Complex Nanophotonics Science Camp

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27th–30th August 2013

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Bringing together early career scientists to bridge Nanophotonics, Plasmonics & Biophotonics of complex media.

SCIENTIFIC COMMITTEE

Jacopo Bertolotti

Twente University, The Netherlands
jacopo.bertolotti@gmail.com
www.jacopobertolotti.com

Otto Muskens

Southampton University, UK
o.muskens@soton.ac.uk
www.ottolmuskens.info

Sylvain Gigan

Langevin Institute, ESPCI, France
sylvain.gigan@espci.fr
www.institut-langevin.espci.fr/Sylvain-Gigan,510

Riccardo Sapienza

King's College London, UK
riccardo.sapienza@kcl.ac.uk
www.sapienzalab.org

Conference Secretary

Julia Kilpatrick

julia.kilpatrick@kcl.ac.uk

www.sciencecamp.eu

KEYNOTE SPEAKERS

INVITED SPEAKERS

CONTRIBUTED SPEAKERS

DEBATE SPEAKERS

Kosmas Tsakmakidis

Editor of Nature Materials

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Ad Lagendijk

AMOLF, FOM-Institute

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Kostas Repanas

*Project Manager & Managing Editor, Joint Council Office, A*STAR Singapore*

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Managing Director, Digital Science, Macmillan Publishers Ltd.

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Nano-optics of complex systems

- RASHID ZIA – *Brown University*
- SEBASTIEN BIDAULT – *Institut Langevin, ESPCI, CNRS, Paris*
- VENTSISLAV VALEV – *University of Cambridge*

Light propagation and imaging in complex systems

- TOMAS CIZMAR – *University of St. Andrews*
- WONSHIK CHOI – *Korea University*
- TIMMO VAN DER BEEK – *AMOLF–FOM Institute*

Strong scattering and Anderson localization of light

- ALBERTO RODRIGUEZ – *Freiburg University*
- TOM STRUDLEY – *University of Southampton*
- PEDRO DAVID GARCÍA – *University of Copenhagen*

Quantum optics of complex media

- FEMIUS KOENDERINK – *Brown University*
- REGINE FRANK – *KIT, Karlsruhe Institute of Technology*
- JAESUK HWANG – *Imperial College*
- MAURO PATERNOSTRO – *Queen's University*
- RUTH OULTON – *University of Bristol*
- YOAV LAHINI – *MIT*

Multiple scattering of light

- NUNO DE SOUSA – *Universidad Autónoma de Madrid*
- SEBASTIEN POPOFF – *Yale University*
- MATTEO BURRESI – *University of Florence*

Complex photonics materials

- ANDREA DI FALCO – *University of St. Andrews*
- SILVIA VIGNOLINI – *Cambridge University*
- FIORENZO OMENETTO – *Tufts University*

SPEAKERS

NIEK VAN HULST

ICFO, The Institute of Photonic Science
Spain
niek.vanhulst@icfo.es

Tuesday 27 August, 14.30–15.30

Niek van Hulst studied Astronomy & Physics, and obtained his PhD in Molecular & Laser-Physics at the University of Nijmegen (1986), on microwave-laser double resonance molecular-beam spectroscopy. After research in non-linear optics of organic materials, integrated optics, atomic force and near-field optical microscopy, in 1997 he became Professor in Applied Optics at MESA+ Institute for NanoTechnology, University of Twente, with focus on single molecule detection, scanning probe technology and applications in molecular biology and chemistry. In 2005, attracted by the Catalan innovative science policy, he started as ICREA Research Professor and senior group leader at ICFO – the Institute of Photonic Sciences, in Barcelona. He is coordinator of the Spanish CONSOLIDER program NanoLight.es; Recipient ERC Advanced Grant; 2010 Barcelona Prize for Scientific Investigation; 2003 European Science Award; Fellow OSA.

TRACKING NANOSCALE COHERENT ENERGY TRANSFER IN SINGLE LIGHT HARVESTING COMPLEXES

BIOLOGICAL PHOTOSYNTHETIC COMPLEXES are in essence nanophotonic systems of high complexity. Interestingly these systems transfer photonic energy with efficiency above 90% even at physiological conditions, despite the intrinsic disorder at room temperature. Addressing such systems requires lifting the disorder in space and time: i.e. detection of fs energy transfer in individual photosynthetic complexes. Here we present such experiments on LH2 a Light-Harvesting complex of the purple bacteria. Interestingly LH2 shows persistent long term coherence, up to a picosecond, which aids to smoothen the energy pathways. Surprisingly, we observe phase jumps, indicating dynamic switching between different coherent pathways. Thus the LH2 adapts its pathway to the environmental conditions while retaining the coherence.

R.Hildner, D.Brinks, J.Nieder, R.Cogdell, N.F. van Hulst, Science 340 (on-line 21 June 2013)

STEFANIA RESIDORI

Institut Non Lineaire de Nice, INLN-CNRS
France
stefania.residori@inln.cnrs.fr

Wednesday 28 August, 14.30–15.30

SELF-ADAPTIVE HOLOGRAPHY IN NONLINEAR MEDIA

A VARIETY OF SELF-INDUCED phenomena can be realised in optically nonlinear media. Self-adaptive or dynamic holography is implemented via wave-mixing processes in which two or more interacting beams give rise to correspondingly self-induced space modulations of the medium optical properties, usually the refractive index. The interacting beams are diffracted by the same grating that they are generating in the medium, hence, they exchange phase and amplitude information one with another. These processes can be exploited to automatically reduce low frequency noise/fluctuations, hence, to enhance the sensitivity of interferometers working in practical and perturbed conditions. As examples, I will present recent experimental achievements in which the nonlinear optical properties of liquid crystals are exploited for implementing dynamic holography and optical wave-mixing under diverse geometrical configurations. The self-adjusting character of the hologram induced in the medium, able to react dynamically to low-frequency changes, allows detecting small phase modulations, correspondingly, displacements as small as fractions of picometers, even when working with complex wavefronts, as in the case of speckles due to the light passing through scattering media, or when working in disturbed environments.

ARISTIDE DOGARIU

CREOL
Florida, USA
adogariu@creol.ucf.edu

Thursday 29 August, 14.30–15.30

MECHANICAL ACTION IN COMPLEX ELECTROMAGNETIC FIELDS

LIGHT INDUCES MECHANICAL action in different ways. The conservation of linear and angular momenta carried by electromagnetic fields is essential for understanding and manipulating the forces generated by light. We will show that harnessing light at scales comparable with the wavelength offers distinctive possibilities not only for sensing material or radiation properties but also for controlling the mechanical effects caused by light.

RASHID ZIA

Brown University
USA
rashid_zia@brown.edu

Tuesday 27 August, 15.30

Rashid is an assistant professor of engineering and of physics at Brown University, where he earned undergraduate degrees in English & American Literature and Engineering before completing his doctorate in Electrical Engineering at Stanford University.

A MULTIPOLAR EMITTER: CAN 1 TRANSITION ILLUMINATE 2 PATHS?

ALTHOUGH IT IS OFTEN ASSUMED that all light-matter interactions at optical frequencies are mediated by electric dipole transitions, strong optical-frequency magnetic dipoles do exist. In fact, we see magnetic dipole emission every day from the many lanthanide ions (such as erbium, europium, and terbium) that help to illuminate everything from fluorescent lighting to telecom fiber amplifiers. Higher-order processes such as magnetic dipole and electric quadrupole transitions also play an important part in the light emission from transition metal ions and semiconductor quantum dots.

In this presentation, we will experimentally characterize the "forbidden" transitions in a range of solid-state emitters and investigate their applications and implications for nanophotonics. We will examine the electric dipole approximation commonly used to describe light-matter interactions and discuss naturally occurring systems that exhibit higher-order magnetic dipole and electric quadrupole emission. We will briefly illustrate how these quantum transitions can provide new ways to probe light-matter interactions and design active photonic devices. Then, we will try to answer a few simple questions: Can a single quantum emitter be multipolar? Are there cases when the same electronic states are connected by different quantum transitions?
What happens when light emission can be mediated by two (seemingly orthogonal) paths?

SEBASTIEN BIDAULT

Institut Langevin, ESPCI, CNRS
Paris, France
sebastien.bidault@espci.fr

Tuesday 27 August, 16.30

Sebastien Bidault obtained a PhD degree from École Normale Supérieure de Cachan in 2004. In 2005, he joined the FOM Institute AMOLF in Amsterdam (group of Prof. A. Polman) as a postdoctoral fellow to develop novel bio-templating techniques. In 2008, he joined ESPCI to apply these self-assembly strategies to the design of optical antennas for surface enhanced spectroscopy and sensing.

http://www.institut-langevin.espci.fr/Optical-Antennas-and-Sensing

DRIVING DNA TEMPLATED OPTICAL ANTENNAS WITH A SINGLE QUANTUM EMITTER

PLASMON BASED OPTICAL antennas are attractive resonators to influence the absorption and emission properties of single quantum emitters at room temperature. In particular, their broad resonances are compensated by nanometric dimensions to induce large spontaneous decay rate enhancements for dye molecules or colloidal quantum dots. We recently demonstrated that optical antennas can be assembled around a single short DNA strand linking two gold nanoparticles [1], on which a single fluorescent molecule can be introduced. Driven by a quantum emitter, these DNA templated optical antennas provide a two order of magnitude increase of the decay rate with single photon emission statistics [2]. As they are obtained pure and in high quantities in water, the photophysical properties of gold dimers coupled to a fluorescent molecule can be fully characterized using fluorescence correlation and lifetime spectroscopies [3]. These structures should offer unprecedented control over the photophysical properties of a single molecule and allow spontaneous emission rates in bright single quantum emitters below one picosecond.

[1] *M. P. Busson et al, Nano Lett. 11, 5060 (2011)*

[2] *M. P. Busson et al, Nature Commun. 3, 962 (2012)*

[3] *M. P. Busson et al, Angew. Chem. Int. Ed. 51, 11083 (2012)*

VENTSISLAV VALEV

University of Cambridge
United Kingdom
vkv23@cam.ac.uk

Tuesday 27 August, 16.50

Ventsi Valev is a research associate at Cambridge University. Born in Bulgaria, he grew up in France, graduated in the UK and got his Ph.D. from the Radboud University of Nijmegen, the Netherlands. As a postdoctoral fellow at the KU Leuven University, in Belgium, he studied organic molecular films and nanostructured metal surfaces.

HIGHLY LOCALIZED NANO-DEFORMATIONS IN PLASMONIC NANO-STRUCTURES CAUSED BY FEMTOSECOND LASER PULSES

RECENTLY, METALLIC NANOSTRUCTURES were demonstrated to exhibit properties that could significantly impact a variety of scientific disciplines, such as medicine,[1] chemistry,[2] physics,[3] material science and engineering [4]. In all of these examples, one of the chief properties driving potential applications is the surface plasmon resonance. Here we show that surface plasmons can be controlled to drive nanostructure buckling in highly-localised regions, enabling optical control of nanomanipulation, as well as direct mapping of the localized plasmonic states. We show that upon illuminating nanostructures made of gold, nickel or palladium above a certain laser fluence threshold, local melting can occur in the plasmonic hotspots but not in the rest of the nanostructures. [5-7] Consequently, the surface plasmon patterns can be imprinted on the structures themselves. More specifically, this imprinting is done through nanobump and nanojet formations, which are due to local melting and hydrodynamic processes in the regions where the plasmonic local field enhancements are the largest. These nanobumps and nanojets allow for subsequent imaging with SEM or AFM. The imprinting constitutes a fast, robust and user-friendly visualization method that can be applied to large sample area.

[1] X. Huang, W. Qian, I.H. El-Sayed, and M.A. El-Sayed, Lasers Surg. Med. 2007, 39, 747.

[2] K.-H. Dostert, M. Álvarez, K. Koynov, A. del Campo, H.-J. Butt, and M. Kreiter, Langmuir 2012, 28, 3699-3703.

[3] J. B. Pendry, Contemp. Phys. 2004, 45, 191.

[4] N. Engheta, Science 2007, 317, 1698.

[5] V. K. Valev, et al., Phys. Rev. Lett. 2011, 106, 226803.

[6] V. K. Valev, et al., Adv. Mater. 2012, 24, OP29-OP35.

[7] V. K. Valev, et al., "Nanostripe length-dependence of plasmon-induced material deformations" (2013)

TOMAS CIZMAR

University of St. Andrews
United Kingdom
tc51@st-andrews.ac.uk

Wednesday 28 August, 09.00

PHOTONICS IN DISORDERED ENVIRONMENTS AND FIBRE BASED IMAGING

ASTRONOMICAL OBSERVATIONS FROM ground-based telescopes are degraded by the random and rapidly varying distribution of refractive index in the Earth's atmosphere. Similarly, in Biology and Medicine, imaging of tissues and living organisms at visible wavelengths is limited by the highly scattering and absorbing nature of these environments; image quality and maximum image depth are both reduced by these conditions. There are a number of disciplines across life sciences that would particularly benefit from the possibility to provide the optimal performance of imaging devices and photonics techniques in vivo.

Novel holography-based strategies to correct these unwanted deviations from the ideal wavefront and thereby redeem the optimal performance of bio-photonic systems in such turbid media will be discussed in the lecture. In addition to their high Bio-Medical relevance, these methods represent a powerful approach towards full understanding of laser light propagation through any randomizing system.

An important example of this is light transmission within a multimode optical fibre. Coherent light propagating through such waveguide is randomized but the image information is not lost and can be decoded once the overall response of the system is measured.The possibility of converting the random output signal into a diffraction limited focus, as well as any other light shapes, will be discussed together with a number of applications including optical manipulation and imaging.

WONSHIK CHOI

Korea University
Korea
wonshik@korea.ac.kr

Wednesday 28 August, 09.30

Dr. Wonshik Choi received his Ph.D. in 2004 from the Department of Physics at Seoul National University. He worked as a postdoctoral researcher at MIT from 2006 and joined the Department of Physics at Korea University in 2009. He is also serving as an associate editor of biomedical optics express.

BIO-SENSING AND IMAGING IN COMPLEX MEDIA

COMPLEX NANOPHOTONICS FOR biomedical applications "Turbidity"caused by multiple light scattering interrupts the propagation of waves, thereby undermining optical imaging. For example, translucent biological tissues exhibiting optical turbidity have posed limitations on the imaging depth and energy transmission. In this talk, I will introduce an experimental system that exploits the transmission matrix of a complex and disordered medium. Using this system, we demonstrated the counterintuitive finding that optical turbidity, rather than being a hindrance to imaging, can in fact dramatically improve both the spatial resolution and the field of view of the target images. As an immediate biomedical application of the developed technique, I will describe an endoscopic system that works with just a single multimode fiber, a special case of turbid medium. I will close my talk by introducing our recent experimental work that demonstrated the significant enhancement of light energy delivery through a highly turbid medium. This seemingly implausible task was made possible by coupling light into the resonance modes, called transmission eigenchannels, of the medium. These studies altogether will lead to great important applications in deep-tissue optical bio-imaging and disease treatment.

[1] *Youngwoon Choi, Taeseok Daniel Yang, Christopher Fang-Yen, Pilsung Kang, Kyoung Jin Lee, Ramachandra R. Dasari, Michael S. Feld, and Wonshik Choi, "Overcoming the diffraction limit using multiple light scattering in a highly disordered medium," Physical Review Letters, 107 023902* (2011)

[2] *Youngwoon Choi, Changhyeong Yoon, Moonseok Kim, Taeseok Daniel Yang, Christopher Fang-Yen, Ramachandra R. Dasari, Kyoung Jin Lee, and Wonshik Choi, "Scanner-free and wide-field endoscopic imaging by using a single multimode optical fiber," Physical Review Letters, 109 203901* (2012)

[3] *Moonseok Kim, Youngwoon Choi, Changhyeong Yoon, Wonjun Choi, Jaisoon Kim, Q-Han Park and Wonshik Choi, "Maximal energy transport through disordered media with the implementation of transmission eigenchannels," Nature Photonics, 6 581* (2012)

TIMMO VAN DER BEEK

AMOLF–FOM Institute
The Netherlands
t.v.d.beek@amolf.nl

Wednesday 28 August, 10.00

PROBING HIDDEN MULTILAYERS WITH DIFFUSION THEORY

BOTH DIFFUSE IMAGING and frequency correlation measurements are powerful and important probes to understand how light propagates through opaque materials. Diffuse imaging is a spatial probe, an image of the exiting diffuse light. Frequency correlation measurement is a temporal probe, used for example to determine the optical diffusion constant and/or the mean free time. We have combined these techniques to create a new method, broad band frequency correlation microscopy (BFCM). The technique resolves coherent frequency speckle across an entire diffuse spot, allowing spatial and temporal information to be resolved simultaneously. I explain the details, and present the latest measurements on paint multilayers.

ALBERTO RODRIGUEZ

Freiburg University
Germany
alberto.rodriguez.gonzalez@physik.uni-freiburg.de

Wednesday 28 August, 11.00

I did my PhD on quantum disordered systems in the University of Salamanca, Spain. After that I worked as a postdoc at the Unversity of Warwick for 3 years, where I focused on the computational analysis of Andersont transitions. Currently I work at the Quantum Optics and Statistics of the University of Freiburg, Germany.

MULTIFRACTAL DISTRIBUTIONS IN DISORDERED MEDIA

WE WILL PRESENT AN ANALYSIS on the properties of quantum wavefunctions and classical intensity distributions in disordered media. In particular, we will describe the multifractal features of these distributions near the critical point of the disorder-induced localization-delocalization transition (LDT). We will discuss the relation between the multifractal spectrum and the probability density function (PDF) of the distribution intensities at criticality, on how to exploit the multifractal fluctuations to make a full characterization of the LDT, including the numerical estimation of the critical exponent. We will illustrate the applicability of this technique by considering the Anderson LDT in a three-dimensional system.[1] The importance of this analysis is emphasized in connection with experimental observations of critical phenomena and LDT: in photonic lattices, using STM techniques on semiconductors, and direct imaging of cold-atom condensates.

[1] *Rodriguez et al., Phys. Rev. B 84, 134209 (2011)*

TOM STRUDLEY

University of Southampton
United Kingdom
tom.strudley@soton.ac.uk

Wednesday 28 August, 11.30

MESOSCOPIC TRANSPORT AND LIGHT TRAPPING IN STRONGLY SCATTERING NANOWIRE LAYERS

SEMICONDUCTOR NANOWIRE mats are important new materials for applications in light emission and solar cells. Nanowires mats are amongst the strongest scattering materials in the world, with a mean free path significantly smaller than visible wavelengths [1]. With light being scattered multiple times within the space of one wavelength, the influence of interference effects on light propagation is dramatically increased. Consequently, such samples are of considerable interest for the investigation of mesoscopic corrections to light transport as the classical diffusion description begins to break down. Using methods from statistical optics, we show that transport through our dense gallium phosphide (GaP) nanowire mats is governed by an average of only 3.6±0.1 independent transmission channels [2]. This is at least two orders of magnitude lower than previously reported values for light in a three-dimensional medium. As a consequence, the light transmitted through such mats is characterised by large intensity fluctuations and strong long-range correlations. Such effects are well known in the domain of solid state electronics, resulting in well-known phenomena such as universal conductance fluctuations and Anderson localization. The strong analogy between quantum and general wave transport has subsequently allowed investigations of mesoscopic effects for electromagnetic and acoustic waves. However, the problem of making samples with sufficiently high scattering strength (along with low absorption) has previously limited investigations at optical wavelengths. Our samples are ideal candidates for exploring in detail the mesoscopic physics of light in three dimensions for the first time. It is also exciting to consider how fundamental mesoscopic effects may be harnessed in the technological applications of nanowires.

[1] *O.L. Muskens, S.L. Diedenhofen, B.C. Kaas, R.E. Algra, E.P.A.M. Bakkers, J.G. Rivas & A. Lagendijk, "Large Photonic Strength of Highly Tuneable Resonant Nanowire Materials", Nano Lett. 9(3), 930-934 (2009)*

[2] *T. Strudley, T. Zehender, C. Blejean, E. P. A. M. Bakkers, O. L. Muskens, Mesoscopic light transport by very strong collective multiple scattering in nanowire mats, Nat.Photon. 7, 413-418 (2013)*

PEDRO DAVID GARCÍA

Neils Bohr Institute, University of Copenhagen
Denmark
garcia@nbi.ku.dk

Wednesday 28 August, 11.50

NONUNIVERSAL INTENSITY CORRELATIONS IN ANDERSON-LOCALIZING DISORDERED PHOTONIC CRYSTALS

MULTIPLE SCATTERING OF waves in a complex random medium induces correlations between waves propagating along different paths, opposed to the common intuition that a random medium fully scrambles all information. These universal correlations induced by random scattering have been studied in optics, electronics, acoustics, and seismology, and are gauged by a single universal transport parameter that describes the system regardless its microscopic composition. A fundamentally new class of nonuniversal correlations was predicted[1] when the light source is embedded in the random material. These nonuniversal correlations strongly depend on the microscopic details and have the remarkable property of imprinting the local quantum-electrodynamics properties deep inside an opaque random medium onto far-field intensity correlations[2]. By recording the radiative decay rate of individual quantum dots embedded in disordered photonic crystals, we probe the near field and relate it to far-field nonuniversal correlations[3]. We show that the new correlation function is non-universal since it does not scale with the parameter determining the universal transport of the medium. A corollary of our work is the demonstration of a >100 times Purcell enhancement due to the presence of Anderson-localized modes. This illustrates the exciting potential of disordered nanostructures for quantum-electrodynamics experiments and light-harvesting applications. In this context, the nonuniversal correlation function paves the way for enhancing and tailoring the light-matter coupling strength to even larger degrees, since it grants access to the local field strength in the complex medium.

[1] *B. Shapiro, Phys. Rev. Lett. 83, 4733 (1999)*

[2] *B. van Tiggelen and S.E. Skipetrov, Phys. Rev. E 73, 045601 (2006)*

[3] *P.D. García, S. Stobbe, I. Söllner and P. Lodahl, Phys. Rev. Lett. 109, 253902 (2012).*

FEMIUS KOENDERINK

AMOLF–FOM Institute
The Netherlands
f.koenderink@amolf.nl

Thursday 29 August, 09.00

HOW A TUTORIAL DIPOLE MODEL CHANGED OUR VIEW ON PLASMONICS AND METAMATERIALS

RESEARCH DIRECTIONS ARE often defined by implicit consensus over what figure of merit to chase. For instance, in plasmonics one chases field enhancement, while in metamaterials one hunts for (negative) effective medium parameters. In our recent research, we found that unexpected insights lie around the corner provided one shifts ones viewpoint a little bit. In particular, we embraced the well-known language of electrodynamic point dipole scatterers, their polarizability and fundamental underlying principles of radiation damping, the optical theorem, and the unitary limit. As two examples I will explain how playing with these concepts led us to two highly surprising experiments. Firstly, I show that metamaterial scatterers are unavoidably strongly 'pseudochiral', as dictated by reciprocity and energy conservation. Secondly, I show that while intuition would have you believe that it is easy to spoil a cavity by placing a strong scatterer in it, in contrast it is actually the scatterer that gets spoiled by the cavity.

REGINE FRANK

KIT, Karlsruhe Institute of Technology
Germany
rfrank@tfp.uni-karlsruhe.de

Thursday 29 August, 09.30

Dr. Regine Frank
PhD: Microscopic Theory of Random Lasing and Light Transport in Amplifying Disordered Media.
Rheinische Friedrich Wilhelms Universität Bonn.
PostDoc: Theoretical Physics.

THE QUANTUM NATURE OF RANDOM LASERS

WITHIN THIS TALK WE PRESENT quantitative theoretical results for the quantum coherence of random laser light [1,2]. The coherence is derived within a closed framework of diagrammatic quantum field theory coupled to a laser rate equation system. Furthermore, it is demonstrated how the ratio between classical coherence and quantum coherence can be tuned by dissipation. Decoherence effects are responsible for the lasing spot diameter on the one hand, but it can be derived quantitatively how the quantum nature of random lasers suffers due to decoherence.

[1] *R. Frank, A. Lubatsch Phys. Rev. A, 013814 (2011)*

[2] *R. Frank, A. Lubatsch, J. Kroha, Journal of Optics A: Pure and Applied Optics 11, 114012 (2009)*

JAESUK HWANG

Imperial College
United Kingdom
j.hwang@imperial.ac.uk

Thursday 29 August, 10.00

I am an experimental physicist working with single molecules, single photons and small optical chips. I am working toward a goal where many single photons are generated, processed, and detected in one small optical chip to make an optical circuit that works in a quantum mechanical fashion.

SINGLE ORGANIC DYE MOLECULES AS SINGLE PHOTON SOURCES AND LARGE OPTICAL NONLINEARITIES ON A PHOTONIC CHIP

TO PROCESS QUANTUM information with photons, one needs to facilitate strong interaction between them. One way to achieve this goal is to take advantage of their quantum interference. The technical challenge is to make those photons completely indistinguishable from one another. The other way is to make them interact via an optically nonlinear medium. The challenge here is to make sure the Kerr nonlinearity at the single photon level is large enough. For practical implementation of these operations, we envision a miniaturized platform where a large number of indistinguishable single photons are generated, guided, processed, and detected, all on a single chip. We believe that first three of these tasks can be implemented by depositing organic dye molecules on a pre-fabricated photonic chip. At cryogenic condition, single organic dye molecules embedded in an organic matrix act as 2-level atoms with a strong dipole moment, serving as nanoscale sources of indistinguishable photons [1] and strong optical nonlinearities [2]. In this talk, current efforts at the Imperial to deposit these molecules on the optical waveguides [3] and the fibre microcavities will be presented.

[1] *R. Lettow, Y. Rezus, A. Renn, G. Zumofen, E. Ikonen, S. Götzinger, V. Sandoghdar, "Quantum interference of tunably indistinguishable photons from remote organic molecules," Phys. Rev. Lett. 104 123605 (2010).*

[2] *J. Hwang, M. Pototschnig, R. Lettow, G. Zumofen, A. Renn, S. Götzinger, and V. Sandoghdar, "A single-molecule optical transistor," Nature, 460 76 (2009)*

[3] *J. Hwang, E. A. Hinds, "Dye molecules as single photon sources and large optical nonlinearities on a chip," New Journal of Physics, 13 085009 (2011)*

MAURO PATERNOSTRO

Queen's University, Belfast
United Kingdom
m.paternostro@qub.ac.uk

Thursday 29 August, 11.00

Mauro Paternostro received his Ph.D. from Queen's University Belfast (QUB) for his work on theoretical quantum information processing. After having been a research fellow at the Institute for Quantum Optics and Quantum Information, University of Vienna, and at QUB, he was awarded in 2008 an EPSRC Career Acceleration Fellowship and appointed Lecturer at QUB, where he is currently a Reader. He co-leads the Quantum Technology group at QUB, where he works on foundations of quantum mechanics and quantum information processing. He is strongly interested and has significantly contributed to quantum optomechanics and the coherent manipulation of open mesoscopic quantum systems. Honors include a Leverhulme Trust Early Career Fellowship and an Alexander von Humboldt Fellowship for experienced researchers.

QUANTUM DISCORD BOUNDS THE AMOUNT OF DISTRIBUTED ENTANGLEMENT

THE ABILITY TO DISTRIBUTE quantum entanglement is a prerequisite for many fundamental tests of quantum theory and numerous quantum information protocols. Distant parties can create quantum correlations among them by means of quantum communication encoded in a carrier that is sent from one party to the other. Intriguingly, entanglement can be increased even when the exchanged carrier is not entangled with the parties. However, in light of the defining property of entanglement stating that it cannot increase under classical communication, the carrier must be quantum. In this talk I will show that, in general, the increase of entanglement between two remote parties is bounded by the amount of non-classical correlations of the carrier with the parties as quantified by what is known as quantum discord, a weaker form of quantum correlations that is, nevertheless, very useful! I will illustrate a linear optics experiment where such predictions have been tested, verified,and pushed to the point of proving even more advantageous than the straightforward use of entanglement itself.

RUTH OULTON

University of Bristol
United Kingdom
ruth.oulton@bristol.ac.uk

Thursday 29 August, 11.20

I am an EPSRC fellow working on solid state quantum emitters in nanophotonic structures. My principle interests are in using electron and nuclear spins to store information, and designing nanophotonic structures to enhance the interaction, preserving spin. I am particularly interested in studying complex light polarization in nanophotonic structures, and the way they interact with quantum emitters. I also do a sideline in exploring the polarization optics of biological structures such as insect eyes and plant leaves.

LIGHT-MATTER ANGULAR MOMENTUM EXCHANGE IN NANOPHOTONIC STRUCTURES: BEYOND "SPIN" AND "ORBITAL" ANGULAR MOMENTUM

THE EXCHANGE OF ANGULAR momentum between photons and "artificial atoms", quantum dots (QDs), is key to many quantum information protocols. QDs are solid-state quasi-two-level systems, where angular momentum information may be transferred between the spin of an electron and a photon, usually conceived as being in an arbitrary superposition of circular polarization states. To increase the light matter interaction strength, the QDs are embedded into photonic crystal nanocavity and waveguide structures that exhibit complex polarization-dependent variation in the local light density of states (LDOS). The transfer of angular momentum in these structures is no longer trivial. The small (>>lambda) QD experiences an modified LDOS particular to its exact position, but it emits a photon in an entire photonic mode. In order to transmit a quantum of angular momentum, or indeed an arbitrary superposition of momenta, one requires that the LDOS at the QD position should allow equal coupling to any superposition state, whilst the photon mode should support superposition states. At present, a description of the LDOS and mode angular momentum in these structures, let alone interactions with quantum emitters, is almost non-existent.

Nevertheless, novel behaviour is already emerging. We will discuss a variety of nanophotonic structures containing QDs, showing that even simple structures, such as a cross-waveguides display counterintuitive behaviour of the emission, due to an interaction between QD position in the structure and its spin[1]. We will also show that in photonic crystal waveguide structures, QDs placed at strategic "C-points"[2] show a direct spin to propagation direction conversion. Finally, we will discuss how photonic crystal cavities designs may be analysed for their suitability to couple QD spin angular momentum to light [3].

[1] *Luxmoore et al. Phys. Rev. Lett.110, 037402 (2013)*

[2] *Burresi et al. Phys. Rev. Lett.102, 033902 (2009)*

[3] *Thijssen et al. Opt. Ex.20, 22412 (2012)*

YOAV LAHINI

MIT
USA
lahini@mit.edu

Thursday 29 August, 11.40

Yoav is a Pappalardo post-doctoral fellow at MIT, working on linear and nonlinear photonics, Quantum photonics and Quantum information, quasicrystals and soft-matter physics. Before MIT Yoav earned his Ph.D. in experimental physics at the Weizmann Institute of Science in Israel, working on non-linear and quantum optics of disordered media.

NONLINEAR AND QUANTUM OPTICS OF ONE DIMENTIONAL DISORDERED MEDIA

I WILL PRESENT A THEORETICAL and experimental study of one-dimensional disordered and quasi-periodic media in two different regimes:

1. Nonlinear optics, in which many photons interact via the medium, resulting in a nontrivial interplay between disorder or quasi-periodicity and non linearity.

2. Quantum optics, in which quantum statistics gives rise to non-local correlations between few non-interacting indistinguishable photons. Some of these correlations survive the effects of disorder, leading to interesting co-localization effects.

I will conclude with remarks on new possibilities to experimentally probe a new regime in complex photonics and other disordered systems, in which interactions take place at the single particle level.

NUNO DE SOUSA

Departmento de Físicao de la Materia Condensada,
Universidad Autónoma de Madrid
Spain
nuno.teixeira@uam.es

Thursday 29 August, 16.00

LIGHT EMISSION STATISTICS IN CORRELATED RANDOM PHOTONIC NANOSTRUCTURES

THE STATISTICAL PROPERTIES of light emission in disordered media have been a matter of intense research during the last decades. Although the limits of perfectly ordered or of uncorrelated and relatively weakly scattering systems are quite well understood, there is a largely unexplored gap between both limits. In particular, it has been shown that disordered systems exhibiting certain structural correlations can present properties of both crystalline and fully disordered systems. In this presentation, we theoretically show how structural correlations affect the fluorescence emission rate statistics in a disordered system. We will use a model based on point-like resonant interacting scatterers randomly distributed, where the emission dynamics of a single emitter is calculated from a set of structural realizations of the system. While keeping constant the scattering properties of single scatterers, the global geometry, density, and structural correlations are controlled by the "temperature" of the ensemble. It is found that the fluorescence decay rate statistics of a single emitter is correlated with the structural phase transitions of the system. For low temperatures, the structure freezes in a face centered cubic lattice, presenting a gap (frequency range of low photonic density of states) corresponding to a vanishing fluorescence decay rate. Equally, it also presents narrow frequency windows of high density of states, corresponding to band edges of the perfect infinite crystalline structure, leading to high decay rates. At frequencies corresponding to a band gap or to a band edge it is shown that, at low temperature, decay rates hardly fluctuate and its average value is close to the crystalline one. On temperature raising, fluctuations of decay rate grow, and the average values undergo a relatively sharp transition to a different value. This transition can be identified with a structural phase transition in the system.

SEBASTIEN POPOFF

Yale University
USA
sebastien.popoff@yale.edu

Thursday 29 August, 16.20

DEMONSTRATION OF A TENFOLD VARIATION OF LIGHT TRANSMISSION THROUGH SCATTERING MEDIA BY WAVEFRONT SHAPING

WE USED WAVEFRONT shaping to enhance/suppress the transmission of coherent light through open highly scattering media. The total transmission was varied by one order of magnitude as a result of mesoscopic correlations of coherent transport.

MATTEO BURRESI

European Laboratory for Non-linear Spectroscopy (LENS),
University of Florence, and National Institute of Optics (CNR-INO)
Italy
burresi@lens.unifi.it

Thursday 29 August, 16.40

ENGINEERING 2D PHOTONIC DISORDER: FROM INCOHERENT TRANSPORT TO INTERFERENCE EFFECTS.

ALTHOUGH DISORDER SYSTEMS are widespread in nature, seldom their geometry is truly random. More commonly, a certain degree of correlation is present in the disorder due to the interactions of the building blocks of the system. Examples of this can be found in amorphous materials, hard-sphere packing and colloidal suspensions. Also, some biological solutions for non-iridescent structural coloring of birds are based on correlated-disordered structures. In general, wave transport in these systems is altered by the presence of correlations, which could be used to manipulate, for instance, the propagation of light. Here, we show how disorder can be engineered in two dimensional photonic materials to control light transport. A semi-analytical model shows how the transport mean free path can be controlled by virtue of the short-range correlation, which also favorites the formation of localized states. A new degree of tunability for the localization length, which can vary over several orders of magnitude, can be achieved, making it possible to move from a quasi-extended to a strongly localized regime by either changing the degree of correlation or the frequency of light. The short-range order not only dominates transport in the plane but also modifies the coupling of the guided modes to the environment. We will show that in a finite two dimensional correlated-disordered system the correlations inhibit the vertical loss as the localization lengths reduces. In essence, the short-range order induces a strongly anisotropic scattering which backscatters light at each scattering event and traps it in the slab.

ANDREA DI FALCO

University of St. Andrews
United Kingdom
adf10@st-andrews.ac.uk

Friday 30 August, 09.00

CHAOTIC BROADBAND PHOTONIC CRYSTAL MICROCAVITIES

PHOTONIC MICROCAVITIES with high quality factor are able to store effectively electromagnetic energy while dissipating little power, for a given frequency. For low losses the energy decay is slow and the lifetime of the mode supported by the cavity is large. In the last decades we have learnt how to maximize this lifetime for monochromatic light, with typical values well exceeding the ns scale. This is mainly the result of technological advances that allow fabricating more and more efficient and tailored mirrors and close to ideal resonators. On the other hand, for some applications like solar energy harvesting, it would be useful to be able to store light for long times and with the largest possible bandwidth.

Here I will present our body of work on chaotic resonators, showing how chaos mediates efficient storage of light for broadband light. To demonstrate our findings we use photonic crystals technology on silicon on insulator platform, as it allows tailoring the shape and loss features of the cavity with high precision. However, the results can be extended to the wider context of energy harvesting in any microresonator, and could lead to energy storage devices with unprecedented efficiency.

SILVIA VIGNOLINI

Cambridge University
United Kingdom
s.vignolini@ucl.ac.uk

Friday 30 August, 09.30

PHOTONIC STRUCTURES IN PLANTS

COLOR IN NATURE IS everywhere: animals and plants develop structures on sub-micrometer scale to manipulate light and to obtain brilliant and iridescent colors. This kind of coloration, named structural since it is not obtained using pigmentation, results from various mechanisms, including multilayered materials, crystalline inclusions and surface diffraction gratings. The study of structural colors in biological species has raised increasing interest in the scientific community, especially in the animal kingdom.

On the other hand, the study of structural color in plants, especially in flower, has been almost ignored in the literature until few years ago. Flowers and leaves use many different mechanisms to produce structural colors that can be also dynamically adapt to light depending on the illumination condition to which are imposed.

In this talk I will revise some example of photonic structures in plants, their biological role, optical properties and how this concept can be easily implemented for general photonic application.

FIORENZO OMENETTO

Tufts University
USA
fiorenzo.omenetto@tufts.edu

Friday 30 August, 10.00

SILK – THE ANCIENT MATERIAL OF THE FUTURE

THE USE OF SILK AS A material for technological applications has been introduced over the past few years. Silk is now finding new applications as a useful biocompatible material platform with utility in photonics and electronics, ranging from nanoscale optical lattices to metamaterials. We will overview how purified silkworm silk can be reassembled, among other things, in a multitude of high quality, micro- and nanostructured optical and optoelectronic elements largely or entirely composed of this organic, biocompatible and implantable protein matrix truly opening a new silk road that brings together the biological and high-tech worlds.

DEBATES

KOSMAS TSAKMIKIDIS

Editor of Nature Materials
United Kingdom

EVENING DEBATE
Tuesday 27th August, 20.45–22.00

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SCIENTIFIC PUBLISHING, BUT WERE AFRAID TO ASK.

AD LAGENDIJK

AMOLF
The Netherlands

EVENING DEBATE
Tuesday 27th August, 20.45–22.00

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SCIENTIFIC PUBLISHING, BUT WERE AFRAID TO ASK.

KOSTAS REPANAS

*Project Manager & Managing Editor, Joint Council Office, A*STAR Singapore*

EVENING DEBATE
Thursday 29th August, 20.45–22.00

DIGITAL TOOLS FOR SCIENCE IN THE NETWORK ERA.

TIMO HANNAY

Managing Director, Digital Science, Macmillan Publishers Ltd.
United Kingdom

EVENING DEBATE
Thursday 29th August, 20.45–22.00

DIGITAL TOOLS FOR SCIENCE IN THE NETWORK ERA.

POSTERS

1. ADRIANA DE MENDOZA

Departamento de Fisica, Universidad de los Andes
Columbia
am.de259@uniandes.edu.co

EFFECTS OF THERMAL LIGHT CORRELATIONS ON PHOTOSYNTHESIS PERFORMANCE

PHOTOSENSITIVE STRUCTURES distributed over biological surfaces including bacterial membranes adjust themselves to the radiation environment, capturing efficiently the light under very low light intensities, and preventing cell death under high intensity radiation exposures. Understanding these naturally evolved mechanisms has become an important challenge for the interdisciplinary research bordering physics and biology. Different approaches have been developed to understand this phenomenon, including the possibility of quantum enhancement of energy transfer from the antenna complexes to the reaction centers. Nevertheless, the photo-detection process itself and its main statistical features have not been properly analyzed to explain the adaptation of these light harvesting biosystems to different conditions. We explore the possibility that photosynthetic structures operating efficiently in very low light environments, may exploit both the classical and quantum correlations which are always present in thermal light. Photons emitted by a thermal light source obey Poissonian statistics, given that the random atomic decays (emission processes) occur independently. Due to their bosonic nature, the photons interfere thorough the empty or dispersive random media leading to photo-detection statistics having bursty structures and definite time correlations. This interference process produces spatial correlations with transverse coherence lengths that match spatial scales in the photosensitive biostructures. Photo-counting and inter-event time distributions are calculated for multidetection schemes taking into account the spatial correlations of a thermal light field. The dependence of the counting and inter-event statistics on the correlations in light is discussed and we show how the actual inter-event time distributions behave between the two reference limits: The exponential distribution in the case of Poissonian emissions and a Pareto distribution for Bose-Einstein distributed arrivals. Finally, we provide some insights into the connection between these photo-statistical features (specifically, the moments, burstiness and memory) with the pigments' spatial distribution in actual photosynthetic membranes and the light's spatial correlation.

2. ALI MAHDAVI

Laboratory of Nanophotonics & Biosensing, Max Planck Institute for the Science of Light, Germany
ali.mahdavi@mpl.mpg.de

OPTIMIZING THE COUPLING TO PHOTONIC CRYSTAL WAVEGUIDES AND CAVITIES BY SCULPTING A FOCUSED LIGHT BEAM

TWO DIMENSIONAL SILICON photonic crystal waveguides are well-established structures for e.g. exciting defect cavities. Such defect cavities can be intentionally embedded by deforming the photonic lattice or omitting lattice sites. Furthermore, by disordering the lattice of the photonic crystal, random cavities with high quality factors can be created at arbitrary locations along the waveguide [1]. The photonic crystal structures under investigation comprise high refractive index silicon slabs with 2D arrays of air holes and exhibit a wide photonic crystal bandgap [2]. By removing a row of air holes, a typical W1 photonic crystal waveguide geometry is created [3]. In our studies, we investigate the coupling efficiency to such photonic crystal waveguides, as well as the properties of embedded defect and random microcavities, by tailoring the state of polarization in the diffraction limited spot of an exciting focused light beam impinging normally onto the waveguide. This configuration offers a more flexible and robust arrangement with regards to sample scanning and ease of coupling, in comparison to the tapered fiber method [3]. Such studies can help to understand the physics of highly localized cavity modes.

[1] *Topolancik, J. et al., Out-of-plane scattering from vertically asymmetric photonic crystal slab waveguides with in-plane disorder. Optics express 17, 12470–80 (2009).*

[2] *Joannopoulos, J. D. et al., Photonic Crystals Molding the Flow of Light. Name of book or journal is missing 305 (2008).*

[3] *Topolancik, J. et al., Random high-Q cavities in disordered photonic crystal waveguides. Applied Physics Letters 91, 201102 (2007).*

3. ANIMESH DATTA

Department of Physics, University of Oxford
United Kingdom
ali.mahdavi@mpl.mpg.de

ESTIMATING AND IMAGING AT THE QUANTUM LIMIT

QUANTUM CORRELATED PROBES have the potential of delivering enhanced precision in estimating individual parameters. This advantage depreciates in the noisy conditions, but criteria are known for obtaining tangible quantum enhanced estimation in realistic conditions. Obtaining quantum enhancements in scenarios of wider appeal such as imaging, however, require an understanding of the quantum limits of estimating several parameters across multiple modes simultaneously. The situation is made practically non-trivial and theoretically interesting by the non-commutativity of the optimal quantum measurements needed to attain the quantum limits. We present developments on the theory of estimating multiple parameters – arising from both unitary dynamics as well as decoherence – simultaneously in a variety of scenarios, and its ramifications in the imaging of real world samples.

4. CLARA I. OSORIO

Centre of Nanophotonics, AMOLF FOM-Institute
The Netherlands
osorio@amolf.nl

CHARACTERIZATION OF EMITTERS AND THEIR PHOTONIC ENVIROMENT BY USING A SIMPLE BALL LENS

THE PROPERTIES OF spontaneous emission are governed equally by the electronic properties of the emitter and its photonic environment. Or, as stated in Fermi's golden rule, the radiative emission rate depends on the local density of optical states (LDOS) of the material surrounding the emitter. Then, the task of optimizing light emission requires first characterizing the emitter properties using calibrated LDOS changes, and second mapping LDOS in uncharted photonic structures using calibrated emitters. However, most current LDOS-changing techniques are cumbersome to implement, irreversibly change the samples and their results are not easily calibrated. We have developed a set of simple, versatile and time-efficient implementations of the Drexhage experiment based on a macroscopic-coated ball lenses, which can be used both to characterize the properties of emitters and their nano-photonic environments. In this poster we will show how, by coating the lens with a thin silver layer, we accurately measured the entire distribution of radiative transition rates of quantum dots. Conversely, by coating the lens with fluorophores using DNA functionalization, we can map the LDOS of partially reflecting structured samples such as metasurfaces. Given the simple requirements for the fabrication of the lens and the non-invasive nature of the measurements, we anticipate that our method can be used to characterize many different solid state emitters, even completely functional devices, as well as plasmon antenna arrays and metamaterials.

5. COSTANZA TONINELLI

INO, CNR
Italy
toninelli@lens.unifi.it

COMMUNICATIONS BETWEEN ISOLATED QUANTUM EMITTERS: WHICH PHOTONIC STRUCTURE DRIVES IT BEST?

NO MATTER WHICH CONTEXT, transport properties depend critically on the interplay between disorder, interactions and noise. Communication, i.e. the transport of information through physical carriers, is governed by similar parameters. We study the possibility of robust hybrid photonic-molecular technologies for quantum communication. At the core is the idea, that the combination of apparently detrimental factors can instead be beneficial in terms of robustness and transmission over complex networks. In the quest for the ideal interface between light and matter at the single photon level, we consider exploiting disordered-induced Anderson Localization (AL) in on-average periodic structures. We perform numerical simulations to determine optimal parameters, yielding AL modes with the appropriate, "controllable" optical properties. In particular we investigate features like the statistical distribution of quality factors and localization length, as well as their dependence on the amount of disorder, sample size and frequency. We also investigate the occurrence of the so-called 'necklace' states, resulting from the coupling of distinct localized modes. We then compare different topologies and discuss general criteria to maximize the probability of observing such connected nodes. In order to show coupling among distant emitters, we consider single Dibenzoterrylene molecules embedded in Anthracene crystals and report on their optical characterization both at room and at cryogenic temperatures. Our results suggest the described system as a novel potential test-bed for the implementation of robust quantum networks.

6. DAAN STELLINGA

University of York
United Kingdom
dps509@york.ac.uk

2D HIGH CONTRAST GRATINGS AS HIGH NUMERICAL APERTURE FOCUSSING ELEMENTS

LENSES AND FOCUSING mirrors are an integral part of most optical and photonic systems. At the micro scale, however, they are often bulky or difficult to manufacture. This issue can be addressed with high contrast gratings that afford both high reflectivity and phase control and that can be used to make flat focusing gratings with a high numerical aperture.

High contrast gratings have recently been shown to function as polarization sensitive broadband mirrors with a reflectivity on a par with that of Bragg reflectors. Moreover, they can be used to manipulate the phase front of the reflected (and transmitted) light. Using rigorous coupled wave analysis, a set of 1D grating parameters can be found that simultaneously keep the reflectivity high while engineering the phase front of the reflected wave to match that of light reflecting from a parabolic mirror [1,2]. Combining this process with a common path finding algorithm, we have extended the phase control to a two dimensional grating structure spanning multiple 0 to 2π phase ranges. Simulations of a 330nm thick silicon grating based on this principle show a high quality focal spot with numerical apertures up to 0.6 being achievable. Corresponding gratings were fabricated and showed excellent agreement with simulations, including the demonstration of a 2μm diameter circular focal spot, i.e. close to the diffraction limit.

In conclusion, we have demonstrated the operation of high contrast gratings in silicon as high NA focussing elements and highlighted their ability to accommodate multiple 2π phase jumps and to create a micrometer-sized focal spot.

[1] *Fattal, D., Li, J., Peng, Z., Fiorentino, M. & Beausoleil, R. G. Nature Photonics 4, 466–470* (2010).

[2] *Lu, F., Sedgwick, F. G., Karagodsky, V., Chase, C. & Chang-Hasnain, C. J. Optics Express 18, 12606–12614* (2010).

7. ERTUGRUL KARADEMIR

Bilkent University
Turkey
ekarademir@fen.bilkent.edu.tr

COUPLING INTERACTIONS BETWEEN LARGE AREA PLASMON CAVITY ARRAYS AND TWO LEVEL SYSTEMS

WE HAVE INVESTIGATED strong and weak coupling regimes of surface plasmon polariton (SPP)-exciton systems. Plasmonic cavity arrays are fabricated with interference lithography technique. Using this approach it is possible to form large SPP cavities with areas as large as 20mm x 20mm. Cavity structures are formed by superposing two uniform gratings with different periods which can result in periodic arrays of biharmonic or Moiré surfaces that act as Bragg mirrors. Tuning the cavity size, we can tune the strength of the interaction between cavities. In this work, latest results on coupling between SPP modes of these structures and excitonic systems will be presented. Exciton systems are chosen as a j-Aggregate dye (TDBC) which has a high quality factor and a core CdSe quantum dot which has a broad absorption band. With high excitonic quality factor, strong coupling between the SPPs and the excitonic transition that lead to Rabi splitting is observed. The effects of plasmon damping on the transition from weak to strong coupling between j-aggregate and SPP has been investigated. With application of SPP modes in imaging of biological molecules in mind, we present data on cavity and band edge modes of Moiré structures and coupling of SPPs in these cavities to emission modes of quantum dots where four-fold enhancement in the emission spectra of QDs has been observed.

8. FRANCESCO PASTORELLI

ICFO, The Institute of Photonic Science
Spain
ceskotwo@gmail.com

LIGHT TRAPPING WITH PLASMONIC OLIGOMERS AND PHOTONIC CRYSTALS TO ENHANCE THE PERFORMANCE OF ORGANIC SOLAR CELLS DEVICES

EFFICIENT CREATION OF excitons in organic photovoltaics (OPVs) requires a large optical path of light through the active material and adequate light confinement. However, OPVs feature low charge mobility requiring very thin active layers around one hundred nanometers. To increase light-matter interactions in thin polymers, metallic particles (NPs) or nanostructuration have been proposed to scatter and confine impinging light into the polymer. Part of the work is focused on incorporating gold NPs dimers and trimers inside the OPV device. The NPs are linked at a controlled distance of a few nanometers by Dithiothreitol molecules (self-assembly method). The spacing molecules ensure a minimum distance that plays a fundamental role in the formation of intensity hot spots in the nanogap as well as large and red-shifted scattering peaks. The scattering of such oligomers leads to a significant increase of the light harvesting in the active material, we fabricated three types of OPV devices: a standard inverted OPV planar device, a similar device with 40 nm diameter particles (monomers) and, a device including 40 nm monomers, dimers and trimers. The latter one exhibited an efficiency 14% higher than the reference one showing a relevant enhancement in the red part of the EQE measurements.

9. GANGA DEVARAPU

CEMPS, University of Exeter
United Kingdom
gcrd201@exeter.ac.uk

EXTREME PHOTONIC-CRYSTAL BASED ABSORPTION CONTROL IN THE INFRARED

INFRARED DETECTORS PLAY a key role to a range of applications such as medical diagnostic imaging or optically-based bio-detection platforms. Their performance and spectral range availability is closely linked to efficient absorption management at the applicable frequency regime. Traditional routes in absorption control involve carefully engineered coatings for the particular absorbing material that facilitate a strong in-coupling of the impinging light as well as back-reflecting elements to allow for additional light-passes. Nanophotonics research has opened new routes to absorption harnessing that enhance absorption by employing resonant metallic metamaterial structures facilitating a near-perfect impedance-matching or nanoplasmonic structures that induce a strong near-field enhancement. Both routes are hinging on the fact that significant portion of the incident light is absorbed by the metallic part of the architecture rather than the semiconductor material.

Here we are proposing a new route based on a semiconductor photonic crystal (PC). In particular, we employ a SiC photonic crystal paradigm within the frequency regime of the phonon-polariton gap where SiC is strongly absorbing but highly reflective as a bulk material. We show that near-perfect absorption can be achieved in a specially designed SiC-dielectric PC in a one-step process without anti-reflection coating and/or back-reflector. Our results show an intricate relationship between in-coupling and the energy velocity of light and reveal that the key mechanism for absorption optimization is appropriate tailoring of the light's energy velocity and its gradient at the photonic crystal interface. By carefully exploiting the latter mechanism we were able to achieve a near-perfect absorption in a compact PC design where 90% of the incident light is absorbed by the entry layer with thickness smaller than $\lambda_0/1000$, with λ_0 being the free space wavelength.

10. GHOLAMREZA FAYAZ

Physics Department, Tafresh University
Iran
reza.fayaz@tafresh.ac.ir

SIMULATION OF ONE DIMENSIONAL RANDOM LASER WITH THE REFLECTIVE BOUNDARIES

WE HAVE STUDIED A one-dimensional random laser by solving Maxwell's equations as well as rate and polarization equations. Random system is considered as a series of one dimensional dielectric particle randomly distributed in an active medium. The active medium is described as a four-level system. The effect of pump power, particle size and particle density are numerically studied by Monte Carlo and FDTD simulations for both reflective and non-reflective boundaries. In our calculations we have solved the equations by FDTD as a part of Monte Carlo simulations in order to increase the precision by randomly choosing of the meshed element. We have considered the Perfectly Matched Layer (PML) boundary conditions for non-reflective boundary. In the case of reflective boundaries, reflection coefficients of 40% and 60% are considered. Our calculations show that by increasing the pump power the laser modes and intensities increase for both of the boundary conditions, however lower threshold and stronger intensity are observed in a system with reflective boundaries. Increasing the pump power results in more fluctuations in laser modes and less localization in laser light loops. Effect of particle density is also studied and our results show that by increasing the particle density the feedback converts from noncoherent to coherent and hence an enhancement in the laser mode and intensity occurs. In this work, we aim to study effects of different parameters on a one dimensional random laser with reflective boundaries which allows us to have a better control on a more realistic system.

11. HAIDER BUTT

University of Cambridge
United Kingdom
hb319@cam.ac.uk

NANOSCALE PIXELS BASED ON CARBON NANOTUBES

THE SIZE OF PIXELS is one of the key limiting features in the state of the art of holographic displays systems. The resolution and field of view in these systems are dictated by the size of the pixel (the smallest light scattering element).[1] We have demonstrated the utilization of carbon nanotubes (nanostructures) as the smallest possible scattering element for diffracting light in a highly controlled manner to produce two dimensional holograms. An array of carbon nanotubes was elegantly patterned to produce a high resolution hologram. In response to the incident light on the hologram a high contrast image of the word CAMBRIDGE was produced. Due to the nanoscale dimensions of the carbon nanotube array the image presented a wide field of view and high resolution. The results have been published in Advanced Optical Materials [1] journal and were also featured as a News and Views article in Nature Journal.[2] These results pave way towards the utilization of nanostructures for producing 3D holograms with wide field of view and high resolution. We also demonstrate the usage of patterned graphene layers for producing the world's thinnest diffraction holograms.

[1] *H. Butt, Y. Montelongo, T. Butler, R. Rajesekharan, Q. Dai, S. G. Shiva-Reddy, T. D. Wilkinson, and G. A. J. Amaratunga, Adv. Mat., Vol. 24 (2012)*

[2] *S. Larouche and D. R. Smith, Nature, Vol. 491 (2012)*

12. HENRI NIELSEN

COPS, University of Twente
The Netherlands
h.t.nielsen@utwente.nl

NON-EXPONENTIAL SPONTANEOUS EMISSION DYNAMICS FOR EMITTERS IN A TIME-DEPENDENT OPTICAL CAVITY

IMPRESSIVE PROGRESS HAS been achieved in controlling the spontaneous emission rate for emitters in Nanophotonic structures, such as microcavities, photonic crystals and nano-antennas. In all cases, however, the modification of the emission is stationary in time. Thus, the emission rate is time-independent and the distribution of photon emission times is stochastic and follows an exponential distribution in the weak coupling regime. Here, we propose to quickly modulate the environment for an ensemble of emitters in time, during the time that they emit photons. We have theoretically studied the effect of deterministic temporal control of spontaneous emission for two-level emitters in a dynamic optical microcavity. A rate equation model is developed for the excited state population of two-level emitters coupled to a time-dependent environment. As an example, we consider emitters in a semiconductor microcavity that is switched by free carrier excitation. The temporal dynamics of the emitted intensity is derived for both continuous wave and pulsed excitation of the embedded emitters. We demonstrate that a short temporal increase of the radiative decay rate depletes the excited state and drastically increases the emission intensity during the switch time. For pulsed excitation, the resulting time-dependent spontaneous emission shows a distribution of photon arrival times that strongly deviates from the standard exponential law: A deterministic burst of photons is spontaneously emitted during the switch event.

13. KEVIN VYNCK

Institut Langevin, ESPCI, ParisTech
France
kevin.vynck@espci.fr

SPATIAL FIELD CORRELATIONS FOR POLARIZED WAVES IN THE NEAR-FIELD OF RANDOM MEDIA

MULTIPLE SCATTERING OF light in random media is characterized by a scrambling of the direction and phase of the wave, which leads to complex fluctuations of the field in space. The spatial correlation of the field was early recognized as a key quantity for the study of mesoscopic phenomena in complex media [1,2] and it was shown recently that information about the microscopic structure of a disordered material could be retrieved through an analysis of the correlation function in its near-field speckle pattern [3].

Interestingly, however, while one expects the vector nature of light waves to be an essential part of the physics underlying spatial field correlations, many aspects of polarized light in random media have not been investigated theoretically so far. Here, we will present our recent progress in the development of a theoretical basis for the spatial field correlation of polarized waves in random media. We will tackle the question of how the states of polarization in two points in the near-field of a random medium relate to each other, and discuss the potential outcomes of our work for mesoscopic phenomena in random media, as well as the optical characterization of complex disordered materials, such as powders, foams, colloids and biological tissues.

[1] B. Shapiro, "Large intensity fluctuations for wave propagation in random media", Phys. Rev. Lett. 57, 2168-2171 (1986).

[2] M. J. Stephen and G. Cwilich, "Intensity correlation functions and fluctuations in light scattered from a random medium", Phys. Rev. Lett. 59, 285-287 (1987).

[3] R. Carminati, "Subwavelength spatial correlations in near-field speckle patterns", Phys. Rev. A 81, 053804 (2010).

14. MARK G. SCULLION

University of York
United Kingdom
mark.scullion@york.ac.uk

PROBING THE SUB-CELLULAR WORLD USING PHOTONIC BIOSENSORS

MANY MICRO/NANOPHOTONIC devices have been demonstrated to be of great promise for lab-on-a-chip style biosensors. For example, we have previously shown the advantages of combining slot waveguides and photonic crystals to create very compact, yet sensitive devices. Whilst there is a plethora of optical biosensor designs available, few have went beyond proof-of-principle due to the many obstacles and questions that remain for practical application, such as the integration of on-chip light sources and spectrometers, and adapting the functionalization protocol. Whilst these issues can conceivably be overcome, we believe that the potential of photonic biosensors is not limited to lab-on-a-chip. Photonic crystal cavities can be much smaller than the size of a typical cell. This small size not only minimises sample volumes and allows dense multiplexing, but also offers a unique opportunity to locally sense biological processes at a sub-cellular level. With our collaborators we are therefore investigating whether photonic devices could allow us to uncover several real problems within biology, such as: how does skin heal, can we probe the contents of an individual cell directly, where does a cell secrete and can we create functional images of neural networks? We also question whether instead of competing with electronic biosensors, there is much to be gained from combining optical and electrical structures to increase functionality and performance. In this talk we will therefore briefly review our previous work, and show details of our current projects to drive forward what we increasingly see as the real advantages of integrated optics for biology.

15. MARTIN LOPEZ-GARCIA

Photonics Group, University of Bristol
United Kingdom
martin.lopezgarcia@bristol.ac.uk

OPTICALLY ACTIVE DEFECTS IN 3D PHOTONIC CRYSTALS

IN THIS CONTRIBUTION we present recent results on the design and fabrication of localized defects in 3D chiral photonic crystals showing optical activity. We have designed, fabricated and measured chiral woodpile photonic crystals [1] where a localized state was generated by introducing a twist defect at half total height of the structure [2]. FDTD and Transfer Matrix Method simulations shown that high Q values can be achieved for the localized mode when the appropriate circular polarization is chosen according to the handedness of the structure. Fabrication was performed by two-photon lithography obtaining left and right handedness for polymer structures. The defect and photonic band of the chiral structures were tuned to different wavelengths between 0.9- 1.5 μm showing good morphological quality for structures formed by 24 layers. Reflectance/transmission measurements performed by Fourier image spectroscopy shown a strong resonant state within the photonic gap when polarization of the probe matches the handedness of the structure. Finally we will show that different angles of twist at the defect produce a tuning of the spectral position of the resonance. We think this structures could be used to generate strong coupling between circular polarized localized modes and single emitters providing a exceptional playground for spin-orbit interaction studies.

[1] *Thiel, M., et al. Layer-by-layer three-dimensional chiral photonic crystals. Opt. Lett., 32(17), 2547–2549 (2007).*

[2] *Kopp, V. I, et al. Twist Defect in Chiral Photonic Structures. Physical Review Letters, 89(3), 33901 (2002).*

16. MARTINA ABB

University of Southampton
United Kingdom
ma2n08@soton.ac.uk

ALL-OPTICAL CONTROL OF PLASMONIC NANOANTENNA-ITO HYBRIDS

NANOSCALE PLASMONIC COMPONENTS such as nanoantennas are of enormous interest for their capabilities of locally enhancing electromagnetic fields and controlling emission. Active control of such components will enable a new generation of tunable devices. We have recently demonstrated experimentally picosecond all-optical control of a plasmonic dimmer nanoantenna on indium tin oxide (ITO). We observe a hybrid nonlinear response which is caused by a picosecond energy transfer mechanism involving hot electron injection from gold into the transparent conductive oxide. Making use of femtosecond pulses, we also demonstrate a new hybrid response in cross resonant optical antennas on ITO where resonant pumping of the antenna along one axis leads to hotspot generation and concomitant free-carrier concentration changes in the ITO. These nonlinear refractive index changes in the ITO substrate in turn modify the plasmon resonance and result in a rapid and sizable modulation of the antenna mode. Hybrid plasmonic components are of great interest for active control of optical fields and integration of photonic and electronic functionalities. The combination of tunable antenna-ITO hybrids with nanoscale plasmonic energy transfer mechanisms, as demonstrated here, opens a path for new ultrafast devices to produce nanoplasmonic switching and control.

17. MICHELE GAIO

King's College London
United Kingdom
michele.gaio@kcl.ac.uk

LOCALISATION PROPERTIES IN COMPLEX PLASMONIC SYSTEMS

SEMICONTINUOUS METALLIC films are known to exhibit peculiar optical properties which strongly differ from those of bulk metal and ensembles of isolated nanoparticles. Close to the electrical percolation threshold, the combination of multiple scattering and the intrinsic material plasmonic excitations leads to strong enhancement of the electromagnetic fields in randomly distributed subwavelength areas, commonly called hot spots. These localised fields are promising for sensing, non-linear optics, and the study of the light-matter interaction at the single-emitter level. We present here a detailed study of these localised modes when they are excited by an individual emitter coupled to their near-field. The local density of optical states (LDOS) that drives the spontaneous emission of light of dipole emitters probes the local environment properties and can be directly obtained experimentally by measuring the variation in the decay rate. Moreover, information on the spatial extent of the electromagnetic modes can be obtained investigating the angular emission distribution giving insights into how light is emitted from such near-field coupled sources.

18. PABLO DE ROQUE

Institute of Photonic Sciences
Spain
pablo.deroque@icfo.es

NANO-ANTENNAS IN OPTICAL CAVITIES

INTERACTION BETWEEN MATTER and electromagnetic (EM) modes can be modified using carefully engineered structures at the nanoscale. Ideally, one would like to increase the light-matter interaction to such extent that one cannot distinguish whether there is an atom in the excited state and/or a photon in a particular cavity mode. In such a case, the system is said to be strongly coupled. Equivalently, we can picture this process as a reversible interaction between an atom and a cavity. The atom emits a photon into a cavity mode that will be reabsorbed back before it escapes the cavity. The strategies to enhance the interaction have been two-fold: increase the time an EM mode lives (using cavities); or localize light to subwavelength volumes (using antennas). The natural step would be then to combine both approaches, such that the interaction becomes doubly enhanced. Some theoretical work has been done to understand the combined system, however two different kinds of reasoning have been publicly communicated in scientific journals. The two of them leading to completely different results. The first approach assumes that the scattering strength of the nanoantenna does not change when interacting with a cavity. In this case, the interaction of an emitter with the combined structures gets boosted and one can see reversible effects. In the second approach, multiple interaction between the emitter, the antenna and the cavity is taken into account. The scattering strength of the antenna is modified by the optical mode such that the enhancement is self-limiting. Thus, the probability of reversible interaction is much less than in the previous case, making it difficult to experimentally verify strong coupling in such systems. We think that the Science Camp is a good place to discuss this apparent controversy in the field of nano-optics.

19. RAVITEJ UPPU

Tata Institute of Fundamental Research
Mumbai, India
ravitejuppu@tifr.res.in

CHARACTERIZATION AND CONTROL OF EMISSION FROM NANOSTRUCTURED DISORDERED AMPLIFYING MEDIA

DISORDERED AMPLIFYING MEDIA, systems termed as random lasers are a class of exciting sources with a possibility of extracting coherent emission from a very small (~10^-3 mm^3) system size. Furthermore, from a basic physics standpoint, the innately random nature of the system gives rise to many interesting statistical features in the emission. We study these statistical features to characterize the nature of emission from the system into three regimes. A pre-lasing Gaussian regime below threshold transits to a Lévy (power-law) regime on the onset of lasing. This is followed by a slow crossover back into the Gaussian regime due to the strong self-averaging of the emission through redistribution of energy among the various open modes in the system. We also propose that the onset of the Lévy regime can act as a universal indicator for the random lasing threshold in the case of coherent as well as diffusive random lasers unlike the existing distinct definitions. Apart from this, we estimate the threshold of random lasing through numero-analytical studies given the experimental parameters. Beyond this, we demonstrate the application of a random laser as a broadband random amplifier for coherent light by seeding the random laser. The origin of this phenomenon can be traced to the physical principles of random lasing. By statistically increasing the population of trigger photons that undergo multiple scattering at a wavelength, we increase the probability of amplification at that particular wavelength. This realizes a random amplification for the photons of the seed wavelength. We further show that such a technique can be used to passively control the frequency of the ultranarrow modes.

20. ROMAN BRUCK

University of Southampton
United Kingdom
r.bruck@soton.ac.uk

INTERACTION OF PLASMONIC NANOSTRUCTURES WITH INTEGRATED SILICON WAVEGUIDES

INTEGRATED OPTICS AND PLASMONICS have both been developed into prosperous platforms in their fields. Integrated optics, in particular silicon photonics with active and passive devices fabricated in a CMOS compatible manner, is to become a major technology driver in optical telecommunication, but is also a promising platform for sensing applications. Plasmonic devices have, despite their inherently lossy nature, been developed for many applications. Exemplarily, plasmonic structures allow for a strong confinement of light in a small volume, correspondingly enhancing the field intensity in this region. Thus, plasmonic structures can interact effectively with their surroundings, which is of particular interest for sensing, where commercially successful products have been released. The combination of photonic and plasmonic concepts opens up a variety of new applications, which have not yet been explored to their full extend. In this study, the interaction of plasmonic nanoantennas with light propagating in silicon waveguides is analysed. By means of 3D finite-difference-time-domain simulations the absorption-, transmission- and scattering-spectra of 220 nm by 400 nm silicon waveguides loaded with various antenna configurations were calculated for both polarizations. Depending on the geometry and the material of the antennas, plasmonic resonances can be efficiently excited by the guided light in the waveguide, which leads to a strong field enhancement around the antennas. The energy transferred from the waveguide mode is absorbed in the antennas or scattered. A single row of antennas on top of a waveguide layer can reduce transmission by almost 50% for TM polarization and 25% for TE polarisation. If the antennas can be placed in the waveguiding layer, transmission can be reduced by almost 80% for TM polarization and 90% for TE polarisation. These sub-wavelength antennas can be utilized as building blocks for new and compact sensing, modulator, and absorber schemes.

21. ROMOLO SAVO

LENS – University of Florence
Italy
savo@lens.unifi.it

FRACTAL DIMENSIONS OF LIGHT IN COMPLEX HETEROGENEOUS MEDIA

COMPLEX SYSTEMS ARE intrinsically heterogeneous, both in their compositions and in the geometry of their structure. This determines a major challenge in understanding and describing transport processes, with an interest ranging from atmospheric physics and biology to chemistry and network science. A starting point is that the disorder characterizing complexity leads the transport to be a stochastic process, in particular a random walk. This mechanism is very general and establishes a link among transport of money, information and waves. A crucial feature is that each random walk traces a self-similar trajectory in space with a fractal dimension dw. The value of dw intimately depends on the topology of the system that is explored and determines the transport dynamics. In macroscopically homogeneous systems (i.e. with transport properties independent from the point) transport is diffusive and dw=2. On contrary the heterogeneity of many complex systems, which can be spread over many orders of magnitude, prohibit a diffusive process. In such condition transport becomes anomalous, showing non-integer fractal dimension different from two. A complete understanding of anomalous transport in strongly heterogeneous system is lacking and novel experimental evidence can be of great interest. In this work we study light transport in engineered disordered scattering materials dubbed Lèvy glasses, where the heterogeneity is fractally distributed over two orders of magnitudes. By means of time-resolved investigations we reveal important features of the dynamics, which show significant deviations from that of the homogeneous counterpart. We perform a scaling experiment in order to measure the fractal dimension of light in the samples, observing values that are significantly smaller than two, giving a dynamical signature of superdiffusion. We discuss the role played by the finite size of samples, which needs to be considered in the size range of investigation.

22. SARA NÚÑEZ-SÁNCHEZ

University of Exeter
United Kingdom
s.nunez-sanchez@exeter.ac.uk

STUDY OF STRONG COUPLING BETWEEN MOLECULES AND METAL-PHOTONIC STRUCTURES

MOLECULAR OPTICAL TRANSITIONS are not properties of isolated molecules, rather they depend on the local optical environment. In the strong coupling regime, optical transitions can be dressed by vacuum fields defined by photonic resonances, modifying the associated transition frequencies and probabilities. The coupling strength is controlled by tuning the molecular optical transition with the photonic resonance and by the effective volume and quality factor of the resonant mode. Understanding how these parameters affect the strong coupling mechanisms is fundamental to a number of exciting possibilities in photochemistry, enhanced spectroscopy or molecular electronics. Our aim in this work is to study both experimentally and theoretically the strong coupling regime between molecules with narrow-band transitions and metal-photonic structures with different coupling strengths. We employ two photonics structures with different effective volumes whose resonances are controlled by geometrical parameters. On one hand TDBC molecules are coupled to a metal-mirror micro-cavity, a cavity that defines a modal resonance confined on length scales of hundred nm. On the other hand we also analyse the strong coupling regime in complex systems composed of TDBC molecules and metal nanoparticles, whose effective volume mode is orders of magnitude smaller than the effective volume of conventional dielectric cavities. We are also working towards studying the response of TDBC doped nanoparticles arranged in two dimensional arrays where the lattice constant is of order the light of wavelength. We will investigate the role of the lattice constant in the collective plasmon oscillations resulting from the coupling of plasmon resonances in these arrays and explore how it affects the strong coupling between TDBC molecules and nanoparticle resonators.

23. XAVIER VIDAL

Macquarie University
Australia
xavier.vidal@mq.edu.au

HELICITY: A NON-BROKEN SYMMETRY FOR THE ROTATION OF LIGHT

In general, the matter response to electromagnetic fields depends on its polarization. In optically active media this response is different to fields with opposite circular polarization and rotates electromagnetic fields linearly polarized. In these scenarios matter is chiral, which implies that the geometrical symmetries of the system have to be broken. However, this behaviour is only accomplished in very particular configurations: forward and backward scattering in random chiral systems. Therefore, we will show that this is not the full picture for obtaining a general description of the interaction. It lacks the conservation of one physical quantity, the helicity. It is defined, as the projection of the angular momentum onto the direction of the linear momentum and is the generator of electromagnetic dual transformations. The non-geometrical symmetry related to the conservation of this physical quantity is only fulfilled when the permittivity and the permeability of the matter are equal. Based on symmetry conditions and conserved quantities, we show the theoretical tools to understand how to design an optically active system. These systems will rotate the polarization of light always by the same amount, independently on the incident polarization and in any scattering direction. We have experimentally analysed the scattering of a random distribution of chiral and achiral scatterers forward and perpendicular to the incident beam. To test our theoretical results, we have measured the degree of change when the incident beam is circularly polarized. In the forward direction no change was observed. On the contrary, in the same system but out of forward scattering the degree of change is considerable. These measurements prove the role of the helicity. Although it is naturally preserved in chiral random systems in the forward direction, it is broken in general, and as a consequence, the optical rotation and the change of ellipticity cannot be measured.

24. YU LUO

Imperial College
United Kingdom
y.luo09@imperial.ac.uk

A MODIFIED HYDRODYNAMICAL MODEL TO DESCRIBE THE NONLOCAL AND QUANTUM TUNNELLING EFFECTS

METALLIC NANOPARTICLES THAT support localized surface plasmon resonances can harvest light into a deep-subwavelength volume, thereby achieving very large field enhancement. Many emerging nanophotonic technologies rely on the careful control of this field enhancement, including cancer therapy, improved photovoltaic devices, and optical antennas for enhanced light-matter interactions. However, at deep subwavelength scales, classical continum electrodynamics fails to describe the optical responses of nanoparticles owing to nonlocal screening and the spill-out of electrons. Electron correlations that are driven by these effects require a new model of nonlocal transport, which is crucial in nanoscale optoelectronics. In this talk, I will present a modified hydrodynamical to study the plasmonic interaction at subnanometer scales. Our approach incorporates radiative, nonlocal, and quantum tunnelling effects, and thus can be applied to design realistically sized plasmonic systems. As an example, I will use this method to elucidate the optimum shape of a nanoparticle that maximizes its absorption and field enhancement capabilities.

PROGRAMME

TUESDAY 27 AUGUST

14.30–15.30 **KEYNOTE TALK**

NIEK VAN HULST
ICFO, The Institute of Photonic Science

TRACKING NANOSCALE COHERENT ENERGY TRANSFER IN SINGLE LIGHT HARVESTING COMPLEXES

15.30–16.30 **NANO-OPTICS OF COMPLEX SYSTEMS**

15.30 **RASHID ZIA**
Brown University
A MULTIPOLAR EMITTER: CAN 1 TRANSITION ILLUMINATE 2 PATHS?

16.00 **COFFEE BREAK**

16.30 **SEBASTIEN BIDAULT**
Institut Langevin, ESPCI, CNRS, Paris
DRIVING DNA TEMPLATED OPTICAL ANTENNAS WITH A SINGLE QUANTUM EMITTER

16.50 **VENTSISLAV VALEV**
University of Cambridge
HIGHLY LOCALIZED NANO-DEFORMATIONS IN PLASMONIC NANO-STRUCTURES CAUSED BY FEMTOSECOND LASER PULSES

20.45–22.00 **EVENING DEBATE:**

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SCIENTIFIC PUBLISHING, BUT WERE AFRAID TO ASK

with
KOSMAS TSAKMAKIDIS
Editor of Nature Materials

AD LAGENDIJK
AMOLF

WEDNESDAY 28 AUGUST

09.00 –10.20 **LIGHT PROPAGATION AND IMAGING IN DISORDERED MEDIA**

09.00 **TOMAS CIZMAR**
University of St. Andrews
PHOTONICS IN DISORDERED ENVIRONMENTS AND FIBRE BASED IMAGING

09.30 **WONSHIK CHOI**
Korea University
BIO-SENSING & IMAGING IN COMPLEX MEDIA

10.00 **TIMMO VAN DER BEEK**
AMOLF, FOM-Institute
PROBING HIDDEN MULTILAYERS WITH DIFFUSION THEORY

10.20 **COFFEE BREAK**

11.00–12.10 **STRONG SCATTERING AND ANDERSON LOCALIZATION OF LIGHT**

11.00 **ALBERTO RODRIGUEZ**
Freiburg University
MULTIFRACTAL DISTRIBUTIONS IN DISORDERED MEDIA

11.30 **TOM STRUDLEY**
University of Southampton
MESOSCOPIC TRANSPORT AND LIGHT TRAPPING IN STRONGLY SCATTERING NANOWIRE LAYERS

11.50 **PEDRO DAVID GARCÍA**
University of Copenhagen
NONUNIVERSAL INTENSITY CORRELATIONS IN ANDERSON-LOCALIZING DISORDERED PHOTONIC CRYSTALS

14.30–15.30 **KEYNOTE TALK**

STEFANIA RESIDORI
Institut Non Lineaire de Nice

SELF-ADAPTIVE HOLOGRAPHY IN NONLINEAR MEDIA

15.30–16.15 **POSTER PITCHES**
~1 minute each

16.15–16.45 **COFFEE BREAK**

16.45–19.15 **POSTER SESSION**
with drinks and refreshments

20.45–22.00 **EVENING DEBATE**
Open Session

THURSDAY 29 AUGUST

09.00 –12.00 **QUANTUM OPTICS OF COMPLEX MEDIA**

09.00 **FEMIUS KOENDERINK**
AMOLF
HOW A TUTORIAL DIPOLE MODEL CHANGED OUR VIEW ON PLASMONICS AND METAMATERIALS

09.30 **REGINE FRANK**
KIT, Karlsruhe Institute of Technology
THE QUANTUM NATURE OF RANDOM LASERS

10.00 **JAESUK HWANG**
Imperial College
SINGLE ORGANIC DYE MOLECULES AS SINGLE PHOTON SOURCES AND LARGE OPTICAL NONLINEARITIES ON A PHOTONIC CHIP

10.30–11.00 **COFFEE BREAK**

11.00 **MAURO PATERNOSTRO**
Queen's University, Belfast
QUANTUM DISCORD BOUNDS THE AMOUNT OF DISTRIBUTED ENTANGLEMENT

11.20 **RUTH OULTON**
University of Bristol
LIGHT-MATTER ANGULAR MOMENTUM EXCHANGE IN NANOPHOTONIC STRUCTURES: BEYOND "SPIN" AND "ORBITAL" ANGULAR MOMENTUM

11.40 **YOAV LAHINI**
MIT
NONLINEAR AND QUANTUM OPTICS OF ONE DIMENTIONAL DISORDERED MEDIA

14.30–15.30 **KEYNOTE TALK**

ARISTIDE DOGARIU
CREOL, Florida

MECHANICAL ACTION IN COMPLEX ELECTROMAGNETIC FIELDS

16.00–17.00 **MULTIPLE SCATTERING OF LIGHT**

16.00 **NUNO DE SOUSA**
Universidad Autónoma de Madrid
LIGHT EMISSION STATISTICS IN CORRELATED RANDOM PHOTONIC NANOSTRUCTURES

16.20 **SEBASTIEN POPOFF**
Yale University
DEMONSTRATION OF A TENFOLD VARIATION OF LIGHT TRANSMISSION THROUGH SCATTERING MEDIA BY WAVEFRONT SHAPING

16.40 **MATTEO BURRESI**
University of Florence
ENGINEERING 2D PHOTONIC DISORDER: FROM INCOHERENT TRANSPORT TO INTERFERENCE EFFECTS

20.45–22.00 **EVENING DEBATE:**

DIGITAL TOOLS FOR SCIENCE IN THE NETWORK ERA

with
KOSTAS REPANAS
*Project Manager & Managing Editor, Joint Council Office, A*STAR Singapore*

TIMO HANNAY
Managing Director, Digital Science, Macmillan Publishers Ltd.

FRIDAY 30 AUGUST

09.00 –10.30	**COMPLEX PHOTONICS MATERIALS**
09.00	**ANDREA DI FALCO** *University of St. Andrews* **CHAOTIC BROADBAND PHOTONIC CRYSTAL MICROCAVITIES**
09.30	**SILVIA VIGNOLINI** *University of Cambridge* **PHOTONIC STRUCTURES IN PLANTS**
10.00	**FIORENZO OMENETTO** *Tufts University* **SILK –THE ANCIENT MATERIAL OF THE FUTURE**
11.00–12.00	**CLOSING REMARKS AND PRIZE AWARDING**