XXV INTERNATIONAL SUMMER SCHOOL
“NICOLÁS CABRERA”

www.nicolascabrera.es/summerschool2018

MIRAFLORES DE LA SIERRA
MADRID, SPAIN
SEPTEMBER 9-14, 2018

MANIPULATING LIGHT AND MATTER AT THE NANOSCALE

XXV International Summer School “Nicolás Cabrera”

SCHEDULE &
BOOK OF ABSTRACTS
Scope and goals

Light is an ideal probe of nature due to the ease of controlling and measuring its properties, which allows reaching extremely high temporal and energy resolution. However, the spatial resolution of photons is limited to the wavelength for most traditional approaches. Over the last few decades, the drive to surpass this constraint and advances in fabrication and characterization techniques have led to the development of the field of nanophotonics, focused on beating the diffraction limit of classical optics. Nowadays, an unprecedented control over light at sub-wavelength scales is possible, which in addition to improved resolution leads to an exceptional enhancement of light-matter interactions. This provides novel mechanisms for the manipulation of the quantum states of light through matter and the quantum states of matter through light, which opens new avenues for the development of materials science and photonic technologies operating at the nanoscale.

The objective of this Nicolás Cabrera Summer School is to provide a general and comprehensive view of the field of quantum nanophotonics, with special emphasis on the physical phenomena which emerge from microscopic strong light-matter coupling. With this purpose, the School will gather a group of leading scientists, both experimentalists and theoreticians, working within this extremely active research area and related topics.

Topics

Near-field photonics; Plasmonics; Metamaterials; Quantum Optics; Quantum Optomechanics; Ultrafast lasers; Bio-photonics

History and venue

The International Summer School “Nicolás Cabrera”, funded by the BBVA Foundation, deals with current topics in materials science, condensed matter physics, nanophysics and biophysics since 1994. The School is a meeting point for numerous scientists all over the world, who share a few days in Madrid in a particularly pleasant and interacting environment.

The School is organized in the residence “La Cristalera” in Miraflores de la Sierra, a small village in the mountains near Madrid. There will be a welcome reception on Sunday, Sep 9, with lectures taking place from the morning of Monday, Sep 10, until lunch on Friday, Sep 14. Bus transport from Madrid airport and back will be provided on Sunday, Sep 9, and Friday, Sep 14, respectively.

Organizers

- Johannes Feist, IFIMAC-UAM
- Antonio I. Fernández-Dominguez, IFIMAC-UAM
- Francisco J. García-Vidal, IFIMAC-UAM
Keynote Speakers and Bios

Prof. Jeremy Baumberg (University of Cambridge)

Jeremy Baumberg is Professor of Nanophotonics and Director of the Nanophotonics Centre in the Cavendish Laboratory at the University of Cambridge. He is widely recognized as a multidisciplinary physicist whose research sits across the fields of nanoscience and nanotechnology. Prof. Baumberg is specifically interested in the development of nanostructured optical materials that undergo unusual interactions with light, and his research has various commercial applications.

His early work led to the development of a number of pioneering experimental techniques. Highlights of Baumberg’s research include his work on confining light to the nanoscale and plasmonic interactions with metals; the ultrafast dynamics of magnetic semiconductors, which made a significant contribution to the area of spintronics; work on coherent control in solids; and studies of semiconductor microcavities.

Baumberg’s first book *The Secret Life of Science: How It Really Works and Why It Matters* was published in May 2018.

Baumberg has received several awards for his research including the Mullard Award in 2004 and Rumford Medal in 2014, both from the Royal Society. The Institute of Physics (IOP) awarded Baumberg with the Silver Young Medal and Prize in 2013 and the Gold Faraday Medal and Prize in 2017. Baumberg was elected a Fellow of the Royal Society (FRS) in 2011, a Fellow of The Optical Society of America in 2006 and has been a Fellow of the Institute of Physics (FIInstP) since 1998.

Prof. Shanhui Fan (Stanford University)

Shanhui Fan is Professor of Electrical Engineering and Applied Physics at Stanford University, where he is also director of the Edward L. Ginzton Laboratory and Senior Fellow of the Precourt Institute of Energy.

Prof. Fan is a world-leading expert on computational and theoretical studies of solid state devices, photonic crystals, plasmonics and metamaterials, solar cells and thermal radiation. He has published more than 450 research papers and issued more than 70 US patents. Fan has been highlighted as a Thomson Reuters Highly Cited Researcher in Physics every year since 2015.

Fan’s work engages in theoretical, computational and experimental research in photonics, focused on microphotonic and nanophotonic structures like photonic crystals, and solid state devices more generally. His motivation focuses on applications in a range of areas including information processing, imaging and renewable energy. His research thus involves fundamental and applied studies in plasmonics, metamaterials, silicon photonics, photovoltaics, quantum optics and computational electromagnetics.

Fan has received a number of honors and awards for his research, such as the National Science Foundation Career Award (2002), the National Academy of Sciences Award for Initiative in Research (2007), or the Adolph Lomb Medal of the Optical Society of America (2007). He is an elected Fellow of the American Physical Society, the Optical Society of America, SPIE and IEEE.
Prof. Ursula Keller (ETH Zürich)

Ursula Keller is a professor at the ETH Zürich, Switzerland. She currently serves as a director of the NCCR MUST which is an interdisciplinary research program of the Swiss National Science Foundation bringing together nearly 20 research groups in Ultrafast Science.

She received her PhD in Applied Physics from Stanford University in 1989 and the Physics "Diplom" from ETH Zürich in 1984. She was a Member of Technical Staff (MTS) at AT&T Bell Laboratories in New Jersey from 1989 to 1993, after which she joined ETH Zürich as a tenured professor of physics.

Prof. Keller is a world-leading expert in ultrafast science and technology, in areas such as ultrafast solid-state and semiconductor lasers, ultrashort pulse generation in the one- to two-optical-cycle regime, frequency comb generation and stabilization, attosecond experiments to test fundamental processes in quantum mechanics using the attoclock and attosecond pulses from high harmonic generation, and attosecond science. She has published more than 420 peer-reviewed journal papers and 11 book chapters and holds or has applied for 17 patents. As of May 2018 she has a Google Scholar h-index of 98 and a Web of Science Core Collection h-index of 76 with more than 20000 citations.

She has received numerous prizes and awards, such as the IEEE Photonics Award in 2018, the Weizmann Women & Science Award in 2017, the OSA Charles H. Townes Award in 2015, the Laser Institute of America’s Arthur L. Schawlow Award in 2013, the EPS (European Physical Society) Senior Prize in 2011, the OSA Fraunhofer/Burley Prize in 2008, the Philip Morris Research Award in 2005, the first-place award of the Berthold Leibinger Innovation Prize in 2004, and the Carl Zeiss Research Award in 1998. In 2000, the Thomson Citation Index highlighted her as the third-place top-cited researcher during a decade (1991-1999) in the field of optoelectronics. She is a Fellow of OSA, EPS, IEEE, SPIE and an elected foreign member of the Royal Swedish Academy of Sciences, the German Academy Leopoldina and the Swiss Academy of Technical Sciences (SATW).

Prof. Luis Martín- Moreno (Universidad de Zaragoza)

Luis Martín-Moreno is Professor at the Instituto de Ciencia de Materiales de Aragón and Departamento de Física de la Materia Condensada, CSIC-Universidad de Zaragoza, Spain.

Martín-Moreno did the PhD in the Universidad Autónoma de Madrid in 1981. From 1989 to 1992, he was a Postdoctoral Research Fellow at the Cavendish Laboratory, Cambridge, U.K., and from 1993 to 1995, he was a Postdoctoral Researcher at the Instituto de Ciencia de Materiales de Madrid, spending several periods at Imperial College London. He joined the Universidad de Zaragoza in 1995 and, since 2008 he is Professor at the Instituto de Ciencia de Materiales de Aragon (Zaragoza, Spain).

Prof. Martín-Moreno is a world-leading theoretician in the field of nanophotonics, and has made key contributions in areas as diverse as extraordinary transmission, optical and acoustic metamaterials, nonlinear optics, electromagnetic properties of graphene and waveguide quantum electrodynamics. He has published more than 260 research papers in these and other topics, having received more than 23000 citations and an h-factor 63. In 2014, he was highlighted as a Thomson Reuters Highly Cited Researcher in Physics. He was awarded the “Premio Centenario de Investigación” of the Real Academia de Ciencias de Zaragoza (2016).
Prof. Sir John B. Pendry (Imperial College London)

John B. Pendry is the Chair in theoretical solid-state physics at Imperial College London, a position that he has held since 1981. A student of the University of Cambridge, he started his research career with a PhD in Physics in 1969, when he became a fellow of Downing College. He left his native England for a research position at Bell Labs in 1972-73. He returned to Cambridge before joining the Daresbury Laboratory in 1975, and eventually Imperial College London, where he has served as head of the Physics Department and as Principal for the Faculty of Physical Sciences.

His early research interests focused on the electronic properties of surfaces. He developed theories that enabled the practical use of techniques for the study of the properties of surfaces, such as low energy electron diffraction and angle-resolved photoemission spectroscopy. In 1992, Pendry started the study of the interaction of light and matter that would lead to the design of “metamaterials” with negative refractive index. In 2000, he then predicted that such metamaterials can focus light with unlimited resolution, proposing the concept of a “perfect lens”.

Almost as a joke, in the early 2000’s Pendry proposed the idea of an “invisibility cloak” that would hide objects from electromagnetic radiation. The proposal was taken more seriously than he thought, and led to experimental realizations of such cloaking at microwave or visible wavelengths.

Pendry has won several awards, including the Dirac Medal in 1996, the Royal Medal in 2006, the UNESCO Niels Bohr gold medal in 2009, the Isaac Newton Medal in 2013, and the Kavli Prize in Nanoscience in 2014. He was elected Fellow of the Royal Society and Fellow of the Institute of Physics in 1984, and in 2004 was knighted in the British Honours for his services to science. In 2013, Pendry was made Foreign Associate of the U.S. National Academy of Sciences.

Prof. Martin Plenio (Ulm University)

Martin Plenio is a Humboldt Professor and Director of the Institute for Theoretical Physics at Ulm University. He obtained his PhD in physics in 1994 at the University of Göttingen, and afterwards was a Feodor Lynen Fellow at Imperial College London, where he also became Lecturer (1998), Senior Lecturer (2001) and Full Professor (2003), before moving to Ulm University in 2009.

Prof. Plenio conducts cutting edge research in a wide variety of areas spanning Quantum Information Science, Quantum Optics, Entanglement Theory, Quantum Sensing & Metrology and Quantum Effects in Biology. The work is based on fundamental theory and explores its implications for experimental physics, with extensive collaborations with experimental teams.

Martin Plenio has published more than 310 papers in refereed journals and holds two patents, with an h-index of 90 and more than 34000 citations according to Google Scholar as of May 2018. He has presented more than 200 invited and plenary lectures at international conferences, has supervised 22 finished PhD theses and is supervising 17 current PhD students. His work has been awarded with a number of awards, such as the The Maxwell Medal and Prize of the UK Institute of Physics (2004), the Royal Society Wolfson Research Merit Award (2006), or the Max Born Medal and Prize (Bilateral Award of the DFG and the IOP). In 2014, he got an Award of Research Building for a Center for Quantum-BioSciences (£27 million) at the University of Ulm as Founder & Managing Director.
Prof. Niek van Hulst (ICFO)
Niek van Hulst is an ICREA Research Professor and senior group leader at ICFO (the Institute of Photonic Sciences) in Castelldefels, Spain. He received his PhD in Molecular & Laser Physics at the University of Nijmegen (Netherlands), on microwave-laser double resonance molecular-beam spectroscopy. From 1997, he was a full Professor for Applied Optics at the MESA+ Institute for NanoTechnology in the Netherlands.

Prof. van Hulst is a world leader in controlling light interaction at the nanometer scale. His research specializes on optical antennas with nanoscale hot spots and on coherent control schemes to command light on the "femto-nano" scale, giving control over excitation-emission rates, and the direction, spectra, polarization, and single-photon character of the emitted light. A particular focus lies on long-lived coherences in single light-harvesting antenna complexes at native conditions, to unravel the remarkably high efficiency of energy conversion in such natural molecular antennas.

Niek van Hulst has written more than 260 refereed papers, with >19000 citations and an h-index of 68 according to Google Scholar. He is a Fellow of the Optical Society of America, has won the European Science prize and been awarded with two ERC Advanced Grants. He is also the coordinator of the Spanish CONSOLIDER program NanoLight and Head of the Academic Program at ICFO.

Prof. Martin Wegener (Karlsruhe Institute of Technology)
Martin Wegener is Professor at the Institute of Applied Physics at the Karlsruhe Institute of Technology (KIT), Germany, Scientific Director of the Institute of Nanotechnology at the KIT and Vice-Coordinator of the Karlsruhe School of Optics & Photonics.

Professor Martin Wegener is among the leading representatives of nanoscience worldwide. In the 1990s, he became internationally known by his work in the area of optical spectroscopy with ultra-short laser pulses and optical near-field microscopy. In the past years, his research interests were photonic crystals and artificial materials called „metamaterials“. Tailoring their "meta-atoms" in the nano- or micrometer scale makes it possible to produce completely new physical properties, which do not naturally occur. For example, his team succeeded in building cloaking devices in various physical systems.

Wegener received, among others, the Leibniz Prize of the German Research Foundation (DFG), the State Research Award of Baden-Wuerttemberg, the Carl Zeiss Research Award and the Descartes Prize of the European Union. Besides, he is a member of the German National Academy of Sciences (Leopoldina) and a fellow of the Optical Society of America. He is the initiator, co-founder and shareholder of Nanoscribe GmbH, a spin-off company that brings 3D laser lithography to the market.
Invited Speakers

- Pablo Alonso González, Universidad de Oviedo, Spain
- Hatice Altug, École Polytechnique Fédérale de Lausanne, Switzerland
- Juan Carlos Cuevas, Universidad Autónoma de Madrid, Spain
- Simone De Liberato, University of Southampton, UK
- Himadri Shekhar Dhar, Vienna University of Technology, Austria
- Rubén Esteban, Donostia International Physics Center (DIPC), San Sebastián-Donostia, Spain
- Juan José García Ripoll, Instituto de Física Fundamental IFF-CSIC, Madrid, Spain
- Ulrich Hohenester, Karl-Franzens-Universität Graz, Austria
- Jonathan Keeling, University of St. Andrews, UK
- Laura Na Liu, Universität Heidelberg, Germany
- Ferry Prins, Universidad Autónoma de Madrid, Spain
- Said R. K. Rodriguez, AMOLF, Amsterdam, The Netherlands
- Michael Ruggenthaler, Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany
- Roy Shiloh, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
- Mário G. Silveirinha, University of Lisbon, Portugal
- Päivi Törmä, Aalto University, Espoo, Finland
- Jana Zaumseil, Universität Heidelberg, Germany
Mon 09:30: Keynote talk

3D optical laser nanolithography
Martin Wegener
Karlsruhe Institute of Technology, Germany

Three-dimensional (3D) laser lithography has become a versatile, reliable, and widespread workhorse for fabricating 3D micro- and nanostructures. I will illustrate the current state-of-the-art and outline remaining technological challenges regarding spatial resolution, scalability, and multi-material 3D nano-printing. Application examples include free-form micro-optics, 3D optical, mechanical, and transport metamaterials, functionalized 3D scaffolds for biological cell culture, and 3D fluorescent security features.

Mon 10:30: Invited talk

Lasing, Superradiance, and the weak—strong coupling crossover for molecular polariton condensates
Jonathan Keeling
University of St. Andrews, UK

I will discuss the relation between lasing and polariton condensation, from the point of view of models of many two-level systems coupled to a cavity mode. When such a model is studied in the presence of incoherent driving and dissipation, it is possible to show both regular lasing, and a polariton condensate state, by varying the coherent and incoherent driving terms [1]. Using such a model, we can relate regular lasing, the behavior of a superradiant laser [2,3], and the superradiant state of the Dicke model. We find that with competition between coherent and incoherent pumping, the regions in the phase diagram corresponding to superradiance and standard lasing are always separated by a normal region. We analyse the behaviour of the system using a combination of exact numerics based on permutation symmetry of the density matrix for small to intermediate numbers of molecules, and second order cumulant equations for large numbers of molecules [4].

Building on this same approach I will discuss how this phase diagram is modified by the coupling between electronic and vibrational states, using the Dicke-Holstein model, which, in the weak coupling limit provides the basis of a dye laser and the photon condensate [5].

References:
Mon 11:45: Invited talk

Probing plasmon and phonon polaritons using electrons
Ulrich Hohenester
Karl-Franzens-Universität Graz, Austria

Electron energy loss spectroscopy (EELS) and microscopy allow probing of evanescent fields of particle plasmons with nanometer resolution. In EELS swift electrons pass by or through a metallic nanoparticle and lose a tiny fraction of their kinetic energy by exciting particle plasmons. By spectrally analyzing the energy loss and raster-scanning the electron beam over the specimen one can map the plasmon polariton nearfields with sub-eV and nanometer resolution. By a similar token, EELS with extremely high energy resolution of about 10 meV allows investigating nanoscale phonon polariton properties [1], which have recently received tremendous attention in the context of phononics and nearfield heat transport at the nanoscale.

In this talk I will discuss our recent efforts to correlate experimental and simulated EELS maps of single and coupled nanostructures [1-3]. The comparison can be brought to a quantitative level when using the precise 3D geometry of the nanoparticles, reconstructed through electron tomography, as an input for simulation. This work paves the way for detailed investigations of the enhanced fields of realistic and complex plasmonic nanostructures and of their full 3D photonic environment [2,3]. A key feature underlying such tomography is the description of the plasmonic response in terms of resonance modes. I will report about our recent efforts to describe resonance modes within a boundary element method approach [4].

References:

Mon 12:30: Invited talk

Exciton-Polaritons, Plexcitons and Trion-Polaritons in Single-Walled Carbon Nanotube Thin Films and Devices
Jana Zaumseil
Universität Heidelberg, Germany

Exciton-polaritons are mixed light-matter quasiparticles that form upon strong coupling between electronic excitations of a material and photonic states of a surrounding microcavity. Highly purified, monochiral (6,5) single-walled carbon nanotubes (SWCNTs) exhibit optical and electronic properties that make them ideal for strong light-matter coupling in combination with fast charge transport, thus enabling optically and electrically pumped near-infrared exciton-polaritons at room temperature [1,2]. While exciton-polaritons can be observed in simple metal-clad microcavities, coherent coupling of carbon nanotube excitons with hybrid plasmon-photonic modes (supported by plasmonic crystals formed by diffractive coupling of periodically arranged gold nanorods) results in plasmon-exciton polaritons ('plexcitons') [3] that can propagate over 20-30 micrometers during their short lifetime (~100 fs). Further, doped (6,5) SWCNTs also exhibit stable trions (positively or negatively charged excitons) at room temperature with red-shifted absorption and emission. Electrochemical hole-doping of a thick film of (6,5) SWCNTs in a suitable metal-clad microcavity enables the formation of emissive trion-polaritons via [4]. These charged polaritons might be interesting for polaritonic devices due to their low effective mass.

References:
In the 1980s, femtosecond ultrafast lasers enabled optical generation of electric fields at terahertz frequencies. With the recent progress in few-optical-cycle femtosecond and attosecond pulse generation with full electric field control, the frequency regime can be extended into the petahertz. The electron motion under the influence of such a high-frequency electric field ultimately determines the material limit for high-speed device performance. We have started to explore materials in a regime where the quiver energy (or ponderomotive energy $U_p$) of the electrons in such an oscillating electrical field becomes comparable to the photon energy of the driving laser. The system transitions from a more classical (field driven) regime to a more quantum-mechanical (photon driven) regime and we explored these regimes in diamond and GaAs. We also explored how long it takes for an excited electron in a metal to “feel” its effective mass and discovered new electron-localization effects in transition metals. The long-term goal is to explore such electric-field-driven dynamics in strongly correlated materials where we have even less physical understanding today.

**Nonclassical light in the quantum dynamics of mesoscopic spin ensembles**

Himadri Shekhar Dhar

*Vienna University of Technology, Austria*

Mesoscopic spin ensembles coupled to a cavity offer the exciting prospect of observing complex nonclassical phenomena with features intermediate between that of single spins and of macroscopic spin ensembles. To unravel the full quantum dynamics and photon statistics of the mesoscopic spin-cavity systems, we present a time-adaptive variational renormalization group method that accurately captures the underlying Lindbladian dynamics. We demonstrate how the collective interactions in an ensemble of as many as 100 spins, arranged in a spectral frequency comb, can be harnessed to obtain a periodic pulse train of sub-Poissonian, nonclassical light.

**Controlling light on the nanoscale**

John Pendry

*Imperial College London, UK*

Our intuitive understanding of light has its foundation in the ray approximation and is intimately connected with our vision: as far as our eyes are concerned light behaves like a stream of particles. Here we look inside the wavelength and study the properties of plasmonic structures with dimensions of just a few nanometres: a tenth or even a hundredth of the wavelength of visible light, where the ray picture fails utterly. In this talk we show how the new concept of transformation optics that manipulates electric and magnetic field lines rather than rays can provide an equally intuitive understanding of sub wavelength phenomena and at the same time be an exact description at the level of Maxwell’s equations. The concepts are applied to a number of plasmonic structures revealing unexpected phenomena such as hidden symmetries and compacted dimensions.
Tue 10:30: Invited talk

**Bose-Einstein Condensation and Ultrafast Lasing in a Plasmonic Lattice**

Päivi Törmä
Aalto University, Espoo, Finland

Bose-Einstein condensation is a remarkable manifestation of quantum statistics and macroscopic quantum coherence. Superconductivity and superfluidity have their origin in Bose-Einstein condensation. Ultracold quantum gases have provided condensates close to the original ideas of Bose and Einstein. Condensation of polaritons, magnons and photons have introduced novel concepts of non-equilibrium condensation. We demonstrate a Bose-Einstein condensate (BEC) of surface plasmon polaritons in lattice modes of a metal nanoparticle array [1]. Interaction of the nanoscale-confined surface plasmons with a room-temperature bath of dye molecules enables thermalization and condensation in picoseconds. The ultrafast thermalization and condensation dynamics are revealed by an experiment that exploits thermalization under propagation and the open cavity character of the system. A crossover from BEC to usual lasing (such as [2]) is realized by tailoring the band structure. This new condensate of surface plasmon lattice excitations has promise for future technologies due to its ultrafast, room-temperature and on-chip nature. We have also shown that lasing in these systems can be ultrafast, providing more than a 100 GHz modulation bandwidth [3].

References:


Tue 11:45: Invited talk

**Nonreciprocal and topological photonics**

Mário G. Silveirinha
University of Lisbon, Portugal

Lorentz reciprocity is intimately related to the linearity and invariance of Maxwell’s equations under time-reversal symmetry, and forbids one-way light flows in standard metal-dielectric platforms. Indeed, reciprocal systems are inherently bidirectional. Asymmetric light flows are typically obtained using magneto-optical materials externally biased with a static magnetic field. Notably, it was recently demonstrated that some of these systems have nontrivial topological properties and support unidirectional backscattering immune chiral edge modes [1].

In this talk, I will review the work of my group on nonreciprocal and topological photonics. In particular, in the first part of the talk I will highlight that biasing a graphene sheet with a direct electric current is a very promising solution to break the Lorentz reciprocity and have a broadband regime of unidirectional propagation of surface plasmons protected against backscattering from obstacles and imperfections [2, 3]. In the second part of the talk, I will focus on topological systems and show that the photonic Chern number has a precise physical meaning as the quantum of the thermal fluctuation-induced light-angular momentum in a closed photonic insulator cavity [4].

References:

Tue 12:30: Invited talk

**The DNA origami route for nanoplasmonics**
Laura Na Liu
*Universität Heidelberg, Germany*

A prerequisite to build advanced plasmonic architectures is the ability to precisely control the organization of metal nanoparticles in space. To this end, DNA origami represents an ideal construction platform owing to its unique sequence specificity and structural versatility. I will present sequentially a diverse set of DNA-assembled plasmonic nanostructures according to their characteristic optical properties. I will also discuss about the inevitable evolution from static to dynamic plasmonic systems along with the fast development of this inter-disciplinary field. Finally, possible future directions and perspectives on the challenges are elucidated.

Tue 15:30: Invited talk

**Light Management in Excitonic Nanomaterials**
Ferry Prins
*Universidad Autónoma de Madrid, Spain*

In contrast to bulk semiconductors, the spatially confined optical excitations in semiconductor nanomaterials are strongly bound by Coulomb forces into quantum confined electron-hole pairs known as excitons [1]. Thanks to recent advances in the size and shape control of semiconductor nanomaterials, this confinement can now be tuned with high precision and has resulted in a rapidly expanding family of high-quality excitonic building blocks. While extensive research has been done to understand and control the excitonic properties of the isolated building blocks, translating these properties to device level thin-film assemblies requires careful consideration of interparticle interactions [2].

In the first part of the talk, I will present some of our efforts in trying to improve our understanding of the exciton dynamics in nanomaterial assemblies. Specifically, I will discuss time-resolved microscopy techniques which allow us to spatially resolve exciton diffusion in colloidal quantum-dot films, highlighting the importance of energetic and structural disorder in these systems [3].

In the second part of the talk, I will focus on photonic control over the optical properties of the excitonic assembly. I will present a strategy for the assembly of excitonic building blocks into high quality wavelength-scale structures, using a newly developed template stripping technique for colloidal quantum-dot films. The wavelength-scale structuring significantly modifies the optical properties of these films, yielding enhanced and highly directional outcoupling of fluorescence [4] as well as heavily reduced lasing thresholds [5].

**References:**

Wed 09:30: Keynote talk

**PicoPhotonics: Extreme Nano-Optics with single molecules and monolayers**

Jeremy J. Baumberg

*Cambridge University, UK*

Coupling between coinage metal ‘plasmonic’ nano-components generates strongly red-shifted optical resonances combined with intense local light amplification on the nanoscale. I will show how we now create ultralow volume plasmonic cavities trapping light to <1nm$^3$. This allows us to routinely watch individual molecules and bonds vibrating. Using DNA origami we can now couple 1-4 dye molecules together optomechanically, and produce strong-light matter coupling that changes their quantum emission properties. We also watch redox chemistry in real time, watching single electrons shuttle in and out of single molecules, as well as 2D materials confined in the same gap. Prospective applications range from (bio)molecular sensing to fundamental quantum science.

References:

[1] Nature **491**, 574 (2012); Revealing the quantum regime in tunnelling plasmonics
Mid-IR spectral range is uniquely positioned for biosensing application, as it encompasses the molecular vibrations of major biomolecules including proteins, lipids, and DNA. Infrared (IR) absorption spectroscopy, by accessing these vibrational fingerprints can provide exquisite biochemical information in a nondestructive and label-free manner. For instance, the mid-IR fingerprints of proteins incorporate comprehensive insight into their conformational state and can provide information beyond basic “detection”. Nevertheless, vibrational absorption signals are prohibitively weak because of the large mismatch between mid-IR wavelengths (2 to 6 µm) and biomolecular dimensions (<10 nm). In addition strong absorption bands of water overlapping important mass-preserving processes that are inaccessible to standard label-free techniques. Strikingly, our sensor can resolve the basic “detection”. Nevertheless, vibrational absorption signals are prohibitively weak because of the large mismatch between mid-IR wavelengths (2 to 6 µm) and biomolecular dimensions (<10 nm). In addition strong absorption bands of water overlapping important mass-preserving processes that are inaccessible to standard label-free techniques. Strikingly, our sensor can resolve the interaction of lipid membranes with a toxic pore-forming peptide such as melittin, both in supported membranes and surfacetethered vesicles loaded with neurotransmitter molecules. Our work shows monitoring of melittin-induced membrane disruption and neurotransmitter cargo release from such synaptic vesicle mimics in real time, with monolayer sensitivity, and without external labels. These important proof of concept experiments pave the way for applying these biosensors to investigate the molecular mechanisms underpinning important processes that have been linked to neurodegenerative diseases such as Alzheimer’s and Parkinson’s disease. In another related two recent works, we demonstrated for the first time real-time secondary structure analysis of protein monolayers using mid-IR plasmonic nanorods. We successfully identified major protein secondary conformations, random coil and cross β-sheet, by analyzing the spectral content of plasmonically enhanced amide-I fingerprint with second derivative procedure [6]. We applied our sensor to α-synuclein protein, which is involved in Parkinson’s disease and studied its aggregation in real-time upon an external stimulus [7].

Concurrently, we are exploiting alternative materials for SEIRA applications including graphene and high-index dielectric materials [8-9]. Dielectrics such as silicon offer low intrinsic loss and complementary metal-oxide semiconductor (CMOS) compatibility. In a recent paper, we report a Mid-IR plasmonic sensor based on all-dielectric high-Q metasurface elements and demonstrate its capability for enhancing, detecting, and differentiating the absorption fingerprints of various molecules [9]. Our design uses collective behavior of Mie resonances which provide resonances that are high-Q as well as spectrally clean without additional resonance background. The last feat is particularly attractive because it allows for the highly spectrally selective enhancement of spectroscopically rich molecular fingerprint information. Specifically, we implement a two-dimensional array of high-Q metasurface pixels, where the resonance positions of individual metapixels are linearly varied over a target mid-IR fingerprint range. This configuration allows us to assign each resonance position to a specific pixel of the metasurface, establishing a one-to-one mapping between spectral and spatial information. By comparing the imaging-based readout of this spatially encoded vibrational information before and after the coating of target analyte molecules, we demonstrate chemically specific molecular barcodes suitable for chemical identification and compositional analysis. Our nanophotonic technique has the prospects of IR absorption spectroscopy without the need for complex instrumentation and ability to be miniaturized. The molecular barcodes obtained with our method offer unique possibilities for advanced image analysis such as those based on machine learning.

References:
Wed 11:45: Invited talk

Introduction to non-perturbative cavity quantum electrodynamics
Simone De Liberato
University of Southampton, UK

When the vacuum Rabi frequency quantifying the interaction between light and matter is comparable to the bare photon frequency, the system enters a novel non-perturbative regime called ultrastrong coupling. In this talk I will introduce the physics of the ultrastrong coupling regime, describing a few aspects of its non-perturbative phenomenology as well as recent experimental efforts to observe them.

Wed 12:30: Invited talk

Classical and quantum descriptions of Surface-Enhanced Raman Spectroscopy
Rubén Esteban
Donostia International Physics Center (DIPC), San Sebastián-Donostia, Spain

In Surface Enhance Raman Spectroscopy, the interchange of energy between a plasmon of frequency $\omega$ and a molecular vibration at frequency $\Omega$ is strongly enhanced by the presence of a nearby metallic structure supporting plasmonic resonances. The result is an increase by many orders of magnitude of the number of Stokes and anti-Stokes photons emitted at $\omega-\Omega$ and $\omega+\Omega$, respectively (see Figure). A common classical description of SERS just takes into account that the plasmonic resonances induce a more intense illumination and lead to more efficient light emission, which (for simple cases) results in an increase equal to the fourth power of the plasmonic electric field enhancement at the position of the molecule. However, this approach neglects important effects that can be described by a more complex semi-classical description taking into account the effect of the vibrational population on the Raman process [1]. Furthermore, recent approaches based on a quantum description of the system have established a connection between the field of SERS and quantum opto-mechanics, so that the former can be considered as a molecular optomechanical process [2-4]. This new description gives novel insights into the physical mechanisms involved, and potentially opens the way to new SERS applications. We would introduce all these descriptions of SERS, and establish the connections between them [5].

Figure: Sketch of a SERS measurement, where an incoming photon gains (anti-Stokes process) or losses (Stokes) energy due to its interaction with a molecular vibration, a process that is enhanced by the interaction with a plasmonic cavity.

References:
Controlling nanoscale interaction of plasmonic antennas and single molecules

Niek F. van Hulst
ICFO – the Institute of Photonic Sciences, Barcelona, Spain

The strong local optical near-fields of nano-antennas and plasmonic nanoparticles enhance excitation and decay rates of emitters in close proximity. As a result, nanoantennas are widely applied to confine light, enhance photon emission and quantum efficiency for superior sensitivity and resolution in sensing and microscopy applications. Critical to the optimal coupling and enhancement is the positioning of the photon emitter at the local hotspot. We apply both deterministic scanning and stochastic mapping of the nanoscale plasmon-molecule interaction, to map the coupling strength and optimize the ultrafast interaction. The large losses of plasmonic nanocavities, far beyond those of dielectric cavities, places them, as exceptional enhancers of light-matter interactions. The ultraconfined mode volumes of plasmonic systems offer huge coupling strengths (~1–100 meV) to single quantum emitters. A simple method to reformulate lifetime measurements of single emitters in terms of coupling strengths, allows a comparison of the performance of plasmonic cavities with that of cavity-QED. It shows that the theoretical limit of coupling strength in plasmonic structures is very much in reach. Yet precise deterministic nanopositioning of the emitter in the nanosized mode volumes stays a challenge. Here first we will address the use of scanning resonant antenna probes to couple effectively and deterministically to single emitters on the nanoscale. We achieve relatively strong coupling (~100GHz), speeding up the radiative decay to picosecond time scale, enhancing the photo-stability and allowing > GHz single photon emission.

Localization images of fluorescence enhancement of single molecules at gold nanorods of increasing length.

Second, we image the local excitation/emission enhancement of freely diffusing dye molecules close to plasmonic nanoantennas (gold nanorods) using super-resolution based fluorescence localisation microscopy. Changing antenna length and excitation polarization, we tune the molecule-antenna interaction and observe change in the spatial extent of the region of strong enhancement, due to the transition from excitation to emission enhancement. We map the spatial extent of the coupling of molecule-antenna, the rotation of polarization emission and the spectral emission of the coupled system. Finally, we apply the plasmonic cavity enhancement to LH2 and FMO, to detect a single FMO complex at room temperature and assess the photon correlation.

References:
Thu 10:30: Invited talk

Classical simulation of quantum emitters and ultrastrong coupling
Juan José García Ripoll
Instituto de Física Fundamental IFF-CSIC, Madrid, Spain

In this talk I will review our work with the spin boson model as a description for how few-level systems interact with propagating light. I will introduce the different regimes of this model—weak, strong and ultrastrong-coupling—, the numerical methods that we use to study it—dynamical polaron ansatz [1] and matrix product states [2,3] in various forms—, and various analytical approximations that we have developed [1,3]. I will review various physical phenomena, such as the renormalization of the emitter’s resonant frequency due to the environment’s influence, and how such phenomena have been observed in the laboratory [4,5].

References:
In this talk I will present a brief overview of how the standard description of quantum chemistry and material sciences have to be adapted when photons become important in correlated light-matter problems [1,2], and possible ways to tackle such situations with ab-initio methods [3-7]. I will highlight how ad-hoc models of light-matter interactions can lead to qualitatively wrong results even in the weak-coupling limit [7], and argue that quantum-electrodynamical density-functional theory [3,5], an exact quantum-fluid reformulation of quantum electrodynamics, is a natural framework to determine equilibrium as well as non-equilibrium properties of coupled matter-photon systems. This framework allows us to determine for the first time the intrinsic life times of excited states [8], modifications of Maxwell equations due to coupling with quantum matter [8], the emergence of polaritonic states due to changes in the electromagnetic vacuum [8], and the photon contribution to the molecular ground state [9] from first principles.

References:
Thursday 12:30: Invited talk

**Super-Planckian Radiative Heat Transfer**

Juan Carlos Cuevas

*Universidad Autónoma de Madrid, Spain*

Understanding heat exchange via thermal radiation is key for many areas of science and engineering [1]. Our knowledge about the thermal radiation is still largely based on Planck's law for black bodies. In particular, Planck's law establishes an upper limit for the thermal energy that can be transferred between two objects via radiation. However, as acknowledged by Planck's himself, this fundamental law of physics has known limitations and, in principle, it is only valid when all the dimensions involved in the problem are larger than the so-called thermal wavelength ($\lambda_{TH}$), which is around 10 microns at room temperature. In this talk, I will present our recent efforts devoted to explore the limits of Planck’s law and I will focus on two situations in which this law is no longer valid. First of all, I will discuss the radiative heat transfer between two objects in a variety of situations in which they are separated by a distance smaller than $\lambda_{TH}$ [2-4]. In this case, it is well-known that the radiative heat transfer can be dominated by the so-called near-field in the form of evanescent waves, and the Planckian limit can be largely overcome by bringing the two objects sufficiently close.

On the other hand, I will also discuss the radiative heat transfer between objects whose characteristics dimensions are smaller than $\lambda_{TH}$. In this case, Planck’s law, which is based on ray optics, is also expected to fail even in the far-field regime, i.e., when the separation between the objects is larger than $\lambda_{TH}$. In this sense, I will present a thorough analysis of the radiative heat transfer between small objects in the far-field regime and show for the first time that the Planckian limit can also be overcome in this regime [5,6].

**References:**


Thursday 15:30: Keynote talk

**Topology in nanophotonics: real space, synthetic space and scattering matrices**

Shanhui Fan

*Stanford University, USA*

Nanophotonics provide a very rich and fruitful environment to explore new topological physics. In this talk, we will discuss our efforts in developing photonic structures for demonstration of novel topological bandstructures, in both real space using three dimensional metamaterials, and as well as in synthetic space by considering light transport along the frequency axis in dynamically modulated structures. We also explore the topological features in the wavevector dependence of scattering matrices of nanophotonic structures.

Friday 09:30: Keynote talk

**Nanophotonics with atomically thick materials**

Luis Martín Moreno

*Universidad de Zaragoza, Spain*

Atomically thick materials, of which graphene is the paradigmatic example, are remarkable for their electronic and elastic properties. No less remarkable is their electromagnetic response. For instance, graphene supports electromagnetic modes (known as graphene plasmons), which can be electrically controlled by applying an external DC bias. These modes are extremely bounded, which makes them ideal for applications such as sensing. In this presentation I will summarise the basic properties of the electromagnetic modes in these 2D materials, and discuss how they scatter when encountering typical defects.
Fri 10:30: Invited talk

**Nano-optics with van der Waals materials**

Pablo Alonso González

*Universidad de Oviedo, Spain*

A promising solution to bring light to the nanoscale and thus circumvent the fundamental diffraction limit of light is provided by the excitation of surface plasmon polaritons (SPPs) or surface phonon polaritons (SPhPs) –surface waves originated by coupled excitations of photons and mobile/bound charges in metals/polar materials, respectively- and their ability to enhance and confine optical fields into deeply sub-diffracting volumes. Recently, optical studies in van der Waals materials such as graphene, h-BN, or metal oxides, have revealed the existence of SPPs and SPhPs with unprecedented properties, which establish a very encouraging arena towards the control of light at the nanoscale. In this talk, we will show some proof-of-concept devices that permit to control the excitation, propagation and detection of SPPs or SPhPs at the nanoscale.

Fri 11:45: Invited talk

**Critical phenomena with interacting photons in driven-dissipative systems**

Said R. K. Rodriguez

*AMOLF, Amsterdam, The Netherlands*

The physics emerging from fluctuations in nonlinear resonators is receiving renewed interest in photonics. Thanks to recent theoretical and experimental developments, it has become evident that networks of coupled nonlinear photonic resonators offer unprecedented opportunities for exploring novel phases of strongly correlated light and matter with potential applications to computation and optoelectronics. In this talk I will focus on the nonlinear and quantum physics of the fundamental building-blocks of such networks: single and coupled nonlinear photonic resonators.

I will discuss the interplay of fluctuations and optical bistability wherein two steady-states can be observed at a single driving condition. I will present measurements of dynamic optical hysteresis influenced by fluctuations. I will show how the hysteresis area can be understood within the framework of the Kibble-Zurek mechanism, which describes the onset of non-adiabatic dynamics near a critical point. In addition, I will introduce the concept of a dissipative phase transition, and I will explain how to optically measure its key quantity – the Liouvillian gap – based on the statistics of quantum jumps in a nonlinear resonator.

In the second part of the talk, I will introduce the experimental platforms we are currently developing at AMOLF, and the perspectives that these open for exploring critical phenomena with interacting photons in tunable multicavity systems.

Fri 12:30: Invited talk

**Laser acceleration of electrons at photonic nanostructures: accelerator on a chip**

Roy Shiloh

*Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*

Dielectric Laser Acceleration (DLA) is a novel particle acceleration scheme based on utilizing the large fields of lasers rather than electrical DC or RF fields. The limiting mechanism, preventing traditional accelerators from reaching very high acceleration gradients, is electrical breakdown of the accelerator’s material. The acceleration gradient is bounded at roughly 10MV/m for DC fields and 100MV/m for RF fields; dielectrics, however, can withstand laser fields in the order of 10GV/m. The opportunity to reach such high fields in such small scales enables potential applications such as miniature, hand-held x-ray and electron sources for medical treatments [1]. DLAs were first experimentally demonstrated in 2013 [2,3], and today the on-going Accelerator On a Chip International Program (ACHIP) is investigating how, aside from acceleration, auxiliary dielectric elements can be integrated [4,5] to additionally provide spatial focusing, steering, and bunching of electron pulses - important elements making up an essential toolbox in any particle accelerator. The principles of DLAs and the current state-of-the-art in this novel scheme will be discussed.

References:


1. Multilayered nanocapsules for fluorescence enhancement under electron excitation

J. Abad-Arredondo, F. J. García-Vidal, A. I. Fernández-Domínguez

Universidad Autónoma de Madrid

We present a theoretical study of fluorescence of dye molecules embedded within metallic (Ag or Au) multilayered nanocapsules. The photon emission is triggered by the $\beta^{-}$ radiative decay of an isotope attached to the capsule external boundary. We combine numerical and quasi-analytical calculations showing that by designing the metallic structure properly enhancements of several orders of magnitude can be obtained in the fluorescence power per radioactive decay.

![Figure](image)

**Figure:** Left: Schematic representation of our system. Right: Field enhancement at the center of the multilayered system for gold computed using Mie theory for different number of layers.

2. Optomechanical heat transfer between molecules in a nanoplasmonic cavity

S. M. Ashrafi$^1$, R. Malekfar$^1$, A. R. Bahrampour$^2$, J. Feist$^3$

1. Department of Physics, Tarbiat Modares University, Tehran, Iran
2. Department of Physics, Sharif University of Technology, Tehran, Iran
3. Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Spain

Achieving thermal control of molecular systems is a topic of current interest for a wide variety of applications. In this study, we explore whether localized surface plasmon polariton modes can transfer heat between molecules placed in the hot spot of a nanoplasmonic cavity through optomechanical interaction with the molecular vibrations. We demonstrate that external driving of the plasmon resonance indeed can lead to heat transfer between molecules. The plasmonic resonance induces an effective molecule-molecule interaction corresponding to a new heat transfer mechanism. This allows to actively control the rate of heat flow through the pumping and detuning frequency of the driving laser.
3. Interference in edge-scattering from monocrystalline gold flakes


Center for Nano Optics, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark

In recent years, chemically synthesized monocrystalline gold flakes have drawn considerable attention within the plasmonic community. Well-defined crystal structure as well as superior optical properties of this material are primarily important for applications, but also are interesting for the basic research.

In this work we report on strongly dissimilar scattering from two types of edges in hexagonal quasi-monocrystalline gold flakes with thicknesses around 1 micron. Experimentally it manifests in dark field microscopy, appearing as distinct colors of the adjacent edges that alter around the flake. Morphologically, the two types of edges differ in the orientation of asymmetrically tapered facets, which is a direct consequence of the three-fold symmetry around the [111]-axis and the intrinsic chirality of a face-centred cubic lattice.

In order to explain the apparent difference in scattering, we have developed a numerical model and filtering method which allows to simulate the experimental conditions. Based on the numerical results we propose an analytical model and identify the main physical mechanism of the observed phenomenon. In short, that is the interference between a direct, quasi-specular scattering and an indirect scattering process involving an intermediate surface-plasmon state.

We propose that this effect can be used to estimate flake thickness, crystal morphology, surface contamination and (assuming those parameters are fixed by other means) could provide a sensitive probe to the plasmonic properties of monocrystalline metals.

Figure: (a) SEM image of the Au monocrystalline flake (75° tilted view, scale bar: 10 µm) (b) and (c) close-up high resolution SEM image of the two corners of the flake (75° tilted view, scale bar: 500 nm); Artificial coloration is used to highlight different crystallographic planes of the facets: {111} (light yellow) and {100} (dark yellow); (d) bright-field optical image of the flake and (e-h) dark-field optical images of the flake captured with 4 different NA’s (indicated in the images) (scale bars: 10 µm)
4. Reduced Density Matrix Theory for Coupled Fermion-Boson Systems

F. Buchholz¹, M. Ruggenthaler¹, I. Theophilou¹, A. Rubio¹²

1. Max-Planck Institute for the Structure and Dynamics of Matter, Hamburg
2. Center for Computational Quantum Physics (CCQ), The Flatiron Institute, New York

In the last decade experiments at the interface between chemistry, material science and quantum optics have uncovered situations in which the strong interplay between the quantized electromagnetic field and the matter degrees of freedom lead to interesting physical effects and novel states of matter [1,2]. The theoretical description of such situations require a precise description of the involved (correlated) many-electron system, the full quantum mechanical treatment of the electromagnetic field, and validity in the strong coupling regime. It seems natural to extend electronic many-body theories to such coupled electron-photon systems, and for example recently, quantum-electrodynamical density functional theory (QED-DFT) was proposed [3]. However, the strong coupling regime is difficult to capture in QED-DFT, and learning from electronic structure theory, a promising candidate that describes strongly-correlated electrons well in many situations, is reduced density matrix functional theory (RDMFT). RDMFT approximates the 2-body reduced density matrix (2RDM), that carries all important information about electronic (Coulomb) interaction, by a functional of the 1-body reduced density matrix (1RDM). Instead in the present case, the respective RDM that carries all information about the electron-photon interaction, has to be characterized and approximated. In my poster I want to briefly explain the problems of transferring RDMFT from the purely electronic to the coupled electron-photon case. Then I will show an alternative approach that circumvents these problems by embedding the coupled system in a higher dimensional space. This allows for introducing new (quasi-) particles that are fermions and that's energy can be expressed completely by the 2RDM of this higher dimensional system. Thus any standard electronic many-body technique can be applied to approximate the 2RDM and I will show results for Hartree-Fock Theory and RDMFT. This is to my knowledge the first RDMFT for coupled electron-boson systems.

References:

5. Quantum yield enhancement of 2D-TMDs with nanoantenna arrays: A numerical study

Gabriel W. Castellanos¹, Jaime Gomez Rivas¹²

1. Department of Applied Physics and Institute for Photonic Integration, Eindhoven University of Technology, P.O. Box 513, 5600 MB, Eindhoven, The Netherlands

Monolayer transition metal dichalcogenides (2D-TMDs) with the chemical formula MX₂ (M = Mo, W and X = Se, S) are direct bandgap semiconductors that exhibit strong excitonic resonances resulting in large absorption and photoluminescence. Therefore, they offer an excellent platform for low-dimensional optoelectronic applications. However, typical optoelectronic devices, such as lasers and light-emitting diodes, must meet requirements that include high quantum yield (QY), large spontaneous emission and directional emission. In contrast, 2D-TMDs exhibit long emission lifetimes (~ns) and poor quantum yields (~1-10%). The relaxation pathways of these materials are dominated by nonradiative processes, namely defect-mediated recombination and exciton-exciton annihilation. While defect-mediated recombination has been observed to disappear after treatment with organic superacids, exciton-exciton annihilation remains a problem at typical excitation powers used in optoelectronic devices. One way to improve the emission properties consists in modifying the photonic environment by coupling 2D-TMDs to optical nanocavities. In the weak-coupling regime, the increased local density of states (LDOS) results in emission rate enhancements (the Purcell effect). In this contribution, we investigate with FDTD simulations the QY enhancements in 2D-TMDs achievable with array of nanoantennas. Owing to the coherent scattering, arrays offer higher directionality than single antennas. In addition, diffractive coupling of nanoantennas by Rayleigh anomalies results in extended optical modes known as surface lattice resonances (SLRs). Here we use these SLRs to obtain an average QY enhancement over large areas. Finally, we have considered both plasmonic and all-dielectric arrays. While plasmonic antennas offer small mode volumes, high-index dielectric nanoparticles present smaller absorption. Combining high-directionality with a moderate QY enhancement opens the possibility of low-dimensional and efficient light-emitting devices.
6. 2D Photonic Crystal Band Gap Structures of Optical Communications

Mayur Kumar Chhipa

Department of Electronics and Communication Engineering, K L (Deemed to be University), Guntur, Andhra Pradesh, 522502 India

The exponentially increasing bandwidth requirement for the internet generation and multimedia applications is pushing optical communications ever closer to the end user. In the last 20 years, the development of new optical technologies for device miniaturization has accelerated significantly. Comparing with conventional optical devices, the PC based optical devices have attracted great interest due to their compactness, speed of operation, long life and suitability for PICs. Typically, PCs are composed of periodic dielectric and/or metallo-dielectric nanostructures that have alternate low and high relative permittivity materials to affect the propagation of electromagnetic (e.m) waves inside the periodic structure in certain frequency ranges. As a result of this periodicity the transmission of light is absolutely zero over certain frequency ranges which are called as Photonic Bandgap (PBG). By introducing the defects in these structures, the periodicity and thus the completeness of the PBG are broken. Recent years, many Two Dimensional (2D) PC based optical devices are designed and analyzed to name a few, optical filters, power splitters, multiplexers, demultiplexers, polarization beam splitters, tripplexers, switches, directional couplers etc. Conventional CDFs, such as Bragg grating filters, Fabry-Perot filters, acoustic optic filters, thin film filters, arrayed waveguide grating filters and micro-ring resonator filters are in the scale of centimeters, which may not be suitable for PICs. Among these, the micro-ring resonator based CDF is an attractive candidate for filtering applications and contribute better performance because of its circular resonating mode. However, when the radius of the ring resonator decreases below 5 µm, it exponentially increases the propagation and bending losses. These affect the coupling and dropping efficiencies, passband width in turn Q factor of the filter. Photonic Crystal (PC) based Channel Drop Filter (CDF) is one of the right candidates to overcome this issue as it is not allowing these losses to increase exponentially.

7. Theory of vibro-polaritonic chemistry

C. Climent¹, J. Galego¹, F. J. Garcia-Vidal¹², J. Feist¹

1. Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain
2. Donostia International Physics Center (DIPC), Donostia, Spain

When matter strongly couples to confined light modes, new hybrid light-matter states so-called polaritons can form. Within this context, polaritonic chemistry aims to manipulate molecular structure under such strong coupling regime. While the general theory of polaritonic chemistry due to electronic strong coupling is well established [1], theoretical studies describing the modification of ground-state chemistry through strong coupling between molecular vibrations and microcavity modes [2,3] are still missing. In this communication we will show our recent efforts in this direction. We use the cavity Born-Oppenheimer [4] description of the coupled light-matter system as a starting point and show that the effective light-matter potential energy surface governing ground-state reactions depends sensitively on the molecular dipole moment. Based on full electronic-structure calculations for complex molecules, we identify several reactions that could be promising candidates for control through vibrational strong coupling.

References:

8. Collective optomechanical effects in cavity quantum electrodynamics

E. Cortese, P. G. Lagoudakis, S. De Liberato
School of Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ, United Kingdom

In the last few years a number of papers investigated the possibility to exploit light-matter coupling to modify chemical or mechanical properties of molecules strongly coupled to a cavity photonic field [1,2]. Those seminal works demonstrated that only very specific, collective observables are accessible in this way. Single-molecule properties are instead usually not accessible, because the relevant energy scale is in this case not the collective, superradiant vacuum Rabi frequency, but the tiny single-molecule one. In a recent work [3] we showed that this limitation can be overcome in highly excited systems. In particular we studied a collection of asymmetric two-dimensional, freely rotating dipoles coupled to a cavity field, sketched in the left panel of Fig. 1. We demonstrated that the thermodynamics of the system is regulated by the single parameter $\Lambda$, which is the inverse temperature renormalized by the vacuum Rabi frequency and the excitation density. At low $\Lambda$ (high temperature or low excitation density) the molecules are isotropically distributed, while at high $\Lambda$ (low temperature or high excitation density) all the molecules are aligned with the cavity field. In the right panel of Fig. 1 we can see that, as $\Lambda$ is modified, the system undergoes a second order phase transition from the disordered to the ordered phase, which can be detected as a change in the frequency of polaritonic luminescence. Such a phase transition should be observable in organic, liquid phase microcavities [4].

References:

Figure: (left) Schematic representation of the system under investigation: a set of asymmetric, freely rotating molecules coupled to the field of a photonic cavity. (right) Frequency of the polaritonic emission as a function of the normalized inverse temperature $\Lambda$, clearly showing a second order phase transition.
9. Light-Forbidden Transitions in Plasmon-Emitter Coupling

Álvaro Cuartero, Antonio I. Fernández Domínguez

Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049, Madrid, Spain

By means of Transformation Optics [1], we investigate theoretically the interaction between particle-on-a-mirror localized plasmons and two types of nano-emitters: dipolar and quadrupolar ones. Our 2D conformal mapping technique allows for the exact description of the Purcell effect in this geometry within the quasi-static limit. The analytical character of our solutions provides deep insights into the dependence of the emitter-plasmon coupling on the system parameters. Our results indicate that the large near-field gradients [2] taking place at the nanogap yield quadrupolar emission rate enhancements (into the plasmon field) orders of magnitude larger than those experienced by dipolar emitters. Further analysis delves into Near Field Dynamics and Far Field Signatures, providing a platform to study the emergence of different regimes of Strong Coupling among the emitter levels and the plasmonic modes.

References:
10. Light-driven processing of resonant and non-resonant Silicon Nanostructures
Stefano Danesi\textsuperscript{1,2}, Marco Gandolfi\textsuperscript{3,4}, Luca Carletti\textsuperscript{5}, Nicolò Bontempi\textsuperscript{6}, Costantino De Angelis\textsuperscript{5}, Francesco Banfi\textsuperscript{3}, Ivano Alessandri\textsuperscript{1,5,6}
\textsuperscript{1}. INSTM-UdR Brescia, via Branze 38, 2513 Brescia, Italy
\textsuperscript{2}. Department of Mechanical and Industrial Engineering, via Branze 38, 2513 Brescia, Italy
\textsuperscript{3}. Interdisciplinary Laboratories for Advanced Materials Physics (I-LAMP) and Dipartimento di Matematica e Fisica, Università Cattolica del Sacro Cuore, Via Musei 41, 25121 Brescia, Italy
\textsuperscript{4}. Laboratory of Soft Matter and Biophysics, Department of Physics and Astronomy, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
\textsuperscript{5}. Department of Information Engineering, University of Brescia, via Branze 38, 2513 Brescia, Italy
\textsuperscript{6}. INO-CNR, via Branze 38, 2513 Brescia, Italy

Light driven processing of amorphous materials is widely studied in the field of nano-manufacturing, laser information storage, optoelectronics and material science. Recently it was found that resonating dielectric nanoparticles can experience a large temperature, even with low exciting power [1,2]. However contradictory results are present in literature about the topic [3]. When considering the laser processing of nanostructures, the resonant driven melting or crystallization has never been studied before. In this work we first elucidate the features affecting heating in Silicon nanostructures, the role of resonance and of structural features. Afterwards we study the light driven processes of crystallization and melting as a function of different light-coupling condition. Considering the change of thermal and optical proprieties during the process, we found that a wide variety of unexplored phenomena take place. Light coupling, drive the crystallization/melting kinetics and even have a crucial role in the spatial evolution of the process. Deep subwavelength domains of crystalline material, can be embedded in an amorphous nanoantenna matrix. While the process take place, optical proprieties has been monitored, showing largely enhanced optical absorbance and scattering respect to the fully amorphous or fully crystalline counterparts. When melting temperature is reached, the resonating particles, show a self-limiting melting, due to the decoupling of the antenna from the radiation. The result is a partially melted system. If the unmelted portion of a-Si undergoes the crystallization, the melted region re-solidify in a crystalline way. Counterwise, melting of a non-resonating system, can bring the particle in resonance, resulting in a self-sustaining explosive melting.

References:

11. Tuning chiral interactions among quantum emitters at the subwavelength scale
Universidad Autonoma de Madrid

We investigate the dipole-dipole interactions between two circularly-polarized quantum emitters held above a metallic surface hosting plasmons. Depending on the positions of the emitters, we find that the nature of the coupling evolves from non-chiral to chiral, thus realizing non-reciprocity at the subwavelength scale in a tunable manner. We explore the physically rich phase space of the effective coupling, which is a combination of coherent and dissipative components, and find novel and exotic features in both the one and two-photon spectra of the system. In particular, we highlight that the quasichiral regime, that between the reciprocal and chiral limits, is interesting by itself, and report hitherto unknown spectral peaks and photon correlations.
12. Spontaneous patterns in coherently driven polariton microcavities

G. Díaz-Camacho, C. Tejedor, F. M. Marchetti

Departamento de Física Teórica de la Materia Condensada & Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid 28049, Spain

In recent years, hybrid matter-light systems such as microcavity polaritons have been proven ideal for the study of spontaneous pattern formation. Resulting from the strong coupling between cavity photons and quantum well excitons, microcavity polaritons share the properties of both components and, thus, display unique properties: among those, optical and electrical injection, a high degree of tunability and control, easy detection and direct read-out. There has been an increasing interest in recent years on pattern formation in microcavity structures. Optical parametric oscillation is a paradigm of polariton spontaneous pattern formation. More recently, same energy instabilities have been realised in triple and double cavities, as well as by blue-shifting the pump above the polariton dispersion in one dimensional cavities. Interestingly, there is an analogy between optical patterns and Turing patterns, where spontaneous self-organised repetitive spatial configurations emerge out of a homogeneous distribution.

In this contribution [1], we consider a polariton microcavity resonantly driven by two external lasers which simultaneously pump both lower and upper polariton branches at normal incidence. In this setup, we study the occurrence of instabilities of the pump only solutions towards the spontaneous formation of patterns. Their appearance is a consequence of the spontaneous symmetry breaking of translational and rotational invariance due to interaction induced parametric scattering. We observe the evolution between diverse patterns which can be classified as single-pump, where parametric scattering occurs at the same energy as one of the pumps, and as two-pump, where scattering occurs at a different energy. For two-pump instabilities, stripe and chequerboard patterns become the dominant steady-state solutions because cubic parametric scattering processes are forbidden. This contrasts with the single-pump case, where hexagonal patterns are the most common arrangements. We study the possibility of controlling the evolution between different patterns. Our results are obtained within a linear stability analysis and are confirmed by finite size full numerical calculations.

![Figure: Photon emission from a specific stable chequerboard configuration. Top panels: Photonic spectra. Bottom panels: Photon density profiles in real (right) and reciprocal (left) spaces, filtered at the energy of the signal states $\omega_\alpha = (\omega_{p1} + \omega_{p2})/2$.](image)

References:

13. Non-adiabatic dynamics on hybrid light-matter states

J. Fregoni1,2, G. Granucci3, M. Persico3, S. Corni2,4

1. F.I.M. Dept., University of Modena and Reggio Emilia, via Campi 213/a, Modena, Italy
2. CNR-Institute of Nanosciences, via G. Campi 213/a, Modena
3. Dept. of Chemistry and Industrial Chemistry, University of Pisa, Via Moruzzi 13, Pisa
4. Dept. of Chemical Sciences, University of Padova, Via Marzolo 1, Padova

The strong coupling regime, i.e. the coherent exchange of energy between matter and radiation in optical cavities, was initially modelled by Jaynes and Cummings [1]. Recent achievements of strong light-matter couplings [2] have unravelled a manyfold of exotic applications, ranging from enhanced optical response to quantum information, sensing and polaritonic chemistry [3]. The latter aims to study how the electronic states of molecules are modified by the coherent coupling of molecules with an electromagnetic field. The system potential energy surfaces are then described by the definition of hybrid light-matter states: the polaritons. The modulation of Polaritonic Potential Energy Surfaces (PoPESs) through light-matter coupling brings, in principle, the possibility to control the quantum yields of photochemical reactions, recently shown on model molecules [4]. Non-adiabatic dynamics (NAD) methods have been developed to simulate photochemical reactions extensively, providing a good starting point for polaritonic chemistry. In our work, we make a step toward the realistic description of azobenzene photoisomerization reaction on PoPESs. To this aim, we exploit a modified version of the Direct Trajectory Surface Hopping (DTSH) [5] method devised by Granucci, Persico and coworkers. Such method conjugates the low computational burden of a semiempirical description with a good level of accuracy provided by high-quality parametrization of the electronic hamiltonian. The results in the computation of PoPESs with an extended Jaynes-Cummings model and some examples of photoisomerization on polaritonic states are presented.

References:
14. Polaritonic chemistry: influencing photochemical and ground-state reactions

Javier Galego\textsuperscript{1}, Francisco J. García-Vidal\textsuperscript{1,2}, Johannes Feist\textsuperscript{1}

1. Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain
2. Donostia International Physics Center (DIPC), E-20018 Donostia/San Sebastián, Spain

Controlling chemical processes with light has long been a topic of great interest in many different fields of science. One of the most promising directions towards this goal is employing the light-matter strong coupling phenomenon with organic molecules. This interaction regime is achieved when the coherent energy exchange between a confined electromagnetic field mode and material excitations (excitons) becomes faster than the decay and decoherence of either constituent. The resulting excitations of the system, the so-called polaritons, have a hybrid behavior, presenting both light and matter characteristics. Under strong coupling, the molecular “landscape”, i.e., the potential energy surfaces (PES) that describe nuclear motion in a given electronic state, are modified by the coupling of the electronic transitions to the light mode. This opens the possibility to modify chemical reactions under strong coupling, as first experimentally demonstrated in 2012 \cite{1}. Since then, many theoretical and experimental efforts have been devoted to this new field of research, known as polaritonic chemistry \cite{2}. We will discuss the possibilities of polaritonic chemistry, and demonstrate that it can be used to influence chemical reactions and organic molecule properties in different manners, such as complete suppression of photochemical reactions, or triggering of excited-state reactions in many molecules through single-photon absorption. We additionally present a quantum mechanical formalism that allows to study the influence of strong coupling on ground state reactivity. We will study which molecular properties this approach is sensitive to and discuss candidate molecules and reactions that could be modified through vibrational strong coupling.

References:
\begin{itemize}
  \item [2] J. Feist, J. Galego, and F. J. García-Vidal, ACS Photonics, Vol. 5, 205, 2018
\end{itemize}

15. Strong light-matter coupling in open-access tunable microcavities

Z. Geng\textsuperscript{1}, D. van der Flier\textsuperscript{1}, B. Patra\textsuperscript{1}, A. Trichter\textsuperscript{2}, K. Malmir\textsuperscript{2}, E. Garnett\textsuperscript{1}, J. Smith\textsuperscript{2}, S.R.K. Rodriguez\textsuperscript{1}

1. Center for Nanophotonics, AMOLF, Amsterdam, The Netherlands
2. Department of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, United Kingdom

Open-access tunable microcavities offer the possibility to spatially and spectrally match any nanoscale emitter to any confined cavity mode in-situ. State-of-the-art tunable cavity systems have demonstrated mode volumes on the order of $\lambda^3$, and quality factors $Q \sim 10^8$. Herein, we present preliminary experimental results we have obtained with open-access tunable microcavities hosting different emitters at room-temperature, such as organic molecules and perovskites. In white light transmission spectra as a function of the cavity length, we have observed the avoided resonance crossing characterizing the strong light-matter coupling regime. We have also observed a strong cavity-enhanced emission from perovskite quantum cubes. We are planning to investigate nonlinear phenomena emerging from polariton-polariton interactions, and to extend the single nonlinear microcavity to microcavity lattices. We will also present our current plans to perform similar experiments in a closed-cycle cryostat.
16. Radiative emission tuning of Si nanocrystals by employing the Purcell effect

M. Greben, J. Valenta

Charles University

Silicon nanocrystals (Si NCs) embedded in silicon dioxide (SiO$_2$) or oxinitrides (SiO$_x$N$_y$) have been shown to provide high photoluminescence (PL) external quantum yield (EQY) of up to 27% which is size-tunable in the spectral region from orange to near infrared (NIR), i.e. about 650 – 1100 nm [1]. Such quality can be potentially exploited to provide photon conversion in lighting and photovoltaic devices. We provide comprehensive study of both external and internal luminescence quantum yield (IQY) of Si NC/SiO$_2$ multilayers for different temperatures (4 – 300 K). EQY is defined as the ratio of total number of emitted to absorbed photons for the whole ensemble, while IQY concerns only the luminescing (bright) subensemble of NCs and is equal to the ratio of radiative and total decay rates. Some Si NCs in ensemble are “dark”, i.e. they absorb but not emit photons due to the presence of non-radiative recombination centres (defects) or due to transient switching-off (blinking). EQY is measured using an integrating sphere [2] while IQY is derived using variation of local density of optical states (LDOS) which affects radiative but not non-radiative lifetime, so enabling to decouple these two components. We study IQY using special wedge samples with variable distance between Si NCs and a high-n substrate resulting in position-depending Purcell factor (which directly effects radiative lifetimes) [3]. While the near-infrared emission (close to the bulk Si bandgap) is almost ideal (IQY > 80 %), both IQY and population of bright NCs decreases toward shorter wavelengths causing vanishing PL below 600 nm.

References:

17. Hybrid Longitudinal-Transverse Modes in Surface Phonon Polariton Systems

Christopher Gubbin

University of Southampton

Surface phonon polaritons (SPhPs) are formed by hybridisation of photons with the coherent oscillations of a polar dielectric crystal. Like plasmons these modes allow for confinement of light on the nanoscale. Unlike plasmons, SPhPs typically have narrow linewidths and corresponding long lifetimes [1]. SPhPs are supported in the mid-infrared spectral region, specifically in the Reststrahlen region between the supporting polar dielectric’s transverse and longitudinal optical phonon frequencies. Their large intrinsic nonlinearities [2,3] and ease of fabrication make SPhP systems an excellent platform for mid-infrared nonlinear optics. Although the phonon branches of a polar dielectric crystal are dispersive the optical properties of the SPhP systems studied thusfar are dependent solely on the zone-centre phonon frequencies of the lattice. This is because the lengthscale of a typical SPhP nanoresonator is 100nm, many orders of magnitude larger than the supporting polar dielectric’s lattice constant. This talk will discuss a system where this zone-centre treatment of the lattice fails. Exploiting the polymorphism of silicon carbide, whose polytypes unit cells are identical in two dimensions but extended to varying degree in the third, it is possible to fold the dispersive longitudinal optical phonon of the lattice back to zone-centre. We will discuss the implications of this folding for the optical response of SPhP nanoresonators, demonstrating that their optical modes can be hybridised with this folded longitudinal phonon to create a mixed longitudinal-transverse mode. In addition we will discuss the possibility of exploiting these hybridised modes to create electrically pumped SPhP devices.

References:
18. Super-resolution microscopy on single molecules for plasmon-activated catalysis and LDOS mapping
Ruben F. Hamans1,2, Matteo Parente1,2, Mohammad Ramezani1,3, Jaime Gómez Rivas1,3, Andrea Baldi1,2
1. Dutch Institute for Fundamental Energy Research (DIFFER), De Zaale 20, 5612 AJ Eindhoven, The Netherlands
2. Institute for Complex Molecular Systems, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
3. Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
Super-resolution microscopy is a form of optical microscopy that allows images to be taken with a higher resolution than the diffraction limit1,2. We use super-resolution microscopy 1) to study site-selective catalysis on individual Au nanostructures and 2) to map the coupling between fluorescent molecules and metal nanoparticle arrays. First, we study the effect of the decay of localized surface plasmon resonances on the catalytic properties of metal nanoparticles3. As a test reaction we use the nanoparticle-catalyzed reduction of the weakly fluorescent molecule resazurin to the strongly fluorescent molecule resorufin4,5. By using catalysts with a plasmon resonance spectrally separated from the absorption and emission of the reaction products and by controlling the polarization of the incident fields, we can study the different contributions of plasmonic hot electrons, plasmonic heating, and coupling between the reactions products and the catalysts. Second, we investigate the coupling between fluorescent molecules and a periodic array of metallic nanoparticles. Due to their ability to support surface lattice resonances6, these arrays can enhance the emissive properties of fluorescent molecules across the whole unit cell of the array, instead of just in the vicinity of the nanostructure7. However, accurately mapping this enhancement is challenging, as the pitch of the array is typically of the order of the diffraction limit. Using our super-resolution microscope, we are able to map the emission of fluorescent molecules dispersed above a nanoparticle array with a spatial accuracy of ~20 nm, allowing sub-unit cell properties to be visualized. As the influence of the particle array on the emission depends strongly on the position of the fluorescent molecule in the unit cell, mapping the emission enhancement as a function of position in the unit cell is instrumental for the optimization of these devices.
References:
[1] Hess et al. (2006), Biophys. J. 91(11), 4258–4272
[3] Cortés et al. (2017), Nat. Commun. 8, 14880
[4] Xu et al. (2008), Nat. Mater. 7(12), 992-996

19. New Materials For Light-Driven Microswimmers
Sandra Heckel
Technische Universität Dresden
Micromotion is a quickly evolving research field. To enable motion at the microscale, a swimmer requires constant energy input. Because of the high Reynolds number at such conditions, a discontinuation of energy input would immediately cause a micromotor to stop. Among different motion mechanisms for micromotors such as catalytic reactions, magnetic fields and ultrasound, light-driven micromotors show some advantageous properties. Light as an energy source can easily be applied remotely and is also renewable. When excited by light of a certain wavelength, a photocatalytic material in the micromotor catalyses the degradation of a certain fuel and is accelerated by the gas formation of that reaction. Until a few years ago, light-driven micromotors could only move in highly oxidizing fuels like H2O2 due to a lack of sufficient photocatalysis materials that enable other fuels. This prevented micromotors to develop towards application-oriented research. Recently, materials like BiVO4 showed great potential as such photocatalytic materials and micromotors that use H2O as a fuel, activated by UV light, could be demonstrated. Despite those advances, light-driven micromotors still lack a general understanding of their motion principles and collective behaviour on the one side and photoactive materials that can be activated by visible light on the other side. Only by expanding the pool of materials, light-driven micromotors will become possible alternatives for sensing, environmental remediation and bioapplications. To achieve those goals, this poster presents new photoactive materials for micromotors.
20. Referenced resonator sensor platform for high sensitivity biomarker monitoring

Ward Hendriks
Universiteit Twente

Aiming for the improved performance of a micro ring resonator biosensor platform we will analyse the influence of noise on the limit of detection and investigate the effect of the field overlap with the analyte. As the physical limit of detection is primarily determined by the noise floor of the sensors and the sensitivity of the sensor. We will show that an increased field overlap increases the sensitivity of our system while simultaneously leading to a higher noise floor thereby not improving the actual limit of detection. Therefore In order to reduce the noise influence we consider the improvement that can be obtained by a referenced sensor configuration.

21. Optical response of magnetoplasmonic nanodisks in the mean field approximation

C.A. Herreño-Fierro, G. Armelles, A. Cebollada
Universidad Distrital Franciso José de Caldas

The anisotropic optical response of Au/Co magnetoplasmonic nanodisks is studied in the mean field approximation. Lorentz like oscillators are considered to model the real and imaginary components of the dielectric tensor of the system showing good agreement with spectral ellipsometry measurements. The analysis allows for the detection of two in-plane plasmonic modes, as well as a normal to the disks mode. A further analysis of the sensitivity of the optical properties to the dielectric environment of the nanodisks shows al well-behaved evolution of the in-plane modes which undergo a red-shift, while the out-of-plan mode suffers an unexpected blue-shift.
22. Atomic Version Of A Pinhole Camera Using Hole-Mask Colloidal Lithography

Maria H. Salazar, V. E. Bochenkov, D. S. Sutherland

Aarhus University

Hole-mask colloidal lithography is a low cost nanofabrication technique, which involves self-organization of colloidal particles on a thin PMMA layer to perform a sacrificial mask, from which nanostructures are created by physical vapor deposition over large areas [1]. However, it has some limitations in the range of patterns that can be fabricated due to its formation principle, where the inclination of sample is necessary [2]. In order to extend the range of possible patterns that can be fabricated and their potential applicability we have created an atomic version of a pinhole camera using hole-mask colloidal lithography. Previously nanolithography based on an atom pinhole camera has been demonstrated [3], but nanoscale membranes manufactured by the method of ion beam milling are required, restricting the fabrication of nanostructures to a small area. In this work, we have created colloidal hole-masks based on self-assembly with thick PMMA layers to avoid the use of membranes allowing nanostructures fabrication over large areas. Traditional hole-mask colloidal lithography typically works with thin PMMA layers around 200 nanometers in thickness. In this work, we use PMMA layers of several micrometers thickness, we have modified etching conditions increasing the power to create a thick hole-mask. Initial experiments using 2-micrometer PMMA layer showed a partial projection of a gammadion design with an approximate size reduction of 4800. Different parts of the gammadion were projected in different parts of the sample due to the limited surface area at the bottom of the etched hole and the small angle of view. We have chosen this design due to its rotational symmetry for sensitivity enhancement in sensing applications [4, 5]. By modifying hole-mask characteristics and adding an intersection mask, we have developed a novel fabrication route to achieve nanostructures for a broad range of future applications.

References:
23. Strong Light–Matter Interaction Enhancement Through Molecular Dipole Alignment

Manuel Hertzog\textsuperscript{1}, Per Rudquist\textsuperscript{2}, James A. Hutchison\textsuperscript{3}, Jino George\textsuperscript{3}, Thomas W. Ebbesen\textsuperscript{3}, Karl Börjesson\textsuperscript{1}

\textsuperscript{1} University of Gothenburg, Department of Chemistry and Molecular Biology, Kemigården 4, 412 96, Gothenburg, Sweden
\textsuperscript{2} Chalmers University of Technology, Department of Microtechnology and Nanoscience, MC2, Kemivägen 9, 412 96, Gothenburg, Sweden
\textsuperscript{3} University of Strasbourg, CNRS, ISIS & icFRC, 8 allée Gaspard Monge, Strasbourg, 67000, France

In this work, we present a fine control over the coupling strength of light–matter hybrid states by controlling the orientation of a nematic liquid crystal. The microcavity was made from ITO-Gold electrode/mirrors on IR-transparent CaF\textsubscript{2} substrates (Fig. 1a). Through an external voltage, the liquid crystal is seamlessly switched between two orthogonal directions. The C – N vibration on the liquid crystal molecule is coupled to a cavity mode, and FT-IR is used to probe the formed vibro–polaritonic states. Using these features, we demonstrate electrical switching and increased Rabi splitting through transition dipole moment alignment compared to an isotropic phase. Moreover, the scalar product used in the modelisation of light–matter interaction is verified \cite{1}.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure.png}
\caption{Left: Photography of a microcavity. Right: Rabi-splitting $\hbar \Omega_R$ as a function of applied voltage over the cavity monitoring with the polarizer parallel (orange) or perpendicular (grey) to the alignment layer.}
\end{figure}

References:


24. A DNA origami for circular dichroism sensing

Yike Huang
Aalto University
25. Transport mechanism of ultrathin Fe-Co nanowires in self-assembled arrays
Shivam Kansara¹, Sanjeev K. Gupta², Yogesh Sonvane¹, Igor Lukačević³
1. Department of Applied Physics, S.V. National Institute of Technology, Surat 395007, India
2. Department of Physics, St. Xavier’s College, Ahmedabad 380009, India
3. Department of Physics, University J. J. Strossmayer, 31000 Osijek, Croatia

In the view of the recent work, we have investigated the development of the electronic, magnetic, and optical properties of ferromagnetic materials of iron (Fe) and cobalt (Co) nanowires. All calculations are systematically investigated using the first principles approach, with ultrasoft and spin–orbit coupling potentials within density functional theory under generalized gradient approximation as from linear chains (LCs) (1-D structure) to zigzag (ZZ) structure to 2×2 NWs. The magnetic properties of Fe and Co (spin and orbital magnetic moments, magnetocrystalline anisotropy energy) in multifarious geometries are calculated by using a first principles calculation in atomic orbital basis set including spin polarization and the effect of SOC. Here we have also compared the axial anisotropy, magnetic moment and cohesive energy for the different diameter of all three structures and also accumulation transverse of charge density. The thermodynamical properties are calculated using BoltzTrap code in quasi harmonic approximation (QHA). This work looks into the properties of nanowires and the multiple ways in which they have been exploited for energy generation, from photovoltaics to piezoelectric generators.

26. Using plasmonic nanoantennas to read out the orbital angular momentum of light
Richard M. Kerber¹, Jamie M. Fitzgerald², Sang Soon Oh³,³, Ortwin Hess³, Doris E. Reiter¹,²
1. Institut für Festkörpertheorie, Universität Münster, 48149 Münster, Germany
2. Department of Physics, Imperial College London, London SW7 2AZ, United Kingdom
3. School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, United Kingdom

Spatial structured light fields can carry an orbital angular momentum encoded in their phase, in addition to the spin angular momentum connected with the circular polarization. The additional degree of freedom of orbital angular momentum can be exploited to carry information, what makes orbital angular momentum light attractive for future communication technologies. Because of the helical wavefront these light beams are also called twisted light. To measure the value of orbital angular momentum of a twisted light beam we here propose an approach using plasmonic nanostructures to convert the phase information into spectral information. We analyze the resonance modes of nanoantennas excited by orbital angular momentum light numerically using the boundary element method and analytically using a line antenna model. For rotation-symmetrical nanorod antennas we show that dependent on the combination of the value of orbital angular momentum, the handedness of circular polarization and the discrete rotation symmetry of the antenna the scattering cross-section exhibits different resonance modes which can be classified into bright and dark modes [¹]. Using these resonance modes we propose a scheme to read out the OAM of a twisted light beam.

References:
27. X-ray cavity QED in the overlapping mode regime

Dominik Lentrodt
Max-Planck-Institute for Nuclear Physics

The use of cavities to shape the electromagnetic field has been a successful tool across many experimental platforms and has enabled the access to new regimes of light-matter interaction. In recent years X-ray nanomaterials doped with Mössbauer nuclei have been added as yet another platform of cavity QED and have shown their potential with the observation of a number of quantum optical phenomena in this system [1,2]. With a new platform come new theoretical challenges. Due to material limitations X-ray cavities do not have the quality factors that can be achieved for example in microwave cavities. This inhibits progress in several ways, since strong coupling and non-linearities become hard to achieve. However it allows to explore a new cavity QED regime, where multiple broad cavity resonances participate in the dynamics, known as the “overlapping mode regime”. On the other hand the Mössbauer nuclei have extremely narrow resonances and can be employed as an essentially decoherence free quantum system. As a result it is possible to very precisely measure interference effects and gain insight into overlapping mode physics this way. Indeed explaining recent experimental findings required heuristic extensions [3] to well known multi-mode models based on the input-output formalism. In this poster we present a theoretical tool for the ab-initio description of such quantum effects in the overlapping mode regime of cavity QED. By linking methods from scattering theory and quantum noise theory we are able to compute reflection spectra and show the relevance of multi-mode effects in X-ray cavities which go beyond input-output models. Our work builds on and connects to recently developed techniques for multi-mode random lasers [4], non-Markovian cavity QED [5] and mesoscopic scattering in complex nanophotonic systems [6].

References:
[1] Röhrsberger et al., Science 2010
[5] Sundaresan et al., PRX 2015


Phillip Manley1,4,5, Fatwa F. Abdi2, Sean Berglund2, Islam Nazmul3, Martina Schmid4, Christiane Becker1, Roel van de Krol2, Sven Burger5

1. Nanostructured Silicon for Photonic and Photovoltaic Implementations, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Kekuléstrasse 5, 12489 Berlin, Germany
2. Institute for Solar Fuels, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner-Platz 1, 14109 Berlin, Germany
3. Department Quantum Phenomena in Novel Materials, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner-Platz 1, 14109 Berlin, Germany
4. Zuse Institute Berlin, Takustrasse 7, 14195 Berlin, Germany
5. Nanooptical Concepts for Photovoltaics, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner-Platz 1, 14109 Berlin, Germany
6. University of Duisburg-Essen and CENIDE, Lotharstrasse 1, 47057, Duisburg, Germany

We present rigorous optical simulations of the modes present in an ultra-thin solar fuels device. Optical resonances are classified into traveling modes which contribute to the large absorption enhancement in the device and localized modes which mainly contribute to parasitic losses. Using the finite element method we are able to quantify the absorption enhancement of the device and optimise the geometry for an optimal mode distribution within the wavelength range of interest. Through the dependence of the optical resonances on geometrical parameters we are able to draw an analogy for the modes to those of simple analytical systems, thereby obtaining a deeper understanding of the underlying physics. Our simulations show how the absorbed photocurrent density of the ultra-thin solar fuels device can be increased by 5.2 mAcm⁻² (47%). This emphasises the ability for plasmonics to provide absorption enhancement in ultra-thin optoelectronic devices.
29. Radiative properties of atoms near and within metamaterials
Anette Messinger, Stephen M. Barnett
University of Glasgow
The spontaneous emission rate of atoms can be modified due to boundary conditions or by embedding the atoms in media. The modifications due to dielectrics have been well studied [1] in recent decades. We extend this framework to magnetodielectric materials, including those with negative refractive index [2], i.e. materials that exhibit simultaneous negative ε and negative μ.

References:

30. Angle dependent lifetime measurements of perylene strongly coupled to the vacuum field
Jürgen Mony, Karl Börjesson
University of Gothenburg, Department of Chemistry and Molecular Biology, Kemigården 4, 412 96, Gothenburg, Sweden
Strong coupling between light and matter leads to the formation of two new optically active hybrid states. The formed states are polaritonic and separated in energy by the Rabi splitting $\hbar \Omega_R$, which magnitude depends on the concentration and the transition dipole moment of the molecule. These states show a dispersive behaviour, which means that their energy and the spectral envelope of the emission are angle dependent. In this work, we studied the dependence of the polaritonic lifetime on the angle between the outgoing light beam and the optical cavity. A homemade setup with moveable excitation and emission branches was built in order to measure the dependence. Tetra-tert-butylperylene in a polystyrene matrix was used as organic dye in the optical cavity. The organic film was deposited on a silver mirror by spincoating and another silver mirror was sputtered on the organic layer to obtain a cavity. All in all, our results suggest that no angle dependence on the cavity lifetime exist as predicted by theory.

Figure: Absorbance and emission spectrum of tetra-tert-butylperylene.
31. 2D Epsilon-Near-Zero Metamaterials

S. A. O'Brien, F. Bello, D. McCloskey, J. F. Donegan

Department of Physics, Trinity College Dublin, College Green, Dublin 2, Ireland

The interaction of electromagnetic waves with a material and their propagation are governed by two parameters, the electric permittivity, $\varepsilon$ and the magnetic permeability, $\mu$, which determine how the electric and magnetic fields respectively interact with the material. By simply setting either of these parameters to zero for a material, a plethora of interesting effects and counterintuitive physics reveal themselves such as zero refractive index, zero wavenumber, infinite wavelength and phase velocity, which is often described as a “tunneling” or “supercoupling” through an $\varepsilon = 0$ medium.\[1\] An astounding effect of ENZ media is the ability for ENZ materials to theoretically confine light. If we consider the displacement current, $\vec{J}_D = \varepsilon_0 \varepsilon \frac{d\vec{E}}{dt}$ when $\varepsilon \to 0$ it’s clear that $\vec{J}_D \to 0$. If we now consider an ENZ medium with a dielectric inclusion such as an air pocket, it’s evident that the displacement field, $\vec{D} = \varepsilon_0 \varepsilon \vec{E}$ is zero everywhere except within the dielectric inclusion, effectively confining the light within the ENZ structure. Silveirinha et al.\[2\] and Alù et al.\[3\] have independently shown that a spherical ENZ shell with a dielectric inclusion can support solutions to Maxwell’s equations that are confined to a region of space irrespective of whether the region is bounded or not. Engheta et al. took this further and have theoretically demonstrated that this is independent of the geometry of the ENZ shell and have suggested that ENZs may lead to the development of geometry-invariant resonant cavities.\[4\] Another well documented effect of ENZ materials is near-perfect absorption (NPA). NPA has been theoretically and experimentally demonstrated by Yoon et al.\[5\] in multilayer thin films of ITO on a metallic substrate, shown in Figure 2 below. In an ENZ material, such as ITO at the ENZ wavelength, the normal electric field becomes very strong as it couples to a radiative bulk plasmon mode known as a Berreman mode which results in NPA of $\sim 100\%$, exceeding the limit of $A = 50\%$ for a free-standing thin film. We report the design and fabrication of a structure composed of a thin film of PtSe$_2$ sandwiched between a thin film of ITO superstrate and a bulk SiO$_2$ substrate, which has been theoretically shown to excite a Ferrel-Berreman mode of ITO at $\sim 1250$ nm and to exhibit near-perfect absorption of light at this ENZ wavelength, similar to that observed by Yoon et al.\[5\] Our devices has also been shown, via transfer matrix simulations, to exhibit slow light as low as $10^{-3}$ of the speed of light in vacuum. These factors would make our device an ideal candidate for use in the design of a novel near-field transducer. The high thermal stability of ITO in such a device makes it a better alternative as an NFT compared to commonly used plasmonic materials such as gold which undergo severe thermal degradation.

Fig. 1. Theoretical demonstration by Engheta et al. of 3D cavities supporting spatially electrostatic modes with the same eigenfrequency in ENZ structures of various geometries.\[4\]

Fig. 2. Theoretical and experimental demonstration of near-perfect broadband absorbance in multilayer ITO thin-films as reported by Yoon et al.\[5\]

References:

32. Antibonding Ground state of Adatom Molecules in Bulk Dirac Semimetals
Y. Marques, Angel Obispo, L. Ricco, I. Shelykh, M. De Souza, A. C. Seridonio

*Universidade Federal do Maranhão*

The ground state of the diatomic molecules in nature is inevitably bonding, and its first excited state is antibonding. We demonstrate theoretically that, for a pair of distant adatoms placed buried in three-dimensional-Dirac semimetals, this natural order of the states can be reversed and an antibonding ground state occurs at the lowest energy of the so-called bound states in the continuum. We propose an experimental protocol with the use of a scanning tunneling microscope tip to visualize the topographic map of the local density of states on the surface of the system to reveal the emerging physics.

33. Light-matter interaction in the long-wavelength limit: necessity of the dipole self-energy
Vasil Rokaj, Davis Welakuh, Michael Ruggenthaler, Angel Rubio

*Max Planck Institute for Structure and Dynamics of Matter, Hamburg, Germany*

Most theoretical studies for correlated light-matter systems are performed within the long-wavelength limit, i.e., the electromagnetic field is assumed to be spatially uniform. In this limit the so-called length-gauge transformation for a fully quantized light-matter system gives rise to the dipole self-energy of the electrons. In practice this term is often discarded as it is assumed to be subsumed in the kinetic energy term. In this presentation we show the necessity of the dipole self-energy term. First and foremost, without it the light-matter system in the long-wavelength limit does not have a ground-state. Further implications of the dipole self-energy will be presented, such as the change of the translation operator and how this influences the Bloch theorem.

References:

34. Compact metasurface-based free-electron hard X-ray source
G. Rosolen¹, L. J. Wong², N. Rivera³, B. Maes¹, M. Soljačić³, I. Kaminer³,⁴

¹. University of Mons, 20 Place du Parc, Mons 7000, Belgium*
². Singapore Institute of Manufacturing Technology, 2 Fusionopolis Way, Innovis, Singapore 138634, Singapore
³. Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge MA 02139, USA
⁴. Technion - Israel Institute of Technology, Haifa 32000, Israel

X-rays are employed across a wide range of industrial sectors and research fields, with applications ranging from airport security to medical radiography. Therefore, the development of efficient and ultra-compact X-ray sources with highly directional output is a long-standing goal in physics. A new approach addressing this challenge was recently proposed[1], where the interaction between graphene plasmons and relatively low-energy electrons generated highly-directional X-ray photons. In that scheme, the high confinement of graphene plasmons is the key property that enables modestly relativistic electrons to generate mono-energetic hard X-rays. Here, we show that the localized surface plasmon resonance of a metasurface, excited by a few-cycle optical pulse, contains high-order spatial harmonics, which interacts with modestly relativistic electrons to efficiently generate multi-harmonic hard X-rays. Moreover, the metasurface geometry and the optical pulse properties are powerful knobs to control and optimize the properties of the high-order spatial harmonics, resulting in a tunable source of multi-harmonic radiation. These conclusions are supported by our analytical formulation, in excellent agreement with ab initio simulations. As an example, we design a multi-color hard X-ray source, potentially useful as a mean to investigate electron transition dynamics, and could be useful in imaging techniques such as multiple-wavelength anomalous diffraction.

References:
35. Understanding single photon detection with nanoscale superconducting detectors
Jaime Saez Mollejo
Universidad Autónoma de Madrid
Detecting single photons and understanding photons detection are key challenges in quantum optics. One of the most promising technologies for fast, noise-free photon detection in the infrared are superconducting nanowire single-photon detectors (SSPDs). These SSPDs consist of a thin and narrow strip of a superconducting material cooled below the superconducting critical temperature. When a bias current is applied to the nanowire a transition to the normal state can be induced by absorption of a photon of sufficient energy and generates a measurable voltage pulse that is detected as a count. We perform quantum detector tomography measurements on nanofabricated NbN constrictions to extend our understanding of the detection mechanism. Detector tomography is an agnostic method based on the Positive-Operator Valued Measure formalism and translates measured count rates as a function of the average number of photons to a quantum detector response in the photon number basis. We find a linear relation between the current needed to achieve efficient (>1%) detection probability and the energy of the absorbed photons with a surprising offset at zero energy. These observations can be explained by models that combine diffusion of quasiparticles and a photon-assisted vortex entry at the edge of the wire. The photon-assisted vortex model predicts that the edges of the wire are more efficient when detecting photons. Polarization depend detector tomography experiments are consistent with this idea and allow to deduce a position-dependent single photon detection efficiency from the experimental data. We present additional data on the temperature dependence of the detection process to reveal the role of a Berezinskii-Kosterlitz-Thouless transition that limits detections above $T/T_c = 0.8$. We explore the role of power fluctuations in detector tomography and discuss the direct observation of polarization dependent multi-photon events in the measurements and breakdown of the model for higher photon energies.

36. Dynamical Casimir effect in an ultrastrongly coupled hybrid optomechanical system
K. Seibold, H. Flayac, V. Savona
Institute of Theoretical Physics, École Polytechnique Fédérale de Lausanne EPFL, CH-1015 Lausanne, Switzerland
We investigate a dissipative tripartite atom-cavity-optomechanical system. We focus on the configuration where the two-level system and the cavity mode are assumed to be in the ultrastrong coupling regime, while the mechanical part interacts with the confined electromagnetic field via the standard optomechanical coupling. We explore the nontrivial ground state structure of such a hybrid system, which hosts a coherent phonon occupation. While in the steady-state this population remains virtual and therefore the system does not emit real phonons, our work explores the possibility to extract real and coherent excitations from the mechanical mode by a non-adiabatic quench of the atom-cavity interaction. We finally study the dependence of the extracted phonon population on the initial coupling strength and the switching amplitude. Our analysis shows that an indirect dynamical Casimir effect occurs where, thanks to the tripartite nature of the system, a perturbation of the atom-cavity system indirectly triggers the emission of phonons.

Figure: Real phonon population produced in the mechanical resonator of the tripartite system by modulating the qubit-optical resonator coupling strength. Here the real phonon occupation is plotted in function of the initial and increase of the atom-cavity coupling strength respectively $g_0$ and $\Delta g_m$. 
37. Perovskite Nanoplatelets – A New 2D Excitonic Material

Michael Seitz\textsuperscript{1,2}, Mark C. Weidman\textsuperscript{2}, Daniel N. Congreve\textsuperscript{2}, William A. Tisdale\textsuperscript{2}, Ferry Prins\textsuperscript{1}

1. Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain
2. Center for Excitonics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Colloidal perovskite nanoplatelets, \(L_2[ABX_3]_{n-1}BX_4\), are a promising class of semiconductor nanomaterials, exhibiting bright luminescence, tunable and spectrally narrow absorption and emission features, strongly confined excitonic states, and facile colloidal synthesis.\cite{1} Here, we demonstrate their extensive spectral tunability by changing the chemical constituents and nanoplatelet thickness, where \(L\) is an organic ligand (butyl-ammonium, octylammonium), \(A\) is a monovalent cation (cesium, methylammonium, formamidinium), \(B\) is a divalent metal cation (lead, tin), \(X\) is a halide anion (chloride, bromide, iodide), and \(n-1\) is the number of perovskite unit cells in thickness. We show that variation of \(n, B, \text{ and } X\) leads to large changes in absorption and emission energy, from the deep UV, across the visible, into the near-IR. On the other hand, changing \(L, A, \text{ or the solvent}\) leads to only subtle changes but can significantly impact the nanoplatelet stability and PLQY with values of up to \(22\%\), outperforming previously reported values. Furthermore, using mixed halide (\(X\)) compositions allows a continuous spectral tunability over a \(1.5\text{ eV}\) spectral range, from \(2.2\text{ eV}\) to \(3.7\text{ eV}\). Using TEM, SEM and XRD, we show that nanoplatelets have large lateral dimensions (100 nm – 1 \(\mu\)m), which promote self-assembly into stacked superlattice structures – the periodicity of which can be adjusted based on the nanoplatelet surface ligand length. With focus on the most quantum confined thicknesses, \(n = 1\) and \(n = 2\), we demonstrate the versatility of colloidal perovskite nanoplatelets as a material platform, with tunability extending from the deep UV, across the visible, into the near-IR. In particular, the tin-containing nanoplatelets represent a significant addition to the small but increasingly important family of lead- and cadmium-free colloidal semiconductors.\cite{2,3}

![Perovskite nanoplatelets](image)

**Figure:** Perovskite nanoplatelets of thicknesses \(n = 2\) and photograph of perovskite nanoplatelets with different chemical compositions and thicknesses (\(A = \text{organic cation, B = metal, X = halide, n = thickness}\)).

References:

\cite{1} Huang H, Polavarapu L, Sichert JA, Susha AS, Urban AS, Rogach AL, NPG Asia Mater, 8, e328 (2016)
\cite{2} Weidman MC, Seitz M, Stranks SD, Tisdale WA, ACS Nano, 10, 7830–7839 (2016)
\cite{3} Seitz M, Master Thesis, ETH Zurich (2016)
38. Temperature-Dependent Thermal Conductivity and Viscosity of Synthesized α-Alumina Nanofluids

Janki Shah1, Mukesh Ranjan2, Sanjeev K. Gupta3, Yogesh Sonvane4
1. Department of Applied Physics, S.V. National Institute of Technology, Surat 395007, India
2. FCIPT, Institute for Plasma Research, Sector-25, Gandhinagar 382044, India
3. Department of Physics, St. Xavier’s College, Ahmedabad 380009, India

In the present work, we focused on the thermal conductivity and viscosity of the synthesis as well as characterize metal oxide α-Al₂O₃ nanoparticles suspended in distilled water (DW): ethylene glycol (EG) (60:40) ratio based stable colloidal nanofluid. The band gap of the α-Al₂O₃ with and without surfactant is 4.42eV and 4.59eV, respectively. The results show that polyvinyl alcohol (PVA) surfactant having smaller crystalline size (~23 nm) then without surfactant has large (~36 nm). The synthesized nanofluids have good stability after 15 days of synthesis which is characterized by zeta potential analyzer. Thermal conductivity and viscosity are measured for 0.1 wt. % and 0.5 wt. % concentration of alumina for with and without surfactant. The concentration of particles and added surfactant are responsible for stable fluid, increased thermal conductivity and viscosity of nanofluid with respect to temperature. Therefore, the novel combinations of characterized properties of α-Al₂O₃ nanofluid proven the best thermally stable heat transfer fluid compare to conventional cooling fluids.

References:

39. Study of non-Markovian dynamics in organic polaritons induced by a multimode coherent field

R. E. F. Silva¹, Javier del Pino¹, Florian A. Y. N. Schröder², Alex W. Chin², Francesco J. Garcia-Vidal³,⁴, Johannes Feist¹
1. Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain
2. Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge, CB3 0HE, UK
3. Institut des NanoSciences de Paris, Sorbonne Université, 4 place Jussieu, boîte courrier 840, 75252, PARIS Cedex 05, France
4. Donostia International Physics Center (DIPC), E-20018 Donostia/San Sebastián, Spain

Organic polaritons are hybrid light-matter systems that present several advantages with respect to semiconductor polaritons. Among them, they present larger binding energies and allow for larger Rabi splitting. For a deeper understanding, the study of the dynamics of these systems is desirable, and little is known about their non-Markovian dynamics. In particular, the excitation from the groundstate of the system to the polaritonic states is the first step in any experiment and its modelling is the target of our work. To that purpose, the use of tensor network states is a fascinating tool that allows exact propagation of the system, treating thousands of degrees of freedom (plasmonic, phononic and radiative) on an equal foot. In this work, we show the results of the simulation of a prototype organic molecule (Rhodamine800) that is excited with a coherent multimode laser field. To see how the absorption spectrum changes we do a scan over the central frequency of the pulse and we analyse the influence of the phononic degrees of freedom.

References:
**40. Computational Modeling of Carbon Nanotubes’ Electronic and Optical Properties**

Katya Simeonova

*Institute of Mechanics, Bulgarian Academy of Sciences*

Carbon nanotubes (CNTs), discovered by S. Iijima (1991), possess exceptional physic-mechanical, electronic, electrical, chemical, thermal, optical etc. properties [1]. Moreover these nanomaterial have chiral nanostructure and semiconductors or metallic behavior, depending on structure and electrical field applied. CNTs, play an important role in many different areas of technique, engineering, transistors, electronics, optics and so on, [2]. Recently has been established that these nanomaterials are very useful tool for treatment of cancer especially for leukemia, [3]. So, all these facts mentioned above, show that study of CNTs has perspective and useful future effects. The aim of the work, presented could be formulated as follows: 1) To develop a theoretical model, background on the computational studies for electronic properties of carbon naotubes; 2) To develop a new theoretical model, and computational one of carbon nanotubes’ optical properties By numerical author’s algorithms and numerical FORTRAN programs, have been investigated the effects of different model’s characteristics, defined electronic and optical properties of carbon nanotubes. Comparison by experiments, shows a good agreement with theoretical (computational) results of the work presented. Graphics, reflecting the results have been given as well.

References:


---

**41. Theory of Long-Distance Energy Transfer Mediated by Collective Strong Coupling**

R. Sáez-Blázquez¹, J. Feist¹, A. I. Fernández-Domínguez¹, F. J. García-Vidal¹,²

1. Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, c/ Francisco Tomás y Valiente 7, E-28049 Madrid, Spain
2. Donostia International Physics Center (DIPC), c/ Manuel Lardizabal Ibilbidea 4, E-20018 Donostia/San Sebastián, Spain

The process of energy transfer in organic molecules has been extensively studied in the frame of the Förster mechanism, as a result of the dipole-dipole interactions between molecules. Their short-range character limits the typical range to about 10 nm. As recently experimentally demonstrated by Zhong et al [1], this limit can be overcome by strongly coupling the molecules to a cavity mode. Here, we shed light into the physical mechanism that allows excitation transfer of the acceptor molecules even for physical separations from the donor molecules of 100 nm or more. Thanks to the appearance of polaritons (delocalized hybrid light-matter states extended over the entire system) in the strong coupling regime and the resulting mixing of donor and acceptor states with the cavity, non-local energy transfer can be driven by local non-radiative processes [2]. We demonstrate and study this effect based on Bloch-Redfield theory, which allows to reproduce the effect of a complex vibrational bath.

References:

42. A theoretical approach for collective strong coupling of organic molecules with arbitrary photonic structures

Mónica Sánchez-Barquilla, Johannes Feist
Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain

Strong coupling of a dense collection of organic molecules with the electromagnetic modes of nanophotonic and/or plasmonic devices holds great interest for a wide variety of applications. Currently, most theoretical models of such devices use strongly simplified models for at least one of their constituents, typically either treating the molecules as two-level systems, or describing the photonic environment through a single bosonic mode. We here implement an intermediate approach where both complex molecular dynamics as well as arbitrary photonic mode structures can be treated directly. This approach is based on the Maxwell-Bloch approximation using a multi-level description of the molecules. We first treat a simple one-dimensional model to compare and evaluate the respective strengths and weaknesses of a fully classical, a fully quantum and a Maxwell-Bloch approach. We then investigate which effects in organic polaritonics and polaritonic chemistry can be represented within the mean-field description inherent in the Maxwell-Bloch approximation.

43. Force balance equation and exchange-correlation potentials in time-dependent current density functional theory (tdCDFT)

Mary-Leena Martine Tchenkoue Djouom, Markus Penz, Michael Ruggenthaler, Angel Rubio
Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

The Runge-Gross theorem as the conceptual basis of tdCDFT is based on a force balance equation from which the existence of a unique mapping between potentials (including a vector potential) on the one side and one-particle densities and currents on the other side is derived. Since tdCDFT is expected to solve important problems that persist in tdDFT (without regarding vector potentials and currents) the study of this force equation is of special interest. Here we use the force balance equation to derive approximate exchange-correlation potentials that obey basic conditions such as zero-force and zero-torque. Such approximations will be useful in the calculation of dynamical properties of many-particle systems.
44. Controlled coherent excitation of ultra-compact double plasmonic slot waveguide systems

Martin Thomaschewski, Yuanqing Yang, Sergey I. Bozhevolnyi

Centre for Nano Optics, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark

Device miniaturization of functional optical circuits has been shown to be a prerequisite for aiming high efficient, small-footprint devices in sensing\textsuperscript{1,2} and communication\textsuperscript{3}. We study the synchronous and phase matching state of two simultaneously excited propagating plasmonic gap modes and demonstrate power-controllable and coherent waveguide feeding with high coupling efficiency of up to 17%. The combination of the subwavelength waveguides separation distance and its ultra-compact pair of coupling nanoantennas enables efficient shaping of the power distribution routed through the double slot waveguide system. Furthermore, experiments show a 10% increase of the free-space coupling efficiency compared to single antenna systems. Finally, it is demonstrated that this system is well suited to being used as an ultra-compact branchless Mach-Zehnder interferometer device with the capability of loss discrepancies compensation. Thus, the proposed system opens up new possibilities for highly-sensitive and ultra-compact sensing applications.

Figure: (a) Three-dimensional rendering of the proposed parallel plasmonic slot waveguides fed by a pair of optical-loaded nanoantennas with side reflectors at the input and output ports. (b) Schematic cross-section of the device.

References:
45. Resolving Distinct Metal Nanoantennas’ Optical Properties and their Impact on Surface Enhanced Infrared Absorption

Michael Tzschoppe, Christian Huck, Jochen Vogt, Frank Neubrech, Annemarie Pucci

Kirchhoff Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg

During the last years, it has been shown in lots of publications that surface enhanced infrared absorption (SEIRA) spectroscopy is a powerful tool to study minute amounts of molecules or particles on the basis of enhanced vibrational signals. In order to improve sensitivity, the impact of the structures’ geometry as well as their interaction have been investigated. Here, we present an experimental work which is focused on the impact of plasmonic nanoantennas’ metal-optical properties on SEIRA. Various geometries of cuboid nanoantennas have been prepared in arrays by means of standard electron beam lithography. To tune the metal-optical properties, we used the metals gold, silver, copper, aluminum, and iron. From the fundamental plasmonic resonance, the contribution of the intrinsic damping (electronic scattering) as well as of the radiative damping were evaluated separately. For a thin organic probe layer on the different antennas, we determined SEIRA enhancement factors. So, our investigation yields a correlation between the ratio of intrinsic damping and radiation damping with SEIRA enhancement which clearly shows the maximum enhancement when both damping mechanisms contribute equally. Finally, we provide recommendations which metal and geometry should be used for highest SEIRA enhancement.

References:

46. All dielectric Si nanoresonator based color filters

Vishal Vashistha¹, Maciej Krawczyk¹, Kuo-Ping Chen²

1. Faculty of Physics, Adam Mickiewicz University in Poznan, Poznan, Poland
2. National Chiao-Tung University, College of Photonics, Tainan, Taiwan

Pigments based color filters absorbed the certain spectrum of light and reflect the remaining portion of light. These kind of color printing have low resolution, thicker in size and degradeable with time. Plasmonics based color printing can be treat as solution, where light interact with nanostructure at subwavelength scale. Certain portion of light is reflected based on the size and periodicity of artificially designed nano structures. The structural printing concept is inspired by observations in nature, such as morpho butterflies, beetles, and the feathers of peacocks. In this work, we presented a new approach to achieved high quality of colors using cross shaped Si nanoantennas. We interplayed with Mie resonances in Si nanoantenna to achieve a single narrow resonances throughout the visible range, which results in high quality of primary colors. We numerically predict and experimentally demonstrated the series of high quality of colors by adjusting the size and periodicity of cross-shaped nanoantennas.

References:
**47. Understanding the effect of light on active propulsion**

Linlin Wang  
*Technische Universität Dresden*

We used semiconductor TiO2 colloids as base material for microswimmers owing to efficient activity, environmental benigity, low-cost and chemical stability. Here, we try to elucidate how the fuel and irradiation conditions influence the gradients around the particles which translate into motion. These conditions were probed by traditional analytics as well as using passive colloids as probes.


Davis Welakuh  
*Max Planck Institute for the Structure and Dynamics of Matter*

Novel experiments in cavity QED is at the interface between quantum optics and chemistry. Ab initio methods that treats an interacting many-electron system coupled to photons on an equal quantized footing has been developed and it’s termed Quantum-Electrodynamical Density-Functional theory (QEDFT) [1]. The Kohn-Sham scheme of QEDFT has been used to study ground-state properties of an interacting electron-photon system [2]. Here, we present an ab-initio linear-response (LR) formalism that allows to calculate excited states phenomena for general matter-photon coupled systems. Beside the usual density-density response function known in time-dependent DFT, we have three new response functions due to coupling matter to photons. We reformulate the response functions and develop a numerically feasible and tractable pseudo-eigenvalue problem for the coupled electron-photon system. We present first principle calculations for excited state properties for a specific molecule coupled to a cavity photon.

References:


**49. Silicon-based resonant nanostructures as a versatile tool for optical heating and thermometry at nanoscale**

George Zograf  
*ITMO University*

Recent studies demonstrated considerable interest in plasmonic nanoparticles as nanoscale heat sources for different applications. However, there are limitations with their applicability governed by skin-layer effect and presence of only localized plasmon resonance. In this study, we reveal theoretically and prove experimentally novel concept for non-plasmonic effective optical heating [1]. Contrary to plasmonics, the interaction of light with dielectric or semiconductor nanoparticles of small imaginary part of the permittivity leads to localization of the electromagnetic field inside them. For certain high-Q resonances, it turns out that our optical heating approach is more effective and spectrally broadband than plasmonic one. In addition, non-plasmonic nanoparticles demonstrate temperature dependent optical feedback, which allows to control local temperature more precise and simultaneously with heating via thermally-dependent Raman scattering. Moreover, will be revealed possible applications of this concept such as real-time tracing of molecular events [2] and temperature-feedback direct laser reshaping of dielectric metasurfaces [3].

References: