Complex Nanophotonics **Science Camp**

CUMBERLAND LODGE
Windsor Great Park
Berkshire, SL4 2HP, UK

18th-21st August 2015

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

The Camp will be held at Cumberland Lodge, a beautiful 17th Century country house in Windsor Great Park, close to London. The Lodge is now occupied by a education charitable foundation and holds a very diverse range of conferences, lectures and discussions.

Directions

By Plane

The closest airport is Heathrow, at just 20 minutes by car. Gatwick airport is 40 minutes by car.

By Train

The closest train station is Egham, that is well connected to both London Waterloo and Reading.

By Taxi

The appropriate fares to Cumberland Lodge are about £9 from Egham Station, £25 from Heathrow and £65 from Gatwick.

By Car

Cumberland Lodge has plenty of free parking.
Please note that for Crown Estate legal reasons, GPS SatNav Systems do not work within the Great Park. However, they do work for Bishopsgate Road, Englefield Green, TW20 0XU, which is just outside the Bishopsgate entrance to the Park, and SL4 2JA is for drivers coming from the Windsor and Ascot direction using the Ranger's Gate entrance.

Historical Foundations

Cumberland Lodge is a former Royal residence inThe Great Park at Windsor. In 1947 King George VI granted the Lodge to St Catharine's, a then newly established educational charitable trust. They would be given the opportunity to discuss important social and ethical issues and to reflect on the value of their academic work in relation to society.

The Grounds

There are two main buildings - the Lodge and the Mews.The dining rooms, lounges, chapel, library and administrative offices are housed in the Lodge, while the two conference rooms and four seminar rooms are located on the ground floor of the Mews.

Accommodation

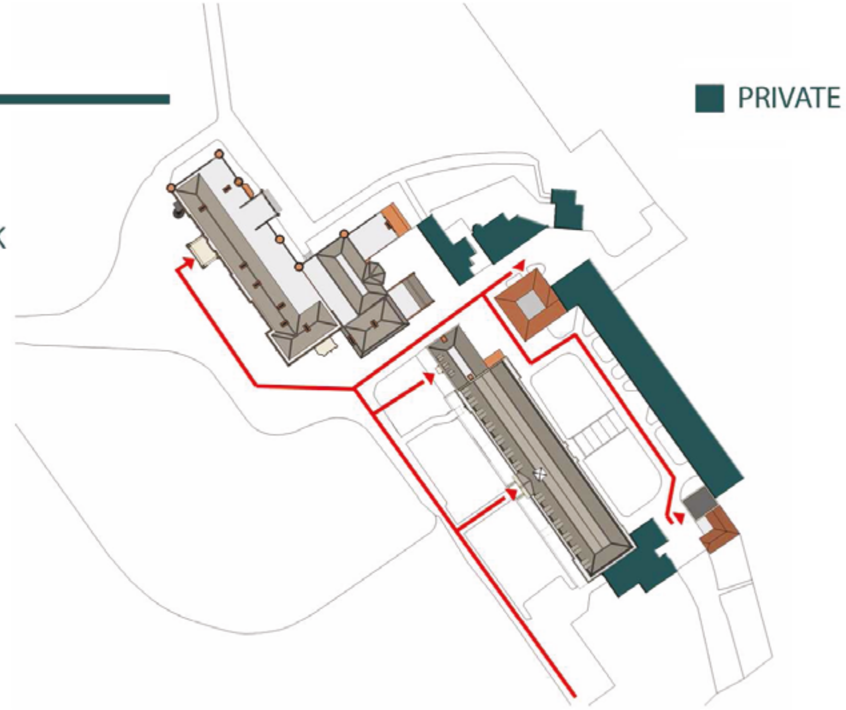
All bedrooms have en-suite bathrooms and are primarily located on the higher floors of both buildings. New visitors are surprised to learn that there are no room keys. However, we are able to secure valuables in one of our insurance-rated safes by arrangement. Guests are asked to vacate bedrooms by 9.00 AM on the day of departure. Free Internet access is offered on PCs in the Mews and the basement of the Lodge, and both buildings have free Wi-Fi as well.

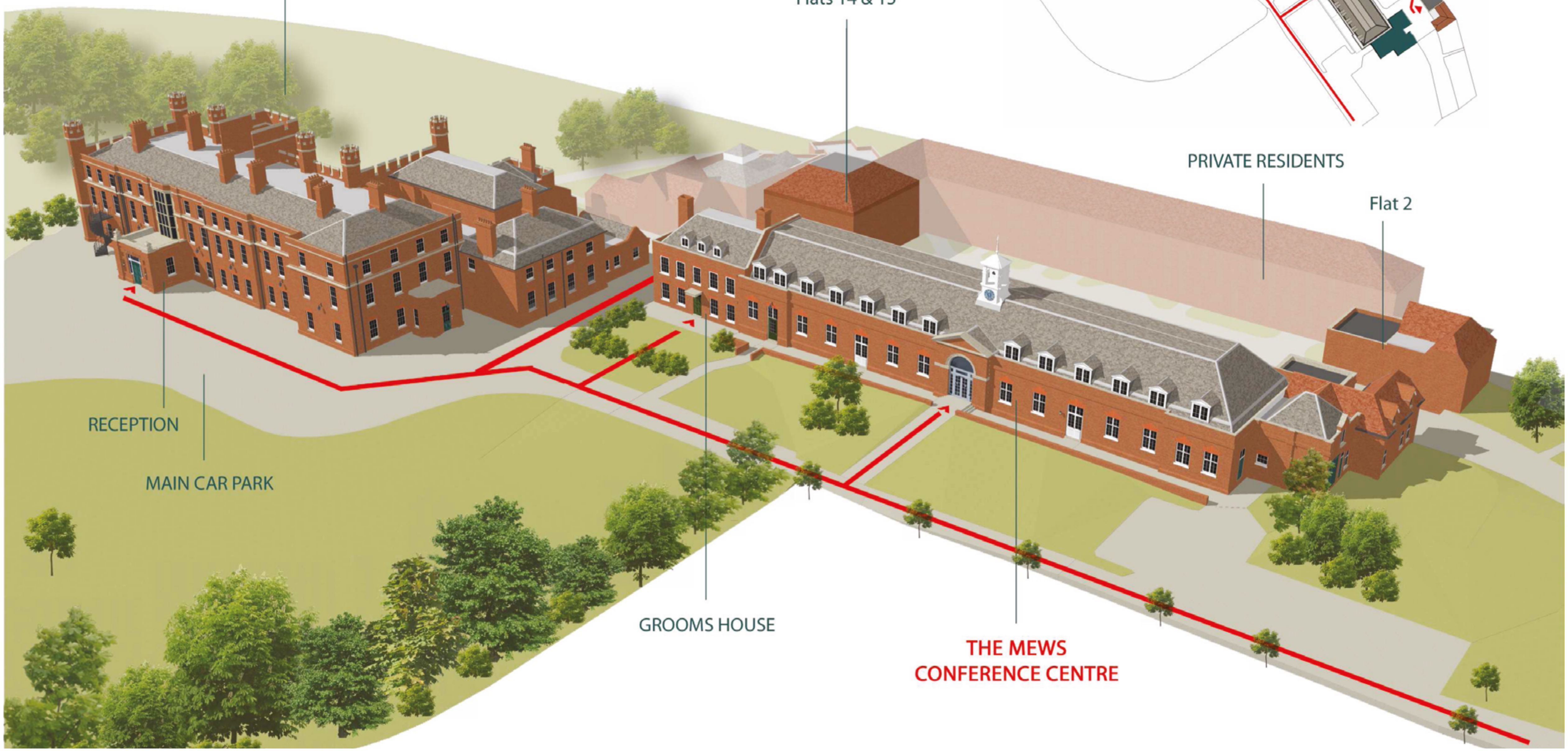
Recreational Facilities

Recreational facilities at the Lodge include a small gymnasium, tennis court, croquet, snooker, pool, table tennis and table football.We may also be able to provide a small number of bicycles, subject to availability. A wide variety of board games are available in the bar. There is an electronic organ in the Chapel and a grand piano in both the Drawing Room and Tapestry Hall.

Cumberland Lodge, The Great Park, Windsor SL4 2HP
www.cumberlandlodge.ac.uk
tel: 01784432316   fax: 01784497799

CUMBERLAND LODGE - *A House for Ideas*





In the past years the number of fields influenced by photonics and nanophotonics have increased steadily. And the boundaries between what is considered to be nanophotonics and what is not have become more and more fuzzy and difficult to define. Nowadays disciplines like biophotonics, plasmonics, bio-sensing, optical imaging, quantum nanophotonics etc. are deeply interconnected with each other. And the tendency is to go in the direction of increasing the interdisciplinarity of research. In this novel landscape a new generation of scientists is now emerging, carrying the necessity to rethink the traditional conference format, which are often showcases of career-long investigators. The Complex Nanophotonics Science Camp is meant to break with the conventional schemes to engage the creativity of early-stage scientists and create new scientific connections, fostering critical thinking.

A Camp for Young Minds

The main target of this Science Camp are junior scientists, post-docs and PhD students. In order to give them space to discuss and present their own work and ideas, we decided on a strict <10 from PhD rule for both invited and submitted contributions.

The Poster Session

The poster session is a very important part of the Science Camp. We think that a poster session is a magnificent occasion to discuss that must be exploited. In addition we will feature a "poster pitch" session. Everyone presenting a poster will be given the possibility to make a 60 seconds pitch, aimed at advertising the work and attract public to the poster. Clarity and conciseness will have to be staple of the pitches, that will have to be delivered without the aid of computer slides. The time constraint will be strictly enforced.

Support & Prizes

We thank EPSRC and ESF for their kind support that makes this Science Camp possible. In addition we acknowledge Nanophotonics for Energy Efficiency for providing travel grants and Philips for sponsoring the conference prizes.

A prize for the best poster will be awarded at the end of the Camp. Sponsored by Andor.

ANDOR
an Oxford Instruments company

Evening Debate

There will be a open debate on the second evening with:
Marian Maragkou (Nature Materials) & Etienne Castanié (Qivivo).

Having a conference aimed at young researchers does not mean to refuse any contact with the seniors. On the contrary, we believe that discussing with more experienced scientists can be extremely useful. Therefore we secured a small number of extremely high profile speakers to interact with the junior scientists. Keynote speakers will be:

00 **Allard Mosk**

Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente, Netherlands

SHAPED WAVEFRONTS AND SPECKLE CORRELATIONS: A WINDOW INTO OPAQUE MEDIA

00 **Hui Cao**

Yale University, USA

COHERENT CONTROL OF OPTICAL ABSORPTION

00 **Remi Carminati**

Langevin Institute, ESPCI, France

FLUORESCENT EMITTERS IN COMPLEX MEDIA: FROM SOURCE LOCATION TO CAVITY QED

00 **Benjamin Judkiewitz**

University of Berlin, Germany

CORRELATIONS IN ANISOTROPICALLY SCATTERING MEDIA

00 **Stefan Rotter**

Vienna University of Technology, Austria

THE CONCEPT OF TIME IN SCATTERING THROUGH COMPLEX MEDIA

00 **Marian Florescu**

University of Surrey, UK

HYPERUNIFORM DISORDERED PHOTONIC SOLIDS

00 **Thomas Wellens**

University of Freiburg, Germany

SCATTERING LASER LIGHT ON COLD ATOMS: MULTIPLE SCATTERING SIGNALS FROM SINGLE-ATOM RESPONSES

00 **Alexander Szameit**

University of Jena, Germany

INTEGRATED LASER-WRITTEN QUANTUM PHOTONICS

00 **Vincenzo Giannini**

Imperial College London, UK

QUANTUM PLASMONICS AND NON-LOCAL NANOPHOTONICS

00 **Laura Waller**

Berkeley University, USA

COMPUTATIONAL IMAGING FOR REAL-TIME GIGAPIXEL MICROSCOPY

00 **Silvia Vignolini**

Cambridge University, UK

CELLULOSE PHOTONICS: FROM NATURE TO APPLICATIONS

00 **Hugo Defienne**

Laboratoire Kastler Brossel, École Normale Supérieure, France

CONTROL OF MULTIPHOTON PROPAGATION IN A COMPLEX MULTIMODE SYSTEM

00 **Marco Leonetti**

Center for Life Nano Science@Sapienza, Istituto Italiano di Tecnologia, Italy

ADAPTIVE AND NONLINEAR OPTICS IN THE TRANSVERSE LOCALIZATION REGIME

00 **Bergin Gjonaj**

Technion – Israel Institute of Technology, Israel

SILICON MICROSCOPY VIA WAVEFRONT SHAPING

00 **Michele Celebrano**

Politecnico di Milano, Italy

MODE-MATCHING IN MULTIRESONANT PLASMONIC NANOANTENNAS FOR ENHANCED SECOND HARMONIC GENERATION

00 **Ion Hancu**

ICFO - The Institute of Photonic Sciences, Spain

CONTROLLING SECOND HARMONIC GENERATION WITH PLASMONIC NANOANTENNAS

00 **Hilton Barbosa de Aguiar**

Institut Fresnel, Marseille, France

SECOND-HARMONIC GENERATION IMAGING ENHANCEMENT THROUGH SCATTERING MEDIA VIA WAVEFRONT SHAPING

00 **Raktim Sarma**

Yale University, USA

CONTROL OF LIGHT TRANSPORT VIA NON-LOCAL WAVE INTERFERENCE EFFECTS IN RANDOM MEDIA

00 **Aude Martin**

Laboratoire de Photonique et de Nanostructures (UPR20–CNRS), France

PHASE SENSITIVE AMPLIFICATION ON CHIP: BEYOND THE LINEAR LIMIT

00 **Kevin Vynck**

LP2N, Institut d'Optique Graduate School – CNRS – Univ. Bordeaux, France

FORMATION AND PROPERTIES OF LOCALIZED MODES NEAR PHOTONIC BAND EDGES

00 **Francesco Riboli**

University of Trento, Italy

FREQUENCY CORRELATION SPECTROSCOPY OF THE LOCAL DENSITY OF STATES IN STRONGLY SCATTERING DISORDERED MEDIA

00 **Haider Butt**

University of Birmingham, UK

HOLOGRAPHIC FABRICATION OF NANOPHOTONIC DEVICES

00 **Niccolò Caselli**

LENS – Department of Physics, University of Florence, Italy

PHASE-SENSITIVE FANO IMAGING OF PHOTONIC LOCALIZED MODES

00 **Bas Goorden**

University of Twente, Netherlands

THE QUANTUM CREDIT CARD

00 **Sanli Faez**

Leiden University, Netherlands

ELECTROKINETIC ULTRAMICROSCOPY: PROBING CHEMICAL REACTIONS ON A SINGLE NANOPARTICLE

00 **Michele Gaio**

King's College London, UK

QUANTIFYING THE COUPLING OF A SINGLE EMITTER TO INDIVIDUAL MODES OF A NANO-FIBRE BY MOMENTUM SPECTROSCOPY

00 **Richard Bowman**

University of Cambridge, UK

NOTHING'S REFLECTION: PLASMONS, MIRRORS, AND MOLECULES

00

Ioannis Papadopoulos

Bioimaging and Neurophotonics Lab, Charite University Hospital Berlin, Germany

SUBMICRON RESOLUTION ENDOSCOPES USING MULTIMODE FIBERS

00

Filippo Alpeggiani

Department of Physics, University of Pavia, Italy

RADIATIVE PROPERTIES OF MULTISUBBAND PLASMONS IN SEMICONDUCTOR QUANTUM WELLS

00

Leo-Jay Black

University of Southampton, UK

TUNING THE LINEAR AND NON-LINEAR OPTICAL RESPONSE OF ORTHOGONAL DIMER PLASMONIC ANTENNAS FOR METASURFACES

00

Wonjun Choi

University of Exeter, UK

PREFERENTIAL COUPLING OF AN INCIDENT WAVE TO REFLECTION EIGENCHANNELS OF DISORDERED MEDIA

00

Peter Wiecha

CEMES CNRS – Toulouse, France

NONLINEAR MICROSCOPY ON SINGLE SILICON NANOWIRES USING SECOND HARMONIC GENERATION

00

Lorenzo Cortese

LENS European Laboratory for Non-Linear Spectroscopy, University of Florence, Italy

LESSONS FROM NATURE: HOW WHITE BEETLES OPTIMISE MULTIPLE SCATTERING OF LIGHT

00

Dmitry Khlopin

University of Technology of Troyes, France

LATTICE MODES FOR ALUMINUM PLASMONICS

00

James Dolan

University of Cambridge, UK

LIQUID CRYSTAL-INFILTRATED SELF-ASSEMBLED GYROID OPTICAL METAMATERIALS

00

Rebecca French

University of Southampton, UK

HYPERSPECTRAL IMAGING USING A COMPLEX MEDIUM

00

Rox Middleton

University of Cambridge, UK

PATTERNED CELLULOSE FOR OPTICAL METERIALS

00

Jamie Fitzgerald

Imperial College,London, UK

QUANTUM PLASMONICS

00

Thomas Chaigne

Langevin Institute, France

LIGHT CONTROL IN DEEP TISSUE VIA PHOTOACOUSTIC-GUIDED WAVEFRONT SHAPING

00

Mickael Mounaix

Laboratoire Kastler Brossel, École Normale Supérieure, France

SPATIO-TEMPORAL FOCUSING OF AN ULTRASHORT PULSE USING THE MULTI SPECTRAL TRANSMISSION MATRIX

00

Romolo, Savo

Laboratoire Kastler Brossel, École Normale Supérieure, France

AN INVARIANCE PROPERTY OF MULTIPLE LIGHT SCATTERING

00

Soraya Carlos Caixeiro

King's College London, UK

RANDOM LASING IN BIOCOMPATIBLE MATERIALS

00

Khunsin Worawut

Imperial College London, UK

QUANTITATIVE NEAR-FIELD ANALYSIS OF PLASMONIC FANO INTERFERENCES: THE EFFECT OF COUPLING STRENGTH, SPATIAL MODE PROFILE MATCHING, POLARIZATION AND ANGLE OF INCIDENCE ON BRIGHT-DARK MODE INTERACTION

00

Jin Lian

Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente, Netherlands

DISPERSION OF MODE-GAP CAVITIES

Posters

00

Sergei, Sokolov

Complex Photonic Systems, MESA+ Institute for Nanotechnology, Univeristy of Twente, Netherlands

LOCAL THERMAL CONTROL OF 2D GAINP PHOTONIC CRYSTAL CAVITIES IN DIFFERENT AMBIENT MEDIA

00

Hasan Yilmaz

Complex Photonic Systems, MESA+ Institute for Nanotechnology, Univeristy of Twente, Netherlands

SPECKLE CORRELATION RESOLUTION ENHANCEMENT OF WIDE-FIELD FLUORESCENCE IMAGING

00

Marta Castro-Lopez

King's College London, UK

RANDOM, PERIODIC AND HYPERUNIFORM NETWORKS

00

Oluwafemi S. Ojambati

Complex Photonic Systems, MESA+ Institute for Nanotechnology, Univeristy of Twente, Netherlands

SELECTIVE COUPLING OF OPTICAL ENERGY INTO THE FUNDAMENTAL DIFFUSION MODE OF A SCATTERING MEDIUM

Debate

00

Maria Maragkou

Nature Materials

Etienne Castanié

Qivivo

Special

00

Nadyalka Panova

Art Exhibition

SPEAKERS

Allard Mosk

Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente, Netherlands

SHAPED WAVEFRONTS AND SPECKLE CORRELATIONS: A WINDOW INTO OPAQUE MEDIA

Random scattering of light, which takes place in paper, paint and biological tissue is an obstacle to imaging and focusing of light and thus hampers many applications. At the same time scattering is a phenomenon of basic physical interest as it allows the study of interference effects such as Anderson localization, open transport channels and speckle correlations [1,2].

Propagation of laser light in scattering media can be controlled by shaping the incident wavefront using the massive number of degrees of freedom offered by digital spatial light modulators. Wavefront shaping methods in scattering media have given rise to a new wave of fundamental studies of light propagation as well as new modalities of imaging and focusing of scattered light. The resolution of this focusing can exceed that of conventional focusing optics.

Recently we demonstrated that speckle correlations enable non-invasive fluorescence imaging through strongly scattering layers, without the need of prior calibration. The same principles allow for high-resolution imaging through scattering lenses made of high-index materials, allowing wide-field speckle-illumination microscopy with a resolution approaching 110 nm [3].

Finally, non-imaging applications of wavefront-shaped scattered light are emerging in the context of lighting, cryptography and security [4].

[1] A. P. Mosk, A. Lagendijk, G. Lerosey, and M. Fink, Controlling waves in space and time for imaging and focusing in complex media, Nat. Photon., 6, 283-292, 2012.

[2] T. Strudley, D. Akbulut, W. L. Vos, A. Lagendijk, A. P. Mosk, and O. L. Muskens, Observation of intensity statistics of light transmitted through 3D random media, Opt. Lett. 39, 6347-6350 (2014).

[3] H. Yılmaz, E. G. van Putten, J. Bertolotti, A. Lagendijk, W. L. Vos, and A. P. Mosk, Exploiting speckle correlations to improve the resolution of wide-field fluorescence microscopy, Optica, in press (2015).

[4] S. A. Goorden, M. Horstmann, A. P. Mosk, B. Škorić, and P. W. H. Pinkse, Quantum-secure authentication of a physical unclonable key, Optica 1, 421-424 (2014).

Hui Cao

Yale University, USA

COHERENT CONTROL OF OPTICAL ABSORPTION

Optical absorption is commonly considered an intrinsic property of a medium, independent of the details of the illumination source. However, for spatially coherent illumination of a disordered medium, interference effects play a major role and it is now understood

that the dwell time of light and its spatial distribution depend sensitively on the the incident wavefront, allowing coherent control of absorption. Consequently, in an absorbing random medium, global or local absorption can be tuned by modifying an input beam's spatial characteristics.

I will review our recent experimental and theoretical studies on the coherent control of light absorption in complex media, and discuss potential applications.

Remi Carminati

Langevin Institute, ESPCI, France

FLUORESCENT EMITTERS IN COMPLEX MEDIA: FROM SOURCE LOCATION TO CAVITY QED

Light-matter interaction in disordered materials is at the centre of current issues in photonics: The detection of fluorescent molecules in complex media (such as biological tissues), the design of amorphous materials to enhance light emission or absorption, the use of light localization induced by disorder to explore cavity-QED regimes, to cite just a few. In this talk we will illustrate the fruitful marriage of spontaneous emission and multiple scattering. We will describe the emission from one or two classical nanosources [1,2] or single-photon sources [3] in disordered dielectrics, and connect the fluctuations and correlations in the emitted intensity to the local and cross density of states in the medium [4]. We will discuss the implications for sensing in complex media. We will also describe the transition to the strong coupling regime with Anderson localized modes [5,6]. Changes in the spontaneous emission dynamics provide an efficient way of probing photonic modes in complex media "from the inside". Conversely, disordered media offer a large number of degrees of freedom to control light-matter interaction.

[1] A. Dogariu and R. Carminati, Phys. Rep. 559, 1 (2015).

[2] R. Carminati, G. Cwilich, L.S. Froufe-Pérez and J.J. Saenz, Phys. Rev. A 91, 023807 (2015).

[3] A. Canaguier-Durand and R. Carminati, in preparation (2015).

[4] A. Cazé, R. Pierrat and R. Carminati, Phys. Rev. Lett. 110, 063903 (2013).

[5] A. Cazé, R. Pierrat and R. Carminati, Phys. Rev. Lett. 111, 053901 (2013).

[6] N. Bachelard, R. Carminati, P. Sebbah and C. Vanneste, Phys. Rev. A 91, 043810 (2015).

Hugo Defienne

Laboratoire Kastler Brossel, École Normale Supérieure, France

CONTROL OF MULTIPHOTON PROPAGATION IN A COMPLEX MULTIMODE SYSTEM

Taking advantages of the quantum nature of light, quantum walk of photons is considered as a very powerful model for quantum information science, and integrated photonic devices have proven a versatile architecture for their implementation. Demonstrations range from walks with entangled photons, to analogues of Anderson localization in condensed matter, to the implementation of boson sampling problem with multi-photon state.

While waveguide structures allow only near-neighbor coupling between up to a few tens of modes, complex linear systems, such as white paint layer or multimode fiber, permit to couple efficiently a huge numbers of optical modes. Unstable and lossy, these systems have always been considered unpractical for quantum optics experiments. Wavefront shaping methods, developed in the last decade to control light propagating in complex media, permit to move beyond these limitations and make them exploitable with non-classical light [2].

In this work, we use a multimode fiber as a coherent multimode optical platform to implement multi-photon quantum walk. Propagation of indistinguishable pair of photons through a linear system can be fully predicted using the knowledge of its scattering matrix. Using wavefront shaping techniques, we show that this matrix can also be used to manipulate the propagation of a two-photon state of light. We report the observation of a two-photon speckle pattern and we demonstrate the focusing of a two-photon state of light in a selected output mode of the fiber. We also characterize the role played by non-classical interferences in the focusing process.

In this experiment, we have generalized wavefront shaping method to the control of non-classical light in complex media. The capability to manipulate photons performing quantum walks paves the way of building a controllable multimode optical system opening a number of potential routes to implement quantum information processing.

[1] Mosk, A. P., Lagendijk, A., Lerosey, G. & Fink, M. Controlling waves in space and time for imaging and focusing in complex media. Nat Photon 6, 283–292 (2012).

[2] Defienne, H. et al. Nonclassical light manipulation in a multiple-scattering medium. Opt. Lett. 39, 6090–6093 (2014).

Marco Leonetti

Center for Life Nano Science@Sapienza,
Istituto Italiano di Tecnologia, Italy

ADAPTIVE AND NONLINEAR OPTICS IN THE TRANSVERSE LOCALIZATION REGIME

Transverse Anderson localization is the trapping of waves due a disordered potential which is invariant along propagation direction, cancelling the effects of diffraction.

If disorder induces exponential localizations and reduces the interactions of distant modes, nonlocality (i.e., a nonlinear perturbation that extends far beyond the region of interaction) is expected to create some action at a distance dependent on power. We demonstrate the effects of nonlinearity in disordered optical fibers supporting Anderson Localization. We notice two different striking phenomena: disorder induced self focusing and mode migration. In a nutshell exploiting nonlinearity and nonlocality it is possible to control light modes by tuning intensity in distant control beams that modify the refractive index landscape.

Moreover we performed adaptive focusing experiments in disordered optical fibers in the transverse Anderson localization regime. By wavefront shaping and optimization, we observe the generation of a propagation-invariant beam, where light is trapped transversally by disorder, and show that localized states can be excited by extended speckled beams. We demonstrate that disordered fibers allow a more efficient focusing action with respect to standard fibers. This enhancement isto the cooperative action of adaptive focusing with localization, which forbids light paths far from the target.

Bergin Gjonaj

Technion - Israel Institute of Technology, Israel

SILICON MICROSCOPY VIA WAVEFRONT SHAPING

Planar Silicon waveguides provide up to 4 times wavelength compression, yielding a diffraction limited focus of nearly 50 nm for visible light, and therefore microscopy at this resolution. Near-field characterization of 100-200 nm thick polysilicon membranes for red light (671 nm) shows:

-1 wavelength compression down to 187 nm, -2 super-focusing down to 50 nm, -3 superoscillations. As compared to plasmonic platforms, polycrystalline Silicon provides an improved figure of merit for both, the wavelength and the propagation length.

Using wavefront shaping to focus and scan the short wavelength modes supported by Silicon, we demonstarte a robust far-field microscopy at 50 nm resolution.

Benjamin Judkiewitz

University of Berlin, Germany

CORRELATIONS IN ANISOTROPICALLY SCATTERING MEDIA

Controlling light propagation across scattering media by wavefront shaping holds great promise for a wide range of communications and imaging applications. However, finding the right shape for the wavefront is a challenge when the mapping between input and output scattered wavefronts (i.e. the transmission matrix) is not known. Correlations in transmission matrices, especially the so-called memory-effect, have been exploited to address this limitation. However, the traditional memory-effect applies to thin scattering layers at a distance from the target, which precludes its use within thick scattering media, such as fog and biological tissue. In my talk I will present a theoretical prediction and experimental verification of new transmission matrix correlations within thick anisotropically scattering media, with potential implications for biomedical imaging and adaptive optics.

Michele, Celebrano

Politecnico di Milano, Italy

MODE-MATCHING IN MULTIRESONANT PLASMONIC NANOANTENNAS FOR ENHANCED SECOND HARMONIC GENERATION

Second Harmonic Generation (SHG) is well known to be a powerful tool for background-free and non-damaging living tissue imaging. To obtain brighter nanoscale nonlinear probes, field enhancements in plasmonic nanostructures are often exploited to effectively compensate for the lack of phase-matching in confined volumes. However, the high degree of symmetry in the crystalline structure of plasmonic materials (i.e. metals) and in nanoantenna designs have so far limited SHG efficiency. Here we report on especially engineered gold single-crystalline nanoantennas working in the near-infrared that show unprecedented SHG efficiency thanks to: a multi-resonant response occurring at both the excitation and SH wavelength, a significant spatial overlap of the localized fields at the wavelengths of interest and a broken-symmetry geometry to achieve dipole-allowed SHG. The effective combination of these key features in a single plasmonic antenna, characterized by the absence of local defects, allows optimizing SHG efficiency in a well-controlled fashion.

Once the antenna geometry is properly tuned to display a double resonance matching simultaneously the laser excitation (1560 nm) and the SHG wavelength, it demonstrates a SHG nonlinear coefficient γ_SHG = (P^_SH)/((P^_FW)^2)≈ 5×10^-10, where P^_SH and P^_FW are the SH and excitation peak powers, respectively. This figure of merit is well above the ones reported in other SHG studies on broken-symmetry plasmonic structures [1] and allows achieving an extremely high conversion efficiency η_SHG ~ 6.4×10^-9 [2].

These results shed new light on the optimization of nanoscale SHG via metal nanoantennas, paving the way to a new class of tunable molecular sensing devices and nanoscale coherent light sources based on nonlinear plasmonic platforms.

[1] Y. Zhang et al., Nano Lett. 11, 5519–5523 (2011).

[2] M. Celebrano et al., Arxiv, arXiv:1412.0698.

Ion M., Hancu

ICFO – The Institute of Photonic Sciences, Spain

CONTROLLING SECOND HARMONIC GENERATION WITH PLASMONIC NANOANTENNAS

Optical antennas enhance light-matter interaction due to their ability to confine electromagnetic fields within nanometric volumes, which may be crucial in future nanophotonic devices. The interference of coexisting multipole moments in a plasmonic structure has been used to direct the emission of quantum dots. However, such configurations are still limited by the fact that we cannot, for example, actively control the emission direction as the phases between different multipoles are predefined by the emitter/antenna geometry. Considering that a femtosecond timescale is needed, we use the second harmonic generation (SHG) directly from plasmonic structures to gain control of the phase of the radiated fields.

To our knowledge the SHG emission pattern of a single nanostructure has yet to be measured, likely due to low signals. To obtain enough signal, we focus 20 fs pulses from a Ti:Sapphire laser to a diffraction-limited spot using a high-NA oil-immersion objective and image the SHG from single nanostructures at the objective's back focal plane. Thus we directly measure the momentum space and characterize the angular distribution of the SHG.

Hilton Barbosa de Aguiar

Institut Fresnel, Marseille, France

SECOND-HARMONIC GENERATION IMAGING ENHANCEMENT THROUGH SCATTERING MEDIA VIA WAVEFRONT SHAPING

Wavefront shaping (WS) is an emerging field which has lead recently to the possibility of reestablishing a “focus” after a strongly scattering medium. These refocusing capabilities are achieved by coherently controlling the spatial degrees of freedom of light with spatial light modulators using various algorithms. On the other hand, nonlinear microscopy (NLM) is a powerful technique for biological imaging in a label-free manner, however, only able to image at shallow depths further hindered by scattering phenomena. Here, we combine WS experiments with NLM for the enhancement of second-harmonic generation of nanosources (nanocrystals of potassium titanyl phosphate) positioned behind a scattering medium. We exploit different feedback regimes (linear and nonlinear) and evaluate the experimental parameters most relevant for nonlinear contrast enhancement. We demonstrate signal enhancements in the order of 1000s by simply controlling the wavefront spatial degrees of freedom (256 independent ones). Surprisingly, the polarization state of the focus after a few scattering mean free path deep is highly polarized. This allows polarization-resolved imaging and analysis of the nanosources polarized response without the need of multiple runs of the refocusing algorithm, considerably reducing the speed for attaining the focus. These results show that the combination of WS and NLM will enable label-free imaging at unprecedented depth in biological media.

Stefan Rotter

Vienna University of Technology, Austria

THE CONCEPT OF TIME IN SCATTERING THROUGH COMPLEX MEDIA

In my talk I will first review what it means to measure time in a scattering experiment where waves propagate through disordered or otherwise complex media. Based on the concept of the scattering time-delay, I will then present a number of recent insights with very practical relevance for the recently emerging field of wave front shaping. In a first step, I will show that the average time waves spend inside a disordered medium is invariant with respect to the mean free path of this medium - a result that holds in the ballistic, diffusive and in the Anderson localised regime [1]. This invariance property is particularly counter-intuitive when considering that many other properties of the medium do depend on the mean free path (like the transmission and reflection of the medium and the times associated with each of these quantities). In a second step, I will take a closer look at those scattering states to which a well-defined scattering time can be associated. These “time-delay eigenstates” have the unique feature of having speckle patterns at the output facet of the medium, which are invariant with respect to a small frequency change [2]. Due to this fundamental property, these states have been termed “principal modes” in the domain of multi-mode fiber optics [2], where one tries to exploit the states’ robustness for efficient information transfer. At the same time the principal modes share an interesting connection to the geometric optics states in a scattering process that feature a particle-like bouncing pattern and a much broader frequency stability [3]. I will discuss these connections in detail and will report on recent progress in this field, both from a theoretical and from an experimental perspective.

[1] R. Pierrat, P. Ambichl, S. Gigan, A. Haber, R. Carminati, and S. Rotter, Invariance property of wave scattering through disordered media, PNAS - Proc. Natl. Acad. Sci. U.S.A. 111, 17765 (2014).

[2] S. Fan and J. Kahn, Principal modes in multimode waveguides, Optics letters 30, 135 (2005).

[3] S. Rotter, P. Ambichl, and F. Libisch, Generating particle-like scattering states in wave transport, Phys. Rev. Lett. 106, 120602 (2011).

Marian Florescu

University of Surrey, UK

Invited

HYPERUNIFORM DISORDERED PHOTONIC SOLIDS

Due to their ability to control the most fundamental properties of light, photonic band gap materials have opened a new frontier in both science and technology. Until recently, the only materials known to have complete photonic band gaps were photonic crystals, periodic structures. In this talk, I will show that there exists a more general class of systems, called hyperuniform photonic structures, which exhibit large and complete photonic band gaps. This classification includes not only crystalline structures, but also non-crystalline materials, ranging from isotropic, translationally-disordered structures to quasicrystals with crystallographically-forbidden rotational symmetries. Both periodic and aperiodic photonic band gap structures can be systematically generated through a universal tessellation protocol. I will show that the non-crystalline photonic band systems display distinctive optical and structural properties, and I will introduce the first hyperuniform disordered structures ever fabricated. The newly discovered photonic materials are expected to facilitate unprecedented capabilities for controlling light, with great impact for quantum information processing, solar energy conversion, sensing, and lighting applications. I will introduce the first applications of hyperuniform disordered materials to integrated photonic circuitry. I will also argue that the discovery of non-crystallographic photonic band gap materials has fundamental implications for biophotonic, electronic and phononic systems as well.

Raktim, Sarma

Yale University, USA

CONTROL OF LIGHT TRANSPORT VIA NON-LOCAL WAVE INTERFERENCE EFFECTS IN RANDOM MEDIA

The concept of diffusion is widely used to study the propagation of light through multiple scattering media such as clouds, colloidal solutions, paint, and biological tissues. Diffusion, however, is an approximation as it neglects wave interference effects. Most of the scattered waves follow independent paths and have uncorrelated phases, so their interference is averaged out. Notwithstanding, a wave may return to a position it has previously visited after multiple scattering events, and there always exists the time-reversed path which yields identical phase delay. Contributions due to constructive interference between these pairs of paths to transport coefficients, in particular second order quantities such as correlations, do not average out to zero. We describe a novel scheme of manipulating light transport in random media via coherent effects. Changing the waveguide geometry allows us to control the crossing probability of scattering paths as a function of position. We illustrate our approach with several experiments demonstrating how the spatial dependence of the average intensity as well as the long-range correlations can be effectively modified. We also present a detail analysis of the modification of the transmission channels and their spatial profiles due to change in geometry.

This work opens the possibility of using geometry to control non-local effects in mesoscopic transport without changing structural disorder. In addition to the fundamental importance, understanding and manipulating the spatial dependence of average intensity and correlations of light inside the random system is useful for imaging and focusing of light in multiply scattering media using wavefront shaping techniques. The degree of such coherent control is limited by the number of modes that can be controlled. Our results suggest that the overall geometry can provide an additional degree of freedom and can be used along with wavefront shaping techniques to more efficiently control the light transport through random media.

Aude Martin

Laboratoire de Photonique et de Nanostructures (UPR20- CNRS), France

PHASE SENSITIVE AMPLIFICATION ON CHIP: BEYOND THE LINEAR LIMIT

Phase sensitive amplification (PSA) is a key function towards all optical signal processing since it can selectively process the two complex quadratures of the optical field used to encode information. Moreover it enables signal regeneration with very low noise. Based on parametric processes in chi(3) media, PSA is a consequence of Four Wave Mixing (FWM) when all four involved waves are injected at the input. Analytic theory predicts the amplitude gain to be sinusoidal on the input relative phase $\Delta\Phi=\phi_1+\phi_2-\phi_3-\phi_4$. It is hence possible to tune the amplification of the signal by changing the input phase. PSA was first demonstrated in highly non linear fibers (HLNF) and there has been lately numerous demonstration in nanowaveguides. Particularly, Silicon photonic crystal waveguides have demonstrated their potential for compact PSA.

I experimentally explore the behaviour of PSA in the limit of high power levels, where single analytic theory might no longer hold. In this regime, Gallium Indium Phosphide (GaInP) slow light waveguides exhibit less nonlinear losses.

We developed an accurate measurement technique enabling a precise estimation of the extinction ratio, i.e. the maximum over the minimum of amplification, as a function of the phase. In the linearized limit (moderate power), the agreement with the expectation of a sinusoidal dependance is very good. We prove over 10 dB of extinction ratio with a coupled input peak power of 0.8W. Under certain circumstances, as power increases, we observe a clear deviation from the theory which we explain using generalized Schroedinger equation.

Kevin Vynck

LP2N, Institut d'Optique Graduate School – CNRS – Univ. Bordeaux, France

FORMATION AND PROPERTIES OF LOCALIZED MODES NEAR PHOTONIC BAND EDGES

Random imperfections can have a profound impact on light propagation in periodic media, the most striking phenomenon being undoubtedly the formation of localized modes near photonic band edges. It is widely accepted that Anderson localization is enhanced with decreasing group velocity when approaching the band edge and that tiny perturbations are sufficient to create defect modes forming the decaying Lifshitz tail in the band gap. The ensemble-averaged quantities generally used to describe these behaviors (localization length, density of states), however, only provide limited information about individual localized modes. To date, a comprehensive description of how localized modes near band edges are formed and how their spatial extent relates to the band diagram of the periodic medium and to the disorder level is still missing.

In this work, we investigate the formation and properties of individual localized modes in 1D randomly-perturbed optical periodic media near the band edge. We show that localization in this regime relies on an intricate interplay between multiple scattering of propagating waves and evanescent damping due to the band gap, and argue that the quantity impacting the spatial extent of localized modes is the effective photon mass (i.e. the second-derivative of the dispersion curve) rather than the group index, as commonly believed. A scaling law, which suggests that periodic media exhibiting flatter dispersion curves can form small localized modes more easily at low disorder levels, is proposed and validated by statistical numerical calculations on various structures. The practical importance of this concept is illustrated by demonstrating via near-field measurements that standard W1 photonic-crystal waveguides, supporting heavy photons and fabricated without any intentional disorder (below l/1000), naturally form localized modes with volumes comparable to those achieved in engineered nanocavities.

Thomas Wellens

University of Freiburg, Germany

SCATTERING LASER LIGHT ON COLD ATOMS: MULTIPLE SCATTERING SIGNALS FROM SINGLE-ATOM RESPONSES

The theory of multiple scattering in dilute media that consist of a disordered collection of discrete scatterers relies on the division of the total scattering process into single scattering events. In standard multiple scattering theory, these are assumed to be linear (scattered field proportional to incident field). For atomic scatterers with transition frequency close to the laser frequency, however, nonlinear multi-photon scattering processes are induced at high laser intensities. To account for the impact of these processes on the multiple scattering signal, we present an approach which combines tools of diagrammatic multiple scattering theory (ladder and crossed diagrams) with quantum-optical methods (optical Bloch equations). This approach allows us to evaluate how quantum-mechanical scattering processes influence, both, diffusive propagation of the average light intensity through a dilute cloud of cold atoms (with distances between the atoms much larger than the laser wavelength), as well as effects of coherent light propagation such as coherent backscattering.

Alexander Szameit

University of Jena, Germany

INTEGRATED LASER-WRITTEN QUANTUM PHOTONICS

Integrated photonic devices currently attract highest interest, since they exhibit numerous advantages regarding stability, robustness, and miniaturization. We will report on our most recent results in the field of integrated quantum photonics, demonstrating the high potential of this technological approach.

In our presentation, we discuss the possibility of realizing on-chip wave plates, which are required for the implementation of various quantum gates, such as Hadamard- and Pauli-X-gates. Moreover, we show how high-order W-states can be efficiently produced on chip and demonstrate their application in the generation of genuine random numbers. Finally, we present the first implementation of a discrete fractional Fourier transform of quantum states, which promises to be a powerful tool in various fields, such as quantum mathematics, quantum physics, quantum biology and quantum chemistry.

Francesco, Riboli

University of Trento, Italy

FREQUENCY CORRELATION SPECTROSCOPY OF THE LOCAL DENSITY OF STATES IN STRONGLY SCATTERING DISORDERED MEDIA

We present experimental results about frequency correlation spectroscopy of the local density of states (LDOS) of disordered optical modes in strongly scattering two-dimensional disordered systems. The samples under consideration are 320 nm-thick GaAs planar dielectric waveguides, optically activated by the inclusion of three layers of InAs quantum dots buried in the middle plane of the slab and emitting in a broad range of wavelengths, from 1.15 um to 1.38um. The activated planar waveguide is patterned with disordered distributions of circular holes acting as scattering centers. By varying the structural parameters (density and size of the scattering centers), we are able to cover a wide range of kltr (where k=(2pi/ltr)*n is the wavevector and ltr is the transport mean free path), from kltr =4 to kltr = 22. The corresponding localization lengths range from x = 1um to x = 4um. For each sample we measure the frequency Autocorrelation matrix (Acm), the frequency Autocorrelation function (Acf) and the Spectral form factor (Sff), defined as the Fourier transform (in the time domain) of the Acf of the LDOS. The analysis of the Acm and the Acf shows features at short range and long range in the frequency domain that can be related to (i) the average peak width of localized modes, (ii) the coupling between spatially and spectrally overlapping localized modes and (iii) the near field interaction between the integrated quantum sources and the scattering centers. This last contribution is not universal and depends on the microscopic detail of the measured sample. The same analysis is performed in the time domain by analyzing the Sff from which it is possible to extract parameters like the ballistic time, the diffusion time and the Heisenberg time of the photons emitted by the integrated quantum sources.

Haider Butt

University of Birmingham, UK

HOLOGRAPHIC FABRICATION OF NANOPHOTONIC DEVICES

Holography plays a significant role in applications such as data storage, optical information reconstruction, light trapping, security, and biosensors. However, conventional fabrication methods are time-consuming, costly, and require tedious procedures, limiting the extensive use and fabrication of holograms. Here, we demonstrate an one-step single-pulse laser ablation technique to write surface gratings, Fresnel zone plates and holograms. We utilized a 6 ns high-energy green laser pulse to form interference ablation patterns with around 820 nm periodicity on 4 nm gold coated substrates. The image recording is completed within 30 s. The optical characteristics of the interference patterns have been computationally modelled, and well-ordered polychromatic diffraction was observed from the fabricated holograms. Spectroscopy experiment results for Fresnel zone plate sample showed a significant diffraction angle of 32° from the normal incident direction for the focal point. This zone plate-like hologram functions as a gate to achieve high contrast imaging and angular diffraction. The nanosecond laser interference ablation strategy for rapid hologram fabrication holds potential in a vast range of optical applications.

Niccolò Caselli

LENS - Department of Physics, University of Florence, Italy

PHASE-SENSITIVE FANO IMAGING OF PHOTONIC LOCALIZED MODES

A detailed knowledge of the local density of optical states (LDOS) at the nanoscale is crucial for photonic and plasmonic applications that involve localized modes. However, a pure optical method that can be applied on any kind of nano-resonators to access the frequency as well as the spatial and polarization components of the confined electric fields is actually missing. In our work, we implement a resonant scattering setup on a scanning near-field optical microscope. This scheme allows us to perform hyperspectral imaging of the modes localized in photonic crystal nanocavities and in micro-rings, without the need of internal light sources and independently on the material they are made of. Therefore, this technique can be implemented on silicon, glass, polymer or metal based nanoresonators. The collected spectra exhibit strongly asymmetric Fano resonances, which emerge from the interference between a resonant and a non-resonant signal. This novel imaging method exploits the spectral analysis of Fano resonances. In particular, the Fano lineshapes modifications are proven to depend on the position of the SNOM probe with respect to the sample surface. This allows us to retrieve unprecedented insight both on the electric-LDOS and on the phase spatial modulation of the confined electric fields. In fact, Fano imaging intrinsically includes a near-field integrated interferometer for a direct phase retrieval of the investigated polarization components, without the need of external heterodyne detection. Hence, we achieve a substantial advance in mapping localized optical states with a deep sub-wavelength spatial resolution, down to lambda/19.

Vincenzo Giannini

Imperial College London, UK

QUANTUM PLASMONICS AND NON-LOCAL NANOPHOTONICS

The impressive recent advances in nanofabrication has made possible the observation of quantum effects in small metal nanostructures. In this case, plasmon excitations have a fundamental role, and that is still not completely clear. The main issue resides in the quite hard and numerically expensive many-body problem for a large number of atoms contained in a metal nanoparticle. In addition, are almost lacking analytical formulations.

We will show our recent research on the transition between classical and quantum regime in systems such as metal nanoparticles interacting with light when the excitation of localized plasmons plays an important role.

Laura Waller

Berkeley University, USA

COMPUTATIONAL IMAGING FOR REAL-TIME GIGAPIXEL MICROSCOPY

This talk will describe new methods for achieving high-resolution 3D images in a commercial microscope, by computational approaches. We describe two setups employing illumination-side and detection-side aperture coding of angle (Fourier) space for capturing 4D phase-space (e.g. light field) datasets with fast acquisition times. Using a multi-slice forward model, we develop efficient 3D reconstruction algorithms with robustness to scattering. Experimentally, we achieve real-time 3D and phase imaging with digital aberration correction and mitigation of scattering effects. The result is a high-resolution gigapixel image in multiple depth planes with fast capture times. Such computational approaches to optical microscopy add significant new capabilities to commercial microscopes without significant hardware modification.

Bas Goorden

University of Twente, Netherlands

THE QUANTUM CREDIT CARD

Leakage of authentication information due to e.g. skimming, phishing, software bugs and hacking of databases is a major security risk. It leads to money theft, identity theft, unauthorized access and other undesirable situations. Stolen authentication information typically allows one or both of the two main ways to attack authentication procedures: either copying the key or emulating the behavior of the key using digital devices. The usual way to make attacks more difficult is to more carefully hide the authentication information contained in the key. This typically fails when attackers increase their efforts. We take a fundamentally different approach. We demonstrate Quantum-Secure Authentication (QSA) of a physically unclonable key [1], which is secure even when all information about the key is publicly known.

The key is formed by a multiple scattering medium, which transforms incident “challenge” wavefronts into “response” wavefronts. Authentication of the key is performed by sending challenges that contain fewer photons than spatial degrees of freedom. The shape of a response wavefront depends strongly on the positions of the scatterers as well as on the shape of the challenge, so the key can be authenticated by verifying that the responses to a set of challenges are correct. Copying the multiple scattering key is impossible due to the limits of modern and foreseeable technology [2]. Digital emulation is impossible, because even if the attacker knows everything about the key he must also be able to characterize the challenge. Since we use a very small number of photons, this is not possible by virtue of quantum-physical principles. Moreover, QSA does not rely on unproven mathematical assumptions and is relatively straightforward to implement. We believe it is the most secure object authentication method currently available.

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Sanli, Faez

Leiden University, Netherlands

ELECTROKINETIC ULTRAMICROSCOPY: PROBING CHEMICAL REACTIONS ON A SINGLE NANOPARTICLE

More than 100 years ago the ultramicroscope was developed by Richard Zsigmondy and Henry Siedentopf to study tiny microparticles based on light scattering. Zsigmondy was awarded the Nobel Prize in Chemistry (1925) for his research on colloids and the ultramicroscope. Although this technique was used to *detect* particles as small as 4 nm a century ago, conventional ultramicroscopy and even its advanced counterparts are ineffective in *tracking* small nanoparticles to this date. Tracking the motion of single nanoparticles is a gateway to understanding physical, chemical, and biological processes at the nanoscale. For example, by rapidly monitoring the charge (or the electrophoretic mobility) of a single solute, one will be able to study kinetic interactions such as ionization, hydrolysis, or charge transfer at the single particle level. In such an experiment, one can directly visualize the intermediate steps of a reaction, which is often untraceable in bulk experiments due to the sheer magnitude of the Avogadro's number.

I present a new experimental platform that enables tracking of free, unlabeled nanoparticles and macromolecules over a wide range of time-scales, from microseconds to hours. The key element of this technique is a single-mode opto-fluidic fiber, in which the high-index core contains an open nanometric channel that runs along the entire fiber axis. I report experimental detection of faint scattering and fast thermal diffusion of single dielectric particles as small as 10 nm and single unlabeled viruses with a mere scattering cross-section of 0.1 square-angstrom (0.05 times the absorption cross-section of a single R6G molecule) at a frame rate of more than 2 kHz. I present an

optimized design for MHz-rate monitoring of the single nanoparticle mobility, based on this platform, with a single quadrant photodiode. I dub this technique electrokinetic ultramicroscopy.

Michele, Gaio

Department of Physics, King's College London, UK

QUANTIFYING THE COUPLING OF A SINGLE EMITTER TO INDIVIDUAL MODES OF A NANO-FIBRE BY MOMENTUM SPECTROSCOPY

Efficient coupling of light from a single emitter into the guided modes of a waveguide is a key step towards the realisation of networks at the single photon level as it would provide the basic building block for long range transport of light and enhanced interaction with other coupled emitters. Various schemes have been proposed but they often rely on complicated fabrication techniques or working condition, hindering their application to complex extended geometries.

We present here a detailed experimental study of coupling of single emitters to polymer nano-fibres fabricated by electrospinning of a PMMA solution with quantum dots dissolved prior to fabrication. Cylindrical step-index subwavelength fibres with isolated quantum dots embedded into the nano-fibre core were obtained. We demonstrate an efficient coupling and transport of single photons into freestanding fibres with a diameter in the range 200 to 1000 nm. We measure coupling to individual guided modes via momentum spectroscopy and obtain a maximum coupling to the fundamental mode up to β_{01}=31%, in good agreement with theoretical calculations. These nano-fibres are a robust, flexible and inexpensive tool for the fabrication of interconnected optical networks, providing large room-temperature broadband coupling of single emitters to the fibre modes in a platform suitable for the design of complex topologies.

Richard Bowman

University of Cambridge, UK

NOTHING'S REFLECTION: PLASMONS, MIRRORS, AND MOLECULES

Noble metals can structure light on the nanometre scale thanks to their ability to support plasma oscillations (plasmons) at optical frequencies in their conduction electrons. The plasmon resonance of a gold nanoparticle is already sufficient to create optical 'hot spots' that can significantly enhance Raman scattering. Orders of magnitude more Raman enhancement can be obtained by using two such particles, but assembling a dimer around the molecule of interest is prohibitively difficult.

The problem of assembling dimers can be neatly sidestepped by placing a single nanoparticle on a mirror, as the electric field resembles very strongly that from a dimer, and depositing a surface layer of analyte molecules gives us a simple way to place them directly in the gap. This provides a ready method to work with single-layered materials in the gap, for example Van der Waals semiconductors or surface assembled monolayers.

A major issue with using nanoparticle-based systems as probes is repeatability between particles; ideally one should take many measurements of different particles before drawing conclusions. We have developed an automated system to do this, capable of taking hundreds or more of spectra unattended, over a period of hours. This has enabled us to measure statistical properties of the distribution of nano-assemblies and the nano-scale optical fields.

One recent trend in lab automation is the advent of affordable 3D printing, and we have used this technology to construct mechanical parts of sufficient quality to be useful for high-magnification microscopy. This emerging technology may well change the way laboratory science is done, and I will outline some principles and examples from our group.

Ioannis Papadopoulos

*Bioimaging and Neurophotonics Lab,
Charite University Hospital Berlin, Germany*

SUBMICRON RESOLUTION ENDOSCOPES USING MULTIMODE FIBERS

We demonstrate how under the appropriate dynamic control of light propagation, multimode fibers can be transformed into deterministic optical elements that along with their ultra- thin size, large number of degrees of freedom and high Numerical Aperture, can be used as a new platform to fabricate miniature optical elements with applications in minimally invasive endoscopy, phototherapy and photoexcitation deep inside biological tissue.

Firstly we use Digital Phase Conjugation, in order to focus light into a diffraction limited spot at the output of a multimode fiber. The handling of the data in the digital domain, allows us to dynamically raster scan the focused spot across the whole fiber facet thus enabling the use of the system in scanning fluorescent imaging. We demonstrate a rigid ultrathin high-resolution endoscopic modality and perform fluorescence imaging of stained neuronal cells. The high quality of the obtained images allows the use of the system as a minimally invasive endoscope for cellular diagnosis via direct tissue penetration. Moreover, we extend the capabilities of the demonstrated device by performing imaging based on the optical absorption properties of samples via the photoacoustic effect. The use of a multimode fiber as the optical excitation part can enable the generation of new photoacoustic endoscopic modalities that can deliver optical resolution images deeper than the ballistic range of light propagation in tissue.

Overall, the presented results verify that the ultra-thin diameter of multimode fibers, in conjunction with the dynamic control of light transmission through them, allow us to envision multimode fibers as a new family of miniature versatile optical elements with multiple applications in biomedical optics and nanophotonics.

Silvia Vignolini

Cambridge University, UK

CELLULOSE PHOTONICS: FROM NATURE TO APPLICATIONS

Nature's most vivid colours are produced when light repeatedly scatters against periodically organized interfaces within nanostructured materials. This brilliant iridescent colouration is frequently used in many insect and animals but also in different species of plants.

One of the most striking example is the colour of Pollia fruits [1] is the results of chiral multilayered structures composed of cellulose micro-fibrils, which from a layered structures. In each component layer, cellulose micro-fibrils lie parallel to one another, with successive layers offset from each other at a small angle, so that the direction of the parallel-aligned micro-fibrils changes consistently, rotating from one layer to another and producing an intense colour-selective reflection.

Biomimetic with cellulose-based architectures enables us to fabricate novel photonic structures using low cost materials in ambient conditions [2-4]. Importantly, it also allows us to understand the biological processes at work during the growth of these structures in plants.

In this work the route for the fabrication of cellulose-base architecture will be presented and the optical properties of cellulose artificial structures will be analyzed and compared with natural ones.

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Filippo Alpeggiani

Department of Physics, University of Pavia, Italy

RADIATIVE PROPERTIES OF MULTISUBBAND PLASMONS IN SEMICONDUCTOR QUANTUM WELLS

Plasmonic excitations are ordinarily associated to intraband transitions in metal-like electronic systems dressed by the mutual Coulomb interaction [1]. A quasi-two-dimensional electron gas with multiple subbands, such as a highly doped semiconductor quantum well, presents additional plasmonic excitations that originate from intersubband transitions, known as "intersubband plasmons" [2,3], which show several similarities to surface plasmons of metallic nanostructures and have recently become of interest due to strong collective effects in the electromagnetic response [4]. We present a semiclassical theory of intersubband plasmons in quantum wells, based on nonlocal electrodynamics [5]. The theory is formulated in a very general way, and it can be applied to stratified geometries of any degree of complexity, including planar microcavities, where plasmon-polariton effects are predicted. Electrostatic coupling among different intersubband transitions gives rise to strongly radiative modes with subpicosecond radiative lifetimes. These modes are very promising for attaining a significant enhancement of light-matter interaction [6], up to the "ultrastrong coupling regime", where quantum and nonlinear phenomena, such as the dynamical Casimir effect, are expected to play a significant role.

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Leo-Jay Black

University of Southampton, UK

TUNING THE LINEAR AND NON-LINEAR OPTICAL RESPONSE OF ORTHOGONAL DIMER PLASMONIC ANTENNAS FOR METASURFACES

Today, there is an increasing interest in using nanoscale plasmonic devices to control the polarization and propagation states of light. In particular, several designs of plasmonic metamaterials have been proposed with strong birefringence and chirality and applications in tunable waveplates and optical biosensor. In this context, connected L-shaped nanoantennas have particularly received interest for their noncentrosymmetric properties in the generation of second harmonic generation, in polarization conversion and birefringence. In this work, we show that it is possible to tune the linear and non-linear optical response of disconnected antennas through the control of the morphology and gap width.

We demonstrate that polarization conversion in coupled dimer antennas, used in phase discontinuity metasurfaces, can be tuned by careful design. By controlling the gap width, a strong variation of the coupling strength and polarization conversion is found between capacitively and conductively coupled antennas. A theoretical two-oscillator model is proposed, which shows a universal scaling of the degree of polarization conversion with the energy splitting of the symmetric and antisymmetric modes supported by the antennas. This picture is supported by extensive electrodynamical simulations based on the 3D-Green's dyadic method.

Using e-beam lithography we fabricated nano-antennas consisting in orthogonal dimers of gold nanorods of fixed widths and heights of 120 and 40 nm, respectively, and with nanorod lengths between 100 and 300 nm. Using Spatial Modulation Spectroscopy on individual antennas, we measured first the "pure" bonding and antibonding states of several representative L = 230 nm antennas. We then measured the intensity of the scattered light along different polarizations for an incident optical excitation polarized along one of the antenna arms. These measurements allowed to quantify the polarization conversion achieved by these nanostructures. We find good agreement with theory for the scaling of mode splitting and polarization conversion with gap width over the range from capacitive to conductive coupling. Next to linear polarization conversion, we demonstrate single-antenna linear to circular polarization conversion, which could offer many interesting sensing applications.

Besides the linear optical properties, we have investigated Second Harmonic Generation (SHG) in these structures. Our experimental results supported by numerical simulations show that both the intensity and polarization of the SHG emission strongly depend on the gap width and antenna arm length. Our results provide strategies for designing the linear and non-linear response of plasmonic metasurfaces.

Wonjun Choi

University of Exeter, UK

PREFERENTIAL COUPLING OF AN INCIDENT WAVE TO REFLECTION EIGENCHANNELS OF DISORDERED MEDIA

Light waves incident to a highly scattering medium are incapable of penetrating deep into the medium due to the multiple scattering process. This poses a fundamental limitation to optically imaging, sensing, and manipulating targets embedded in opaque scattering layers such as biological tissues. One strategy for mitigating the shallow wave penetration is to exploit eigenchannels with anomalously high transmittance existing in any scattering medium. However, finding such eigenchannels has been a challenging task due to the complexity of disordered media. Moreover, it is even more difficult to identify those eigenchannels from the practically relevant reflection geometry of measurements.

In this research, we present an iterative wavefront control method that either minimizes or maximizes the total intensity of the reflected waves. We proved that this process led to the preferential coupling of incident wave to either low or high-reflection eigenchannels, and observed either enhanced or reduced wave transmission as a consequence. In order to prove it, we measured the reflection matrix of same medium and obtained all the eigenchannels present in the system. And then we calculated the cross-correlation between the coupled incident light and each eigenchannels. From this, we assured that the contribution of eigenchannels with high transmission was increased in the incident light, which well agreed with theoretical prediction.

Since our approach is free from prior characterization measurements such as the recording of transmission matrix, and also able to keep up with sample perturbation, it is readily applicable to in vivo applications. Enhancing light penetration will help improving the working depth of optical sensing and treatment techniques.

Peter Wiecha

CEMES CNRS – Toulouse, France

NONLINEAR MICROSCOPY ON SINGLE SILICON NANOWIRES USING SECOND HARMONIC GENERATION

Peter Wiecha, Arnaud Arbouet, Houssem Kallel, Priyanka Periwal, Thierry Baron, Vincent Paillard.

Semiconducting nanowires (NWs) are promising candidates for applications such as light management, light trapping or field-enhanced spectroscopy, and interesting as possible alternative for plasmonic nanoantennas, which usually suffer from high losses. The most important capacity of nanoantennas is the possibility to selectively tune optical properties like scattering or absorption efficiencies within engineered spectral and spatial constraints. One can compare this figuratively with radio-frequency antennas, where the design has a substantial impact on properties like the resonance wavelength or the directivity of the antenna.

As an example, silicon nanoantennas could be used to design physically thin, yet optically thick solar cells, or be employed to control the emission of quantum dots or molecules positioned in their near field. For such developments, the knowledge of the electromagnetic field distribution around the nanostructure is crucial.

We use nonlinear microscopy on individual silicon NWs in order to gain insight in the local electromagnetic field distribution. We exploit the second harmonic generation (SHG), which is highly sensitive to small variations of the local electric field due to the nonlinear response to the electric field amplitude. This effect furthermore boosts the resolution of the SHG images by sharpening the Airy disc of the focused laser beam.

Beside qualitative conclusions, another important result is that silicon NWs may exhibit significant SHG, depending on the incident light's polarization and the optical resonance modes supported by the NW. While SHG mappings of individual Si-NWs reflect the local field distribution at the fundamental frequency, the SHG intensity strongly depends on the presence of a resonant mode. It ranges from entirely suppressed (no resonant mode exists) to strongly enhanced compared to bulk Si. This may open a route towards new Si-based nonlinear optical devices.

Lorenzo Cortese

LENS European Laboratory for Non-Linear Spectroscopy, University of Florence, Italy

LESSONS FROM NATURE: HOW WHITE BEETLES OPTIMISE MULTIPLE SCATTERING OF LIGHT

The colours shown by several insects often arise from light scattering by very complex photonic structures rather than selective absorption by pigments. Such structures are the result of optical strategies developed during millions of years of evolution. The bright and iridescent colours shown by certain butterflies and beetles, for example, arise from interference effects which requires ultrathin periodic layers of material. In contrast, a bright white coloration is more complicated to achieve, since all colours has to be scattered with the same high efficiency. In this case the wave nature of light is not involved in the appearance of the object, and a bright white is achieved only in presence of multiple scattering, for which thick, high refractive index contrast systems are usually required. Nevertheless, the extremely brilliant whiteness shown by the Cyphochilus beetle is generated by multiple scattering of light inside the ultra-thin, low-refractive-index scales that cover its body. The intra scale structure is characterized by a dense, nanostructured network of chitin filaments, which seems to be optimised to increase the total reflectance, and thus the bright appearance of the beetle, employing as less material as possible.

In this work we analysed light transport inside the beetle's scales, showing that multiple scattering of light occurs, in spite of their thinness (5–9 µm). We proved, with static and time-resolved experiments, that white beetle's scales show the lowest transport mean free path for low-refractive-index systems (n=1.5) reported until now. We found that the crucial aspect of the optimisation of light scattering is the structural anisotropy of the chitin network. We indeed demonstrated that light transport inside the scales is anisotropic, and it is engineered to increment the scattering strength in the direction orthogonal to the scale surface, at expense of the in plane scattering, which is not relevant for the total reflectance.

Dmitry Khlopin

University of Technology of Troyes, France

LATTICE MODES FOR ALUMINUM PLASMONICS

Aluminium is an important candidate for the future nanoplasmonics material, especially in UV range, due to the low price and formation of a self-limiting native oxide protecting layer. But there is also an obstacle represented by a broad plasmonic resonance in comparison with noble metals. Possibility of tuning and improvement of the quality factor and the position of the resonance is open question for aluminium. In this communication, we report one of the possible way of improvement - coupling between localised surface plasmon (LSPR) observed in aluminium nanoparticles and Rayleigh anomaly in metallic diffraction gratings, i.e. lattice modes. Main variables that affect Rayleigh anomaly are the pitch of the grating, the refractive index of the environment and the angle of incidence of the light. Different gratings contains aluminium nanorods with variation of the pitch size was made in order to discover influence. Two Rayleigh anomalies, in air and in substrate, take place in the investigated samples. Coupling of LSPR and Rayleigh anomaly leads to the Fano-type resonance with reduced width against raw LSPR. Also there is shifting of the position of resonance in presence of lattice modes Improving of the quality factor was clearly observed on obtained spectra. This study presents possibility to enhance plasmonic properties of aluminium for application in UV range or as an alternative material to gold and silver in visible spectrum.

James Dolan

University of Cambridge, UK

LIQUID CRYSTAL-INFILTRATED SELF-ASSEMBLED GYROID OPTICAL METAMATERIALS

Block copolymers consisting of two or more covalently tethered and chemically distinct homopolymers may self-assemble into a range of equilibrium morphologies by microphase separation. One such morphology, characterised by the presence of the chiral and triply periodic constant mean curvature surface of the same name, is the gyroid. As the characteristic length scale of polymer self-assembly is often deeply sub-wavelength for visible light, block copolymers represent a fascinating route by which to template truly three dimensional optical metamaterials [1]. Gold gyroids fabricated in this manner may exhibit a striking range of optical properties depending upon the long range order, and therefore self-assembly conditions, of the block copolymer template. Small domain gyroids, fabricated by thermal annealing, behave largely as nanoporous gold and exhibit a plasma frequency greatly depressed from that of the constituent gold; whereas large domain gyroids, fabricated by solvent vapour annealing, additionally exhibit an anisotropic linear and circular dichroism [2]. Infiltration of the gyroid metamaterial with various dielectric media allows the tuning of its optical response across the visible spectrum [3]. When infiltrated with a nematic liquid crystal, however, not only is the optical response of the material modulated, but an intriguing liquid crystal defect structure is also predicted to be templated. We therefore here present recent data on the optical characterisation by angularly resolved reflectivity measurements of both small and large domain gold gyroid metamaterials infiltrated with nematic liquid crystals. We develop an effective medium model to describe the red-shifted plasma wavelength of the former and its observed variation with volume fraction and dielectric fill, and seek corroborating evidence of the liquid crystal defect structure in the circular polarisation response of the latter, e.g. through a potential increase in circular dichroism.

[1] J. Dolan et al., "Optical Properties of Gyroid Structured Materials: From Photonic Crystals to Metamaterials", Advanced Optical Materials, 3, 12-32 (2015).

[2] S. Vignolini et al., "A 3D Optical Metamaterial Made by Self-Assembly", Advanced Materials, 24, OP23-OP27 (2012)

[3] S. Salvatore et al., "Tunable 3D Extended Self-Assembled Gold Metamaterial with Enhanced Light Transmission", Advanced Materials, 25, 2713-2716 (2013).

Rebecca French

University of Southampton, UK

HYPERSPECTRAL IMAGING USING A COMPLEX MEDIUM

The spatial transmission matrix of a multiply scattering medium was determined by mapping the input modes to the output signal recorded by a CCD camera. The inverse of the measured transmission matrix of the sample was exploited to unscramble the randomly scattered information from an input image after propagation through the system. It is hoped that a similar concept of transmission matrix measurements of complex media can be used to measure a spectral transmission matrix, allowing a hyperspectral imaging system to be developed. It is well known that different wavelengths of light do not interfere, suggesting that, after travelling through a complex medium, each wavelength should output a unique 'fingerprint' in the form of a speckle pattern. It is expected that these 'fingerprints' can be used to identify individual, and perhaps multiple, wavelengths after propagation through a highly scattering medium.

Rox Middleton

University of Cambridge, UK

PATTERNED CELLULOSE FOR OPTICAL MATERIALS

Recent studies have shown that cellulose microfibrils form helicoidal stacks in plant cells, which selectively reflect circularly polarised light of a specific wavelength and handedness. This arresting optical effect can also be replicated by self-assembly of chiral nanostructure within cellulose nanocrystal films.

I present work on patterning this lab-made cellulose material for use in novel optical materials. We aim to broaden the optical properties available, reaching towards the complex hierarchical structures that have developed in plants to enhance their naturally reflective cells.

Jamie Fitzgerald

Imperial College London, UK

QUANTUM PLASMONICS

Quantum plasmonics is an expanding area of research using the laws of quantum mechanics to explore how light and matter couple in nanostructures. With the continued development of fabrication techniques to make smaller and smaller nanostructures comes the need to improve on the classical models which fail at small scales to describe the interaction with light. These small nanoparticles are important to study as they may be used to build nanometer components in miniaturized photonic devices, using the plasmonic properties to confine the light to regions of space smaller than the diffraction limit. Recent interest in the quantum behaviour of the plasmons themselves further increases the need for a simple fully quantum mechanical description.

We are developing a simple 'electron gas in a box' model to explore how single electron transitions, induced by a classical light field, can form a collective plasma oscillation in small nanoparticles. Our model includes essential behaviour such as size quantisation and electron spill out and allows one to see the quantum origins of a localised plasma resonance. It also gives a great opportunity to explore in detail the effect that the Coulomb interaction as well as the number of electrons have on the plasma resonance. The model can explain a lot of interesting physics whilst maintaining a simplicity that will allow it be of use to researchers in the field who come from many different scientific backgrounds.

Thomas Chaigne

Langevin Institute, France

LIGHT CONTROL IN DEEP TISSUE VIA PHOTOACOUSTIC-GUIDED WAVEFRONT SHAPING

In biological tissue, light scattering limits the penetration depth of most optical imaging techniques to a few hundred micrometers. In the last few years, wavefront shaping appeared as a powerful tool to compensate light scattering and focus light in deep tissue. However it requires a feedback signal that monitors the light intensity on the target. In most practical scenarios, one cannot directly place a photodetector at the target position. Photoacoustic imaging has been investigated to provide such a feedback and to perform controlled focusing deep inside scattering media. We recently demonstrated light focusing using photoacoustic feedback from an ultrasound array and a transmission-matrix approach [Chaigne et al., Opt. Letters 39(9), 2014; Chaigne et al., Nat. Photonics 8, 2014].

Moreover, coherent illumination (but without precise wavefront control) has been found to be useful for photoacoustic imaging to overcome limited view detection [Gateau et al., Opt. letters 38 (23), 2013], revealing structures that are invisible in conventional photoacoustic imaging. We also observed that such speckle illumination could enhance the imaging resolution.

We will report on our last investigations and will discuss about necessary improvements to apply these techniques in actual biological samples. Fast decorrelation of the tissue and wavelength mismatch between acoustics and optics will be addressed, either via upgraded instrumentation and or signal processing.

Mickael Mounaix

Laboratoire Kastler Brossel, École Normale Supérieure, France

SPATIO-TEMPORAL FOCUSING OF AN ULTRASHORT PULSE USING THE MULTI SPECTRAL TRANSMISSION MATRIX

Optical imaging through random media such as biological tissue remains a challenge as spatial and phase informations are mixed because of multiple scattering. Previous work had shown that using a spatial light modulator (SLM)and a monochromatic laser, the spatial speckle pattern can be controlled at the output of a random medium with wavefront shaping techniques (WFS), for instance to focus light and improve imaging resolution and depth penetration.

However, if the laser generates a broadband ultrashort pulse, the transmitted signal can be temporally broadened as the medium respond differently for different spectral components of the pulse.

In this work, we present a technique to measure the Multi Spectral Transmission Matrix (MSTM) of a medium. thus allowing to describe fully the propagation of a broadband pulse through a thick scattering medium. Once the MSTM is known, one can use wavefront shaping to control both spatial and spectral components of the output field, we demonstrate experimentally spectrally selective spatial focusing, focusing of multiple spectral component of a pulse. The control of spectral degrees of freedom also gives access to temporal control, and we demonstrate deterministic temporal recompression of a pulse to its initial bandwidth after the medium and enhanced non-linear excitation.

Romolo, Savo

Laboratoire Kastler Brossel, CNRS, École Normale Supérieure, France

AN INVARIANCE PROPERTY OF MULTIPLE LIGHT SCATTERING

Common experience suggests that when varying the concentration of scattering centers in a disordered medium transport properties are inevitably affected. However, a fundamental property of random walks states that one exception, at least, exists.

Taking inspiration from the trajectories traced by ants in their random motions, it has been shown theoretically that the mean path length of a random walk in a bounded region does not depend on the random walk features, i.e. the scattering mean free path, but only the geometry of the bounding region counts [1]. Particularly counterintuitive, this invariance property stems from a delicate, yet universal, balance between very short paths and more penetrating long ones.

This invariance property has been recently extended to wave scattering theory, surprisingly showing that coherent effects, such as resonances and Anderson localization, do not affect this property [2].

Here, for the first time, we investigate experimentally the invariance of the mean path length for multiple light scattering in complex media, from weak scattering to deep multiple scattering. We measure average light trajectories length by using a steady state source and by monitoring the decorrelation in time of the speckle pattern due to the brownian motion of the scatterers. Our preliminary results go in the direction of confirming theoretical predictions.

[1] S. Blanco and R. Furnier, "An invariance property of diffusive random walks", Europhys. Lett. (2003).

[2] R. Pierrat et al. , "Invariance property of wave scattering through disordered media", PNAS (2014).

Soraya Carlos Caixeiro

King's College London, UK

RANDOM LASING IN BIOCOMPATIBLE MATERIALS

I will report on the lasing and scattering properties of a self-assembled inverse photonic architecture made entirely of a doped biomaterials, such as proteins as silk and polysaccharides as chitosan, with outlook in sensing applications. Unlike conventional lasing devices based on a rigid geometry, which have to be carefully aligned, we propose silk and chitosan random lasing as a source of laser emission biocompatible for both materials and shape. Silk and chitosan are biocompatible, biodegradable and mechanically stable materials, versatile and easy to fabricate with a potential for in-human implantation.

Khunsin Worawut

Imperial College London, UK

QUANTITATIVE NEAR-FIELD ANALYSIS OF PLASMONIC FANO INTERFERENCES: THE EFFECT OF COUPLING STRENGTH, SPATIAL MODE PROFILE MATCHING, POLARIZATION AND ANGLE OF INCIDENCE ON BRIGHT-DARK MODE INTERACTION

We investigate experimentally and numerically in the optical near-field a plasmonic system that bears analogy to plasmonic-induced transparency (PIT). We identify the governing geometrical and illumination parameters that affect the excitation and the structure of the induced dark mode. By varying the coupling conditions we show that spatial mode overlap and phase retardation cross the structures are essential parameters to achieve a designed constraint that the bright mode imposes on the excitation of dark modes via near-field interaction. We show that quantitative analysis of near-field amplitude and excitation strength can provide complementary information that allows identifying the interaction strength between the bright and the dark mode and how it leads to the formation of Fano resonance and induced transparency. In addition, we demonstrate the excitation of a dark mode akin to a symmetry-forbidden plasmonic breathing mode using a linearly polarized light. This work introduces a mechanism to excite field distributions in plasmonic structures which cannot be accessed directly using far-field means. The ability to control bright-dark mode interaction shown herein is believed to be useful for the engineering of PIT and Fano resonance with potential applications in ultrasensitive biochemical sensors, nonlinear optics, and enhanced solar energy harvesting, and may pave the way for excitation of more complex dark plasmonic modes.

Poster

Jin Lian

Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente, Netherlands

DISPERSION OF MODE-GAP CAVITIES

Arrays of coupled nanocavities are fascinating for their slow-light applications and light-matter interaction enhancement [1]. High Q and wavelength sized cavities, especially the photonic crystal mode gap cavities are more attractive for people to making large scale arrays [2]. For a long time, the tight binding (TB) model is the most widely used model for modeling and optimizing the light transport in such systems [3, 4]. However, the distinction between symmetric spectrum which predicted by the TB model and asymmetric spectrum which has been calculated and measured on arrays of coupled mode gap cavities [5] proves that the TB model should be modified in order to make the modelling and optimization more accurately. Thus, to investigate the origin of the deviation from the TB model becomes crucial.

Here we represent systematic numerical calculation of the dispersion of coupled mode-gap cavities. We show the dispersion deviates strongly from the TB model especially depending on the resonant frequency of the single cavity. We prepare an improved TB model to account for this dispersion.

[1] A. Yariv, Y. Xu, R. K. Lee and A. Scherer, "Coupled-resonator optical waveguide: a proposal and analysis", Opt. Lett. 24 711 (1999).

[2] M. Notomi, E. Kuramochi and T. Tanabe , "Large-scale arrays of ultrahigh-Q coupled nanocavities", Nature Photon 2 741 (2008).

[3] P. Chak and J. E. Sipe Opt. Lett, "Minimizing finite-size effects in artificial resonance tunneling structures", 31 2568 (2006).

[4] M. Sumetsky and B. J. Eggleton, "Modeling and optimization of complex photonic resonant cavity circuits", Opt. Express 11, 381 (2003).

[5] N. Matsuda, E. Kuramochi, H. Takesue, and M. Notomi. "Dispersion and light transport characteristics of large-scale photonic-crystal coupled nanocavity arrays", Opt. Lett 39 2290 (2014).

Sergei, Sokolov

Complex Photonic Systems, MESA+ Institute for Nanotechnology, Univeristy of Twente, Netherlands

LOCAL THERMAL CONTROL OF 2D GA-IN-P PHOTONIC CRYSTAL CAVITIES IN DIFFERENT AMBIENT MEDIA

Multiple coupled high-Q photonic crystal nanocavities are very interesting objects for investigation due to their various applications [1,2]. Fabrication imperfections may lead to disorder which detunes cavities from designed resonance frequencies and reduces transmission of an array. By thermally controlling resonance properties of each particular cavity it is possible to restore the initially designed performance of coupled nanocavities.

While controlling a particular cavity using thermal tuning neighbour cavities may be also affected due to the heat diffusion in the sample. In this work we experimentally investigate how heat spreads inside the sample containing single H0 nanocavity [3]. We measure out-of-plane scattered light from the cavity to detect resonance spectra, and we apply 405 nm pump light to tune the cavity and measure spatially dependent cavity responses on pump.

It appears that material of the sample and ambient media play a great role in a heat diffusion process. We describe experiments with a model which takes into account heat diffusion inside the sample. We found that our model has a very good agreement with experiment.

[1] Y. Yariv, Y. Xu, R. K. Lee, and A. Scherer, "Coupled-resonator optical waveguide: a proposal and analysis", Opt. Lett. 24, 711 (1999).

[2] M. Notomi, E. Kuramochi, and T. Tanabe, "Large-scale arrays of ultrahigh-Q coupled nanocavities", Nat Photonics, 2,741 (2008).

[3] N. Tran, S. Combrie, P. Colman, A. De Rossi, T. Mei, "Vertical high emission in photonic crystal nanocavities by band-folding design", Phys. Rev. B, 82,075120 (2010)

Hasan Yilmaz

Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente, Netherlands

SPECKLE CORRELATION RESOLUTION ENHANCEMENT OF WIDE-FIELD FLUORESCENCE IMAGING

High-resolution fluorescence imaging is indispensable to study structure and function of bio- and nano-materials at nanoscale. Here we report speckle correlation resolution enhancement (SCORE) imaging which exploits correlations in speckle illumination through a randomly scattering high-index medium. Parallel detection of the speckle pattern provides wide-field imaging beyond the range of the optical memory effect. We obtain a high-resolution and wide-field two-dimensional fluorescence image of dye-doped nanospheres with a diameter of 100 nm. We have developed a new image reconstruction algorithm that converges even for complex object structures. Our method works with general fluorescent dyes and we demonstrate a deconvolved resolution of 116 nm with a field of view of 10 µm x 10 µm.

Marta Castro-Lopez

King's College London, UK

RANDOM, PERIODIC AND HYPERUNIFORM NETWORKS

Plasmonic networks combine localised optical fields into nanometer volumes with delocalised optical excitation over the network, properties which make them good candidate as a platform for fluorescence control and emitter coupling. Here we study, by scattering and fluorescence measurements, the properties of three different type of optical networks, i.e. random, periodic and hyperuniform plasmonic networks. After fabrication via thermal evaporation and e-beam lithography, nano-sized probes are coupled to them in order to reconstruct their LDOS distribution and reveal their optical modes. The random and periodic networks show a Purcell factor range of 1 to 5, with long asymmetric tails. The hyperuniform networks instead, show a characteristic k-space correlation which is visible by angular momentum spectroscopy. The ability of these optical networks to control the emission and scatter of light from the near to the far field open new interesting possibilities for multiscale fluorescence engineering.

Oluwafemi S. Ojambati

Complex Photonic Systems (COPS) MESA+ Institute for Nanotechnology
University of Twente, Netherlands

SELECTIVE COUPLING OF OPTICAL ENERGY INTO THE FUNDAMENTAL DIFFUSION MODE OF A SCATTERING MEDIUM

It is known that light transport through scattering media is described by the diffusion equation. The fundamental question we want to answer is the possibility of selectively coupling light to one of the eigensolutions of the diffusion equation. We demonstrate experimentally that optical wavefront shaping selectively couples light into the fundamental diffusion mode of a scattering medium. The total energy density inside a scattering medium of zinc oxide (ZnO) nanoparticles was probed by measuring the emitted fluorescent power of spheres that were randomly positioned inside the medium. The fluorescent power of an optimized incident wavefront is observed to be enhanced compared to a non-optimized incident wavefront. The observed enhancement increases with sample thickness. Based on diffusion theory, we derive a model wherein the distribution of energy density of wavefront-shaped light is described by the fundamental diffusion mode. The agreement between our model and the data is striking, not in the least since there are no adjustable parameters. Enhanced total energy density is crucial to increase the efficiency of white LEDs, solar cells, and of random lasers, as well as to realize controlled illumination in biomedical optics.

PROGRAMME

TUESDAY 18 AUGUST

15:00 ARRIVAL AT CUMBERLAND LODGE

15:50–16:00 OPENING

—

16:00–17:00 KEYNOTE TALK:

ALLARD MOSK
Complex Photonic Systems, MESA+ Institute for Nanotechnology, University of Twente
SHAPED WAVEFRONTS AND SPECKLE CORRELATIONS: A WINDOW INTO OPAQUE MEDIA

—

17:00–18:00 CONTRIBUTED TALKS:

HUGO DEFIENNE
Laboratoire Kastler Brossel, École Normale Supérieure
CONTROL OF MULTIPHOTON PROPAGATION IN A COMPLEX MULTIMODE SYSTEM

—

MARCO LEONETTI
Center for Life Nano Science@Sapienza, Istituto Italiano di Tecnologia
ADAPTIVE AND NONLINEAR OPTICS IN THE TRANSVERSE LOCALIZATION REGIME

—

BERGIN GJONAJ
Technion – Israel Institute of Technology
SILICON MICROSCOPY VIA WAVEFRONT SHAPING

—

18:00–18:30 INVITED TALK:

BENJAMIN JUDKIEWITZ
University of Berlin
CORRELATIONS IN ANISOTROPICALLY SCATTERING MEDIA

—

18:30–20:30 DINNER

20:30–21:00 FREE EVENING

WEDNESDAY 19 AUGUST

09:30–10:30 CONTRIBUTED TALKS:

MICHELE CELEBRANO
Politecnico di Milano
MODE-MATCHING IN MULTIRESONANT PLASMONIC NANOANTENNAS FOR ENHANCED SECOND HARMONIC GENERATION

—

ION HANCU
ICFO, The Institute of Photonic Sciences
CONTROLLING SECOND HARMONIC GENERATION WITH PLASMONIC NANOANTENNAS

—

HILTON BARBOSA DE AGUIAR
Institut Fresnel
SECOND-HARMONIC GENERATION IMAGING ENHANCEMENT THROUGH SCATTERING MEDIA VIA WAVEFRONT SHAPING

—

10:30–11:30 COFFEE BREAK

11:30–12:30 INVITED TALKS:

STEFAN ROTTER
Vienna University of Technology
THE CONCEPT OF TIME IN SCATTERING THROUGH COMPLEX MEDIA

—

MARIAN FLORESCU
University of Surrey
HYPERUNIFORM DISORDERED PHOTONIC SOLIDS

—

12:30–15:00 LUNCH

15:00–16:00 KEYNOTE TALK:

HUI CAO
Yale university
COHERENT CONTROL OF OPTICAL ABSORPTION

16:00–16:30 POSTER PITCH

16:30–18:30 POSTER SESSION

18:30–20:30 DINNER

20:30–21:30 EVENING DEBATE
with
MARIA MARAGKOU
Nature Materials
ETIENNE CASTANIÉ
Qivivo

THURSDAY 20 AUGUST

09:30–10:30 CONTRIBUTED TALKS:

RAKTIM SARMA
Yale University
CONTROL OF LIGHT TRANSPORT VIA NON-LOCAL WAVE INTERFERENCE EFFECTS IN RANDOM MEDIA
—
AUDE MARTIN
Laboratoire de Photonique et de Nanostructures (UPR20- CNRS)
PHASE SENSITIVE AMPLIFICATION ON CHIP: BEYOND THE LINEAR LIMIT
—
KEVIN VYNCK
LP2N, Institut d'Optique Graduate School – CNRS – Univ. Bordeaux
FORMATION AND PROPERTIES OF LOCALIZED MODES NEAR PHOTONIC BAND EDGES
—

10:30–11:30 COFFEE BREAK
—

11:30–12:30 INVITED TALKS:

THOMAS WELLENS
University of Freiburg
SCATTERING LASER LIGHT ON COLD ATOMS: MULTIPLE SCATTERING SIGNALS FROM SINGLE-ATOM RESPONSES
—
ALEXANDER SZAMEIT
University of Jena
INTEGRATED LASER-WRITTEN QUANTUM PHOTONICS

12:30–15:00 LUNCH

15:00–16:00 KEYNOTE TALK:

REMI CARMINATI
Langevin Institute, ESPCI
FLUORESCENT EMITTERS IN COMPLEX MEDIA: FROM SOURCE LOCATION TO CAVITY QED
—

16:00–17:00 CONTRIBUTED TALKS:

FRANCESCO RIBOLI
University of Trento
FREQUENCY CORRELATION SPECTROSCOPY OF THE LOCAL DENSITY OF STATES IN STRONGLY SCATTERING DISORDERED MEDIA
—
HAIDER BUTT
University of Birmingham
HOLOGRAPHIC FABRICATION OF NANOPHOTONIC DEVICES

NICCOLÒ CASELLI
LENS - Department of Physics, University of Florence
PHASE-SENSITIVE FANO IMAGING OF PHOTONIC LOCALIZED MODES

17:00–17:30 COFFEE BREAK

17:30–18:30 INVITED TALKS:

VINCENZO GIANNINI
Imperial College London
QUANTUM PLASMONICS AND NON-LOCAL NANOPHOTONICS
—
LAURA WALLER
Berkeley University
COMPUTATIONAL IMAGING FOR REAL-TIME GIGAPIXEL MICROSCOPY
—

18:30–20:30 DINNER

20:30–21:30 SELF-ORGANISED SESSION

FRIDAY 21 AUGUST

09:30–10:30 CONTRIBUTED TALKS:

BAS GOORDEN
University of Twente
THE QUANTUM CREDIT CARD
—

SANLI FAEZ
Leiden University
ELECTROKINETIC ULTRAMICROSCOPY: PROBING CHEMICAL REACTIONS ON A SINGLE NANOPARTICLE
—

MICHELE GAIO
King's College London
LIGHT EMISSION IN COMPLEX PHOTONIC NETWORKS
—

10:30–11:20 COFFEE BREAK

11:20–12:00 CONTRIBUTED TALKS:

RICHARD BOWMAN
University of Cambridge
NOTHING'S REFLECTION: PLASMONS, MIRRORS, AND MOLECULES
—

IOANNIS PAPADOPOULOS
Bioimaging and Neurophotonics Lab, Charite University Hospital Berlin
SUBMICRON RESOLUTION ENDOSCOPES USING MULTIMODE FIBERS
—

12:00–12:30 INVITED TALK:

SILVIA VIGNOLINI
Cambridge University
CELLULOSE PHOTONICS: FROM NATURE TO APPLICATIONS
—

12:30–13:00 CLOSING REMARKS AND POSTER AWARD

13:00–14:00 LUNCH

14:00 DEPARTURE