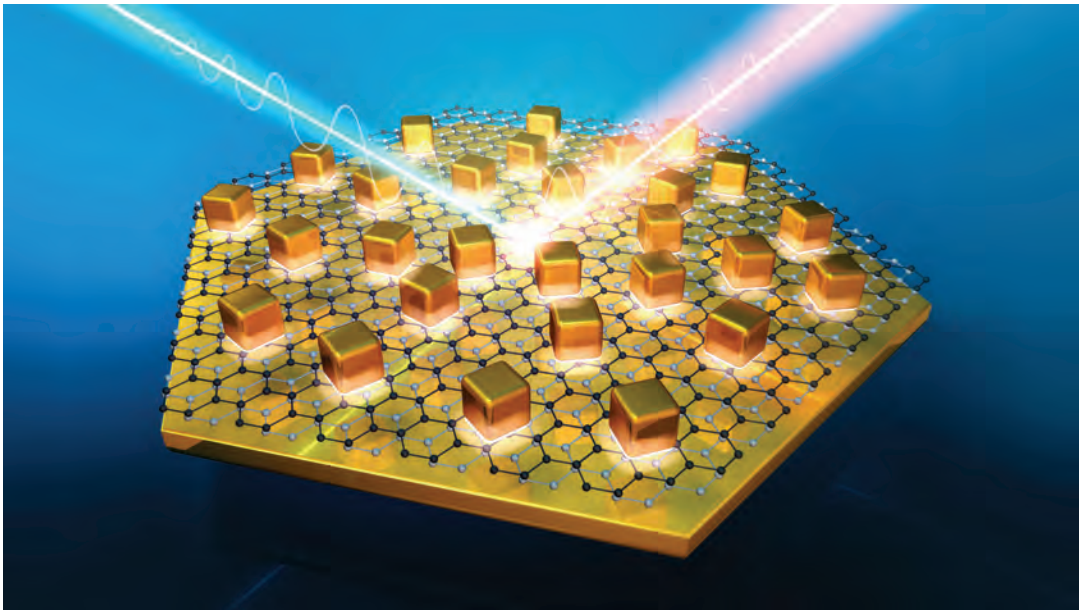
Polariton Science Conference 2024

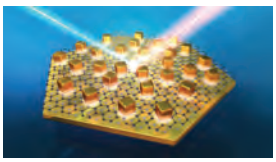
4–7 June 2024, Odense, Denmark



SDU
UNIVERSITY OF SOUTHERN DENMARK

POLIMA
Center for Polariton-driven Light-Matter Interactions

Danmarks Grundforskningsfond
Danish National Research Foundation



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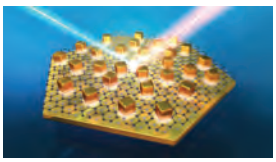
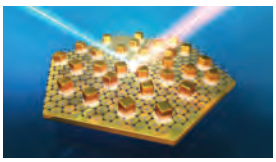


Welcome

It is with great pleasure that we welcome you to the Polariton Science Conference 2024, organized by POLIMA—Center for Polariton-driven Light–Matter Interactions at the University of Southern Denmark (SDU). The conference is generously funded by the Danish National Research Foundation (DNRF) as part of POLIMA's inauguration as a DNRF center of excellence focused on polaritons and nanoscale light–matter interactions. More information is available on www.polima.org. The conference programme features invited talks from emerging research leaders in all aspects of polariton science, preceded by a two-day PhD school with inspirational lectures from established international experts. We hope that you will all enjoy four days full of social activities and scientific interactions that will help identify, and possibly trigger, the future directions for polaritonics!

The organizers
SDU POLIMA



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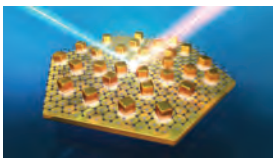

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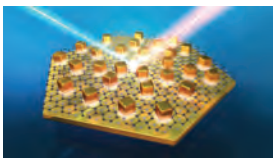
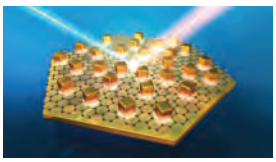


Practical Information

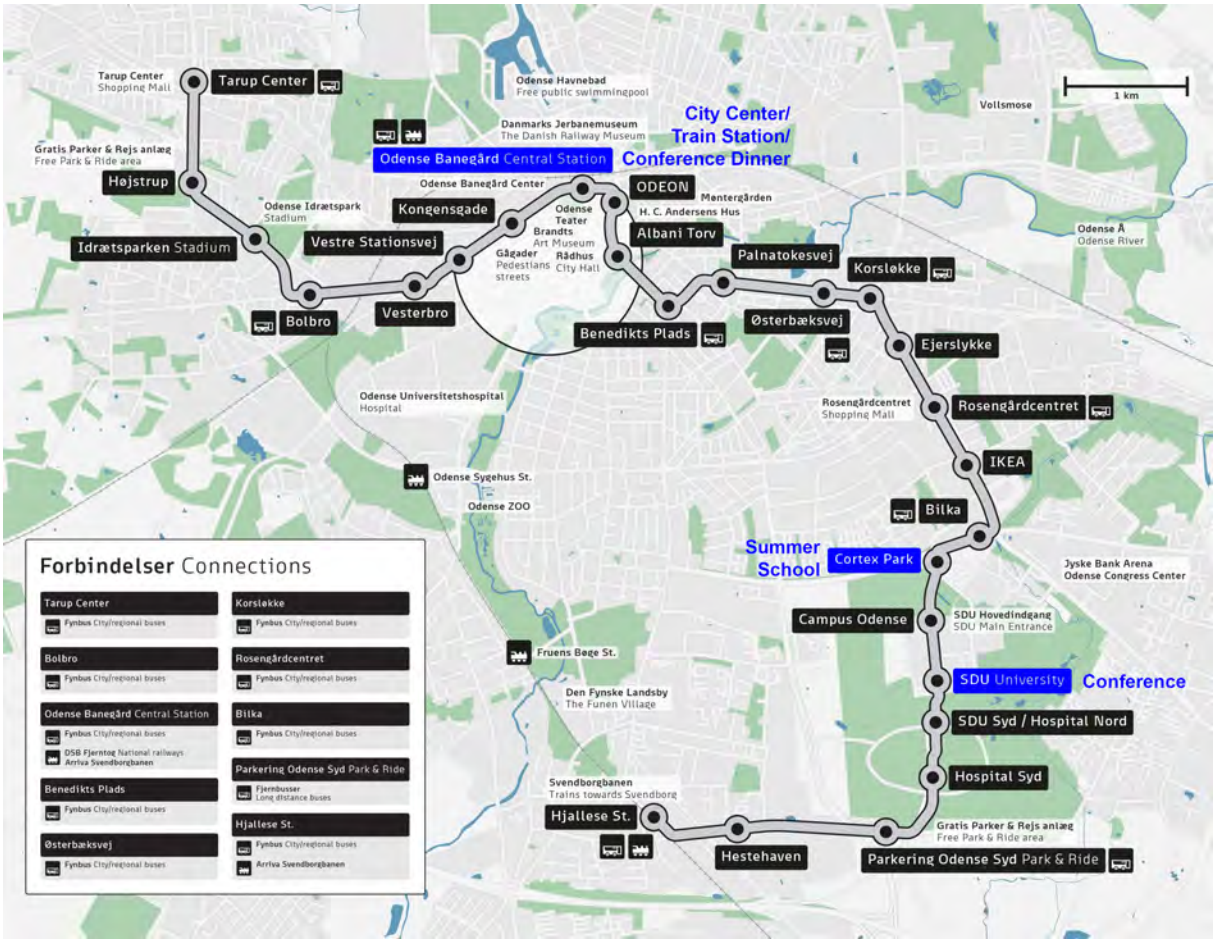
How to Get Here

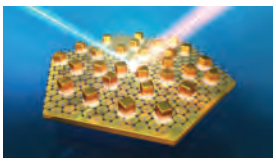
Both the Summer School (4–5 June) and the Conference (5–7 June) take place at the University of Southern Denmark, in Odense, Denmark. Odense is situated on the island Funen in the middle of Denmark. The nearest airport is Copenhagen Airport. Direct trains leave from Copenhagen Airport to Odense hourly and the duration of the trip is approximately 1 hour 45 min. More information about public transport in Denmark can be found on Rejseplanen. Tickets for the train can be bought online on DSB or at all stations.



Moving Around in Odense

To move around in Odense, specially between city center and SDU campus (where both Summer School and Conference take place), the preferred option is the light rail tram (Letbane). Below we show a map of the tram network in Odense where some relevant stops are marked. Tickets can be bought via QR codes at the tram stops with credit card, or online.





Summer School Venue

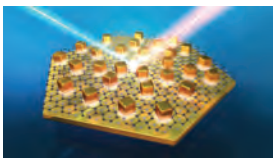
The venue for the Summer School (4–5 June) is room SKY on the 14th floor of Campus Kollegiet.

- How to get to Campus Kollegiet by car: Follow Google Maps for the address: Campusvej 1, 5230 Odense M. Parking outside the building is possible, but you need to register the license plate of your car in the online system available in the ground floor of the building.
- How to get to Campus Kollegiet by public transport: Take the tram/Odense Letbane from Odense train station with direction towards Hjallese Station. Get off the tram at the stop 'Cortex Park' (see map below). The Campus Kollegiet is app. 50 meters from the tram stop.
- The Summer School takes place on the 14th floor (SKY). **You will need the following codes for the elevator:** 4 June: 17 89 33 and 5 June: 52 43 09.

Conference Venue

The venue of the conference (5-7 June) is the Danish Institute for Advanced Study (D-IAS) building.

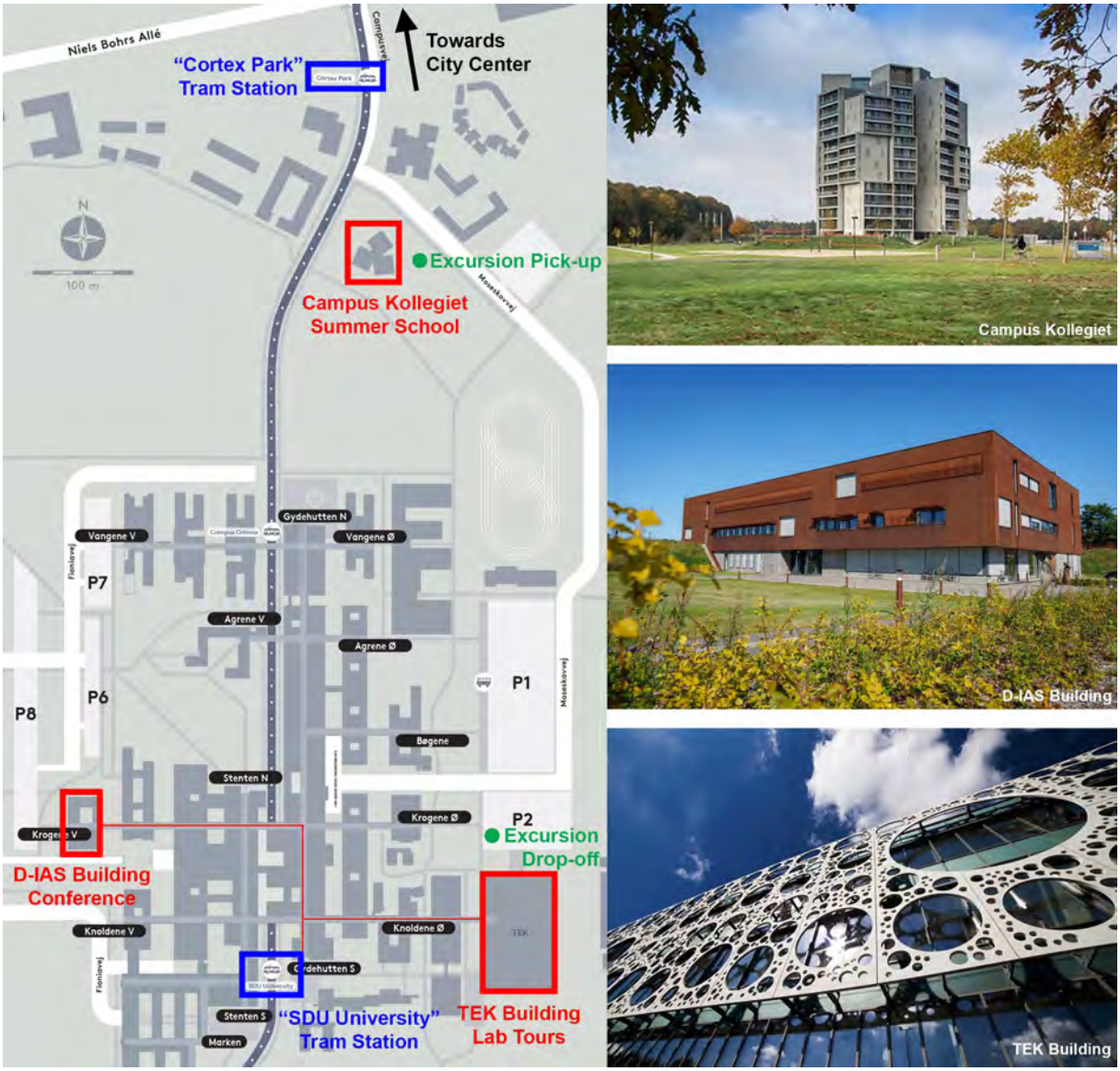
- How to get to the D-IAS building by car: Follow Google Maps for the address: Fioniavej 34, 5230 Odense M.
- How to get to the D-IAS building by public transport: Take the tram/Odense Letbane from Odense train station with direction towards Hjallese Station. Get off the tram at the second stop in the university campus, the stop is called 'SDU/University' (see map above). At the tram stop, take the stairs to the first floor, go left and turn right at Stenten after a few meters. After app. 100 meters turn left at Krogene V and follow the hallway until the end, where you will find the D-IAS building.
- You can also use SDU Maps to find directions.

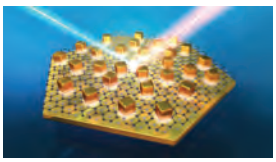


SDU Campus Map

We present below a map of the SDU Odense, with all relevant points for Summer School and Conference. The venues for Summer School (Campus Kollegiet), Conference (D-IAS building) and Lab Tours (TEK building) are marked in red, and the relevant tram stations are marked in blue.

Additionally, you can also use SDU Maps to find directions.

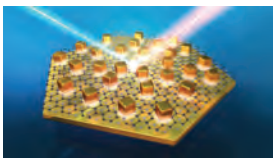




Program

Program at a Glance

	Tuesday, June 4	Wednesday, June 5	Thursday, June 6	Friday, June 7
09.00 09.15 09.30 09.45		**Bert Hecht**	**Laura Na Liu** **Johannes Feist**	**Cristian Ciracì** **Karolina Słowik**
10.00 10.15		*Break*	*Break*	*Break*
10.30 10.45 11.00 11.15		**Thomas Pertsch**	Oliver Kuster Vesanthan Devaraj Saad Abdullah Dorte R. Danielsen	Abhik Chakraborty Line Jelver Sergii Morozov Mariola O. Ramírez
11.30 11.45		*Break*	**Angela Demetriadou**	**Andrea Marini**
12.00 12.15 12.30 12.45 13.00	*Lunch*	**Joel K. W. Yang**	*Lunch*	*Lunch*
13.15	*Setting the scene*	*Egeskov Slot trip*	**Nicholas Rivera** Antton Babaze Xuezhi Zheng Filipa R. Prudêncio Angus Crookes	**Stéphane Kena-Cohen** André J. Chaves Leila Rocio Prelat Villads E. Johansen Gonzalo Álvarez-Pérez
13.30 13.45 14.00 14.15	**F. Javier García de Abajo**			
14.30 14.45	*Break*		*Break & Poster session*	
15.00 15.15 15.30 15.45	**Nahid Talebi**			
16.00 16.15	*Break*		**Thomas Christensen** **Andrea Toma**	
16.30 16.45 17.00 17.15	**Sergey I. Bozhevolnyi**	*Lab tours*		
17.30 17.45 18.00 18.15	*Free time*	**Ido Kaminer**	*Free time*	
18.30 18.45 19.00 ...	*Beers & Plasmonics*	*Opening reception*	*Dinner*	



Tuesday, June 4—Summer School

Venue: Campus Kollegiet

12.00 Lunch

13.15 *Setting the scene thematically of the summer school*

13.30 F. Javier García de Abajo, *Quantum Interactions of Free Electrons and Confined Optical Modes*

14.30 Break

15.00 Nahid Talebi, *Mapping the Optical Excitations with Electron Beams*

16.00 Break

16.30 Sergey I. Bozhevolnyi, *Metasurface-enabled Single-photon Emission*

17.30 Break

18.30 Beers and plasmonics; optional pre-poster session

Wednesday, June 5—Summer School & Conference

Venue: Campus Kollegiet (school) & D-IAS building (conference)

09.00 Bert Hecht, *He-ion Beam Milling of High-end Plasmonic Nanostructures: Forces, Strong Coupling, Nonlinearities*

10.00 Break

10.30 Thomas Pertsch, *Nanophotonic Quantum State Generation and its Applications*

11.30 Break

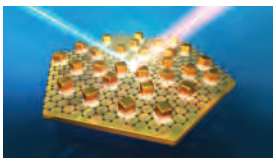
12.00 Joel K. W. Yang, *3D Printing With Light For Light*

13.00 Lunch & Social activity: visit to Egeskov Slot

16.30 Tour of selected labs

18.00 Conference keynote speaker: Ido Kaminer, *Mapping Light-Matter Interactions Using Ultrafast Free Electrons*

19.00 Opening Reception



Thursday, June 6—Conference

Venue: D-IAS building

09.00 Invited talk: Laura Na Liu, *Programmable Metasurfaces at Visible Frequencies*

09.30 Invited talk: Johannes Feist, *Polariton-mediated Modification of Material Properties*

10.00 Break

10.30 Oliver Kuster, *Inverse design of Polariton Devices*

10.45 Vasanthan Devaraj, *3D Printing of Self-Assembled Metallic Architectures: Fabrication Perspectives and its Application in Plasmonics, Quantum photonics and Biosensing*

11.00 Saad Abdullah, *Optimizing the Coupling of Light to Plasmons through Engineered Dipolar Scatterers*

11.15 Dorte R. Danielsen, *Encapsulated Void Resonators in a Lossy Dielectric van der Waals Heterostructure*

11.30 Invited talk: Angela Demetriadou, *Entanglement in extreme nanophotonic cavities*

12.00 Lunch

13.15 Invited talk: Nicholas Rivera, *Controlling quantum noise with nonlinear interactions*

13.45 Antton Babaze, *Quantum Surface Effects and Charge Transfer in the Optoelectronic Coupling between Single Emitters and Plasmonic Nanoantennas*

14.00 Xuezhi Zheng, *A T-matrix Method for Nonclassical Optical Response from Generic Nanospherical Boundaries*

14.15 Filipa R. Prudêncio, *Topological Origin of Chiral Gain in the Non-Hermitian Electro-Optic Effect*

14.30 Angus Crookes, *Subradiant Entanglement in Nanoplasmonics via Dissipation*

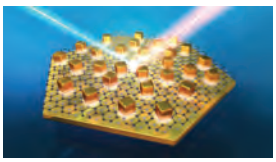
14.45 Break & Poster session

16.15 Invited talk: Thomas Christensen, *Prevalence of Photonic Topology*

16.45 Invited talk: Andrea Toma, *Strong light-matter interaction in periodic and quasi-periodic systems*

17.15 Leisure time

19.00 Dinner at Restaurant Nordatlanten



Friday, June 7—Conference

Venue: D-IAS building

09.00 Invited talk: Cristian Ciracì, *Free-electrons Optical Nonlinearity in Semiconductors*

09.30 Invited talk: Karolina Słowik, *Light Interactions with Polar Quantum Systems*

10.00 Break

10.30 Abhik Chakraborty, *Tailoring the Cavity-Induced Interplay of Modes to Enhance Four-Wave Mixing over a Broadband Molecular Fingerprint Regime*

10.45 Line Jelver, *Nonlinear Plasmonics in Nanostructured Phosphorene*

11.00 Sergii Morozov, *Room-temperature Valley Polarization of Excitonic Emission in Transition Metal Dichalcogenide Monolayers*

11.15 Mariola O. Ramírez, *Second Harmonic Generation in 2D Materials Integrated on $LiNbO_3$*

11.30 Invited talk: Andrea Marini, *Nonlinear Effects Driven by Out-of-equilibrium Electron Dynamics in Extreme Ultraviolet Near-zero Index Thin Films*

12.00 Lunch

13.15 Invited talk: Stéphane Kéna-Cohen, *Exciton-polaritons and Nonlocal Plasmon-polaritons for Emission and Field Enhancement*

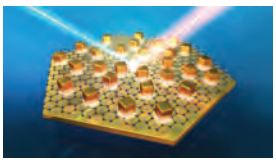
13.45 André J. Chaves, *Madelung's Approach for Obtaining the Hydrodynamic Model of Plasmon-polaritons in Anisotropic Systems*

14.00 Leila Rocio Prelat, *Polariton Smith-Purcell Emission*

14.15 Villads Egede Johansen, *Required Nanoscale Precision for High Efficiency Metalenses*

14.30 Gonzalo Álvarez-Pérez, *Tunable Nonlinear Plasmonic Response in Heavily Doped Semiconductor Waveguides*

14.45 *End of conference*



Poster Session

6 June, 14.45-16.15—D-IAS building

Please carefully read the following guidelines to prepare for your participation:

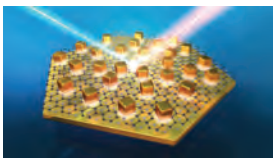
Poster Specifications Each poster must adhere to the A0 size standard with portrait orientation. All fonts must be readable from 1 m distance. Ensure that your poster is designed accordingly to fit these specifications.

When and Where The poster session will take place on the 6th of June, from 14:45 to 16:15, at the Seminar Room in the D-IAS building. Please check this program for the exact location within the campus.

Poster Setup Posters must be placed before the start of the poster session. The poster venue will be open for setup starting at 16:00 on the 5th of June. Spots are allocated on a first-come, first-served basis, so early setup is recommended to secure the best location. Materials and tools necessary for hanging posters will be available at the venue.

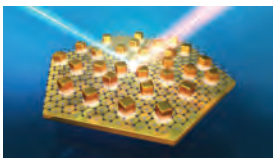
Best Poster Award of DKK 2500 We are pleased to announce that NIL Technologies is sponsoring the Best Poster Award. A scientific committee will evaluate the posters. Each poster presenter will have an interview with one or more committee members during the poster session. The committee will assess the posters based on content, presentation, and the presenter's ability to communicate their research effectively. The winner of the Best Poster Award will be announced at the conference dinner on the 6th of June. Make sure to attend the award ceremony for the announcement and to celebrate with your peers!

Miscellaneous Your poster can remain hung until the end of the conference. Please plan to remove your poster by the closing hours of the last day.



List of Posters

1. Ahmed Gaber Abdelmagid, *Organic Infrared Exciton-Polaritons in Non-fullerene Acceptors Strongly Coupled to an Optical Cavity Mode*
2. Viincenzo Aglieri, *Plasmonic Lattices: Influence of their Collective Response on Strong Light–Matter Hybridization*
3. Kristín Björg Arnardóttir, *Exciton-Polariton Mediated Energy Transfer between Layers of Molecules*
4. Luca Assogna, *Near Zero Index Heterostructures for XUV Plasmonic Waveguides*
5. Christopher Damgaard-Carstensen, *Analysis of Guided Mode Quasi-bound States in the Continuum Resonances in Various Material Platforms*
6. Eduardo J. C. Dias, *Active Control of Smith-Purcell Radiation Emission Using Graphene Ribbons*
7. Blas Durá-Azorín, *Geometrical Anticorrelations: Changing the Photon Statistics with the Geometry of the Electromagnetic Environment*
8. Sven Ebel, *Shaping Free Electron Wavepackets with Structured Light*
9. Khairi Fahad Elyas, *Controlling Exciton Polaritons by Nanopatterning Thin Film WSe_2*
10. Javier Fernández-Martínez, *Effects of Strain and Electron Transfer on the Exciton Density of Monolayer MoS_2 on Plasmonic Silver Nanoparticle Chains*
11. Abhishek Ghosh, *GRANAD: GRAphene Nanoantennas with ADatoms toolbox*
12. Maria Vittoria Gurrieri, *Polaritonic Confined System, Study of Correlation Functions beyond a Mean-Field Approach*
13. Mikkel Have Eriksen, *Nonlocal Effects in Emitter–Plasmon Interactions*
14. Ishita Jena, *Quantum Emitters in Coupled Plasmonic Nanocavities*
15. Xin Jin, *Improving Photocatalytic Efficiency in Porous Shell Resonators*
16. Nikolaos Kyvelos, *Spherical Topological Insulators in Light–Matter Interactions*
17. Yonas Lebsir, *Strain Engineering Valley Polarization in Monolayer Transition Metal Dichalcogenides*
18. Hongfeng Ma, *Metasurfaces for Structured Light Applications*
19. Daniel de Abreu Miranda, *Su-Schrieffer-Heeger Quasicrystal: Topology, Localization, and Mobility Edge*
20. Sergii Morozov, *Sub-to-super-Poissonian Photon Statistics in Cathodoluminescence of Color Centers in Diamonds*
21. Sergii Morozov, *Photon superbunching in cathodoluminescence of WS_2 monolayer*
22. Pedro Ninhos, *Tunable Exciton Polaritons in Band-Gap Engineered Hexagonal Boron Nitride*
23. Álvaro Rodríguez Echarri, *Generation of Entangled Photon Pairs by Swift Electrons and Free-space Illumination into Guided Modes*
24. Hassan Ali Qureshi, *Low Cost Solution Processed Microcavities for Polaritonics Application*
25. Matteo Venturi, *Plasmonic Circular Dichroism Enhancement in Chiral Drug Solution*
26. Wenhua Zhao, *Real-Time Surface Plasmon Polariton Propagation in Silver Nanowires*



Lab Tours

5 June, 16.30-17.45—POLIMA and Centre for Nano Optics labs

At the University of Southern Denmark (SDU) in Odense, there are two research groups that share some of the experimental facilities: The Centre for Nano Optics (CNO) and the Center for Polariton-driven Light-Matter Interactions (POLIMA). As part of the Summer School program, a lab tour has been organized, allowing interested participants to learn about the experimental capabilities and activities of both groups. The tour is scheduled for June 5th at 16:40, upoon return from the visit to Egeskov Slot.

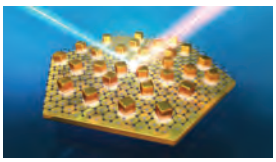
The labs are located at the ground floor of the TEK building, see SDU Maps or the campus map in page 9. The bus from Egeskov will leave us at the main entrance of the TEK building. A short description of the selected labs follows below.

Photoluminescence lab: Here we perform optical characterization of 2D materials and isolated quantum emitters. Our PL setup based on a Zeiss microscope is used for identification and localization of TMD monolayers on exfoliation stamps, while also used for conventional imaging and dark-field microscopy. The lab also has a custom-made confocal scanning microscope for probing localized emitters (lifetime measurements and photon correlation) as well as for characterization of valley states in TMD monolayers and heterostructures (valley polarization). It is equipped with CW and pulsed lasers with excitation wavelength spanning from 405 nm to 780 nm.

Cathodoluminescence lab: Here you will encounter state-of-the-art equipment tailored for probing the optical properties of materials at the nanoscale. The lab is equipped with an SEM operating at $0.1 - 30\,\mathrm{kV}$ acceleration voltages. Utilizing an electron beam, this technique induces luminescence in a sample, providing insights into its composition, defects, and electronic structure. The SEM has a parabolic mirror to outcouple the generated light for spectroscopic, polarization and angle-resolved examination. Besides, the photon correlation in cathodoluminescence can be assessed with a custom made Hanbury Brown and Twiss (HBT) interferometer.

Raman and 2D Material Transfer lab: Here we use a transfer setup for transferring flakes onto different substrates/textured substrates. We can make so-called dry visco-elastic and hot-pickup transfers, as well as heterostructure assembly. We can also investigate material composition and its quality using our Raman microscope.

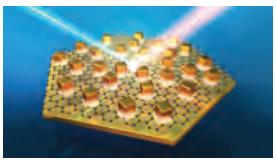
TPL lab: In a lab equipped with a TPL (two-photon-luminescence) set-up the main concept is to investigate local field enhancement with the use of nonlinear luminescence. The setup consists of a confocal microscope with an incident pulsed laser (pulse duration of 100 fs) for the excitation and a photomultiplying tube in the detection path. The setup is also used for characterization of nonlinear materials and local modifications of materials with the tightly focused fs laser beam.



Scanning near-field optical microscopy: In a lab equipped for s-SNOM (Scattering-type Scanning Near-field Optical Microscopy), you find cutting-edge technology enabling nanoscale imaging and spectroscopy. This technology allows us to explore structures with resolutions beyond the diffraction limit, study material properties at the nanoscale, and monitor and analyze the emergence and propagation of plasmons and other polaritons with high detail.

Scanning Electron Microscopy lab In the lab with SEM (Scanning Electron Microscope) and EBL (Electron Beam Lithography) capabilities, you will find essential tools for nanoscale imaging and precision nanofabrication. The SEM provides high-resolution imaging of sample surfaces, while EBL enables for precise patterning of materials at the nanometer scale using lithographic methods. These capabilities are crucial across various fields, to be able to characterize surfaces and fabricate structures.

Quantum lab In the quantum laboratory, we analyze the performance of custom-designed quantum nanophotonic devices. These devices allow us to measure various properties of quantum light sources, including lifetime, spectrum, spin, and orbital angular momentum. Examples of such light sources include color centers in nanodiamonds and various molecules.



Social Activities

Beers and Plasmonics

4 June, 18.30—Campus Kollegiet

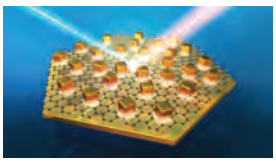
To close the first day of school, the participants will be offered a social dinner where antipasti, Danish beer, and soft drinks will be provided to boost interaction and networking in a fun and relaxed environment. To foster discussions and exchange of ideas, the members of the hosting group POLIMA will put up some posters showcasing their recent research at SDU. All participants that are presenting a poster for the conference Poster Session are invited to put up their poster and take this opportunity to gather some feedback from their peers. This event will take place at *Campus Kollegiet* (same place as the Summer School lectures) on June 4 from 18:30.

Egeskov Slot Excursion

5 June, 13.15-16.30—bus trip

Egeskov, where we will enjoy our lunch in the picturesque surroundings of the 16th century castle, has one of the best-preserved moated Renaissance castles in Northern Europe today. We will leave for Egeskov in a bus departing from Campus Kollegiet at 13.15, and at 16.30 we will be back at the University of Southern Denmark just at the entrance for the labs.
After lunch, you can enjoy three main attractions at Egeskov:

- **Classics Museum:** Explore vintage cars, aircrafts, and more and learn about their fascinating history. After the visit, people enjoying the museums shall meet latest at 15:50 at the fighter jet outside the museums.



- **Egeskov Gardens:** Stroll through the award-winning beautifully landscaped gardens, try out the tree-top walking with awesome view of the castle, and enjoy the serene atmosphere. After the visit, we shall meet latest at 15:50 at the lunch area.
- **Egeskov Castle:** Explore the famous renaissance castle where the count of Egeskov still lives today. After the visit, we shall meet latest at 15:50 at the entrance of the castle.

As we are limited in time, one should plan on only enjoying one of the three main attractions, and to be ready at the meeting points latest at 15:50 to go back to the conference venue by bus.
In case of getting lost, or for any other problem that might occur during the visit, Mikkel Have Eriksen can be reached at +**45 65503556**.

Opening Reception

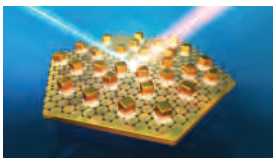
5 June, 19.00—D-IAS building

Following the keynote presentation from Ido Kaminer, everybody is invited for the opening reception. The reception will take place at the rooftop terrace at the D-IAS building. We will enjoy a glass of wine and some canapés, hopefully accompanied by some nice Danish summer weather.

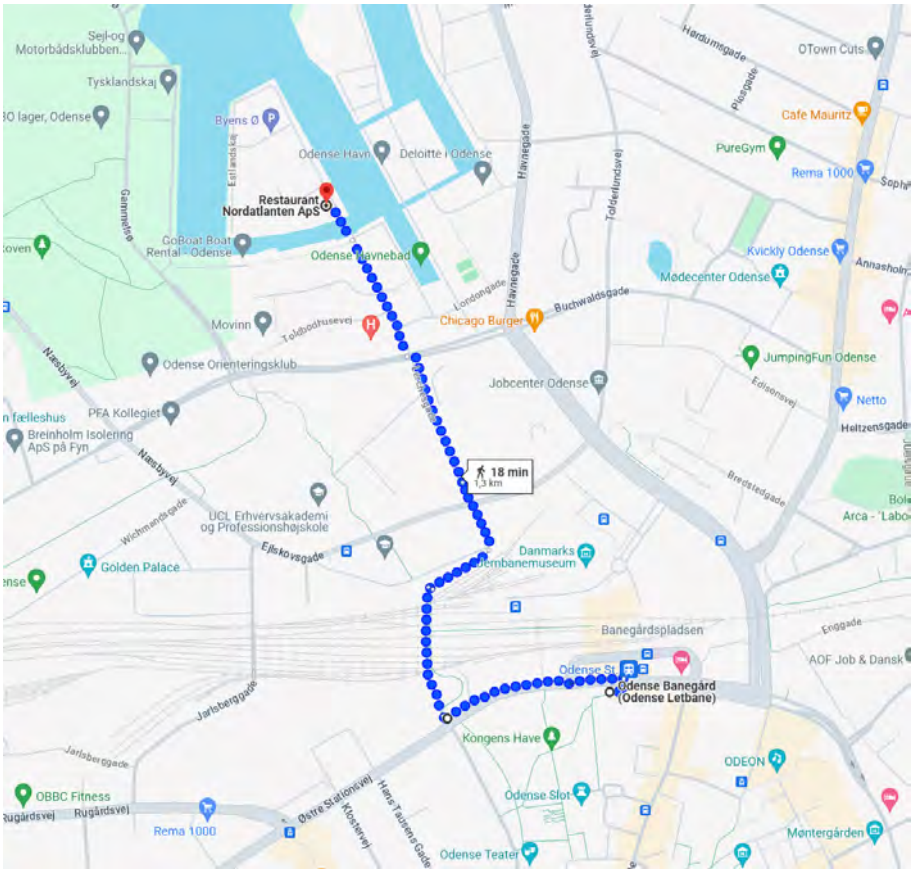
Conference Dinner

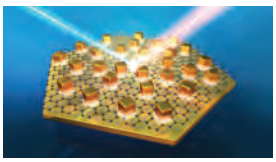
6 June, 19:00—Restaurant Nordatlanten

The conference Dinner takes place at Restaurant Nordatlanten, which is located at the harbour area in Odense. The restaurant serves food with a Nordic touch.



- How to get to Nordatlanten by car: Follow Google Maps for the address: Nordatlantisk Promenade 1, 5000 Odense C. Parking is possible in the area, however it might be subject to payment. If in doubt about the rules, ask in the restaurant.
- How to get to Nordatlanten by public transport: Take the tram to Odense Station and walk from the station to Restaurant Nordatlanten. There is a nice bridge for pedestrians to use from the train station to the harbour area, see map below. Distance from the station 1.3 km.





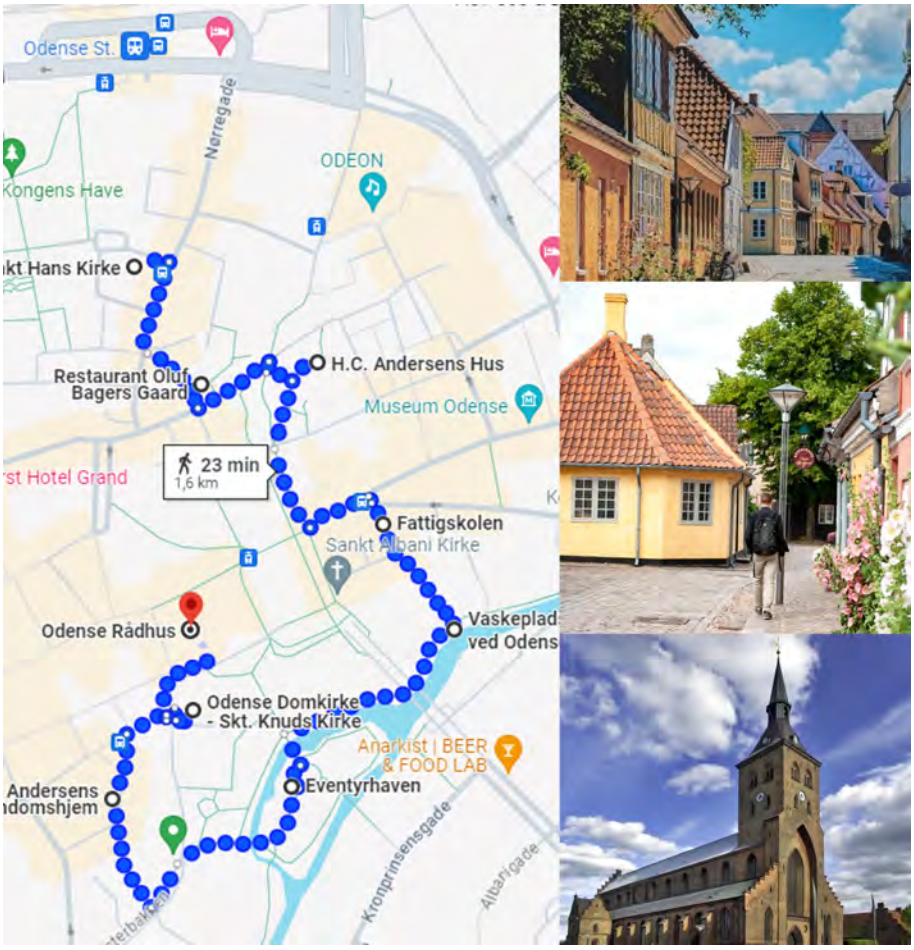
What to do in Odense

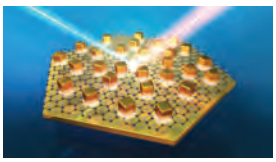
Please find below a few suggestions for activities in Odense. For more options visit the official tourist website of Odense. Welcome to Odense!

A walk in the footprints of Hans Christian Andersen

Go for a walk in the old part of Odense and follow in the footprints of Hans Christian Andersen. By following the suggested route, you will pass by Skt. Hans Kirke (where Hans Christian Andersen was baptized), H.C. Andersens Hus (the birth place of Hans Christian Andersen), Fattigskolen (the school for poor kids that Hans Christian Andersen attended), Hans Christian Andersens Barndomshjem (where Hans Christian Andersen lived during his childhood) and ending the walk at the Odense Cathedral and the town hall of Odense. The walk is app. 1.6 km and will take you trough some nice parts of Odense.

Link to map of the walk



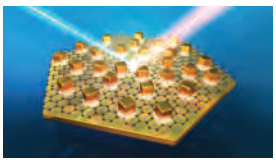


Odense Harbor Bath

What about going for a swim in Odense Harbor Bath in the morning before the conference starts? Odense Harbor Bath resembles the top deck of a ship, with a pool in the center plus sauna and changing facilities are available. The Harbor Bath is open in the morning 6.00-7.30 and later from 11.00-18.30. Access is free of charge. The walking distance from Odense Station to the Harbor Bath is 1 KM.

Address: Gamle Havnekaj 3, 5000 Odense C

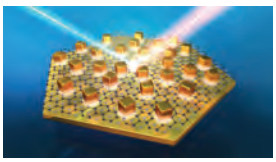
In 2023, Vogue wrote an article about Danish Harbor Baths, which is a year-round activity in Denmark.



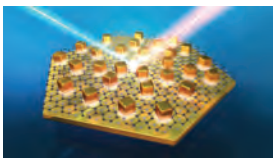
Food and beers at Storms Pakhus!

Grab some food and a beer at Storms Pakhus, which is a very popular street food market in Odense with both indoor and outdoor seating. It is open every day 11.00-23.00. This is a great place to bring your old and new friends from the conference! The walking distance from Odense Station to Storms Pakhus is 500 m.

Address: Lerchesgade 4, 5000 Odense C



Abstracts



Organic Infrared Exciton-Polaritons in Non-fullerene Acceptors Strongly Coupled to an Optical Cavity Mode

Ahmed Gaber Abdelmagid[1], Gaon Yu, Thomas Anthopoulos, and Konstantinos Daskalakis

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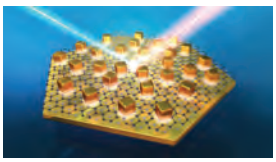
ahmed.abdelmagid@utu.fi

Presentation type: Poster

Strong-coupling between the vacuum electro-magnetic field and the electronic transition in a material results in new light-matter eigenstates called polaritons. In particular, organic polaritons offer an outstanding platform to study and modify the molecular dynamics allowing precise tuning of the molecular energy landscape and photophysical and photochemical properties at room temperature. While organic polaritons have primarily been studied in the visible spectrum, there's a growing need to explore these effects in the infrared range. This is crucial for applications in telecommunications, image sensors, and biomedical devices.

Non-fullerene acceptors used in organic solar cells and photodetectors feature excellent properties such as high oscillator strength, good film quality, and strong photon absorptions in the infrared region. In addition, their solid-state films are developed through a cost-effective and facile methods such as spin coating. This makes them a potential candidate to study organic exciton-polaritons in the infrared.

In this work, different types of non-fullerene acceptors are strongly coupled to a cavity mode. The reflectivity results are fitted to a coupled harmonic oscillator model showing Rabi splitting values $0.8 - 1\,\text{eV}$. Moreover, the effect of cavity parameters such as cavity or mirror thickness on the properties of the polaritons is investigated. These results represent potential path for practical infrared exciton-polariton devices.



Optimizing the Coupling of Light to Plasmons through Engineered Dipolar Scatterers

Saad Abdullah[1], Eduardo J. C. Dias, Jan Krpensky, Vahagn Mkhitaryan, and F. Javier García de Abajo

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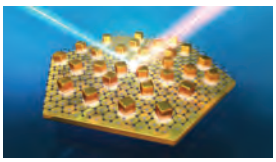
Presentation type: Contributed talk

We experimentally demonstrate a high coupling of light to surface polaritons by means of optimized scatterers (with variable disc diameter D) placed at a suitable distance (z_0) from a polariton-supporting surface. Specifically, we consider poorly-absorbing gold disks acting as nearly-perfect resonant scatterers, which we separate from a gold film by means of a dielectric silica spacer. In this configuration, the scatterer develops a strong induced dipole under external illumination tuned to the particle resonance, which mediates the coupling between light and surface polaritons. However, if the scatterer is too close to the surface, the resonance is quenched by the very same coupling that we intend to achieve, thus reducing the overall dipolar strength and, consequently, the efficiency of the coupling scheme. By separating the particle from the surface, an optimum distance is found for which a compromise between resonance strength (increasing with separation) and efficiency of coupling (decreasing with separation) is optimized. We report experimental results showing nearly complete coupling by means of gold-disk scatterers coupled to plasmon polaritons in a planar gold surface. Thereby, we measure the infrared reflectance spectra of the system, from which we extract the effective polarizability as well as the associated coupling cross sections, which surpass the fundamental limit ~ 2 imposed by the light wavelength for an optimum z_0. These findings provide a disruptive, efficient approach to solving the long-standing problem of unity-order in/out coupling in nanophotonics.



Plasmonic Lattices: Influence of their Collective Response on Strong Light–Matter Hybridization

Vincenzo Aglieri[1], Jacopo Stefano Pelli Cresi, Elena Ghidorsi, and Andrea Toma

[1] *Istituto Italiano di Tecnologia, Genova, Italy*

vincenzo.aglieri@iit.it

Presentation type: Poster

Metallic nanoparticles (NPs) are widely used as plasmonic resonators due to their strong optical response and subwavelength field confinement. These properties make NPs particularly appealing for applications that usually require collective and long-range order effects [1]. If periodically arranged, ensembles of NPs present indeed a stronger response than their individual localized surface plasmon resonances, resulting in a collective array behavior known as surface lattice resonance (SLR) [2]. These collective modes arise from the constructive interference between NPs, thus allowing for a significant improvement of the overall quality-factor. Thanks to their enhanced response, SLRs have been successfully employed to promote interaction under strong coupling (SC) regime with quantum emitters [3,4]. In this study, we investigate the influence of NP periodic arrangement on hybrid light-matter states formation by exploring different high-symmetry geometries such as square, hexagonal and honeycomb lattice structures. To fairly compare the three geometry responses, the arrays have been designed to presents the same SLR wavelength position. In addition, a detailed investigation of the temporal evolution of the strongly coupled systems has been carried out through ultra-fast transient absorption measurements.

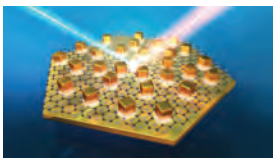
The authors acknowledge support by the European Research Council under the project "REPLY ERC-2020-COG Grant agreement No. 101002422".

[1] Wang W. et al., *The rich photonic world of plasmonic nanoparticle arrays*, Mater. Today 21, 303 (2018).

[2] A. Zundel and A. Manjavacas, *Finite-size effects on periodic arrays of nanostructures*, J. Phys. Photonics 1, 015004 (2019).

[3] R. K. Yadav et al., *Room temperature weak-to-strong coupling and the emergence of collective emission from quantum dots coupled to plasmonic arrays*, ACS Nano 14, 7347 (2020).

[4] A. I. Väkeväinen et al., *Plasmonic surface lattice resonances at the strong coupling regime*, Nano Lett. 14, 1721 (2014).



Tunable Nonlinear Plasmonic Response in Heavily Doped Semiconductor Waveguides

Gonzalo Álvarez-Pérez[1], Huatian Hu, and Cristian Ciracì

[1] *Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia, Arnesano, Italy.*

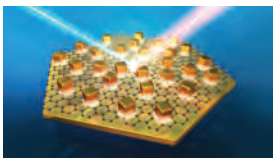
gonzalo.alvarezperez@iit.it

Presentation type: Contributed talk

Heavily doped semiconductors offer a promising platform for nanoscale nonlinear optics due to their unique properties compared to both noble metals and dielectrics. Compared to metals, their lower free carrier densities and smaller effective carrier masses enable stronger nonlocal effects and larger nonlinear active volumes, surpassing noble metals by up to 1000 times. Unlike dielectrics, heavily doped semiconductors evade limitations on nonlinear susceptibilities, making them ideal for nonlinear elements in photonic integrated circuits. Their nonlinear behavior, linked to the kinetic energy of free-electron gas, can be modeled accurately using hydrodynamic equations akin to fluid dynamics.

Here, we design nonlinear plasmonic waveguides using heavily doped semiconductors to enhance third harmonic generation, employing InGaAs/InP for its broad applicability in all-semiconductor photonic integrated circuits. We derive a generalized framework that incorporates a hydrodynamic nonlocal description and enables us to compute second and third harmonic nonlinearities. Based on this, we can predict the power transfer efficiency and optimize the waveguide structure. Gating effects to actively control plasmonic nonlinearities in these structures, crucial for their practical implementation, can also be accounted for in our model.

Nonlinear plasmonic waveguides could be integrated in all-semiconductor photonic circuits, as well as play a key role in emulating, through optical means, the nonlinear activation function, a critical part of the computational power of neural networks.



Exciton-Polariton Mediated Energy Transfer between Layers of Molecules

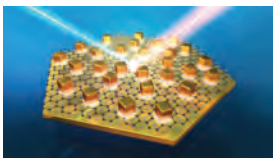
Kristín Björg Arnardóttir[1], Piper Fowler-Wright, Brendon W. Lovett, and Jonathan Keeling

[1] *POLIMA—Center for Polariton-driven Light–Matter Interactions, University of Southern Denmark, Odense, Denmark*

arnardottir@mci.sdu.dk

Presentation type: Poster

The growing field of polariton chemistry calls for a deeper understanding of the role different vibrational modes play in these systems. The low frequency vibrational modes are likely to play an important role, as they can act like a reservoir for energy to facilitate off-resonant transitions. However, the non-Markovian nature of those modes makes them hard to model. One way to capture these effects is using process tensor matrix product operator methods to describe the vibrational environment of the molecules while describing the light using mean-field approximations. Extending this approach to capture multiple species of molecules or different environments, one can model energy transfer between the species or the effect of disorder in the form of inhomogeneous broadening. We will demonstrate the use of this approach to describe a system inspired by a recent experiment that showed that energy in the form of molecular excitations can be transferred between layers of spatially separated layers of two species of molecules through coupling to the same cavity mode. To study this we look at how the emission spectra of the combined system evolve over time, and how this is affected by coupling to a continuum of vibrational modes. We find that the vibrational coupling strength is an important parameter in controlling whether (and how) polariton mediated energy transfer occurs.



Near Zero Index Heterostructures for XUV Plasmonic Waveguides

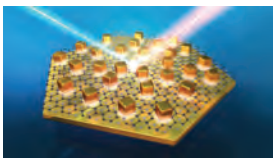
Luca Assogna[1], Carino Ferrante, Alessandro Ciattoni, and Andrea Marini

[1] *Dipartimento di Fisica, Università degli studi di L'Aquila, L'Aquila, Italy*

luca.assogna@student.univaq.it

Presentation type: Poster

In the extreme ultraviolet (XUV) the high absorption, combined with the limited power of current XUV tabletop sources, hamper the disruptive potential for ultrafast spectroscopy and extreme nonlinear optics applications in this regime. Radiation–matter interaction can get enhanced by plasmonic nanostructures, particularly composed of near-zero-index (NZI) media that support slow light propagation. In the present work, we develop a method to localize XUV radiation at the nanometer scale by exploiting NZI heterostructures, with a particular focus on Titanium-Aluminum-Titanium multilayers. By solving fully vectorial Maxwell's equations semi-analytically, we obtain the transcendental dispersion relations of several transverse-electric (TE) and transverse-magnetic (TM) plasmon polariton modes. The dispersion relations of these modes are numerically evaluated using a Newton-Raphson algorithm. We systematically analyze the confinement properties and attenuation length of such modes, discovering that radiation confinement can be efficiently manipulated by the Al thickness. In fact, we observe that 20 nm wavelength radiation can propagate through this kind of heterostructure more than 10 times its wavelength (about 500 nm) and, at the same time, be highly confined (less than 10 nm) at the interface between Titanium and Aluminum. We also find that TM modes offer the best effective mode length for nonlinear XUV applications in correspondence of NZI condition of Al (about 80 nm).



Quantum Surface Effects and Charge Transfer in the Optoelectronic Coupling between Single Emitters and Plasmonic Nanoantennas

Antton Babaze[1], Ruben Esteban, Javier Aizpurua, and Andrei G. Borisov

[1] *Center for Materials Physics CSIC-UPV/EHU, Donostia-San Sebastián, Spain*

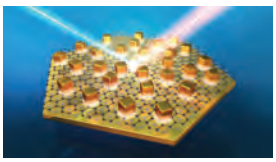
anttonbabaze@dipc.org

Presentation type: Contributed talk

In this work, we explore the optoelectronic response of plasmonic nanoantennas coupled to single emitters via plasmon–exciton interaction at the nanoscale. Our analysis encompasses nonlocality, surface effects, and electron-transfer processes, crucial factors in these complex interactions at the nanoscale. Time-Dependent Density Functional Theory (TDDFT) is used primarily, complemented by the semiclassical Surface-Response Formalism (SRF) that accommodates quantum surface effects via Feibelman parameters in the boundary conditions of Maxwell's equations.

Our results highlight electron spill-out and surface-induced Landau damping as main factors influencing the electromagnetic coupling between plasmonic nanoantennas and single emitters at the nanoscale. These effects induce a redshift and broadening of plasmonic resonances not captured by classical theories. The semiclassical SRF, especially when considering the nonlocal response parallel to the metal surface, accurately accounts for these phenomena.

Moreover, our analysis predicts significant modifications of the optical response in the coupled system at subnanometric distances due to hybridization between the electronic states of the emitter and those of the plasmonic nanoantennas. This electronic exciton–plasmon coupling entirely quenches the emitter electronic transition, profoundly modifying the optical resonances and widths of the coupled structure and impeding strong exciton-plasmon coupling. These findings deepen our understanding of quantum phenomena in nanoscale plasmon-exciton interactions.



Metasurface-enabled Single-photon Emission

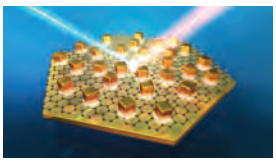
Sergey I. Bozhevolnyi

Centre for Nano Optics, University of Southern Denmark, Odense M, Denmark

seib@mci.sdu.dk

Presentation type: Invited school lecture

Manipulation of single-photon emission from quantum emitters (QEs) has attracted a considerable attention in recent years due to its importance for quantum information technologies. In this lecture, recent progress in on-chip manipulation of the polarization, directionality, and phase distribution in single-photon emission by making use of planar holographic QE-coupled metasurfaces is presented discussing underlying physical mechanisms involved. The realization of single-photon sources with radiation channels exhibiting diverse wavefronts and polarization characteristics is also considered along with the generation of quantum structured light in high dimensions.



Tailoring the Cavity-Induced Interplay of Modes to Enhance Four-Wave Mixing over a Broadband Molecular Fingerprint Regime

Abhik Chakraborty[1], Parijat Barman, Ankit Kumar Singh, Xiaofei Wu, Denis A. Akimov, Tobias Meyer-Zedler, Carsten Ronning, Michael Schmitt, Jürgen Popp, and Jer-Shing Huang

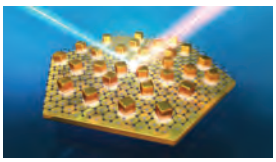
[1] *Institute of Physical Chemistry and Abbe Center of Photonics, Friedrich Schiller University Jena, Jena, Germany*

abhik.chakraborty@uni-jena.de

Presentation type: Contributed talk

For the most effective manifestation of nonlinear nano-optics, a rigorous optimization of the interplay between the electromagnetic modes involved is pivotal. The plasmonic azimuthally chirped grating (ACG) consists of a series of eccentrically displaced rings (grooves) that provides the platform with azimuthally varying grating periodicity and broadband spectral tunability. The azimuthally varying periodicity offers the necessary phase-matching conditions capable of producing field enhancement through in-plane plasmonic surface lattice resonances at certain grating periods of the ACG. In addition to the period-driven effect, the V-shaped grating grooves individually act as hosts of localized surface plasmon resonances. Therefore, at certain other periods of the ACG, the vertical geometry of the individual grooves determine the field enhancement and frequency conversion. With full-wave vectorial analysis and broadband four-wave mixing (FWM) measurements, we shed light on the mode-interplay mechanism to optimize broadband multiphoton processes in a complex periodic system like the ACG.

Furthermore, with the conclusions drawn from the aforementioned work, we demonstrate time-resolved surface-enhanced broadband coherent anti-Stokes Raman scattering from a molecular monolayer deposited on a linear plasmonic grating. Our optical configuration achieves the complete filtering of background FWM noise and delineates the vibrational dynamics of our molecular monolayer with tailored field-enhanced sensitivity over a broadband molecular fingerprint regime.



Madelung's Approach for Obtaining the Hydrodynamic Model of Plasmon-polaritons in Anisotropic Systems

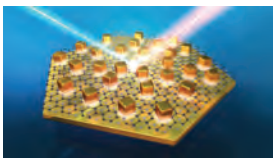
André J. Chaves[1], Diego Rabelo da Costa, Line Jelver, Joel D. Cox, N. Asger Mortensen, and Nuno M. R. Peres

[1] *Grupo de Materiais Semicondutores e Nanotecnologia, Instituto Tecnológico de Aeronáutica, DCTA, 12228-900 São José dos Campos, Brazil*

andrej6@gmail.com

Presentation type: Contributed talk

A hydrodynamic model based on Madelung's formalism for a collective electronic motion in anisotropic materials was derived, including nonlocontributions from the Thomas-Fermi quantum pressure and quantum effects from the Bohm potential. Analytical expressions for the magnetoplasmon dispersion and nonlocal optical conductivity were obtained. As a case study for anisotropic two-dimensional electron gas, we apply our model to electrons in the conduction band of monolayer phosphorene. Our hydrodynamic obtained plasmon dispersion results show a very good agreement with *ab-initio* calculations. Our findings demonstrate that including nonlocal and quantum effects in the optical conductivity inhibits phosphorene to host hyperbolic surface plasmon-polaritons. Therefore, it is fundamental to go beyond the local approximation in those anisotropic systems that can support strongly confined plasmon-polaritons.



Prevalence of Photonic Topology

Thomas Christensen

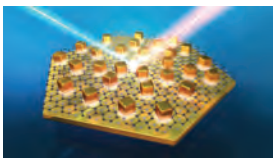
Department of Electrical and Photonics Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark

thomas@dtu.dk

Presentation type: Invited talk

Photonic band topology has generally been associated with exotic behavior and, consequently, has implicitly been regarded as a rare phenomenon. To assess whether this association is in fact warranted, we have conducted a large-scale sampling of randomly generated two-dimensional photonic crystals, evaluating various kinds of band topological properties [1]. The results of this sampling show that photonic topology is generally widely prevalent statistically. However, it is rare to find photonic band topology in conjunction with desirable spectral features, such as large band gaps or frequency-isolated features. Motivated by this, I will outline an approach to automate the search for such cases, using inverse design, with examples spanning photonic Chern, Weyl, and nodal line phases [2].

[1] Ghorashi, Vaidya, Rechtsman, Benalcazar, Soljačić, & Christensen, arXiv, 2307.15701 (2023).
[2] Kim, Christensen, Johnson, & Soljačić, ACS Photonics 10, 861 (2023).



Free-electrons optical nonlinearity in semiconductors

Cristian Ciracì

Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia, Arnesano, Italy.

cristian.ciraci@iit.it

Presentation type: Invited talk

The control and the concentration of light at subwavelength scales are of extreme importance for the realization of integrated optical technologies, especially to reach operational efficiencies in devices based on nonlinear optical effects. In this context, the study of light interaction with free electrons (FEs), i.e. plasmonics, in materials characterized by a high carrier density has a central role. Notoriously, noble metals have been the main material choice for plasmonic devices in the visible spectrum for many years. Heavily doped semiconductors (i.e. with charge densities $n_0 \sim 10^{10} - 10^{20}\,\mathrm{cm}^{-3}$), on the other hand, have recently emerged as alternative materials for plasmonics in the near-infrared (NIR), $0.8 < \lambda < 2\,\mu$m, and in the mid-infrared (MIR), $2 < \lambda < 20\,\mu$m. Being low-loss high-quality materials that can be compatible with standard microelectronics fabrication processes and being their optical response tunable through electrical or optical doping, heavily doped semiconductors offer a unique perspective for integrated optical devices in the NIR and in the MIR.

In this talk we investigate the origin of ultrafast optical nonlinearity in plasmonic systems by employing doped semiconductors instead of metals, leveraging on the degree of tunability provided by doping [1]. Tuning the plasma frequency allows us to compare nonlinear efficiency measurements with advanced hydrodynamic modeling of the nonlinear response. We show that the nonlinearity comes from the collective electronic motion rather than from the sum of the local response of individual electrons.

These results have profound implications in understanding how collective excitations leads to nonlinearity in plasmonic systems.

This research was funded by the European Innovation Council (NEHO, 101046329).

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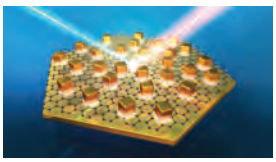

Subradiant Entanglement in Nanoplasmonics via Dissipation

Angus Crookes[1], Ben Yuen, and Angela Demetriadou

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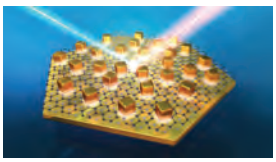
Presentation type: Contributed talk

Recent advances in nanoplasmonics offer the potential for generating quantum entanglement at room temperature via dissipation. However, in contrast to high finesse cavities, quantum emitters in plasmonic systems interact with multiple dissipative and broadband modes with large field enhancements. In this work, we demonstrate that these many plasmonic modes play an important role in the formation of subradiant entanglement. We find that due to a combination of even and odd plasmonic modes, quantum emitters experience both symmetric and anti-symmetric coupling, which results in the total loss of entanglement. To address this challenge, we design a new plasmonic nanocavity that suppresses odd modes in the region that the quantum emitters reside, enabling robust subradiant entanglement. Our results open exciting prospects for generating entanglement at room temperature through harnessing simple plasmonic setups.



Analysis of Guided Mode Quasi-bound States in the Continuum Resonances in Various Material Platforms

Christopher Damgaard-Carstensen[1] and Sergey I. Bozhevolnyi

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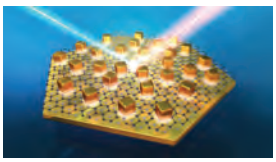
Presentation type: Poster

Quasi-bound states in the continuum (qBICs) provide the opportunity of achieving very high quality factor (Q-factor) resonances, which allows for enhanced light matter interactions and very narrow resonances. Both these advantages are beneficial when designing ultrafast and ultrathin electro-optical modulators. Herein, we present a thorough computational analysis of the presence and behavior of qBICs based on the periodic perturbation of photonic guided modes in the near-infrared to telecom wavelength range and for various material platforms, i.e., both all dielectric, metal-insulator-metal, and combinations thereof. We consider various dielectric materials with a focus on lithium niobate as it is a suitable electro-optic material for realization of dynamic optical metasurfaces for modern highly integrated optics and photonics. This analysis gives an overview of the presence and behavior of qBICs and allows for simpler decision-making on the applicability of qBICs for future works.



Encapsulated Void Resonators in a Lossy Dielectric van der Waals Heterostructure

Dorte R. Danielsen[1], Avishek Sarbajna, Laura N. Casses, Nicolas Stenger, Peter Bøggild, and Søren Raza

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Presentation type: Contributed talk

Nanostructured high-refractive-index materials that host Mie resonances provide control of light–matter interaction due to the resonant confinement of light inside the materials. However, Mie resonators require near-lossless materials to ensure that the light is reradiated and not absorbed. This limits the range of suitable materials as well as the spectral range of operation [1]. In contrast, when light is confined in air surrounded by a high-refractive-index material, so-called Mie voids, the same material constraints do not apply. Mie voids have been studied theoretically [2] and recently demonstrated experimentally for the first time in silicon [3].

We experimentally realize Mie voids in bulk tungsten diselenide and develop a theoretical framework to separate different resonant pathways of the Mie void system. The presence of Mie voids is supported by far-field reflectance measurements and near-field scanning optical microscopy. By utilizing van der Waals heterostructure assembly to transfer flakes of tungsten diselenide as well as hexagonal boron nitride on top of the voids, we realize encapsulated Mie voids for the first time. Encapsulation allows us to engineer the void volume and shift the void resonances to shorter wavelengths. The flexibility of van der Waals heterostructure assembly makes our device architecture readily applicable to other material combinations.

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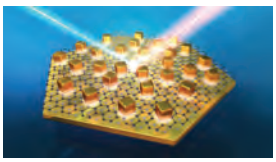

Entanglement in Extreme Nanophotonic Cavities

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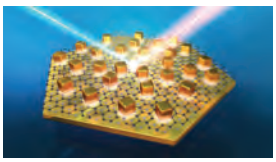
Presentation type: Invited talk

Light-matter strong coupling at room temperature can be reached with molecular emitters placed in plasmonic gaps. This has paved the way for controlling quantum matter with light, and ultimately generating quantum states at room temperature, without the complex and cumbersome experimental methods required at cryogenic temperatures. Since the first experimetal demonstration of strong coupling at room temperature, we have gained a lot of understanding on how light-matter interactions occur at such small plasmonic gaps. Here, we use a quantum electrodynamics description for an open cavity to obtain the quantum dynamics of the system, and demonstrate persistent sub-radiant states formed between 2 or more quantum emitters residing within plasmonic nanocavities. Although the Rabi oscillations between the plasmon and emitters decay very fast (within few tens of fsec), the sub-radiant states persist for up to 100 fsec, limited only by the inherent non-radiative losses of the molecular emitters chosen.



Su-Schrieffer-Heeger Quasicrystal: Topology, Localization, and Mobility Edge

Daniel de Abreu Miranda[1], Tiago Antão, and Nuno M. R. Peres

[1] *Departamento de Física, Universidade do Minho, Braga, Portugal*

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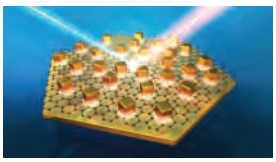
Presentation type: Poster

In this paper we discussed the topological transition between trivial and nontrivial phases of a quasi-periodic (Aubry-André like) mechanical Su-Schrieffer-Heeger (SSH) model. We find that there exists a nontrivial boundary separating the two topological phases and an analytical expression for this boundary is found. We discuss the localization of the vibrational modes using the calculation of the inverse participation ratio (IPR) and access the localization nature of the states of the system. We find three different regimes: extended, localized, and critical, depending on the intensity of the Aubry-André spring. We further study the energy dependent mobility edge (ME) separating localized from extended eigenstates and find its analytical expression for both commensurate and incommensurate modulation wavelengths, thus enlarging the library of models possessing analytical expressions for the ME. Our results extend previous results for the theory of fermionic topological insulators and localization theory in quantum matter to the classical realm.



3D Printing of Self-Assembled Metallic Architectures: Fabrication Perspectives and its Application in Plasmonics, Quantum photonics and Biosensing

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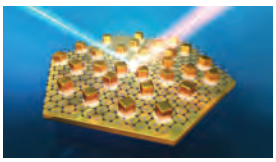
Presentation type: Contributed talk

Self-assembled plasmonic clusters are renowned for producing custom optical properties by manipulating electromagnetic fields at sub-wavelength scales. Engineering and fabricating three-dimensional (3D) metallized architectures enable us to delve into new realms within plasmonics, photonics, nanoelectronics, and sensing. Utilizing a custom 3D printer with a femtoliter meniscus guided self-assembly on a motorized XYZ stage, we've fabricated diverse 3D architectures. By fine-tuning the nanoparticle solution's concentration, pulling speed, material mix ratio, and stage movements, we create an extensive range of self-assembled 3D geometries, compositions, and forms. This method uses a broad spectrum of materials, including metallic/dielectric nanoparticles, quantum dots, and biomaterials, facilitating the creation of versatile nanostructures. Our research uncovers exceptional plasmonic resonances, mode manipulations, and precise light directionality. Integrating quantum dots enhances photoluminescent intensity, emission dynamics, and narrows Z-directional projection. Moreover, combining surface-engineered biomaterials with metallic NP clusters has yielded a biosensor platform for detecting virus variants and diagnosing ophthalmic diseases. Our 3D printing approach promises a simplified, low-cost fabrication of diverse free-form structures on any substrate, opening up vast possibilities across various domains.



Active Control of Smith-Purcell Radiation Emission Using Graphene Ribbons

Eduardo J. C. Dias[1], Theis P. Rasmussen, Á. Rodríguez Echarri, F. Javier García de Abajo, and Joel D. Cox

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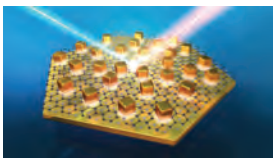
Presentation type: Poster

Smith-Purcell radiation, a phenomenon arising from the interaction between charged particles and periodic structures, holds immense promise for various applications, from particle accelerators to broadband radiation sources.

In this study, we propose a novel approach to actively control and tune the emission of Smith-Purcell radiation in free space by leveraging the unique properties of graphene ribbons. Specifically, by adjusting the doping of individual graphene ribbons within an array, we demonstrate precise control over the directionality of Smith-Purcell radiation. The fact that the doping level of graphene can be actively tuned though electrical gating provides our system with a versatile knob to control the emission properties of the array with a large degree of precision.

Furthermore, we explore additional mechanisms for achieving a controllable level doping in each ribbon, including optothermal doping techniques through spatially-modulated high-intensity laser pulses. This mechanism not only enables the fine-tuning of the emission characteristics, but also provides a practical platform for the experimental investigation of such effects while also offering insights into the underlying physics governing the ultrafast thermal dynamics in graphene-based systems.

Our findings pave the way for the development of advanced Smith-Purcell radiation sources with tailored and actively-controllable emission properties, opening up new avenues for applications in spectroscopy, sensing, and communication.



Geometrical Anticorrelations: Changing the Photon Statistics with the Geometry of the Electromagnetic Environment

Blas Durá-Azorín[1], Alejandro Manjavacas, and Antonio I. Fernández-Domínguez

[1] *Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain*

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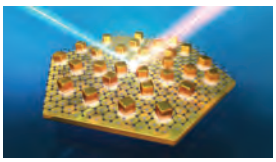
Presentation type: Poster

The study of the second order temporal coherence of the electric field has lead to several important concepts such as photon bunching and antibunching, photon anticorrelations and, in general, have demonstrated the intrinsic quantum nature of light. Nevertheless, the second order spatial coherence has been much less analyzed. In this work, we study how the spatial correlations of the light emitted by two quantum emitters, modelled as two-level systems, can be totally modified by the geometry of the electromagnetic environment due to interferences between the indistinguishable optical pathways of pairs of photons. Moreover, we show how the $g^{(2)}(r, r'; \tau = 0)$ can vanish for special pairs of points, independently of the steady state of the emitters. We derive an expression for the $g^{(2)}$ in general electromagnetic media in terms of the dyadic Green's function and we apply our theory to the next simplest case beyond the free-space: two emitters placed over a substrate. We find that the position of the zeros in the $g^{(2)}$ are totally different from those of the free-space, as well as the complete map of correlations. Some of these zeros are also independent of the electric permittivity of the substrate and the emitters' dipole moments. The only conditions are that both dipoles have to be oriented in the same direction, and the distance between them has to be larger than their natural wavelength.



Shaping Free Electron Wavepackets with Structured Light

Sven Ebel[1] and Nahid Talebi

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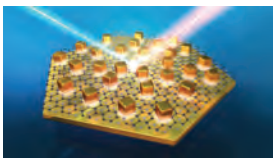
Presentation type: Poster

Controlling free-electron momentum states is of high interest in electron microscopy to achieve momentum and energy resolved probing and manipulation of physical systems. Free-electron and light interactions have emerged as a powerful technique to accomplish this. Here, we demonstrate both longitudinal and transverse phase control of a slow electron wavepacket by extending the Kapitza-Dirac effect to spatially-structured pulsed laser beams. This extension enables both inelastic and elastic stimulated Compton scattering. The interaction reveals the formation of distinct electron transverse momentum orders, each demonstrating a comb-like electron energy spectrum. By exerting complete control over light parameters, including wavelength, field intensity, pulse duration, and spatial mode order, as well as their combinations, it is possible to coherently control the population of these electron energy-momentum states that are separated by a few meV energy and multiple photon momentum orders. This free-space electron-light interaction phenomenon possesses the capability to coherently control the energy and momentum of electron beams in electron microscopes. Moreover, it has the potential to facilitate the selective probing of various material excitations, including plasmons, excitons, and phonons, and performing matter-wave interferometry with transversely shaped electron beams.



Required Nanoscale Precision for High Efficiency Metalenses

Villads Egede Johansen[1], Uur Meriç Gür, Jade Martınez-Llinàs, Jesper Fly Hansen, Akbar Samadi, Maria Skak Vestergaard Larsen, Theodor Nielsen, Fredrik Mattinson, Moritz Schmidlin, N. Asger Mortensen, and Ulrich J. Quaade

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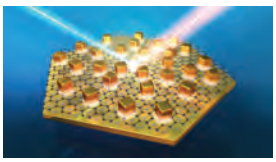
Presentation type: Contributed talk

Focusing Efficiency is a critical parameter for metalenses in many applications, yet there is little available literature on how to achieve this experimentally. In this presentation we combine measurements and simulations to show which nanoscale precision is required to obtain as-simulated performance.

In detail: Metalenses are flat lenses, where sub-wavelength, so-called meta-atoms manipulate the electric field to perform a given lens function. The lenses are slowly but surely making their way into commercial products but are limited in applicability due to their achromatic behaviour and low efficiency. Achromaticity is not an issue for laser sensing applications, but high efficiency is necessary to reduce stray light and stay within the power budget. While there are many reports showing simulated efficiencies above 90% for low numerical apertures (NA), there is a limited amount of experimental reports confirming such high efficiencies. In this study we therefore realise a set of lenses with varying NAs from 0.08 to 0.93 using electron-beam lithography. The low NAs were expected to fit the model, and the higher NAs determine the validity range of the model. We find that measured efficiencies above 92% for NA= 0.24 are achievable, and that a slight modification of the simulation model extends its validity to NA= 0.6. Based on the results, we argue that the efficiencies reported in the literature are often influenced by low-fidelity manufacturing.



Controlling Exciton Polaritons by Nanopatterning Thin Film WSe_2

Khairi Fahad Elyas[1], Hannah C. Nerl, Christoph T. Koch, and Katja Höflich

[1] *Ferdinand-Braun-Institut (FBH), Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany*

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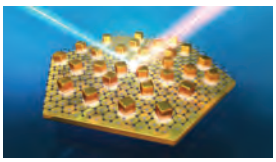
Presentation type: Poster

Polaritons in 2D materials exhibit enhanced light–matter interactions, which makes them interesting for low-loss, highly confined light transport. The semiconducting transition metal dichalcogenide (TMDC) WSe_2 is especially interesting as it supports exciton polaritons, i.e. Coulomb bound electron hole pairs coupled to the electromagnetic field, at room-temperature. Here, we study exciton polaritons in patterned and unpatterned thin film WSe_2 using a combination of helium ion microscopy and scanning transmission electron microscopy (STEM) electron energy-loss spectroscopy (EELS).

Samples were produced by dry transfer using polydimethylsiloxane (PDMS) and poly(propylene) carbonate (PPC) films due to their favourable viscoelastic and thermoplastic properties. The geometry of the 2D-materials was modified using HIM patterning. Beam settings and scanning routines had to be optimized to mitigate damage of the crystal lattice. The patterned WSe_2 were studied to first evaluate possible beam induced damage and to map out the local exciton intensity at the nanoscale.

The cut edges from nanopatterning exhibited similar behavior to natural edges in 2D materials. Both were found to host edge polaritons using STEM EEL spectral mapping, which lead to localized enhancement of typical energy-loss peaks near the edges. This suggests that it is possible to control exciton polaritons by using HIM nanopatterning in TMDCs.



Polariton-mediated Modification of Material Properties

Johannes Feist

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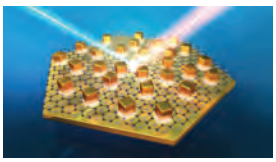
Presentation type: Invited talk

The use of cavity quantum electrodynamical effects to modify material properties has rapidly gained popularity and interest in the last decade. A canonical example is given when light and matter are coupled strongly enough to overcome dissipation, leading to the formation of polaritons, hybrid light-matter states. Polaritons inherit properties of both light and matter excitations and additionally display fundamentally new phenomena. I will discuss several topics related to this overall field, including the modification and photophysics and photochemistry in organic molecules, some fundamental results and pitfalls for the modification of low-energy excitations, and recent progress on few-mode field quantization in complex nanophotonic structures, i.e., strategies to obtain cavity-QED-like models for arbitrary cavity geometries and materials.



Effects of Strain and Electron Transfer on the Exciton Density of Monolayer MoS_2 on Plasmonic Silver Nanoparticle Chains

Javier Fernández-Martínez[1], Herko P. van der Meulen, Pablo Ares, Daniel Gallego Fuente, David Hernández Pinilla, Guillermo López Polín, Julio Gómez Herrero, Mariola O. Ramírez, and Luisa E. Bausá

[1] *IFIMAC - Condensed Matter Physics Center, Universidad Autónoma de Madrid, Madrid, Spain*

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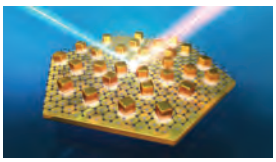
Presentation type: Poster

Monolayer (1L) transition metal dichalcogenides (TMDs), such as 1L-MoS_2, are promising candidates for the development of next-generation optoelectronic devices due to their direct optical gap and atomic thickness. TMD electronic properties can be readily tuned by strain, which enables, among other effects, bandgap control and quasi-particle conversion.

Here, we study the combined effects of strain and electron transfer on 1L-MoS_2 photoluminescence (PL) when it is placed on top of a metallic chain of Ag NPs grown on a $LiNbO_3$ substrate. At 10 K the strain produced by the metallic chain on 1L-MoS_2 results in a pronounced redshift and broadening of the spectral line associated with the A exciton, in contrast with the smooth spectral changes observed at RT. This behaviour is related to the thermal expansion coefficient mismatch between the $LiNbO_3$ substrate and the 1L MoS_2, which leads to a notable strain increase at 10 K.

Moreover, opposite to the exciton-to-trion transformation usually observed under inhomogeneous strain in MoS_2, a trion-to-exciton conversion is detected in the vicinity of the metallic chain. This effect is attributed to the presence of the metallic chain, which allows electron transfer between the 1L-MoS_2 and the Ag NPs and induces a localized exciton density enhancement in the proximity of the chain.

The results show the potential of integrating 2D semiconductors and plasmonic nanostructures for exploring strain-driven phenomena and quasiparticle conversion and opens a pathway for novel optoelectronic devices.



Quantum Interactions of Free Electrons and Confined Optical Modes

F. Javier García de Abajo

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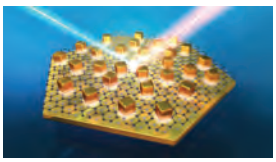
Presentation type: Invited school lecture

The synergetic combination of electron microscopy and ultrafast optics has given birth to ultrafast electron microscopy as a research field aiming to investigate material excitations with an unprecedented combination of spatiotemporal resolution. In this presentation, we will overview the fundamental principles ruling the interactions between free electrons, light, and photonic nanostructures, with an emphasis on exploring quantum aspects that include electron decoherence caused by coupling to radiative modes, the generation of quantum states of light, and the emergence of non-classical distributions of electron and photon fields after interaction. In particular, radiative decoherence could be potentially useful to sense the presence of distant objects and measure the vacuum temperature, the study of quantum correlations between electrons and surface polaritons could enable the generation of single and entangled photons, and measurement of the statistics imprinted on the post-interaction states of electrons and radiation could serve as a quantum tomography tool.



GRANAD: GRAphene Nanoantennas with ADatoms toolbox

Abhishek Ghosh[1], David Dams, Garnett Bryant, Andres Ayuela, Carsten Rockstuhl, Marta Pelc, and Karolina Słowik

[1] *Institute of Physics, Nicolaus Copernicus University in Toruń, Toruń, Poland*

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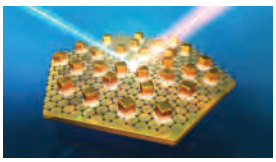
Presentation type: Poster

Understanding the optoelectronic properties of mesoscopic graphene nanoflakes and one-dimensional polymer chains with adatom defects presents significant conceptual and computational challenges. Traditional methods, including commercially available software, may lack the capability to capture quantum effects at this scale, while ab initio quantum mechanical approaches are computationally demanding. To address this gap, we introduce GRANAD: the GRAphene Nanoantennas with ADatoms toolbox, an open-source software package.

GRANAD employs the tight-binding approximation to model the underlying matter and treats light semiclassically. With a focus on mesoscopic systems, GRANAD utilizes a single electron mean-field method for many-body systems, where interactions are mediated through non-linearities in the Hamiltonian [1,2]. It evolves the system using a Lindblad-like master equation for the spin-traced one-particle reduced density matrix, incorporating dissipative processes within the master equation. This approach allows GRANAD to calculate various static quantities such as the energy landscape, density of states, absorption spectra, and dynamic quantities like induced dipole moment and energy-based plasmonicity index (EPI) [3].

GRANAD's foundational implementation relies on conventional Python-based object-oriented programming. However, its core functions are crafted using the functional programming paradigm with GOOGLE's JAX library, enabling an auto-differentiation feature. This functionality, for instance, allows for automatic electric field optimization to elicit a desired response from a nanostructure. Moreover, this JAX implementation demonstrates significantly faster performance on GPU compared to conventional CPU implementations. The complete source code and documentation for GRANAD can be found at [4].

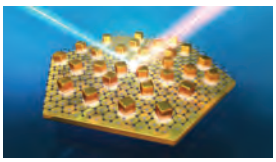
[1] J. D. Cox and F. J. García de Abajo, *Electrically tunable nonlinear plasmonics in graphene nanoislands*, Nat. Commun. 5, 5725 (2014).



[2] M. Kosik et al., *Revising quantum optical phenomena in adatoms coupled to graphene nanoantennas*, Nanophotonics 11, 2281 (2022).

[3] M. M. Müller et al., *Energy-based plasmonicity index to characterize optical resonances in nanostructures*, J. Phys. Chem. C 124, 24331 (2020).

[4] D. Dams et al., *GRANAD — Simulating GRAphene Nanoflakes with ADatoms*, submitted.



Polaritonic Confined System, Study of Correlation Functions beyond a Mean-Field Approach

Maria Vittoria Gurrieri[1], Kristín Björg Arnardóttir, Philip T. Kristensen, and Jesper Mørk

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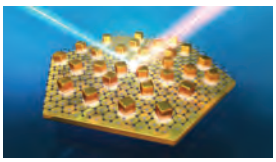
Presentation type: Poster

This work investigates the first and second-order temporal correlation functions of a spatially confined polaritonic system interacting with a reservoir of excitons. The model system consists on a 2D semiconductor sheet coupled to a dielectric nanocavity with deep subwavelength confinement and a spectrally isolated mode. The interaction between the confined polariton state and an exciton continuum is modelled using a Born-Markov master equation in the formalism of Exciton Reaction Coordinates. To predict the polariton emission spectrum, our study involves a comprehensive analysis of the two-time first-order correlation function $g^{(1)}(t)$. We compare the numerical results from full master equations with analytic results obtained by applying the quantum regression theorem and the cumulant expansion, including progressively higher-order terms. A comparison with previous models derived from translationally invariant systems reveals intriguing differences in the spectrum, which are attributed to the existence of a single isolated polaritonic state. Furthermore, we study the zero point of the second-order correlation function $g^{(2)}(0)$ using a beyond-mean-field approach. When the system is tuned below a critical temperature that permits the detection of a macroscopic polariton population, the trend of $g^{(2)}(0)$ deviates from thermal-like emissions. This deviation is noticed in the vicinity of a kink in the polariton population, corresponding to stimulated emission into the condensate. However, the value of $g^{(2)}(0)$ remains approximately 2 and does not suggest a transition to lasing.



Nonlocal Effects in Emitter–Plasmon Interactions

Mikkel Have Eriksen[1], Christos Tserkezis, N. Asger Mortensen, and Joel D. Cox

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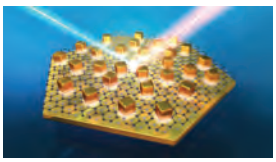
Presentation type: Poster

Light–matter interactions in nanoscale systems consisting of quantum emitters in plasmonic environments offer avenues to explore quantum mechanics while promising applications within fields such as information technologies and sensing. Nonlocal and quantum mechanical corrections to models of the optical response in noble metal nanostructures become increasingly crucial when the relevant length scales in hybrid nanostructures reach the few-nanometer regime. To address this, we include surface response functions (SRFs) in the form of Feibelman d-parameters at metal-dielectric interfaces. We show that SRFs dramatically influence the optical response of metallic nanostructures—also affecting quantum electrodynamic phenomena, such as the Purcell enhancement and Lamb shift, in quantum emitters close to noble metal nanostructures. When increasing the permittivity of the dielectric material interfacing a noble metal, the corrections become more pronounced when calculating the SRFs using the specular-reflection model. Furthermore, the role of SRFs is enhanced in nanostructures characterized by large surface-to-volume ratios, such as thin planar metallic films or shells of core–shell nanoparticles. Decreasing the width of the metal region or elevating the permittivity of the dielectric materials results in larger changes in the Lamb shift, Purcell enhancement, and spontaneous emission spectrum of nearby emitters due to the SRFs in the metallic nanostructure.



He-ion Beam Milling of High-end Plasmonic Nanostructures: Forces, Strong coupling, Nonlinearities

Bert Hecht

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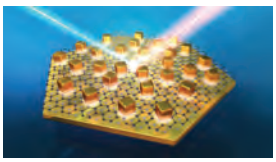
Presentation type: Invited school lecture

The precision afforded by He-ion beam milling on monocrystalline gold and silver flakes presents an opportunity to tailor local fields at an unprecedented level of 1 nm. This method enables the fabrication of intricate structural details, which can be used to create nanoresonators and antennas with unique properties. We leverage these capabilities to create devices that exhibit local symmetry breaking, ultrasmall mode volumes, and precise chiral scattering.

[1] J. Meier et al., *Second harmonic generation from plasmonic hotspots by controlled local symmetry breaking*, Adv. Opt. Mater. 11, 2300731 (2023).
[2] H. Groß et al., *Near-field strong coupling of single quantum dots*, Sci. Adv. 4, eaar4906 (2018).
[3]X. Wu et al. *Light-driven microdrones* Nat. Nanotechnol. 17, 477 (2022).



Nonlinear Plasmonics in Nanostructured Phosphorene

Line Jelver[1] and Joel D. Cox

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Presentation type: Contributed talk

Phosphorene has emerged as a candidate material for optoelectronics as well as extreme-ultraviolet and attosecond nanophotonics due to the excellent nonlinear optical properties as well as the possibility of actively tuning the light–matter interaction through chemical doping and patterning of the two-dimensional crystal [1–4]. In this work [5], we introduce a second-principles framework based on density functional theory (DFT) and maximally localized Wannier functions (MLWFs) which enables the calculation of the plasmonic resonances as well as their related nonlinearities in the optical response of phosphorene nanoribbons (PNRs). We present highly tunable plasmonic resonances which, due to the anisotropy of the crystal structure, can be tuned both in terms of the edge termination, doping level, and width of the ribbons to result in an excellent nonlinear response and high-harmonic generation.

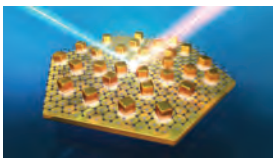
[1] Z.-Y. Chen and R. Qin, *Strong-field nonlinear optical properties of monolayer black phosphorus*, Nanoscale 11, 16377 (2019).

[2] F. Hipolito and T. G. Pedersen, *Optical third harmonic generation in black phosphorus*, Phys. Rev. B 97, 035431 (2018).

[3] A. Autere et al., *Rapid and large-area characterization of exfoliated black phosphorus using third-harmonic generation microscopy*, J. Phys. Chem. Lett. 8, 1343 (2017).

[4] N. Youngblood et al., *Layer-tunable third-harmonic generation in multilayer black phosphorus*, ACS Photonics 4, 8 (2017).

[5] L. Jelver and J. D. Cox, *Nonlinear plasmonics in nanostructured phosphorene*, ACS Nano 17, 20043 (2023).



Quantum Emitters in Coupled Plasmonic Nanocavities

Ishita Jena[1], Angus Crookes, Ben Yuen, and Angela Demetriadou

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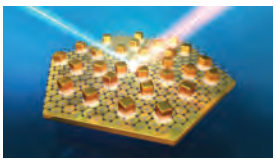
Presentation type: Poster

Plasmonic nanocavities hosting multiple quantum emitters offer an exciting platform to generate subradiant entangled states at room temperature. However, it is not experimentally possible to initialize the system with only one quantum emitter in an excited state, a key ingredient in the formation of subradiant entanglement, since they are all located in the same nanocavity and just few nanometres away from each other. In this work, we design a new nanoplasmonic system of two coupled plasmonic nanocavities, each hosting a single quantum emitter. The two nanocavities can be placed far from each other to allow for the separate external excitation and driving of each nanocavity, and the quantum emitter it hosts. The quantum dynamics of this system show mode beating both between plasmonic modes and the quentum emitters, with interesting regimes emerging. By driving the system in a specific way, one can engineer quantum states in a plasmonic system. Our results open exciting prospects for complex quantum technologies using simple plasmonic setups.



Improving Photocatalytic Efficiency in Porous Shell Resonators

Xin Jin[1], Vincenzo Aglieri, Marzia Ferrera, Andrea Toma, and Luca Razzari

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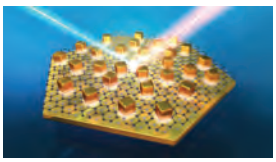
Presentation type: Poster

Developing green energies is crucial in combating climate change. Hydrogen gas, with three times the energy of conventional gasoline, offers an efficient, emission-free alternative to fossil fuels. However, 98% of current hydrogen production relies on unsustainable sources, leading to significant carbon emissions. Photocatalytic water splitting, using solar light to produce hydrogen, provides a clean and renewable solution. For example, semiconducting titanium dioxide (TiO_2) can serve as a photocatalyst, strategically aligning with the water redox potential. Besides, plasmon-assisted photocatalysis, utilizing metallic nanoparticles (NPs) with surface plasmon resonances (SPRs), enhances sunlight absorption in the visible range. Furthermore, resonant cavities, especially those supporting whispering gallery modes (WGMs), can also boost photocatalytic activity by enhancing light harvest and field enhancement. This work explores photocatalytic hybrids with Au NPs fully enclosed in porous TiO_2 shells, efficiently confining light while facilitating water access. Numerical simulations demonstrate significantly higher optical absorption in the porous TiO_2 shell than in unstructured TiO_2 or water, showcasing its potential for photocatalytic applications. Further analysis, such as hot electron generation rates and alternative resonant cavity designs, will be presented on-site.

The authors acknowledge support from the European Union under the projects: "REPLY ERC-2020-COG Grant agreement No. 101002422" and "HORIZON-MSCA-DELATOP Grant agreement No. 101105312".



Mapping Light-Matter Interactions Using Ultrafast Free Electrons

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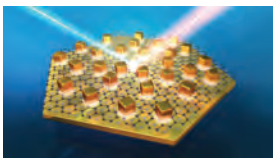
Presentation type: Invited keynote talk

Abstract TBA



Exciton-polaritons and Nonlocal Plasmon-polaritons for Emission and Field Enhancement

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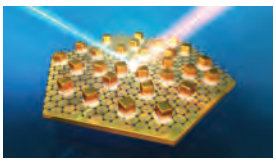
Presentation type: Invited talk

In the first part of the talk, we will discuss our recent work on modifying the emission from molecular emitters beyond the Purcell effect using the collective strong light-matter coupling regime. In planar microcavities, we find that an important process that can dramatically change molecular kinetics is the rapid dephasing of polaritons to dark states, which is absent outside of the cavity. This process can lead to changes in luminescence efficiency and also to the prompt and delayed lifetime of emitters. In the second part of the talk, we will talk about experiments on field enhancement in epsilon-near-zero (ENZ) photonic gap antennas. Initial full wave calculations predicted strongly localized modes with a broadband response. Experiments using third harmonic generation as a probe of the field enhancement, however, showed sharp peaks on top of the broadband response. We find that including nonlocal corrections to the ENZ material's dielectric response can explain the emergence of such peaks. Surprisingly, our modelling predicts a larger field enhancement with nonlocality than in the local case.



Inverse Design of Polariton Devices

Oliver Kuster[1], Yannick Augenstein, Thomas Sturges, and Carsten Rockstuhl

[1] *Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany*

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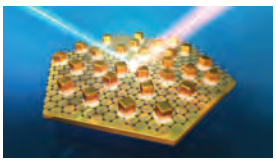
Presentation type: Contributed talk

Polaritonics has shown to be a promising candidate for optoelectronic devices. By using strong light–matter coupling inside microcavities, efficient interfaces between electronic and optical devices can be implemented using polariton condensates. Recent advances in polaritonics allow us to generate polariton condensates at room temperature using organic semiconductors. In addition, improved fabrication methods allow us to manipulate the effective potential the polariton condensate experiences at even smaller scales. Here, we present a polariton device inversely designed using topology optimization. Using gradient-based optimization, we can implement a free-form optimization of the effective potential to design polaritonic devices with desired functionality. In particular, we present a flat top potential, which allows us to generate a square polariton condensate distribution with a constant amplitude profile.



Spherical Topological Insulators in Light–Matter Interactions

Nikolaos Kyvelos[1], Vassilios Yannopapas, N. Asger Mortensen, and Christos Tserkezis

[1] *POLIMA—Center for Polariton-driven Light–Matter Interactions, University of Southern Denmark, Odense, Denmark*

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Presentation type: Poster

In this study, we investigate the optical characteristics of Bi_2Se_3 topological-insulator nanospheres [1], emphasizing their distinctive features such as a notable dielectric function and topologically protected surface states within the terahertz (THz) range. Employing a comprehensive electrodynamic framework and considering discretized, closely spaced surface states, we highlight the appearance of previously unreported magnetic modes induced by Dirac plasmon polaritons resulting from interactions between terahertz photons and Dirac electrons. Furthermore, we observe their significant influence on the electric and magnetic transitions of quantum emitters in proximity to Bi_2Se_3 nanospheres, leading to high Purcell factors [2]. These findings indicate that Bi_2Se_3 nanospheres exhibit a rich optical response, stemming from both bulk and topologically protected surface states, making them promising candidates for enhancing strong light–matter interactions [3,4] in the fields of topological nanophotonics [5] and THz technologies.

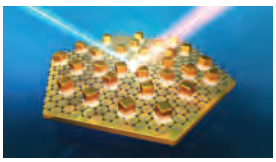
[1] N. Kyvelos et al., *Dirac plasmon polaritons and magnetic modes in topological-insulator nanoparticles*, ACS photonics 11, https://doi.org/10.1021/acsphotonics.4c00265 (2024).

[2] N. Kyvelos et al., *Quantum interference in spontaneous decay of a quantum emitter placed in a dimer of bismuth-chalcogenide microparticles*, Photonics 9, 596 (2022).

[3] C. Tserkezis et al., *On the applicability of quantum-optical concepts in strong-coupling nanophotonics*, Rep. Prog. Phys. 83, 082401 (2020).

[4] G. D. Chatzidakis and V. Yannopapas, *Strong electromagnetic coupling in dimers of topological-insulator nanoparticles and quantum emitters*, Phys. Rev. B 101, 165410 (2020).

[5] N. A. Mortensen et al., *Topological nanophotonics*, Nanophotonics 8, 1315 (2019).



Strain Engineering Valley Polarization in Monolayer Transition Metal Dichalcogenides

Yonas Lebsir[1], Torgom Yezekyan, N. Asger Mortensen, and Sergii Morozov

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Presentation type: Poster

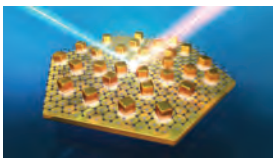
This research explores using non-uniform strain through specific nanostructures to boost trion emission and cause electron funneling in monolayer transition metal dichalcogenides (ML TMDs). Trions in ML TMDs exhibit increased valley polarization, making strain useful for quantum applications. For higher applicability, measurements these studies are performed at room temperature.

Non-uniform strain can be used to enhance trion emission and induce electron funneling in monolayer transition metal dichalcogenides (ML TMDs) [1,2]. In this work, we induce strain in ML TMDs using nanoscale objects with different sizes and shapes to further investigate and optimize the previously observed, increased trion formation under optical excitation. Trions have exhibited a significantly increased degree of valley polarization over neutral excitons [2,3], making strain a powerful tool in the pursuit of high degrees of valley polarization for quantum information and energy conversion applications. To comprehensively understand the impact on valley polarization, we utilize polarization-resolved photoluminescence in our measurements, which are conducted at room temperature to provide a more realistic perspective on the potential for practical device implementations.

[1] M. G. Harats et al., *Dynamics and efficient conversion of excitons to trions in non-uniformly strained monolayer WS_2*, Nat. Photonics 14, 324 (2020).

[2] H. Zheng et al., *Strain-tunable valley polarization and localized excitons in monolayer WSe_2*, Opt. Lett. 48, 2393 (2023).

[3] S. Morozov et al., *Inducing room-temperature valley polarization of excitonic emission in transition metal dichalcogenide monolayers*, npj 2D Mater Appl 8, 24 (2024).



Programmable Metasurfaces at Visible Frequencies

Laura Na Liu

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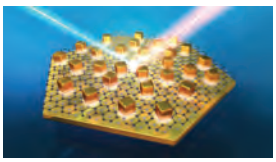
Presentation type: Invited talk

Light projection displays play an increasingly important role in our modern life. Core projection systems including liquid crystal displays and digital micromirror devices can impose spatial light modulation and actively shape light waves. Recently, the advent of metasurfaces has revolutionized the design concepts in display technologies, enabling a new family of optical elements with exceptional degrees of freedom. In this talk, we will present examples of programmble metasurfaces for dynamic holographic displays. We will also outline the possibility to achieve programmability and addressability of optical metasurface devices at the single pixel level.



Metasurfaces for Structured Light Applications

Hongfeng Ma[1], Sif Fugger, Villads Egede Johansen, Ehsan Hashemi, Jonathan Gow, Akbar Samadi, Moritz Schmidlin, Thomas Stadelmann, Mikkel Berri Lotz, and Ulrich J. Quaade

[1] *NIL Technology, Kgs. Lyngby, Denmark*

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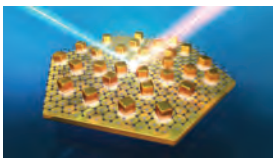
Presentation type: Poster

Structured light utilizing the custom light fields has attracted widespread attentions for industrial applications such as the so-called light detection and ranging (Lidar), three-dimensional sight, and face ID. Metasurfaces of dielectric materials consisting of subwavelength units enable the continuous tuning the wavefront, which attracts lot of industrial interests due to their compact setups, and potentials for mass production on wafer scales. In this work, we discuss the progress of metasurface for structured light applications, and in particular we will discuss the metasurface for vertical-cavity surface-emitting laser (VCSEL) related technology and explore potential applications in the near future.



Nonlinear Effects Driven by Out-of-equilibrium Electron Dynamics in Extreme Ultraviolet Near-zero Index Thin Films

Andrea Marini

Dipartimento di Fisica, Università degli studi di L'Aquila, L'Aquila, Italy

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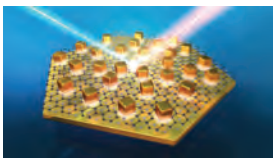
Presentation type: Invited talk

We will discuss a novel hydrodynamical approach to model collision-driven out-of-equilibrium electron dynamics in plasmonic materials upon intense optical excitation. We will discuss the Landau weak coupling formalism to account for electron–electron and electron–phonon scattering processes and the derivation of a novel set of hydrodynamic equations accounting for collision-driven nonlinear dynamics. By perturbatively solving such hydrodynamic equations, we will discuss diverse nonlinear processes, in particular harmonic generation by thin sodium films, sodium–aluminum heterostructures and nanospheres. We will further discuss how such nonlinear processes can get enhanced by near-zero index, surface plasmon polaritons and localised surface plasmon resonances of the fundamental and generated harmonic signals. Our results are relevant for the development of future ultraviolet light sources, with potential impact for innovative integrated spectroscopy schemes.



Sub-to-super-Poissonian Photon Statistics in Cathodoluminescence of Color Centers in Diamonds

Sergii Morozov, Saskia Fiedler, Danylo Komisar, Evgeny A. Ekimov, Liudmila F. Kulikova, Valery A. Davydov, Viatcheslav N. Agafonov, Shailesh Kumar, Christian Wolff, Sergey I. Bozhevolnyi, and N. Asger Mortensen

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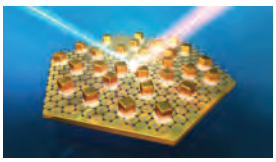
Presentation type: Poster

Impurity-vacancy centers in diamond are emerging as robust, versatile photon sources with unique quantum properties. Typically, individual color centers serve as single-photon emitters; however, their collective behavior has been predicted to feature tunable emission statistics. This work explores how different excitation modes—optical and electron-beam—impact the emission characteristics of color center ensembles [1]. Optical excitation leads to non-synchronized photon emission, whereas electron-beam excitation can synchronize the excitation of emitters, enabling precise control over the second-order correlation function, $g_2(0)$. Our experimental results reveal that photon streams from small ensembles can achieve $g_2(0)$ values both above and below unity, confirming theoretical predictions by Meuret et al. [2]. This demonstrates the potential of using an ensemble of color centers in diamond as a tunable photon source for quantum information technologies at room temperature.

[1] S. Fiedler et al., *Sub-to-super-Poissonian photon statistics in cathodoluminescence of color center ensembles in isolated diamond crystals*, Nanophotonics 12, 12 (2023).
[2] S. Meuret et al., *Photon bunching in cathodoluminescence*, Phys. Rev. Lett. 114, 19 (2015).



Photon superbunching in cathodoluminescence of WS_2 monolayer

Sergii Morozov[1], Saskia Fiedler, Leonid Iliushyn, Sergejs Boroviks, Martin Thomaschewski, Jianfang Wang, Timothy J. Booth, Nicolas Stenger, Christian Wolff, and N. Asger Mortensen

[1] *POLIMA—Center for Polariton-driven Light–Matter Interactions, University of Southern Denmark, Odense, Denmark*

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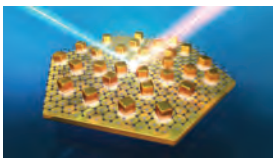
Presentation type: Poster

The photon statistics of emitters within a sub-wavelength volume are highly dependent on excitation synchronization, often resulting in photon bunching. While photoexcitation leads to Poissonian photon arrival statistics, moderate photon bunching ($g_2(0) < 2$) is typical of thermal light, such as solar radiation. However, the generation of superthermal light ($g_2(0) > 2$) has been observed under electron-beam excitation, particularly in cathodoluminescence (CL).

The amplitude and width of the photon bunching peak provide insights into the radiative lifetime of the emitters and the probability of excitation interaction with the ensemble. At high electron-beam currents, the electron arrival mimics Poissonian statistics, flattening the second-order auto-correlation function $g_2(\tau)$. Conversely, reducing the electron-beam current to sub-few hundred pA allows for single-electron excitation, which can synchronously excite multiple electron-hole pairs, triggering simultaneous emission without phase locking.

In our work [1], we investigate the luminescence properties and photon statistics of a tungsten disulfide (WS_2) monolayer encapsulated in hexagonal boron nitride (hBN) layers. We report the first observation of photon bunching in a WS_2 monolayer under electron-beam excitation, achieving $g_2(0) = 156 \pm 16$ at the lowest current attainable by our instrument. Furthermore, we improve excitation synchronization and electron-emitter interaction by incorporating a monocrystalline gold nanodisk. This geometry enables efficient scattering and redirection of incoming electrons, increasing the probability of electron interaction with the sample. Consequently, we achieve a record-high photon bunching of $g_2(0) = 2152 \pm 236$, surpassing previously reported values by over an order of magnitude.

[1] S. Fiedler et al., *Photon superbunching in cathodoluminescence of excitons in WS_2 monolayer*, 2D Mater. 10, 021002 (2023).



Room-temperature Valley Polarization of Excitonic Emission in Transition Metal Dichalcogenide Monolayers

Sergii Morozov[1], Torgom Yezekyan, Christian Wolff, Sergey I. Bozhevolnyi, and N. Asger Mortensen

[1] *POLIMA—Center for Polariton-driven Light–Matter Interactions, University of Southern Denmark, Odense, Denmark*

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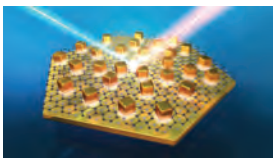
Presentation type: Contributed talk

Transition metal dichalcogenide (TMD) monolayers, with their minimal thickness and accessible valley degrees of freedom, are promising candidates for next-generation electronic and optoelectronic devices. Valleytronic devices exploit the ability to create imbalanced carrier populations in the K and K' valleys of the Brillouin zone through optical pumping. However, valley depolarization can undermine this imbalance, compromising device functionality. Controlling these depolarization processes is thus crucial for advancing the field of valleytronics.

Valley polarization in TMD monolayers is influenced by factors such as temperature, magnetic field, mechanical strain, and charge doping. While cryogenic temperatures can reduce phonon-assisted valley depolarization, they are impractical for ambient applications and do not address all depolarization mechanisms. In our work [1], we employ electrochemical exciton charging [2] to show that strong electron-doping levels beyond $10^{13}\,\mathrm{cm}^{-2}$ can induce 61% and 37% valley contrast at room temperature in tungsten diselenide WSe_2 and molybdenum diselenide $MoSe_2$ monolayers, respectively. Our findings demonstrate that charged excitons in TMD monolayers hold the potential for development of efficient valleytronic devices functional at 300 K.

[1] S. Morozov et al., *Inducing room-temperature valley polarization of excitonic emission in transition metal dichalcogenide monolayers*, npj 2D Mater. Appl. 8, 24 (2024).
[2] S. Morozov et al., *Room-temperature low-voltage control of excitonic emission in transition metal dichalcogenide monolayers*, Adv. Opt. Mater. 9, 22 (2021).



A Semi-Analytical Approach for Spherical Nanoparticles Within the Quantum Hydrodynamic Theory

Christos Mystilidis[1], Guy A. E. Vandenbosch, and Xuezhi Zheng

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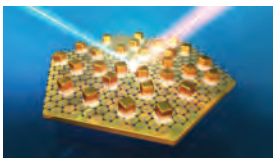
Presentation type: Poster

The past decade has seen a reinvigoration of studies of semi-classical models for plasmonic systems, motivated by the tremendous progress in this field and that of nanofabrication techniques, which allow probing architectures with features in nanoscopic scales. These models aim to correct the divergent behaviour of purely classical predictions with respect to such systems. Hydrodynamic approaches have gained much interest due to their relative simplicity that enables analytical calculations. Recently, a new perspective in hydrodynamics has appeared, where increased accuracy is achieved by relaxing the hard-wall assumption; this is the quantum hydrodynamic theory. The trade-off is, however, increased computational requirements. Thus, the effort to design ad-hoc solution strategies is of paramount importance to bring potentially powerful models to the common practice. Here, we present a semi-analytical method tailored to spheres modelled by the quantum hydrodynamic theory. Inspired by the volume equivalence principle, the sphere is substituted by a current distribution emanating radiation in an infinite space. A Green's formalism allows the reformulation of the problem in terms of integral equations, whilst the symmetry thereof resolves the angular dependence analytically in vector spherical harmonics. The resultant 1D problem can be solved with a standard Method of Moments. Save for the numerical integrations and inversion, the method is as analytical as it gets for a problem of such complexity. We validate against independent solvers and capture salient physical phenomena.



Tunable Exciton Polaritons in Band-Gap Engineered Hexagonal Boron Nitride

Pedro Ninhos[1], Christos Tserkezis, N. Asger Mortensen, and Nuno M. R. Peres

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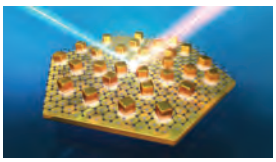
Presentation type: Poster

Monolayer hexagonal boron nitride (hBN), is one of the most promising 2D materials for optoelectronics, since as a large band gap semiconductor, it displays an intense absorption in the ultraviolet range. Due to the reduced thickness of 2D materials, they show a reduced dielectric screening, which makes it possible for formation of excitons with bigger excitonic binding energies compared to 3D semiconductors. Studies on the optical properties of hBN can be found in the literature, but there is the need for ways of controlling the its excitonic properties.

In this work, we suggest a form of tuning the excitonic binding energies by applying a one-dimensional periodic potential on top of hBN. In this way, we form a superlattice structure that has distinct electronic properties from the original lattice. Namely, introducing the one-dimensional potential leads to the renormalization of the gap and of the electron and hole effective masses. We have seen that increasing the period of the potential increases the anisotropy of the dispersion, which results in the red-shift of the excitonic levels. We computed as well the optical conductivity, and have observed that the intensity of the peaks in the conductivity increases as the frequency of the peaks red-shift. Finally, we determine the dispersion relation of the exciton-polaritons the light–matter hybrid modes that arise from the coupling of the exciton with light. Our results show that as the period of the potential increases and the energies of the excitonic states red-shift, the exciton-polaritons become less confined.



Nanophotonic Quantum State Generation and its Applications

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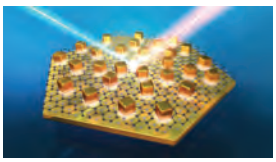
Presentation type: Invited school lecture

Quantum state generation is the basic first step for enabling quantum applications. We therefore review recent activities on generating photonic quantum states in nanophotonic systems. We concentrate on nonlinear nanowaveguides, nanoresonators and metasurfaces made of lithium niobate and semiconducting materials as well as on nanostructures hybridized with transition metal dichalcogenides. We show that second-order nonlinear interactions in such nanostructures enable tailorable entangled photon pair sources by spontaneous parametric down-conversion.

Based on our own research, we will discuss nanoresonators and metasurfaces featuring multiple resonances, where electric dipole and magnetic dipole Mie-type resonances at wavelengths in the near infrared will be the typical example to enhance and control nonlinear interactions. As an intermediate step towards quantum experiments, we characterize second-harmonic generation in the nanophotonic systems, when exciting with the long wavelength fundamental wave. With these results, we show that resonant interactions in nanoresonators are a suitable platform not only for second-harmonic generation, but also for the generation of photon pairs, when exciting with a short wavelength pump wave.

Based on the principle of quantum-classical correspondence, both processes, second-harmonic generation and spontaneous parametric down-conversion, are tied together by the governing system parameters. We exploit this correspondence as the basis for predictive models for the design of nonlinear nanosystems for quantum applications.



Polariton Smith-Purcell Emission

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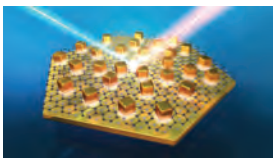
Presentation type: Contributed talk

Surface polaritons (SPs) can concentrate optical energy down to deep-subwavelength regions in which the field intensity is strongly enhanced, enabling promising applications in nanophotonics. Light coupling to strongly confined SPs is however difficult to achieve by optical means due to the photon-polariton wavelength mismatch, and thus, combining electrons and optical scatterers constitutes a potentially useful approach to generating such polaritons.

We start by addressing a simple system composed of an electron beam passing near a single dipolar point particle placed above a polariton-supporting film. We quantify the SP excitation efficiency by finding an analytical expression for the dipole decay rate into SPs and find that this quantity is maximized for a specific scatterer-film optimum separation distance.

We then investigate coupling through a periodic array of scatterers. The SPs generated by the interaction of the electron with each scatterer interfere and generate polaritons through the Smith-Purcell effect, characterized by well-defined frequency-angle relations. We quantify this emission and also find an optimum scattered-surface distance. Examples are offered for the emission of SPs in graphene, thin metal films, and hexagonal boron nitride (hBN).

Our results show that the combination of periodic arrays and electron beams constitutes a versatile and poorly-explored tool to control and optimize the emission of SPs in a wide range of materials.



Topological Origin of Chiral Gain in the Non-Hermitian Electro-Optic Effect

Filipa R. Prudêncio[1] and Mário G. Silveirinha

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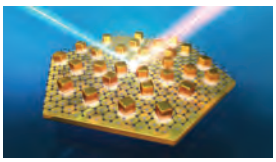
Presentation type: Contributed talk

Topological methods have opened exciting opportunities across fields, from condensed matter to photonics. Time-reversal symmetry breaking, an essential ingredient to engineer nontrivial Chern phases, can be achieved with an electric bias in nonequilibrium situations, for example in time-variant systems or in systems with drifting electrons [1–3].

Recently, we introduced a novel non-Hermitian electro-optic effect with chiral gain governed by the Berry curvature dipole of low-symmetry metallic systems [2–3]. Applying a static electric bias modifies the optical conductivity, breaking electromagnetic reciprocity and producing a non-Hermitian response with gain. Notably, the active or dissipative nature of the material response is dependent on the handedness of the electromagnetic wave. For example, for waves polarized to the right, the response may be active (with optical gain), while the opposite handedness results in a dissipative response. In this talk, we will discuss the topological roots of the non-Hermitian linear electro-optic effect. We will also show how the chiral gain offers a pathway to realize chiral topological lasers, where the orbital angular momentum of the laser mode is closely tied to the electric field bias orientation.

[1] S. Lannebère et al., *Nonreciprocal and non-Hermitian material response inspired by semiconductor transistors*, Phys. Rev. Lett. 128, 013902 (2022).
[2] T. G. Rappoport et al., *Engineering transistorlike optical gain in two-dimensional materials with Berry curvature dipoles*, Phys. Rev. Lett. 130, 076901 (2023).
[3] T. A. Morgado et al., *Non-Hermitian linear electrooptic effect in 3D materials*, arXiv:2401.13764 (2024).



Low Cost Solution Processed Microcavities for Polaritonics Application

Hassan Ali Qureshi[1], Emilia Palo, Micheal Papachatzakis, Manish Kumar, Mikko Salomaki, and Konstantinos Daskalakis

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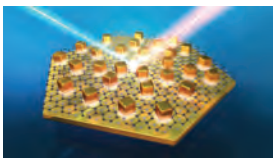
Presentation type: Poster

A microcavity polariton is a quasi-particle formed via the strong coupling of a photon and an exciton of matter inside a microcavity. Polaritons, being a unique hybrid of exciton and photon, exhibit delocalization that can directly influence exciton energy levels. This distinct characteristic of polaritonics offers several applications including organic light-emitting diodes (OLEDs), lasers, diodes, and transistors. Achieving strong coupling requires microcavities that are reflective enough for efficient light confinement. This can be attained using a conventional metallic mirror or a distributed Bragg reflector (DBR). The fabrication of which involves chemical or physical vapor deposition methods that are costly, sophisticated and damaging to the organic layers.

Here, we developed a full solution processed DBR with a high refractive index TiOH/PVA and a low refractive index Nafion film using the dip coating deposition technique. We demonstrated strong coupling with a hybrid microcavity that consists of an aluminum mirror, an organic semiconductor known as 2,7-Bis[9,9-di(4-methylphenyl)-fluoren-2-yl]-9,9-di(4-methylphenyl) fluorene (TDAF), and a DBR. We also fabricated all solution-processed microcavity that achieved a Q of more than 91 with only 6 pairs. This work will encourage new venues for utilizing polaritonics in optoelectronics applications.



Second Harmonic Generation in 2D Materials Integrated on $LiNbO_3$

Mariola O. Ramírez[1], David Hernández-Pinilla, M. Cherta, C. Hernando, Guillermo López-Polin, and Luisa E. Bausá

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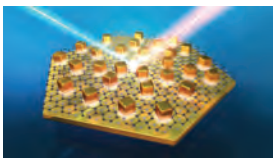
Presentation type: Contributed talk

The integration of ferroelectrics into Transition Metal Dichalcogenides (TMD) devices has recently emerged as a powerful tool to fabricate reconfigurable and nonvolatile 2D optoelectronic devices owing to the electrostatic doping provided by the remnant spontaneous polarization. However, despite intensive research on their electrical and linear optical properties, the nonlinear optical performance of 2D/ferroelectric heterostructures remains almost unexplored.

Here, we show the possibility to spatially modulate the quadratic Second Harmonic Generation (SHG) of monolayer MoS_2 through the underneath spontaneous polarization provided by a periodically poled $LiNbO_3$. Different factors affecting the SHG spatial modulation such as the fundamental wavelength, pump power and polarization of the incident light are discussed with particular emphasis on the role of light induced interfacial charge-transfer processes in TMDs based ferroelectric heterostructures.

The results contribute to the fundamental understanding of the nonlinear properties of TMDs under external stimuli and open new routes to manipulate and control their nonlinear response using patterned ferroelectric substrates.



Controlling Quantum Noise with Nonlinear Interactions

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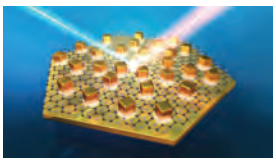
Presentation type: Invited talk

The statistical properties of electromagnetic fields - the subject of quantum optics - are of great practical importance and fundamental interest. In this talk, I will cover some of our recent endeavors in quantum optics, which are concentrated in two directions: (1) using nonlinear optical effects to reduce fluctuations of light, (2) and using quantum noise as a way to probe and understand complex nonlinear interactions.



Generation of Entangled Photon Pairs by Swift Electrons and Free-space Illumination into Guided Modes

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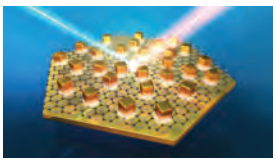
Presentation type: Poster

We introduce two schemes to generate entangled photons pairs into the guided modes of dielectric and metal waveguides:

(1) Direct light illumination of dielectric waveguides: We study this scheme of pair production by employing a rigorous theoretical method relying on the intrinsic second-order optical nonlinearly of the fiber to down-convert a direct incident electric field into guided modes, where energy and momentum conservation restricts the allowed excited modes. We demonstrate that for optical fibers made of a suitable nonlinear material such as $LiNbO_3$, the rate of photon pair production can be $\sim 10^5$ under attainable illumination conditions, thus supporting the feasibility of this disruptive approach to directly generate entangled and waveguided photon pairs. Structuring the external light illumination enables a selection of the guided modes in which the original photon down-converts, such that higher-order modes can be selected on demand.

(2) Free electrons in metals: We investigate the excitation of plasmon polaritons in metal strip waveguides that, within specific frequency regimes, strongly enhance light–matter interactions that lead to two-plasmon generation in comparison to the probability of single-plasmon excitation. We demonstrate that, under appropriate conditions, an electron energy loss detected in an optimal frequency range can reliably signal the generation of a plasmon pair entangled in energy and momentum.



Light Interactions with Polar Quantum Systems

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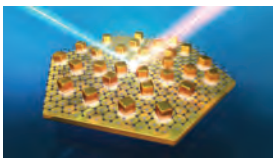
Presentation type: Invited talk

Polar atomic systems sustain permanent dipole moments, which are routinely neglected as causing trivial shifts in the energy spectrum of the system. This contribution studies the light–matter interaction regimes in which this commonly held practice is wrong.

A paradigmatic quantum effect modified in polar quantum systems is the periodic Rabi population transfer. As it occurs between states with permanent dipole moments, the additional oscillating dipole becomes a source of radiation at Rabi frequency. This frequency can be controlled in a broad spectral range, potentially giving rise to all-optically tunable coherent radiation sources.

Permanent dipole moments also affect the light-matter interaction strength. For non-polar systems, the interaction strength scales linearly with the amplitude of the driving electric field. For polar systems in strong fields, this scaling may be modified, suggesting a coherent dynamics regime in high-intensity fields, robust to strong spatial field variations.



Mapping the Optical Excitations with Electron Beams

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Presentation type: Invited school lecture

Van der Waals materials have enabled an exquisite platform for exploring light–matter interactions at the nanoscale. Various forms of van der Waals materials have enabled the observation of strong-coupling effects, in the form of exciton-polaritons, in either a self-hybridized form or in combination with photonic cavities. Here, I will elaborate on the interaction between free electrons and thin films of van der Waals materials, and will show how electron beams can probe self-hybridized exciton-polaritons in transition metal dichalcogenide thin films [1], and describe through a sequential cathodoluminescence spectroscopy technique the formation of a coherent cathodoluminescence radiation from exciton polaritons as well as their decoherence time scale [2]. I will also discuss how exciton-plasmon interactions can be leveraged to control the band structure of a plasmonic crystal [3]. In addition, the formation of exciton polaritons in perovskites [4], hyperbolic exciton polaritons in Bi_2Se_3 [5], and hyperbolic plasmon-polaritons in borophene films [6] will be discussed and explored with electron beams.

[1] M. Taleb et al., *Charting the exciton-polariton landscape of WSe_2 thin flakes by cathodoluminescence spectroscopy*, Adv. Phot. Res. 3, 2100124 (2022).

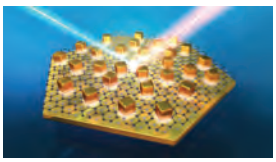
[2] M. Taleb et al., *Phase-Locked photon-electron interactions without a laser*, Nat. Phys. 19, 869 (2023).

[3] F. Davoodi et al., *Tailoring the band Structure of plexcitonic crystals by strong coupling*, ACS Photonics 9, 2473 (2022).

[4] M. Black et al., *Long-range self-hybridized exciton polaritons in two-dimensional Ruddlesden-Popper perovskites*, arXiv:2405.02950 (2024).

[5] R. Lingstädt et al., *Interaction of edge exciton polaritons with engineered defects in the hyperbolic material Bi_2Se_3*, Commun. Mater. 2, 1 (2021).

[6] Y. Abdi et al., *Two-dimensional borophene: in-plane hyperbolic polaritons in the visible spectral range*, arXiv:2404.13609 (2024).



Strong Light–matter Interaction in Periodic and Quasi-periodic Systems

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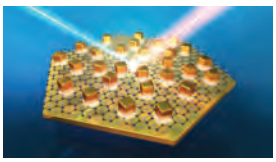
Presentation type: Invited talk

The integration of quantum emitters (dye molecules, low-dimensional semiconductors, etc.) with periodic structures supporting collective modes, such as surface plasmon polariton Bloch waves or surface lattice resonances, is widely spread across the scientific community for the realization of polaritonic devices with various functionalities. New perspectives in the development of hybrid platforms can be opened by acting on the overall photonic architecture. One way to significantly increase the design degrees of freedom of subwavelength plasmonic resonators is the exploitation of systems relaxing periodic translational order. Here, the focus is on hybrid systems composed of either periodic or quasi-periodic plasmonic crystals featuring strong coupling with quantum emitters. Both steady-state and time-resolved spectroscopies are exploited to investigate the properties of the hybrid heterostructures and their intrinsic photophysical behavior.

The authors acknowledge support by the European Research Council under the project "REPLY ERC 2020-COG Grant agreement No. 101002422".



Plasmonic Circular Dichroism Enhancement in Chiral Drug Solution

Matteo Venturi[1], Raju Adhikary, Ambaresh Sahoo, Carino Ferrante, Isabella Daidone, Francesco Di Stasio, Andrea Toma, Francesco Tani, Hatice Altug, Antonio Mecozzi, Massimiliano Aschi, and Andrea Marini

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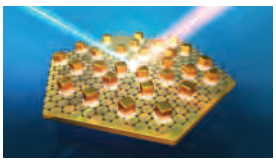
Presentation type: Poster

We are exploring the potential of surface plasmon polaritons at noble metal interfaces for enhancing the detection sensitivity of chiral drug solutions with extremely small volumes. The remarkable quality factor of surface plasmon resonances in configurations like Otto and Kretschmann setups allows us to significantly boost the circular dichroism differential absorption by harnessing the intense near-field produced by these plasmonic excitations. Moreover, the ability to confine surface plasmon polaritons at subwavelength scales is crucial for achieving chiroptical sensitivity towards minute volumes of drugs positioned approximately 100 nm away from the metal surface. Our investigation focuses on reparixin, a pharmaceutical compound presently undergoing clinical trials for conditions such as community-acquired pneumonia, including cases associated with COVID-19, and acute respiratory distress syndrome.

When considering realistic scenarios involving dilute solutions of reparixin dissolved in water at concentrations of 5 mg/ml or lower and with volumes in the nanoliter range, our calculations reveal a substantial enhancement factor of approximately 20 in circular dichroism differential absorption. Additionally, we observe a distortion in chirality-induced polarization upon excitation of surface plasmon polaritons. These findings hold significant implications for the advancement of innovative chiroptical sensors capable of accurately measuring the enantiomeric imbalances present in chiral drug solutions with nanoliter volumes.



3D Printing With Light For Light

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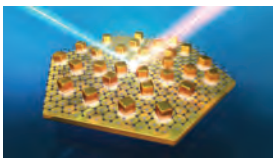
Presentation type: Invited school lecture

3D printing is a cost-effective and convenient means to produce prototypes and test out designs. In our lab, we use high-resolution 3D printers based on two-photon polymerization lithography (TPL) with 780 nm wavelength femtosecond lasers to quickly realize nanoscale structures that are in turn designed to control light. The use of TPL, an additive manufacturing process with sub-micron print resolutions, to produce structures for optical effect is a relatively new endeavor [1].

We demonstrated the printing of structural colors, generated from nanoscale features of dielectric materials. We have previously shown the fabrication of nanopillars, gratings, mesh-like, and woodpile photonic crystal structures that appear colorful under white-light illumination. The ability to achieve a wide range of colors by simply tuning geometric properties opens fascinating opportunities to the nanoengineer or nanoscientist to design colors using material properties, and nanostructure geometry as input parameters. This physical approach differs from the chemical approach for synthesizing pigments and dyes, where colors arise due to optical absorption.

We now demonstrate the integration of these structural colors with other micro-optical elements, such as microlenses and spiral phase plates. Equipped with TPL as a nanoscale 3D printer, structural color geometries are conveniently integrated in a single print run with other user-defined optics. Doing so enables one to produce structured light from incoherent light sources, holographic color prints, and control of the light-field for 3D representation. We will discuss the use of structural colors combined with micro-optics for enhanced information content and optical security [2].

[1] H. Wang et al. *Two-photon polymerization lithography for optics and photonics: fundamentals, materials, technologies, and applications*, Adv. Funct. Mater. 33, 2214211 (2023).
[2] H. Wang et al., *Coloured vortex beams with incoherent white light illumination*, Nat. Nanotechnol. 18, 264 (2023).



Real-Time Surface Plasmon Polariton Propagation in Silver Nanowires

Wenhua Zhao[1], Álvaro Rodríguez Echarri, and Kurt Busch

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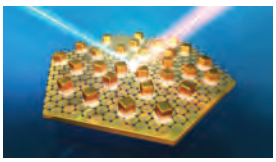
Presentation type: Poster

Controlling light–matter interaction at the nanoscale requires overcoming the well-known Abbe diffraction limit, which dictates the spatial resolution that we can achieve with direct illumination. However, electron beams interacting with nano-sized materials enable both the spatial precision to resolve the nanoscale details and the temporal resolution to study the rapid dynamics of the excited electromagnetic fields in the system. Specifically, we are interested in metallic structures that support plasmons, the collective oscillation of conduction electrons in metals, which are localized in the particle and that can be excited with electrons. Therefore, one way to characterize the plasmonic modes of the system is to study the energy loss of the electrons as they travel near the structure (i.e., electron energy loss spectroscopy (EELS)) due to the interaction with the material.

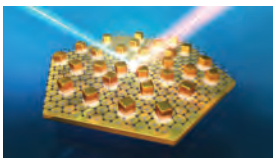
Here, we consider a swift electron passing by/through a metallic structure with a characteristic size of the order of tens of nanometers. To describe the optical properties of the metal, we use a local Drude model and solve Maxwell equations using the Discontinuous Galerkin method in the time domain (DGTD), which allows us to achieve spatio-temporal resolution of the plasmonic modes in the nanometer and femtosecond range, as has been experimentally observed for planar surfaces, and recently investigated in metallic wires.

We have first employed the DGTD method in combination with Mie theory to simulate EELS in metallic spheres for both aloof and penetrating trajectories in a fully retarded formalism, with the latter configuration being explored for the first time. Our numerical approach and Mie theory agree with a high level of accuracy with each other, reproducing surface and bulk fingerprints in the loss spectra.

In this context, we collaborate with the experimental group of Prof. Christoph T. Koch at the Humboldt University of Berlin, which is able to measure the EELS spectra by shooting electrons through/past a nanowire using a state-of-art scanning transmission electron microscope (STEM) featuring an energy resolution in the meV range. In this work, we develop a theoretical and



numerical framework for treating quantitatively the interaction of swift electrons with plasmonic nanostructures with high spatiotemporal resolution. Such an approach has allowed us to understand the mechanism by which the plasmonic fields interact with the electron, giving us a complete picture and full understanding of the dynamics of the electron energy loss and going beyond the current understanding of one-dimensional plasmons traveling in silver and copper nanowires.



A T-matrix Method for Nonclassical Optical Response from Generic Nanospherical Boundaries

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Presentation type: Contributed talk

Scattering of electromagnetic (EM) waves by multiple spheres is a classic problem in electromagnetism. In nano-optics, the problem serves as a prototypical model for many interesting nano-optical phenomena, e.g., self-focusing by a chain of closely spaced nanospheres (NSs), and is often solved by a well-established semi-analytical technique, i.e., the T-matrix method. The research on the T-matrix method started in the late 50s and has led to a full set of well-established computational packages. However, most of these modeling efforts are conducted within macroscopic electrodynamics where the materials are described by the local response model. Especially for metals, when it comes to the deep-nanometric regime, e.g., considering a dimer with a few nm gap, more subtleties, like nonlocalities, spill-out, Landau damping, that have a quantum origin must be accounted for. This requires a significant modification of the underlying material model and a systematic adaptation of the computational method. Here, we propose a key step along this direction where the nonclassical optical response from multiple plasmonic spherical objects is modelled. In our modeling, we describe metals by two nonclassical models: the nonlocal hydrodynamic Drude model and the surface response model, derive the S-matrix for each interface and establish the main equation of the system by the translational addition theorem. The results from the method are then compared with an in-house Boundary Element tool and good agreements are observed.