 - 16:30 - Experimental and Numerical Study of Absorption In Hyperuniform Disordered Plasmonic Metasurfaces at Infrared Wavelengths

Roman Buisine, Eric Lheurette, Olivier Vanbésien, Institut d'Electronique, de Microélectronique et de Nanotechnologie, France

David Dereudre, Laboratoire Painlevé, France

Benoît Cluzel, Thibault Deletang, Laboratoire interdisciplinaire Carnot de Bourgogne, France

We study how disorder in nanocylinder positions affects absorption in a plasmonic MIM metasurface at near-infrared wavelengths. We observe absorption changes when varying the amount of disorder for two nanocylinder densities. Higher density benefits more from disorder in absorption bandwidth, demonstrated both numerically and experimentally.

16:30 - 16:45 - *Fabrication Approach of Resonant Silicon Nanoparticles Doped with Luminescent Defects Emitting in the Near-IR Wavelength Range*

Vitaly Yaroshenko, Anna Dyatlovich, Pavel Kustov, Eduard Ageev, Dmitry Zuev, ITMO University, Russia

Alexander Gudovskikh, Aleksandr Goltaev, Ivan Mukhin, Alferov University, Russia

The nanostructures based on silicon attract attention due to compatibility with existing lithography fabrication approaches. Here we developed an approach for the fabrication of resonant silicon nanoparticles doped with luminescent defects (Er ions). The experimental studies demonstrate the rise in the luminescent intensity several times due to the presence of Mie-resonances in the nanosystem.

16:45 - 17:00 - *Structure Dependent Photoluminescence of Colloidal PbS Quantum Dots in Low Refractive Index Dielectric 3D Infrared Metamaterials*

Angelos Xomalis, Lorenzo Ferraresi, Oriol Busquets, Krzysztof Maćkosz, Ivo Utke, Johann Michler, Jakob Schwiedrzik, Ivan Shorubalko, Empa, Swiss Federal Labs for Materials Science and Technology, Switzerland

Dmitry Dirin, Maksym Kovalenko, Institute of Inorganic Chemistry, Department of Chemistry and Applied Biosciences, ETH Zürich, Switzerland

Colloidal quantum dots (QDs) have been extensively used for their size dependent optoelectronic properties resulting in broadband detection of electromagnetic radiation. While compatible with flat phototransistors, applications beyond 2D architectures remain challenging. Conventionally structure dependent photoluminescence (enhancement requires strictly plasmonic or high refractive index dielectric metamaterials). Here, we report on a 1600% structure dependent PL enhancement with the aid of low refractive index ZnO coated laser printable 3D infrared (IR) metamaterials. We overcome current material limitations utilising the 3D nature of metamaterial structure to increase surface interaction between incoming radiation and PbS QDs dramatically. Our findings not only shed light on conformal QD coating over curved surfaces of 3D structures, but also open new avenues in selecting materials with broader potential use in optoelectronic and nanophotonic applications.

17:00 - 17:30 - *Modulating Refractive Index: Energy, Speed, and Footprint Trade-offs* (Invited Talk)

Jacob Khurgin, Johns Hopkins University, USA

There has been a rising tide of interest to time modulated optics where modulation of permittivity begets new appealing concepts. Some of them have been demonstrated in

the low frequency domain, while in the optical domain the progress has been less spectacular, which is no wonder, since modulation of refractive index in time domain does not conserve energy, and one needs to introduce a certain amount of energy to change index]. Exactly how low this amount can be? In my talk I will hopefully provide some general answers

WEDNESDAY 13th SEPTEMBER 2023**IMPERIAL 4****10:30 - 12:30 - Oral Sessions (Wednesday Morning)****“Reconfigurable intelligent surfaces”**

Chairs: Steven Anlage, Alexandros Ptilakis

10:30 - 11:00 - *Smart Electromagnetic Environment as enabler for 5G mmWave: Research, industry trends and their impact on the mobile communications* (Invited Talk)**Roberto Flamini**, Huawei Technologies, Italy

As the world transitions to 5G and beyond networks, the use of millimeter-wave (mmWave) frequencies is becoming increasingly common due to their high data rates and low latency. However, mmWave frequencies also present unique challenges, such as high propagation losses, susceptibility to blockage, and limited coverage area. To overcome these challenges, a natural solution would be to resort to network densification. A denser deployment of 5G mmWave base stations (gNBs according to the 5G NR terminology) would be preferred from the performance point of view since it would guarantee the desired minimum signal strength in the served area, but it may not be always a feasible or economically viable solution, e.g., due to the lack of wired/wireless backhaul, the higher costs for the acquisition of new sites, rental fees, maintenance and power supply. For these reasons, a smart electromagnetic (Smart EM) environment that intelligently manages the mmWave spectrum and resources is needed.

11:00 - 11:15 - *Non-volatile Memory and Intelligent Terahertz Metasurface by Vanadium Dioxide***Benwen Chen, Jingbo Wu, Biaobing Jin**, Nanjing University, China

In this talk, we presented our spatial light modulators (SLMs) and reconfigurable intelligent surfaces (RISs) based on phase change material of vanadium dioxide (VO₂). After successfully suppressing the crosstalk from adjacent pixels, the THz wave could be modulated in a programmable manner. The switching speed of each pixel was on the order of 1 kHz. In particular, utilising the hysteresis effect of VO₂, the memory effect is demonstrated. In RIS, By applying various coding sequences on the metasurface, it could deflect THz beams over an angle range of 42.9°.

11:15 - 11:30 - Reconfigurable Metasurface Architecture for Complete Wavefront Control in mmWave Programmable Wireless Environments

Alexandros Pitilakis, Nikolaos Kantartzis, Aristotle University of Thessaloniki, Greece
Odysseas Tsilipakos, National Hellenic Research Foundation, Greece

Anna Tasolamprou, Ageliki Tsioliariidou, Sotiris Ioannidis, Maria Kafesaki, Christos Liaskos, Foundation for Research and Technology Hellas, Greece

We design a scalable printed-circuit board based reconfigurable metasurface (MS) architecture, relying on tunable lumped loads, capable of complete wavefront manipulation in both polarizations in the 28 GHz mmWave band. We then show how a set of these MS can enable a non-line-of-sight link in an indoor programmable wireless environment.

11:30 - 11:45 - Reverberation-Induced Non-Locality: Implications for RIS-Based Communications and Opportunities for Scattering Singularity Control

Philipp del Hougne, CNRS, IETR - Univ Rennes, France

In this talk, I will discuss origin, implications and opportunities arising from reverberation-induced non-local effects when programmable metasurfaces are deployed in complex scattering systems rather than free space. Based on a discrete-dipole approximation, I will show how long-range coupling between meta-atoms arises due to rays encountering multiple meta-atoms as they bounce around in the complex scattering system. This implies a non-linear dependence of the linear transfer function on the metasurface configuration. For RIS-assisted wireless communications, common models tacitly assume a linear dependence and their predictions are hence questionable. For extreme scattering control, reverberation-induced non-locality strongly increases the ability of a programmable metasurface to finely tune the location of poles and zeros of the overall system's transfer function. I will show applications to analog differentiation and reflectionless signal routing.

11:45 - 12:00 - Suppression of Quantization Lobes in 1-bit Intelligent Reflective Surfaces

Daniil Vabishchevich, Andrey Sayanskiy, Andrei Belov, ITMO University, Russia

In this work, we present a design-and-manufacture-friendly method for quantization lobes suppression in intelligent reflective surfaces (IRS). Rotation of the 4 identical equally spaced subarrays around their diagonals allows for significant suppression of quantization lobes compared to the panel shift method. Modeling of a 20×20 array shows that this

method can suppress quantization lobes by more than 10dB with very low losses in the main lobe gain.

12:00 - 12:30 - Utilizing Active Metasurfaces to Tame the Scattering Properties of Complex Systems (Invited Talk)

Jared Erb, Isabella Giovannelli, Nadav Shaibe, Steven Anlage, University of Maryland, USA

We discuss the discovery, properties, and systematic manipulation of scattering singularities (CPA, exceptional points, etc.) utilizing a series of tunable metasurfaces in microwave experiments, and summarize our progress toward achieving the general goal of controlling scattering in complex reverberant enclosures.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Wednesday Afternoon 1)
“Engineered diffraction with metasurfaces and metagratings”
Chairs: Enrica Martini, Ariel Epstein

14:00 - 14:30 - Field Manipulation Enabled by Space-to-Surface Wave Conversion through Modulated Metasurfaces (Invited Talk)

Talha Arshed, Stefano Maci, Enrica Martini, University of Siena, Italy

This paper presents an accurate pseudo-analytical approach for the design of modulated metasurfaces able to efficiently convert an arbitrary impinging field into a surface wave with a given wavenumber, or to convert a given surface wave into a leaky wave with a desired pattern. The proposed procedure can find application in the design of high efficiency antennas, as well as of passive smart skins able to increase the effectiveness of communication systems in the framework of the emerging paradigm of smart radio environments.

14:30 - 15:00 - Equivalence of Angular Stability and Reflection Locality for Metasurfaces with Anomalous Reflection

Constantin Simovski, Aalto University, Finland

The so-called generalized reflection law defines the fields reflected from non-uniform boundaries in terms of the local reflection coefficient. Many researchers understand it as

an approximation of reflection locality in which the reflection coefficient at a given point is assumed to be the same as if all unit cells of the metasurface surrounding the reference one were identical. In this talk we will present a mathematical proof that on some realistic conditions this approximation is adequate even for strongly anomalous reflections.

15:00 - 15:30 - *Nonlocal Polarization Manipulation with Anisotropic Metagratings* (Invited Talk)

Sharon Elad, Yuval Shklarsh, Ariel Epstein, Technion - Israel Institute of Technology, Israel

We propose meta-atom configurations suitable for dual-polarized printed-circuit-board (PCB) compatible metagratings (MGs), enabling diffraction engineering combined with polarization-dependent response or polarization conversion. This is achieved by utilizing dog-bone array meta-atoms, allowed to be rotated in plane to couple transverse electric (TE) and transverse magnetic (TM) fields. Augmenting the conventional MG analytical models (suitable to TE-polarized fields) to address such configuration, polarization dependent beam splitting and simultaneous polarization conversion and anomalous reflection are demonstrated. As typical to MG devices, leveraging the nonlocal surface-wave-mediated coupling between the meta-atoms as design degrees of freedom facilitates sparse, simple to design, and efficient devices, useful in modern communication systems.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Wednesday Afternoon 2)
“Nonreciprocal and topological properties in microwave metastructures”
Chairs: Daniel Sievenpiper, Giuseppe Vecchi

16:00 - 16:15 - *Design of Non-Reciprocal Mantle Cloaking for Dipole Antennas*

Zahra Hamzavi-Zarghani, Alessio Monti, Davide Ramaccia, Luca Stefanini, Alessandro Toscano, Filiberto Bilotti, Roma Tre University, Italy
Stefano Vellucci, Michela Longhi, Mirko Barbuto, Niccolò Cusano University, Italy

In this paper, we investigate the possibility to design non-reciprocal bianisotropic metasurfaces to suppress the scattering of a dipole antenna at its resonance frequency without deteriorating its proper operation in the transmission mode. The susceptibilities of the considered metasurface are calculated using generalized sheet transition conditions and imposing zero scattering for external illumination and perfect transmission

for internal radiation of the antenna. The results of some preliminary full-wave simulations are also reported.

16:15 - 16:30 - *Exceptional Robustness and Anomalous Topology in Non-reciprocal Scattering Networks*

Zhe Zhang, Romain Fleury, EPFL, Switzerland

Back-scattering free transport, robust to defects and disorder, is a pivotal characteristic of topological insulators. However, such resilience to physical parameters variations or structural defects is typically limited to weak perturbations. In Chern insulators, for example, on-site energy fluctuations cannot exceed the band-gap size. Here, we demonstrate that non-reciprocal scattering networks exhibit an anomalous topological phase, distinct from the usual Chern phase, capable of withstanding extremely strong levels of disorder, in both periodic (crystalline) and aperiodic (amorphous) settings. Experiments are carried using non-reciprocal microwave networks, validating the exceptional resilience of anomalous edge transport. We provide a direct confirmation of the anomalous topology of our prototypes by measuring the topological invariant in a topological pump experiment, performed both on periodic and amorphous samples. Our results pave the way for robust two-dimensional (2D) wave manipulation with complete topological protection.

16:30 - 17:00 - *Nonreciprocal and Topological Microwave Structures* (Invited Talk)

Daniel Sievenpiper, Prabhakar Bandaru, Robert Davis, Sara Kandil, Feng Li, Erda Wen, Xiaozhen Yang, Yun Zhou, UC San Diego, USA

We will discuss recent work in nonlinear and topological structures in the microwave regime, including tools for analyzing topological structures. We exploit nonlinear effects to create nonreciprocal screens. We will also discuss plasma based topological metasurfaces and machine learning techniques to control metasurfaces for communication and scattering applications.

17:00 - 17:15 - *Phenomenological Model for A Transistor-distributed Material Response*

Sylvain Lannebère, Instituto de Telecomunicações/University of Coimbra, Portugal
Nader Engheta, University of Pennsylvania, USA
Mário G. Silveirinha, University of Lisbon, Portugal

We propose a microscopic model of bound and free charges nonlinearly coupled that in non-equilibrium situation provides a linearized electromagnetic response that is both nonreciprocal and non-Hermitian. It is shown that such a response requires a broken

inversion symmetry and can be implemented in (meta)materials of the 2mm symmetry group biased with a static electric field. The proposed systems may be used to build novel electrically-biased isolators, as well as for light amplification/absorption controlled by the wave polarization.

17:15 - 17:30 - *Non-Hermitian Z2 Photonic Topological Insulators*

Rodrigo Câmara, Mário Silveirinha, Instituto de Telecomunicações, Universidade de Lisboa, Portugal

Tatiana Rappoport, Instituto de Física, Universidade Federal do Rio de Janeiro, Brazil

Here, we extend topological concepts to the realm of non-Hermitian Z2 photonic insulators. We find a surprising resilience of bulk topologies to non-Hermitian effects and uncover a topological phase transition mediated by a continuum of exceptional points.

WEDNESDAY 13th SEPTEMBER 2023**IMPERIAL 5****10:30 - 12:30 - Oral Sessions (Wednesday Morning)****“Reconfigurable and dynamic optical metastructures”**

Chairs: Riccardo Sapienza, Mark Brongersma

10:30 - 11:00 - *Time-varying and Reconfigurable Driven Photonics* (Invited Talk)**Riccardo Sapienza**, Imperial College London, United Kingdom

Metamaterials have revolutionised the way we control light transport and generation. Yet, to date, they rely on passive architectures, only redistributing incident wave energy - for example in a metalens, or a cloak - with no power to locally absorb or produce it to enhance responses. Here I will discuss our first steps towards driven photonic systems, able to convert energy to function and perform actions. In particular I will discuss the temporal analogue of the Young's double slit diffraction.

11:00 - 11:30 - *Flat Optics for Dynamic Wavefront Manipulation* (Invited Talk)**Mark Brongersma**, Stanford University, USA

I will highlight recent efforts in our group to create electrically-tunable metasurfaces can be created that employ nanomechanics, tunable transparent oxides, microfluidics, phase change materials, and atomically-thin semiconductors. Such elements are capable of dynamic wavefront manipulation for optical beam steering and dynamic holography.

11:30 - 12:00 - *Piezoelectric MEMS-empowered Dynamic Metasurfaces* (Invited Talk)**Fei Ding**, University of Southern Denmark, Denmark

We have demonstrated an electrical-driven micro-electro-mechanical (MEMS) empowered dynamic optical metasurface platform for dynamic polarization control with high modulation efficiencies and fast speed by leveraging the commercially available piezoelectric MEMS technique.

12:00 - 12:15 - *Towards a Spatio-Temporal Metasurface***Anthony Harwood, Stefano Vezzoli, Romain Tirole, John Pendry**, Imperial College London, United Kingdom**Stefan Maier**, Monash University, United Kingdom

We present a preliminary investigation into a spatio-temporal metasurface based on the ultrafast modulation of a 310 nm nanofilm of ITO. This nanofilm demonstrates a factor of 10 change in reflectivity, saturating at 125 GW/cm², and generates new frequencies 40 nm from the pump wavelength. Ongoing experiments using pump probe microscopy aim to couple the spatial and temporal modulation of the sample - realising a spatio-temporal metasurface.

12:15 - 12:30 - All-dielectric Reconfigurable Huygens' Metasurface With Only Electric Response

Luis Manuel Máñez-Espina, Universitat Politècnica de València, Spain

Ana Díaz-Rubio, Universitat Politècnica de València, Spain

Efficient wavefront control is crucial for a myriad of applications in free-space optics. In this context, the use of reconfigurable metasurfaces is a go-to solution due to their subwavelength depth, efficiency and versatility. This work presents a germanium-based metasurface capable of performing beam steering operations using non-volatile phase-change materials (PCM) as their active component.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Wednesday Afternoon 1)
"SS - Bio-metamaterials and metamaterials for biosensing I"

Chairs: Motomu Tanaka, Maria Farsari

14:00 - 14:30 - Bio-metamaterials: Mechanical Regulation of Single Mesenchymal Stem Cells by Unit Cell Arrangement (Invited Talk)

Motomu Tanaka, Natalie Munding, Anthony Ho, Heidelberg University, Germany

Magdalena Fladung, Yi Chen, Marc Hippler, Martin Wegener, Martin Bastmeyer, Karlsruhe Institute for Technology, Germany

Metamaterials offer unique advantages over plastic- or hydrogel-based substrates for cell culture, because the effective elastic properties can be adjusted flexibly. In this study, bio-metamaterials based on a soft elastomer-like photoresist have been designed and manufactured using two-photon laser printing. Human mesenchymal stem cells (hMSCs) are cultured on three different types of planar periodic elastic metamaterials. The differential cellular responses on the cellular and sub-cellular levels provided a positive proof of principle, suggesting the potential of bio-metamaterials towards mechanical regulation of cell behaviors by the arrangement of unit cells.

14:30 - 15:00 - *Mechanical Metamaterials: Towards the Development of 4D Scaffolds for Cell Growth* (Invited Talk)

George Flamourakis, Stavros Skrepetos, Anthi Ranella, Maria Farsari, FORTH, Greece

We present our latest results into the design, modelling and additive manufacturing via multiphoton fabrication of adaptable metamaterials scaffolds for cell growth.

15:00 - 15:30 - *Biomimetic Photonic Structures Assembled by DNA* (Invited Talk)

Na Liu, University of Stuttgart, Germany

We will show several types of bio-inspired optical nanosystems, which can perform translation, rotation, twisting, or swinging motions enabled by dynamic DNA nanotechnology. Our approach outlines a general scheme to build dynamic plasmonic nanoarchitectures, in which multiple optical elements can be readily reconfigured or transported to designated locations over distances, resulting in programmed structural changes with high fidelity.

15:30 – 16:00 Coffee Break

16:00 - 17:30 - Oral Sessions (Wednesday Afternoon 2)

“SS - Bio-metamaterials and metamaterials for biosensing II”

Chairs: Gennady Shvets, Francesco De Angelis

16:00 - 16:30 - *Metasurfaces Transform Spectroscopic Assays For Living Cells* (Invited Talk)

Gennady Shvets, Cornell University, USA

The ability to distinguish between different states of a given cell, as well as between different types of cells, is crucial for a variety of fundamental and clinical life sciences applications. I will describe how 3D (elevated) plasmonic metasurfaces can be used for chemical imaging of live cells, and of their responses to various stimuli.

16:30 - 17:00 - *Plasmonic Nanopore Array to Detect Translocating DNA and Proteins at Single Molecule Level by Raman Spectroscopy* (Invited Talk)

Francesco De Angelis, Istituto Italiano di Tecnologia, Italy

We show our latest results on plasmonic nanopores combined with Raman Spectroscopy for amino acids identification and sequencing in flow-through at single molecule level in label-free way. We acknowledge support from Horizon 2020 (ProID GA 964363).

17:00 - 17:30 - *Reconfigurable Metamaterials in Magnetic Resonance Imaging* (Invited Talk)

Matthias Guenther, Dennis Philipp, Fraunhofer MEVIS; University of Bremen, Germany

Simon Konstandin, Juergen Jenne, Fraunhofer MEVIS, Germany

Thomas Bertuch, Endri Stoja, Fraunhofer FHR, Germany

Johannes Mueller, University of Bremen, Germany

Reconfigurable metamaterials offer many degrees of freedom and allow to overcome limitations of present technological capabilities in Magnetic Resonance Imaging (MRI). Various metrics such as speed, efficiency, and local signal-to-noise ratio (SNR) can be drastically improved and tailored applications rather than global effects become possible.

THURSDAY 14th SEPTEMBER 2023

IMPERIAL 1**09:00 - 10:00 - Plenary Session V**

Chair: Alessio Monti

09:00 - 10:00 Plenary talk*Shaping electromagnetic waves with tunable metasurface: from physics to products***Geoffroy Lerosey**, Greenerwave, France

In this talk I will show how, starting from the field of waves in complex media in acoustics and RF, we learned how to control the propagation of light through very scattering media using smart reconfigurable reflectors, namely spatial light modulators.

I will explain how this has led us, almost 10 years ago, to propose to use tunable metasurfaces as smart reflectors to enhance wireless communications. I will show the first results obtained and published in 2014, that proved how a small tunable metasurface placed in an office room can multiply by 10 the energy transmitted between 2 antennas. I will propose a basic application to wireless communications in the context of WIFI, obtained by the startup Greenerwave years ago, thus showing the first use of a Reconfigurable Intelligent Surface (RIS) in a communication system.

Then, I will underline how defining a concept in a lab is very different from designing a product and explain how difficult it was for us to bring these ideas to the market. This will lead me to detail how we have pivoted the company 2 years after creation, to develop more timely products based on the same core technology of reconfigurable metasurfaces and physics-based algorithms to control them. I will underline this pivot with two main applications, the first one in the very low frequency range of RFID, and the second one in the higher one of millimeter wave, with our unique design of electronically steerable antennas for Satcom and 5G applications.

Finally I will make a brief overview of our current developments in the RIS domain, with the first RIS aided wireless communications realized in the mmWave range, demonstrating non line of sight mmWave data transmission using low complexity and low consumption tunable metasurfaces.

10:00 - 10:30 – Coffee Break

11:00 - 12:30 - Oral Sessions (Thursday Morning)
“Nonlocality and bianisotropy”

Chairs: Sander Mann, Juan Domingo Baena Doello

11:00 - 11:15 - *Macroscopic Nonlocality Makes Dielectric Slabs Omnidirectionally Transparent via Printed-Circuit-Board- (PCB-) Compatible Electrically Polarizable Coatings*

Amit Shaham, Ariel Epstein, Technion - Israel Institute of Technology, Israel

We present a rigorous scheme to render planar dielectric slabs omnidirectionally transparent by coating them with adequately engineered simple electrical impedance sheets compatible with standard printed-circuit-board (PCB) technology. In contrast to cylindrical or spherical cloaks, which practice angular stability via symmetry, our approach leverages macroscopic nonlocality to defy the intrinsic spatial dispersion of Fresnel reflection due to planar slabs. To this end, we analytically invoke the generalized Huygens' condition derived in our previous work to tune these coatings; we thus accomplish a composite of extremely low reflectance and, importantly, desired angular behavior of the transmission phase that mimics free-space propagation over all the range of incident angles and preserves wavefronts. Verified via full-wave simulations, these results are expected to facilitate efficient radomes for wide-angle beam-scanning applications and novel optical elements of extreme nonlocality and low reflectance.

11:15 - 11:30 - *Maximum Asymmetric Absorption and Scattering in Bianisotropic Particles*

Sander Mann, Andrea Alù, CUNY ASRC, USA

The extinction cross section of particles excited from opposite directions is necessarily equal due to Lorentz reciprocity. However, if the particle is asymmetric, the scattering and absorption cross sections may differ. Here, we discuss optimal conditions on bianisotropy to break the symmetry between absorption and scattering for dipolar particles. We show that bianisotropic particles can be critically coupled from one side, maximizing absorption, while not absorb at all when excited from the opposite direction, and provide simple identities to achieve this maximal asymmetric absorption. Directional absorption also implies directional emission, and may therefore benefit applications ranging from photovoltaics, heat transfer, one-way mirrors, to light-emitting diodes and lasers.

11:30 - 11:45 - *Gyrotropy-Controlled Uniform Bragg Reflector*

Stefanos Koufidis, Martin McCall, Imperial College London, United Kingdom

We show that a wavelength-independent circular Bragg phenomenon can be exhibited in Faraday chiral media, whereby the externally applied magnetic field not only relaxes the previously identified matching condition but also offers a degree of freedom for manipulating the location of the chirality-domain resonance and the corresponding bandwidth. Due to uniformity, the phenomenon is necessarily broadband, and applications in highly-efficient optical modulators are within reach of parameters currently achieved in complex meta-media.

11:45 - 12:00 - *Supertoroidal Non-Radiating Configurations*

Resmi Ravi Kumar, Nikitas Papasimakis, University of Southampton, United Kingdom
Nikolay I Zheludev, Yijie Shen, University of Southampton; Nanyang Technological University, United Kingdom, Singapore

We report on a new type of non-radiating charge-current configurations, termed supertoroidal anapoles, excited in dielectric particles under illumination with toroidal light pulses. We show that such non-radiating excitations are linked to supertoroidal currents induced in the particle leading to suppression of scattering by over 70%.

12:00 - 12:30 - *Bianisotropic Polarizability Tensor of Subwavelength Resonant Scatterers from Characteristic Mode Analysis* (Invited Talk)

Ana Cristina Escobar Fajardo, Juan Domingo Baena Doello, Universidad Nacional de Colombia, Colombia
Lukas Jelinek, Czech Technical University in Prague, Czech Republic

We will define the bianisotropic polarizability tensor in terms of the multipole moments extracted from a characteristic mode analysis (CMA) which is not depending in any particular choice of the impinging incident wave. When scatterers are electrically small and resonant, this method is very efficient and rapidly converges to the correct value of polarizability. In addition, it will be possible to derive in a very clear way the Casimir-Onsager properties among others.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Thursday Afternoon 1)
“Chiral materials”

Chairs: Ivan Fernandez-Corbaton, Ioannis Katsantonis

14:00 - 14:15 - *Separating the Material and Geometry Contribution to the Circular Dichroism of Chiral Objects Made from Chiral Media***Lukas Rebholz, Marjan Krstic**, Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany**Benedikt Zerulla, Ivan Fernandez-Corbaton**, Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany**Mateusz Pawlak, Wiktor Lewandowski**, Faculty of Chemistry, University of Warsaw, Poland**Carsten Rockstuhl**, Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, and Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany

Considering circular dichroism, the chiral response of an object can have two different origins. It can be linked to the chiral geometry of the object or to a chiral material from which the object is possibly made. We report on the separability of the circular dichroism concerning these two different origins of chirality.

14:15 - 14:30 - *Circularly Polarized Laser using Chiral Metamaterials***Ioannis Katsantonis, Eleftherios Economou, Maria Kafesaki**, Forth and University of Crete, Greece**Anna Tasolamprou**, Forth and University of Athens, Greece**Thomas Koschny**, Ames Laboratory and Iowa State University, USA

We propose and study theoretically and experimentally a chiral metamaterial structure composed of pairs of vertical U-shape resonators of “twisted” arms. We demonstrate that the structure exhibits a large and pure optical activity in the low THz range. The experimental data indicate a polarization rotation of up to 250 over an unmatched bandwidth of 80% (band-width/mid-frequency %). We analyze the enhanced chiral response of the structure using an equivalent RLC circuit model, which can also provide simple optimization rules for the structure response. The proposed chiral structure is easily fabricatable using direct laser writing and electroless metal plating, making it promising candidate for polarization control applications.

14:30 - 14:45 - Chiral Forces in Guided Modes of Dielectric Waveguides

Josep Martinez-Romeu, Iago Diez, Alejandro Martinez, Universitat Politecnica de Valencia, Spain

Jack Kingsley-Smith, King's College London, United Kingdom

Francisco J. Rodriguez-Fortuño, King's College London, United Kingdom

In this work, we study the chiral forces exerted by guided modes in dielectric photonic waveguides. We show that transverse chiral forces arise from the transverse spin associated with TE and TM guided modes. In addition, longitudinal chiral forces can arise when propagating simultaneously degenerate TE and TM modes with a 90° phase shift between them. Such forces can be comparable to or even higher than achiral forces arising from field gradients and momentum transfer. Our results are a first step towards building photonic integrated circuits that can be used to separate enantiomers using light-exerted forces.

14:45 - 15:00 - Spheres of Maximum Electromagnetic Chirality

Jorge Olmos-Trigo, MPC, Spain

Manuel Nieto-Vesperinas, CSIC, SPAIN

Gabriel Molina-Terriza, MPC, DIPC, IKERBASQUE, SPAIN

The search for objects that yield maximum electromagnetic chirality in their emitted wavefield has garnered significant attention in recent years. However, achieving such maximum chirality is challenging, as it typically requires complex chiral metamaterials. Here we show that chiral spheres can yield maximum chirality in their emitted wavefield.

15:00 - 15:15 - Chiral Materials in Parity-Time Symmetric Waveguides

Alice De Corte, Bjorn Maes, University of Mons, Belgium

Mondher Besbes, Henri Benisty, Université Paris Saclay, France

Coupled waveguides with balanced gain and loss form a standard photonic structure for the demonstration of PT-symmetry. We study the influence of chirality on the guided modes of this structure when inserting a chiral material between the waveguides. We observe a strong chiral impact at degeneracies, and elucidate how avoided crossings arise at exceptional points.

15:15 - 15:30 - Chiral Harmonic Generation y Quasi-Bound States In the Continuum

Alexander Antonov, Maxim Gorkunov, Shubnikov Institute of Crystallography, Russia

Yuri Kivshar, Australian National University, Australia

Quasi-bound states in the continuum (quasi-BICs) of dielectric metasurfaces, selectively coupled to circularly polarized waves, provide maximum linear-optical chirality. We consider how they can empower chiral nonlinear-optical processes. We demonstrate that using arbitrarily polarized pumping wave one can generate circularly polarized harmonics at the chiral quasi-BIC wavelength. Conversely, pumping at such a wavelength results in giant harmonic circular dichroism. We design maximum-chiral metasurfaces based on different semiconductor materials and simulate generation of second and third harmonics. We compare various scenarios and reveal feasible limits of generation enhancement and chirality.

15:30 – 16:00 Coffee Break

16:00 - 18:00 - Oral Sessions (Thursday Afternoon 2)

“Non-Hermitian structures”

Chairs: Thomas Koschny, Konstantinos Makris

16:00 - 16:30 - *Dark-state Surface Lasers and Broadband Quadratic Phase Control with Multi-resonant Metasurfaces* (Invited Talk)

Thomas Koschny, Ames National Laboratory - DOE, Iowa State University, USA

Metasurfaces enable us to implement very generic boundary conditions for light. They allow to control the flow of light through them, including arbitrary temporal and spatial phase modulation and impedance match, providing most of the capabilities of bulk metamaterials, but are much easier to fabricate. In this talk, I will highlight two recent achievements with metasurfaces: Dark-state surface lasers and broadband, quadratic phase modulation with multi-resonant metasurfaces.

16:30 - 16:45 - *Anti-Hermitian Optical Media with Gain and Loss*

Lukas Freter, Aalto University and Karlsruhe Institute of Technology, Germany

Mohammad Sajjad Mirmoosa, Ari Sihvola, Constantin Simovski, Sergei Tretyakov, Aalto University, Finland

In this conference talk, we contemplate anti-Hermitian optical media with gain and loss and investigate various aspects of the wave interaction with such media. Particularly, we show that it is possible to fully convert incident evanescent waves to transmitted propagating waves and vice versa or to provide lasing effect for both evanescent and propagating plane wave excitations.

16:45 - 17:00 - *Anti-reflective Gradient-index Metasurface with Correlated Disorder for Light-management in Solar Cells*

Prerak Dhawan, Carsten Rockstuhl, Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany

Maria Gaudig, Alex Sprafke, Peter Piechulla, Ralf Wehrspohn, Institute of Physics, Martin Luther University Halle-Wittenberg, Germany

We experimentally demonstrate and computationally validate the properties of a metasurface made from high-index dielectric discs, arranged with a correlated positional disorder, and covered with a conformal gradient-index layer. The metasurface was perceived to improve the light management in a Silicon solar cell. When integrated into a prototypical device, we observe a broadband reduction in reflection compared to either high-index nanostructures without the gradient layers or a planar anti-reflective coating of the same thickness for the relevant parametric range for scatterers and a consistent enhancement in the photocurrent density.

17:00 - 17:30 - *Localization, Exceptional Points and Symmetries in non-Hermitian Photonics* (Invited Talk)

Konstantinos Makris, IESL-FORTH and University of Crete, Greece

In the context of non-Hermitian photonics, we present recent results regarding two different topics. In particular, the first one is related to the effect of correlated-uncorrelated non-Hermitian disorder in the localization features and the wave dynamics. The second one is relevant to the interplay of robustness and sensitivity in non-Hermitian topological lattices that exhibit higher order exceptional points.

17:30 – 17:45 - *Micro- and nano-laser arrays: new routes to synchronization*

Mercedeh Khajavikhan, University of Southern California, USA

Micro- and nano-lasers form a crucial category of optical components with significant scientific and technological implications. In this presentation, I will discuss the utilization of non-Hermiticity, supersymmetry, and topology principles to design arrays of these devices, resulting in intriguing and unexpected lasing phenomena. By considering the interaction between cavity modes, array geometry, and both short- and long-range coupling among the array elements, we can achieve novel laser phase locking regimes, high radiance emission, rapid beam steering, photonic spin machines, and unidirectional lasing.

17:45 – 18:00 - Trojan optical beams: guiding light via Lagrange points**Demetrios Christodoulides**, University of Southern California

Guided transmission of optical waves is critical to harnessing the power of light for modern communication, information processing, and energy generation systems. Traditionally, guiding lightwaves in structures like optical fibers, is predominantly achieved through the use of total internal reflection (TIR). In periodic platforms, a variety of other physical mechanisms can also be deployed to transport optical waves. However, transversely confining light in fully dielectric, non-periodic, and passive configurations still remains a challenge in situations where TIR is not supported. In this study, we present a novel approach to trapping light that exploits the exotic features of Lagrange points - a special class of equilibrium positions akin to those responsible for capturing Trojan asteroids in celestial mechanics. This is achieved in twisted arrangements, whereby optical “Coriolis forces” induce guiding channels even at locations where the refractive index landscape is defocusing or entirely unremarkable.

18:00 - 18:30 – Closing Ceremony

THURSDAY 14th SEPTEMBER 2023**IMPERIAL 2****10:30 - 12:30 - Oral Sessions (Thursday Morning)****“SS - Time varying metamaterials I”**

Chairs: Davide Ramaccia, Dimitrios Sounas

10:30 - 11:00 - 4D Optics: Sculpting Light in Four Dimensions (Invited Talk)**Nader Engheta**, University of Pennsylvania, USA

In this talk, we will present an overview of some of our most recent results in exploring four-dimensional (4D) optics, i.e., electromagnetic platforms in which material parameters may rapidly vary with time. Manipulating waves with media in four dimensions offers additional degrees of freedom in light-matter interaction, opening doors to possibilities for novel devices and components. We will discuss the roles of temporal change of permittivity functions in various scenarios including anisotropic vs isotropic cases, dispersive vs nondispersive examples, and passive vs active structures. Combining temporal and spatial interfaces, which provides more versatility in tailoring light, will also be considered. We will also present how extreme frequency conversion may be possible in 4D photonics, with potential applications in signal generation and frequency modulation. Some emerging research directions in 4D optics will also be mentioned.

11:00 - 11:30 - Temporal Switching in Open Guiding Structures (Invited Talk)**Yakir Hadad**, Tel-Aviv University, Israel**Amir Shlivinski**, Ben-Gurion University, Israel

We explore using an analytically exact model the wave dynamics in open guiding structures that undergo temporal discontinuities.

11:30 - 12:00 - Impedance in Time-modulated Networks and its Significance for the Derivation of Fundamental Bounds (Invited Talk)**Dimitrios Sounas**, Wayne State University, USA

In this paper, we address the question in which cases time-modulated networks might be equivalent to linear time-invariant ones. For this we examine in which cases the impedance of time-modulated networks satisfies Foster's reactance theorem, which allows us to establish an isomorphism between time-modulated and time-invariant networks. We show how this result can be used to extend fundamental theorems from

time-invariant to time-modulated networks and discuss as an example the case of the Bode-Fano limit.

12:00 - 12:30 - *Scattering Effects Emerging from Time-varying Metastructures: Multi-mode Generation and Continuous Spectrum Radiation* (Invited Talk)

Davide Ramaccia, Luca Stefanini, Alessio Monti, Zaha H.-Zarghani, Alessandro Toscano, Filiberto Bilotti, RomaTre University, Italy
Mirko Barbuto, Stefano Vellucci, Michela Longhi, Niccolò Cusano university, Italy

Temporal metamaterials exploit the time dimension for achieving the time-equivalent scattering processes observed in the space domain. Indeed, reflection and transmission, accompanied by frequency conversion, take place at a temporal interface, i.e., an instant of time at which the refractive index of the metamaterial changes suddenly. Recently, it has been proposed to achieve temporal metamaterials by exploiting the effective refractive index perceived by guiding modes by acting on the boundary conditions. In this contribution, we present our recent findings on boundary-induced temporal interfaces, discussing the scattering effects emerging from two parallel plate waveguides as time-varying metastructures and demonstrating that it is possible to achieve multi-mode generation and radiation of a continuous spatiotemporal spectrum, according to the design on the metastructure.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Thursday Afternoon 1)

“SS - Time varying metamaterials II”

Chairs: Emanuele Galiffi, Carlo Rizza

14:00 - 14:30 - *Some Recent Developments in Temporal Metamaterial* (Invited Talk)

Carlo Rizza, Department of chemical and physical science, University of L'Aquila, Italy
Giuseppe Castaldi, Vincenzo Galdi, University of Sannio, Department of Engineering, Fields & Waves Lab, Italia
Nader Engheta, Department of Electrical and Systems Engineering, University of Pennsylvania, USA

Temporal metamaterials, which have constitutive parameters that vary with time, have become an area of significant research interest due to their potential to enhance light-matter interactions and create devices with unique capabilities. Here, we will review some recent developments in this exciting field, with a particular focus on short-pulsed

metamaterials, which are characterized by a dielectric permittivity waveform that is much shorter in duration than the characteristic wave-dynamical timescale. We will also discuss temporal anisotropic meta-materials, which exhibit changes in their electromagnetic response over time, transitioning from isotropic to anisotropic and vice versa.

14:30 - 15:00 - *Engineering Light Scattering through Temporal Structure* (Invited Talk)

Emanuele Galiffi, Gengyu Xu, Shixiong Yin, Andrea Alu, Advanced Science Research Center, Graduate Center, CUNY, USA

A sufficiently fast temporal drive can induce a host of peculiar temporal scattering phenomena. In this talk I will present key advancements in our ability to engineer efficient broadband scattering of electromagnetic waves with sharp temporal inhomogeneities, present different pioneering experiments in this direction, sparking new applications and scattering phenomenology, and fundamental electrodynamic considerations for dispersionless and dispersive temporal inhomogeneities, both in RF and near-optical domains.

Media link(s):

<https://www.nature.com/articles/s41567-023-01975-y> <https://arxiv.org/abs/2212.02647>
<https://www.degruyter.com/document/doi/10.1515/nanoph-2022-0200/html>
<https://elicht.springeropen.com/articles/10.1186/s43593-022-00015-1>
<https://journals.aps.org/prapplied/abstract/10.1103/PhysRevApplied.18.054067>
<https://arxiv.org/abs/2206.04362>
<https://arxiv.org/abs/2208.11778>

15:00 - 15:15 - *Direction-Dependent Wave Transformations in Switched Artificial Moving Media*

Mohamed Hesham Mostafa, Sergei Tretyakov, Aalto University, Finland
Mohammad Sajjad Mirmoosa, Independent researcher, Finland

Time-invariant bi-anisotropic media have been broadly studied, revealing many interesting effects due to the presence of magnetoelectric coupling between the flux densities and fields. We expect that considering time-dependent coupling phenomena will open an alternative avenue for controlling waves and uncovering novel functionalities. In this talk, in particular, we contemplate nonstationary nondispersive artificial moving media and study wave propagation when the effective velocity parameter, as a nonreciprocal magnetoelectric coupling coefficient, vanishes abruptly in time. We show

that such a temporal discontinuity results in directional effects for the energy transfer and frequency translation.

15:15 - 15:30 - Engineering Topological Phases with Spacetime Modulations

João Câmara Serra, Mário Silveirinha, Instituto de Telecomunicações, Universidade de Lisboa - Instituto Superior Técnico, Portugal

We show that rotating spacetime modulations may be used to engineer topological phases due to the angular momentum provided by the synthetic motion. Furthermore, counterintuitively, we prove that a synthetic linear momentum bias, e.g., a travelling-wave modulation, can be an exciting new solution to create nontrivial topological phases in photonic systems.

15:30 – 16:00 Coffee Break

16:00 - 18:00 - Oral Sessions (Thursday Afternoon 2)

“Space/time engineered metamaterials”

Chairs: Christophe Caloz, Victor Pacheco-Peña

16:00 - 16:15 - Space-time Modulation in a Piezoelectric Phononic Crystal: Experimental Study in Sub-sonic and Sonic Regimes

Sarah Tessier Brothelande, C. Croenne, F. Allein, J.O. Vasseur, B. Dubus, IEMN - ISEN Lille, France

We experimentally study acoustic wave propagation in a spatio-temporally modulated system for different modulation speeds, up to the sonic regime when the modulation speed is similar to the wave propagation speed. The system under study is a piezoelectric phononic crystal whose electrical boundary conditions are modulated in time through external circuits.

16:15 - 16:30 - Space-time Effective Media Enabled by Spatial Interfaces and Temporal Boundaries: a Four-dimensional Approach

Victor Pacheco-Peña, Newcastle University, United Kingdom

Nader Engheta, University of Pennsylvania, United States of America

In this communication, we will present our recent efforts on four-dimensional (4D) metamaterials by merging both spatial and temporal boundaries. We make use of spatial multilayers (arranged either vertically or horizontally within a parallel plate cavity) with

some of the layers being filled with temporal metamaterials having rapid periodic changes between two permittivity values. A closed-form solution for the space-time effective medium will be presented demonstrating the higher degrees of freedom enabled by metamaterials modulated both in space and time.

16:30 - 17:00 - *Classical and Quantum Generalized Space-Time Engineered-Modulation (GSTEM) Metamaterials* (Invited Talk)

Christophe Caloz, Amir Bahrami, Zhiyu Li, Furkan Ok, KU Leuven, Belgium
Zoé-Lise Deck-Léger, Polytechnique Montréal, Canada

This paper extends our previous classification of Generalized Space-Time Modulation-Engineered (GSTEM) metamaterials [1], or GSTEMs for short, by distinguishing classical and quantum GSTEMs, and discusses related principles and concepts. It aims at providing an elegant, insightful and useful perspective of metamaterials that might contribute simulating further advances of the field.

17:00 - 17:15 - *Efficient Modeling of Electromagnetic Wave Scattering from Space-Time-Periodic Structures Using the Photonic Layer Multiple Scattering Method*

Emmanouil Panagiotidis, Ioannis Stefanou, Evangelos Almpanis, Kosmas L. Tsakmakidis, Nikolaos Stefanou, National and Kapodistrian University of Athens, Greece
Nikolaos Papanikolaou, National Centre for Scientific Research DEMOKRITOS, Greece

An extension of the computational framework known as the photonic Layer Multiple Scattering (LMS) method for the simulation of electromagnetic wave scattering from dynamically varying structures is presented. The structures are made up of layers of scatterers and/or homogeneous slabs. The method is flexible since it allows for the determination of the scattering characteristics of a composite system from those of its constituent elements and appropriate propagator functions. Here, it is shown how LMS can be applied to dynamic photonic structures of spherical scatterers that change periodically throughout time. Nonreciprocal effects, without the need of magnetic materials, are demonstrated for arrays of high-index dielectric particles with time-varying permittivity.

17:15 - 17:30 - *Towards Spin-current Driven Time-varying Permeability Metamaterials*

Toshiyuki Kodama, Nobuaki Kikuchi, Satoshi Okamoto, Seigo Ohno, Satoshi Tomita,
Tohoku university, Japan

We study permeability (μ) variation of a lithographically- prepared magnetic metamaterial consisting of Ta/Fe₂₀Ni₈₀/Pt trilayers. With a massive spin-current injection, the metamaterial shows significant changes in the resonance field and Gilbert damping parameter. This leads to the spin-current driven μ variation, which is verified by analytical calculation.

17:30 - 17:45 - *Modified FDTD Scheme for Space-Time Engineered-Modulation (STEM) Structures*

Zoe-Lise Deck-Leger, Polytechnique Montreal, Canada
Christophe Caloz, KU Leuven, Belgium

Space-Time Engineered-Modulation (STEM) structures are currently experiencing massive interest in the metamaterials community, with the manipulation of the additional temporal dimension leading to novel effects and applications. However, there is presently no general numerical tool to simulate such structures. This paper closes this gap by providing a modified FDTD scheme solution, which involves hybrid -- auxiliary (non-physical) and physical -- numerical fields. It describes the corresponding modified Yee cell and derives the update equations. Moreover, it validates the proposed methods with the illustrative examples of a STEM slab and STEM crystal.

17:45 - 18:00 - *Electrodynamics of Accelerated Space-Time Engineered-Modulation Metamaterials*

Amir Bahrami, Christophe Caloz, KU Leuven, Belgium

We present the first systematic study of Accelerated Space-Time Engineered-Modulation (ASTEM) metamaterials, or ASTEMs. Leveraging the tools of general relativity, we establish their electrodynamic principles and describe related fundamental phenomena. We show that an electromagnetic beam propagating in an ASTEM is bent in its course, which reveals that such a medium curves space-time for light, similarly to gravitation, and further demonstrate black hole and white hole gravity analogs. This paper extends the fields of uniform velocity metamaterials and paves the way to a host of related novel physics and applications.

THURSDAY 14th SEPTEMBER 2023**IMPERIAL 3****10:30 - 12:30 - Oral Sessions (Thursday Morning)****“Active optical metastructures”**

Chairs: Humeyra Caglayan, Cesare Soci

10:30 - 11:00 - *All-optical switching in Si-compatible epsilon-near-zero hyperbolic metamaterials* (Invited Talk)**Humeyra Caglayan**, Tampere University, Finland

Put your abstract here All-optical switches enable ON/OFF conversion function by following the concept of light-controlled-by-light and are highly significant due to their potential to overcome speed limitations set by electrical switches. In this talk, the ultra-fast responses of metamaterials at the effective epsilon-near-zero (ENZ) wavelengths and/or resonant wavelengths, unveiling response times down to a few hundred femtoseconds (fs), will be presented. Especially a novel Si-compatible hyperbolic metamaterial based on Titanium nitrides (TiN) and indium-tin-oxide (ITO) multilayers that possess two different ENZ wavelengths will be presented with the switching time, measured in pump and probe, of the metamaterial at both ENZ ranges.

11:00 - 11:30 - *Halide Perovskite Light-Emitting Metadevices* (Invited Talk)**Cesare Soci**, Nanyang Technological University, Singapore

The combination of high refractive index with luminescence and charge transport properties of halide perovskites enables the realization of monolithic metadevices with a plethora of optical functionalities like enhanced, polarized and directional photoluminescence, optical Rashba effect, phase-change dynamic color tuning, topological laser emission with optical bistability, and electrically driven polaritonic emission in the strong coupling regime.

11:30 - 12:00 - *Optical Limiter Based on PT-Symmetry Breaking of Reflectionless Modes* (Invited Talk)**Andrey Chabanov**, Rodion Kononchuk, University of Texas at San Antonio, USA**Suwun Suwunnarat**, Tsampikos Kottos, Wesleyan University, USA**Igor Anisimov**, Ilya Vitebskiy, Air Force Research Laboratory, USA**Stefano Cavalieri**, Federico Tommasi, Università degli Studi di Firenze, Italy

Alice Boschetti, Francesco Riboli, Diederik Wiersma, European Laboratory for Nonlinear Spectroscopy, Italy

We report both on the fabrication of an actual demonstrator as well as a series of measurements that show how PT symmetry-based optical limiters can overcome current technical limitations.

12:00 - 12:30 - III-V Photonic Devices on Silicon (Invited Talk)

Kirsten Moselund, EPFL & PSI, Switzerland

Seonyeong Kim, PSI, EPFL & IBM, Switzerland

simone ladanza, PSI, Switzerland

Noelia V. Trivino, Marilyne Sousa, Heinz Schmid, Markus Scherrer, Anna Fischer, Jakob

Drancewski, Cristina M. Oliver, IBM Research Europe - Zurich, Switzerland

In this talk we will first present our work on the monolithic integration of III-V material on Si for photonic devices using template-assisted selective epitaxy. Then we will specifically focus on nanolasers either in the form of hybrid Si/III-V photonic crystal lasers using topology optimization or III-V microdisk lasers. For the microdisks we will discuss the use of Au nanoantennae in terms of wavelength and temperature stabilization as well as the use of metal clad cavities for dimensional scaling.

12:30 – 14:00 Lunch Break

14:30 - 15:30 - Oral Sessions (Thursday Afternoon 1)

“Nonlinear and topological effects in optical metastructures”

Chairs: Kosmas Tsakmakidis, Giorgio Adamo

14:30 - 14:45 - Interplay Between Optical and Electronic Chiralities in Topological Insulator Metamaterials

Alexander Dubrovkin, Centre for Disruptive Photonic Technologies, NTU, Singapore

Giorgio Adamo, Cesare Soci, Qijie Wang, Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, Singapore, Singapore

Nikolay Zheludev, Centre for Disruptive Photonic Technologies, TPI, Nanyang Technological University, Singapore & Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK, Singapore

Direct evidence of how nanostructuring affects the distribution of light polarization-dependent surface currents on topological insulators is of crucial importance for the

understanding and exploitation of spin-mediated light-matter interaction. Here we report deeply subwavelength nanoimaging of circular polarization dependent surface currents and their local textures on plain and artificially nanostructured topological insulator crystals and discuss how patterns with mirror-symmetric forms of planar chirality locally influence the helicity-dependent photocurrents.

14:45 - 15:00 - *Metal-Insulator-Metal Plasmonic Metasurface for Optical Nonlinear Sensing: Achieving High Field Enhancement and Broadband Optical Response*

Saeid Izadshenas, Karolina Slowik, Nicolaus Copernicus University, Poland

This study proposes a metal-insulator-metal plasmonic metasurface for nonlinear sensing applications. The predicted signal enhancement factor for the coherent anti-Stokes Raman scattering (CARS) reaches 11 orders of magnitude compared to the free-space realization. The metasurface is versatile and highly efficient, supporting signal enhancement for a wide range of Raman shifts and various molecular species without the requirement of tuning. Its relative ease of fabrication, broadband performance, and the high electric field enhancement it supports make it a valuable platform for nonlinear optical sensing, including CARS, surface-enhanced Raman scattering (SERS), and two-photon absorption scenarios.

15:00 - 15:30 - *Science and Applications of Topological Rainbow Trapping* (Invited Talk)

Kosmas Tsakmakidis, National and Kapodistrian University of Athens, Greece

Topologically protected wave transport has recently emerged as an effective means to address a recurring problem hampering the field of ‘slow light’ for the past two decades: its keen sensitivity to disorders and structural imperfections. With it, there has been renewed interest in efforts to overcome the delay-time–bandwidth limitation usually characterizing slow-light devices, on occasion thought to be a ‘fundamental limit’. Our talk will overview latest developments and point out important new functionalities that overcoming the limit can enable.

15:30 – 16:00 Coffee Break

16:00 - 18:00 - Oral Sessions (Thursday Afternoon 2)**“Plasmonics”**

Chairs: Femius Koenderink, Javier Aizpurua

16:00 - 16:30 - *Fourier Microscopy of Nonlinear and Amplifying Light Emitting Metasurfaces* (Invited Talk)**Femius Koenderink, Radoslaw Kolkowski**, AMOLF, Netherlands**Nelson De Gaay Fortman**, Institute of Physics, University of Amsterdam, Netherlands

Nano-antenna lattices and plasmon arrays enjoy a long history for fluorescence control, SERS, sensing and plasmon lasers. Recent theory for honeycomb, Kagomé and distributed loss and gain lattices of optically pumped antenna systems point at the potential to explore topological and pseudochiral bandstructure physics, particularly. We present nonlinear femtosecond Fourier microscopy accessing such amplifying, light-emitting structures in k-space.

16:30 - 17:00 - *Exploiting Strong Coupling in Phononic Materials* (Invited Talk)**Javier Aizpurua**, Center for Materials Physics (CSIC-UPV/EHU), Spain

Electromagnetic resonances at visible and infrared frequencies can be strongly coupled to exciton and vibrational excitations in matter, leading to the formation of polaritonic states, which allow for controlling reactivity, as well as optical and electronic properties of materials.

17:00 - 17:15 - *Heavily Doped Semiconductors: a Platform for Integrated Nonlinear Plasmonics***Cristian Ciraci, Huatian Hu**, Istituto Italiano di Tecnologia, Italy**Federico De Luca**, City University of New York, USA**Michele Ortolani**, Sapienza University of Rome, Italy

In this talk we numerically investigate heavily doped semiconductors as a platform for integrated nonlinear plasmonics at mid-infrared frequencies. We study free-electron nonlinearities and use surface charge density modulation to control and enhance the nonlinear response.

17:15 - 17:30 - *Impact of the Nanoscale Gap on Plasmons in Nanostructure Dimers***Yina Wu, F. Javier García de Abajo**, ICFO-Institut de Ciències Fotoniques, The Barcelona Institute of Science and Technology, Spain

Andrea Konečná, Central European Institute of Technology, Brno University of Technology, Czechia

Shin Cho, Department of Chemical Engineering, Keimyung University, Republic of Korea

Delia Milliron, McKetta Department of Chemical Engineering, The University of Texas at Austin, USA

Jordan Hachtel, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, USA

Through investigating plasmons in dimers near the transition from touching to non-touching configurations, we observe large tunability of hybridized plasmon modes by controlling the gap size and the dimensionality of the gap regions. We present electron energy-loss spectroscopy measurements and detailed theory supporting our results.

17:30 - 17:45 - Spatio-Spectral Metrics in Electron Energy Loss Spectroscopy as a Tool to Resolve Nearly Degenerate Plasmon Modes in Dimer Plasmonic Antennas

Michal Horák, Brno University of Technology, Czech Republic

Electron energy loss spectroscopy (EELS) is often utilized to characterize localized surface plasmon modes supported by plasmonic antennas. However, the spectral resolution of this technique is rather mediocre. We address this issue by analyzing the spectral and spatial distribution of the loss probability simultaneously. We propose several metrics that can be possibly utilized to resolve nearly degenerate modes supported by a pair of plasmonic discs. First, we utilize electrodynamic simulations to verify that the metrics indeed represent the spectral positions of the plasmon modes. Next, we apply the metrics to experimental data, demonstrating their ability to resolve the above-mentioned modes.

Media link(s):

See arXiv preprint, <https://arxiv.org/abs/2302.03838>

17:45 - 18:00 - A Transformation Optics Approach to Nonlinear Plasmonics

Fan Yang, Sichuan University, China

Cristian Ciraci, Istituto Italiano di Tecnologia, Italy

We employ transformation optics to analytically study the nonlinear optical response from plasmonic nanostructures, such as second-harmonic generation (SHG) and third-harmonic generation (THG). These nonlinear processes give rise to inhomogeneous nonlinear polarization in the nanostructure, making an analytical solution unattainable. However, introducing transformation optics circumvents this obstacle by converting the complex geometries into a simple flat structure, where the analytical solution becomes

obtainable. Following this analytical scenario, we found SHG from a singular metasurface weakly depends on the incident angle of the pump field, making it an excellent candidate for an all-angle SHG device. Furthermore, direct THG and cascaded THG from a nanowire dimer are thoroughly explored. The different size dependencies for these two processes can be used in future experiments to clarify the physical origin of a THG signal.

THURSDAY 14th SEPTEMBER 2023**IMPERIAL 4****10:30 - 12:30 - Oral Sessions (Thursday Morning)****“Metasurface synthesis and control methodologies”**

Chairs: Sergei Tretyakov, Jordan Budhu

10:30 - 11:00 - *Automated Design and Conception of Metasurfaces* (Invited Talk)**Giuseppe Vecchi**, Politecnico di Torino, Italy

We discuss a design procedure that does not require any solution of the forward problem during the iterations, allowing to address large problems on standard computational platforms. Feeding structures are included in the automated design. As no a-priori information is required on the structure to be designed, the approach also allows to reach unusual geometries- which can be considered a machine “conception”.

11:00 - 11:30 - *Spatial Multiplexing in Near Field MIMO Channels with Reconfigurable Intelligent Surfaces* (Invited Talk)**Marco Di Renzo**, CNRS & CentraleSupélec - Paris-Saclay University, France

We analyze the spatial multiplexing gains in line-of-sight and low-scattering MIMO channels in the near-field. We prove that the channel capacity is achieved by diagonalizing the end-to-end transmitter-RIS-receiver channel, and applying the water-filling power allocation to the ordered product of the singular values of the transmitter-RIS and RIS-receiver channels (arXiv:2212.11057).

11:30 - 11:45 - *Dispersion Engineering at Ultrathin Thicknesses: Arbitrarily - Broadband Quadratic Phase Manipulations with Multiresonant Metasurfaces***Odysseas Tsilipakos**, National Hellenic Research Foundation (NHRF) and Foundation for Research and Technology Hellas (FORTH), Greece**Thomas Koschny**, Ames Laboratory and Iowa State University, USA

We propose multiresonant metasurfaces exhibiting a purely quadratic spectral phase to be utilized for temporal pulse shaping of broadband signals (e.g. dispersion compensation, chirped pulse amplification, etc.). This overcomes the fundamental limitations of both (i) conventional, non-resonant approaches (too bulky) and (ii) modern, singly- resonant metasurfaces (too narrowband).

11:45 - 12:00 - *Perfect Conformal Plane-Wave to Surface-Wave Couplers***Jordan Budhu**, Virginia Tech, USA

Perfect plane-wave to surface-wave couplers over non-planar port regions are designed. The conformal couplers transfer all of the available power in the incident beam to the surface wave which delivers it to a spatially dislocated output port. At the output port, the surface wave is leaked as a beam with control over its amplitude and phase. As all of the captured power is leaked into the reradiated beam, the transfer efficiency is near unity. The metasurfaces consist of an arbitrarily shaped impedance sheet supported by a grounded dielectric spacer. The design occurs in three phases, an integral equation modelling/method of moment solution stage often resulting in the need for active and/or lossy unit cells, a subsequent optimization phase to remove the need for loss and/or gain rendering the metasurface passive and lossless, and a final unit cell design stage to translate the purely reactive impedance sheet to printed circuits. The couplers can be useful in new high frequency communications systems to increase fields in shadow zones where diffraction strengths are reduced, or for new conformal cloaks, electromagnetic illusions, and camouflage.

12:00 - 12:30 - *Metasurfaces for Engineering Beam Reflections* (Invited Talk)**Sergei Tretyakov**, **Sergei Kosulnikov**, **Francisco Cuesta**, **Aalto University**, Finland
Xuchen Wang, Karlsruhe Institute of Technology, Germany

In this presentation we will review our recent works on designs and testings of effective anomalous reflectors and beam splitters. First, we will make a comparative overview of known methods to design stationary and reconfigurable metasurfaces for shaping reflected waves. Next, we will present our recently developed approach based on optimization of step-wise homogeneous impedance sheets. We will show examples of practical designs and experimental results in the millimeter-wave band. Furthermore, we will discuss reflection and scattering from finite-size metasurfaces mounted on walls and show a possibility to change reflections from the illuminated part of the uniform wall by engineering interference with the waves scattered by the metasurface.

12:30 – 14:00 Lunch Break

14:00 - 15:30 - Oral Sessions (Thursday Afternoon 1)

“Analytical and numerical modeling of metadevices”

Chairs: Sebastien Guenneau, Giuseppe Labate

*14:00 - 14:30 - Effective Dispersion Via Second Order Homogenization of The Wave Equation In Irrational Metamaterials (Invited Talk)***Sebastien Guenneau**, Blackett Laboratory, Imperial College London, United Kingdom

We consider the second order homogenization of the scalar wave equation that involves a fourth-order tensor counterpart of the Burnett tensor, for a quasiperiodic structure. Thus, we replace heterogeneous quasiperiodic structures, coined irrational metamaterials, by homogeneous media with artificial anisotropy and dispersion, obtained from the solution of annex problems in a periodic cell in higher dimensional space.

*14:30 - 14:45 - On the Averaging of the Electromagnetic Field in Metasurface Modeling***Michalis Nitas, Samel Arslanagic**, Department of Space Research and Technology, Technical University of Denmark, Denmark**Maria Kafesaki**, Institute of Electronic Structure and Laser, Foundation for Research and Technology - Hellas (FORTH-IESL), Greece

In this work, we present a fully numerical modeling technique for 2D-periodic composite electromagnetic structures known as metasurfaces. Utilizing the field-flux eigenmode Finite Element formulation, we outline the treatment of the general eigenvalue problem pertaining to metasurfaces. Subsequently, we propose an averaging process of the associated electromagnetic fields at paths prescribed by the Generalized Sheet Transition Conditions. Average field components of a metasurface consisting of split-ring resonators are illustrated and discussed.

*14:45 - 15:00 - Generalized Surface Admittance Equivalence Principle for Non-radiating and Super-scattering Problems***Giuseppe Labate**, Radar Technology Group TNO Defense Safety and Security, The Netherlands**Francesco Monticone**, Cornell University, Ithaca, New York, USA, USA**Andrea Alù**, Advanced Science Research Center, City University of New York, New York, USA, USA

Using Mie theory, the external scattering coefficients c_m can be controlled for any m harmonic by a general equation for a dielectric cylindrical particle, generalizing previous results for single-harmonic cloaking. A multiharmonic non-radiating source and super-

scattering particle can be produced by the insertion of a proper surface admittance needed at the boundary between dielectric and background region. Three separate limiting cases for non-radiating source and super-radiating features are presented and compared for the same bare particle case, with insights on the multi-harmonics suppression or enhancing of monopole, dipole, quadrupole radiation pattern and so on. In a straightforward manner, non-radiating and super-scattering sources can be created with future implementation with active or passive thin metasurfaces.

15:00 - 15:15 - The Fast-sweeping Method for Eikonal and Transport Equations: A very Efficient Numerical Tool for the GO Analysis of GRIN Lenses

Ilir Gashi, Stefano Maci, Matteo Albani, University of Siena, Italy
Anastasios Paraskevopoulos, University of Siena, Italy

Additive manufacturing have permitted easy development and prototyping of GRaded INdex (GRIN) lenses; i.e., lenses made by inhomogeneous dielectric materials. GRIN lenses use a refractive index gradient to bend light rays inside the lens, which can have flat interface surfaces and extreme design flexibility. The Fast Sweeping Method (FSM) is a numerical scheme for efficiently solving both the wavefront propagation and the field amplitude in GRIN lenses. The use of FSM is assessed by proving its accuracy and effectiveness, thus providing an alternative tool with respect to the ray-tracing. Because of its robustness the FSM represents a very good candidate to work as analysis engine in an optimization loop for the GRIN lens automatic design.

15:15 - 15:30 - A Novel Electromagnetic Method to Interpret Scattering Suppression from Spheres

Giuseppe Ruello, Vincenzo Miranda, Daniele Riccio, University of Napoli Federico II, Italy
Riccardo Lattanzi, New York University, USA

An innovative approach to design coated spheres with null or limited scattering is proposed. The method is based on a reformulation of the Mie scattering that allows to describe the sphere in terms of impedance and reflection coefficients between travelling spherical waves. The proposed approach leads to a straightforward physical interpretation of the scattering suppression phenomenon and provides a simple tool to design multilayered spheres transparent to the electromagnetic radiation at a given frequency.

15:30 – 16:00 Coffee Break

16:00 - 18:00 - Oral Sessions (Thursday Afternoon 2)**“Nonlinearity and Non-Foster elements in Microwave Metastructures”**

Chairs: Silvio Hrabar, Daniel Segovia-Vargas

16:00 - 16:30 - *Stability-bandwidth Constrain in Real-world non-Foster Elements* (Invited Talk)**Silvio Hrabar**, University of Zagreb, Croatia

Recent experimental studies have shown that there is an inevitable inverse proportionality between the operating bandwidth of realistic non-Foster elements (negative capacitors and negative inductors) and a set of admissible external networks that ensure stable operation. This paper explores the application of this phenomenon to the design of novel non-Foster elements with extremely robust stability properties.

16:30 - 17:00 - *Small Printed Antenna Array based on Non-Foster Networks* (Invited Talk)**Daniel Segovia-Vargas**, EPS, Universidad Carlos III de Madrid, Spain**Vicente Gonzalez-Posadas**, Universidad Politecnica de Madrid, Spain**Fernando Albarracin-Vargas**, Technology Innovation Institute, Abu Dabi

The design of two small-printed antenna arrays, loaded with an active non-Foster matching network, for multiband applications is presented. The design method includes the use of the recently introduced sensitivity parameter, Sens, in order to find a suitable location for a transistor-based non-Foster network, implemented with a Negative Impedance Converter (NIC).

17:00 - 17:30 - *Frequency Mixing by Conductor Contacts with Rough Surfaces* (Invited Talk)**Alex Schuchinsky**, University of Liverpool, United Kingdom

Sub-nm oxide films in contacts of good conductors cause frequency mixing and signal distortions. A model has been developed and used for evaluating the mixing products generated by MIM junctions of conductors with rough surfaces. The model correlates well with the results of numerical simulations of conductor joints with thin oxide films.

17:30 - 18:00 - *Iterative Technique for Computing Soliton Solutions of Nonlinear Lossless Spatially - Periodic Electrical Networks* (Invited Talk)**Cody Scarborough, Joel Johnson, Zoya Popovic**, University of Colorado Boulder, USA

In this paper, an iterative technique for computing the soliton modes of lossless spatially-periodic electrical networks loaded by nonlinear capacitors is provided. The technique accounts for frequency dispersion introduced by spatial discretization, as well as the frequency dependence of the unit cell elements. Further, the technique can be applied to capacitance models without a known polynomial dependence on the voltage. This makes the technique well suited to unit cell design which incorporate nonlinear elements with extracted/measured C-V curves.

THURSDAY 14th SEPTEMBER 2023**IMPERIAL 5**

10:30 - 12:30 - Oral Sessions (Thursday Morning)
“Nonlocal, non-Hermitian and tunable metastructures”
Chairs: Ekaterina Shamonina, Pai-Yen Chen

10:30 - 10:45 - Tunable Dispersion in Planar Arrays of Coalesced Resonators

Ioannis Spanos, Christopher John Stevens, Laszlo Solymar, Ekaterina Shamonina,
Department of Engineering Science, University of Oxford, United Kingdom

Planar arrays of split-ring resonators are known to support backward magnetoinductive waves. The dispersion character can be switched to a forward wave if the resonators are touching and their shared side is capacitively loaded. By varying the value of the capacitor in the shared side, the dispersion can be tuned.

10:45 - 11:00 - Experimental Validation of a Reconfigurable Coaxial Metasurface Radar Absorber using Varactor Diode Tuning

Tanguy Lopez, Université Paris Nanterre / ONERA, France
Badreddine Ratni, Shah Nawaz Burokur, Université Paris Nanterre, France
Thomas Lepetit, ONERA, France

Reduced sizes and easy implementation of electronics rendered metasurfaces an adequate solution to the challenges of stealth. Finite-element simulations and experimental measurements are compared to validate the frequency-agile behavior of a reconfigurable radar absorbing metasurface, intended as a first-step towards time-modulated metasurfaces.

11:00 - 11:15 - Enabling Frequency-hopping Selectivity with Locally Self-tuned Metasurfaces

Ashif Aminulloh Fathnan, Hiroki Takeshita, Daisuke Nita, Hiroki Wakatsuchi, Nagoya Institute of Technology, Japan
Shinya Sugiura, The University of Tokyo, Japan

Owing to their remarkable electromagnetic properties, metasurfaces have revolutionized many aspects of the design of microwave and optical devices. Their scattering responses, however, typically follow classical dispersion theory with unchanged properties in the variation of incident frequency-hopping signals. Here, we show that by introducing locally

self-tuned resonances, a metasurface can scatter differently depending on how multifrequency pulses are used in different timeslots.

11:15 - 11:30 - *Nonlocal Cable-Network Metamaterials*

Yi Chen, Karlsruhe Institute of Technology, Germany

We discuss nonlocal cable-network metamaterials based on standard BNC connectors and coaxial cables. Nonlocal interactions are realized by connecting BNC connectors to their beyond-nearest-neighbors via cables. Highly unusual dispersion relations can be achieved by tailoring the cable length and the order of nonlocal interactions.

11:30 - 12:00 - *Dispersion-Controlled Unidirectional Magnetoinductive Waves* (Invited Talk)

Jiaruo Yan, Anna Radkovskaya, Laszlo Solymar, Chris Stevens, Ekaterina Shamonina, University of Oxford, UK

We review our recent work on unidirectional wave guiding due to interference of magnetoinductive waves. We derive selectivity rules for switchable unidirectional signal guiding and demonstrate that they are governed by dispersion relations. Expanding our analysis to diatomic structures capable of carrying both forward and backward waves, we realise a frequency-controlled switching of unidirectional wave guidance. A variety of scenarios including both 1D and 2D structures, operating either in the MHz or in the THz frequency range will be presented, with Poynting vector analysis used for visualization of unidirectional signal propagation. Our analytical model will be verified with numerical simulations (THz) and experimental data (MHz).

12:00 - 12:30 - *Electromagnetically Unclonable Function (EMUF) Based on Non-Hermitian Metamaterials* (Invited Talk)

Pai-Yen Chen, University of Illinois Chicago, USA

Mohamed Farhat, King Abdullah University of Science and Technology (KAUST), Saudi Arabia

In this talk, we will present a new concept of electromagnetically unclonable function (EMUF) that exploits the spectral sensitivity associated with exceptional points (EPs) in non-Hermitian systems to build a true random number generator for hardware security applications. Specifically, metamaterials and metasurfaces are used to produce EMUF encryption keys encoded in transient/spectral/spatial responses.

12:30 – 14:00 Lunch Break**14:00 - 15:30 - Oral Sessions (Thursday Afternoon 1)****“Inhomogeneous, gradient, and reconfigurable metasurfaces”**

Chairs: Mohammadjavad Shabanpoursheshpoli, Claudio Massagrande

14:00 - 14:15 - 3D-printed Inhomogeneous Graded-Index Lenses for Antenna Applications**Anastasios Paraskevopoulos**, University of Siena, Italy

This article presents the realization of a 3D printed graded index (GRIN) lens, suitable for antenna applications. By tuning the effective permittivity of the host material using a subwavelength patterning, GRIN lenses can be used for increasing the antenna gain in a range from few gigahertz up to millimeter wave frequencies. This type of 3 D printing procedure is likely to enable many novel antenna and microwave devices based on 3 D metamaterial structures.

14:15 - 14:30 - Bi-Functional Metasurface at Millimetre-wave Band**Maria Ruiz, Miguel Beruete**, Public University of Navarra, Spain

Bi-functional metasurface where the phase modulation is implemented following the Pancharatman-Berry principle. The device operates at millimetre-wave frequencies and is designed to work with the lowest frequency in reflection and the highest in transmission. To verify the double functionality performance, two different beam steerers, one for each working frequency, are designed.

14:30 - 15:00 - Binary Reconfigurable Intelligent Surfaces with Angle-Independent Reflection Phase (Invited Talk)**Javad Shabanpour**, Constantin Simovski, Aalto University, Finland**Vladimir Lenets**, 1ESPCI Paris, PSL University, CNRS, Institut Langevin, France**Geoffroy Lerosey**, Greenerwave, France

In this presentation, we investigate the use of physical optics (PO) approximation in the design of binary reconfigurable intelligent surfaces (RISs). We show that PO may be used to design and study RIS operating in a wide sheer of incidence and deviation angles if the reflection phase is angularly stable for uniform settings of the RIS array realizing both required phase shifts of reflected plane waves.

15:00 - 15:30 - *Meta-radome for Ka-band Active Antenna Enhanced Angular Scan*
(Invited Talk)

Claudio Massagrande, Huawei, Italy

mm-wave phased arrays are subject to scan limitations beyond $\pm 60^\circ$ in Azimuth due to a) scan loss considerations and b) the increased surface currents when the main beam approaches directions close to endfire. In this talk the design method, realization and experimental verification of a metasurface based conformal lens capable of extending the angular coverage range of mm-wave AAs to $\pm 90^\circ$ Azimuth, thus enabling a two back-to-back antennas configuration, will be discussed.

15:30 – 16:00 Coffee Break

16:00 - 18:00 - Oral Sessions (Thursday Afternoon 2)
“Tunable and reconfigurable metastructures”
Chairs: Yang Hao, Galestan Mackertich Sengerdy

16:00 - 16:15 - *Mechanically Tunable Wire Metamaterial*

Rustam Balafendiev, Maxim Gorchak, Pavel Belov, ITMO University, Russia

In this work we propose a new quasianalytical way of obtaining the plasma frequency of a wire medium consisting of two identical sublattices with the aim of mechanically tuning it by adjusting their relative position. Such tuning is required by the new application of the wire medium as a component of proposed detectors of axion dark matter. A dispersion equation for such a metamaterial is given and the results of solving it numerically are plotted for two different geometries of the sublattice. A tuning percentage of about 30% is demonstrated for both.

16:15 - 16:30 - *Compliant Mechanisms and Mechanically Tuned Electromagnetic Metamaterials*

Galestan Mackertich Sengerdy, Sawyer Campbell, Pingjuan Werner, Douglas Werner,
The Pennsylvania State University, United States

Metamaterial devices have shown potential for disrupting conventional RF and microwave system design due to their ability to tailor the propagation of electromagnetic radiation in a desired fashion. Combining ruggedization to the final device or system for harsh environments while maintaining a metamaterials performance advancements are still

considered a challenge. To this end, strategies and examples based on a mechanically robust compliant mechanism solution offer a previously unexplored design space.

16:30 - 17:00 - Programmable Microwave Metasurface from a Materials Perspective
(Invited Talk)

Yang Hao, Queen Mary University of London, United Kingdom

A key technical challenge arising from industry is to develop autonomous and reconfigurable systems which integrate communication, sensing and computing functionalities, operating and delivering effects in contested domains. The talk will provide a summary of scientific research related to above objectives. I will describe our research from a materials perspective, namely, tunable material discovery and machine learning, tunable materials fabrication and characterization, and, topology optimization in ferroelectrics. A final demonstration of programmable microwave metasurface will be also presented.

17:00 - 17:15 - Binary Tunable Metasurfaces in Complex Media Empowered by Topology Optimization

Theodosios Karamanos, Fabrice Lemoult, Institut Langevin, France

During the past years, topology optimization has been successfully utilized as an inverse design tool in electromagnetics. In this work, we apply a gradient-based topology optimization for the reconfiguration of the elements of a binary metasurface for the goal of focusing in a complex environment. First, the metasurface elements are modeled as point sources and, then, the optimization problem is formulated. Afterwards, the optimization process is applied to acquire the solution parameter set *and the resulting focusing is validated via simulations*.

17:15 - 17:30 - A Reconfigurable Metadevice that Solves Equations and Constrained Optimization Problems – Mathematical Considerations and Aspects of Experimental Implementation

Dimitrios Tzarouchis, Brian Edwards, Nader Engheta, University of Pennsylvania, USA

This work presents theoretical investigation and experimental validation of a reconfigurable metastructure that performs analog complex mathematical computations using electromagnetic waves. Our device is equipped with reconfigurable, RF-based components that enable it to perform stationary and non-stationary iterative algorithms. To demonstrate its effectiveness, we showcase our platform's ability to solve a stationary problem (matrix inversion), as well as two non-stationary problems (root finding with

Newton's method and inverse design via the Lagrange multiplier method). This work presents a promising ultrafast parallelized platform for wave-based, analog computations for general linear algebraic problems and beyond.

17:30 - 18:00 - *Overview of Transmissive and Reflective Huygens' Metasurfaces for Antenna Beamsteering and Beamforming* (Invited Talk)

George Eleftheriades, Vasileios Ataloglou, University of Toronto, Canada

In this paper we will review recent progress in Huygens' Metasurfaces for antenna beamforming and beamsteering. Topics to be discussed include antenna aperture beamforming with simultaneous magnitude and phase control, high aperture efficiency/low-profile antennas and electronic beamsteering/beamforming.