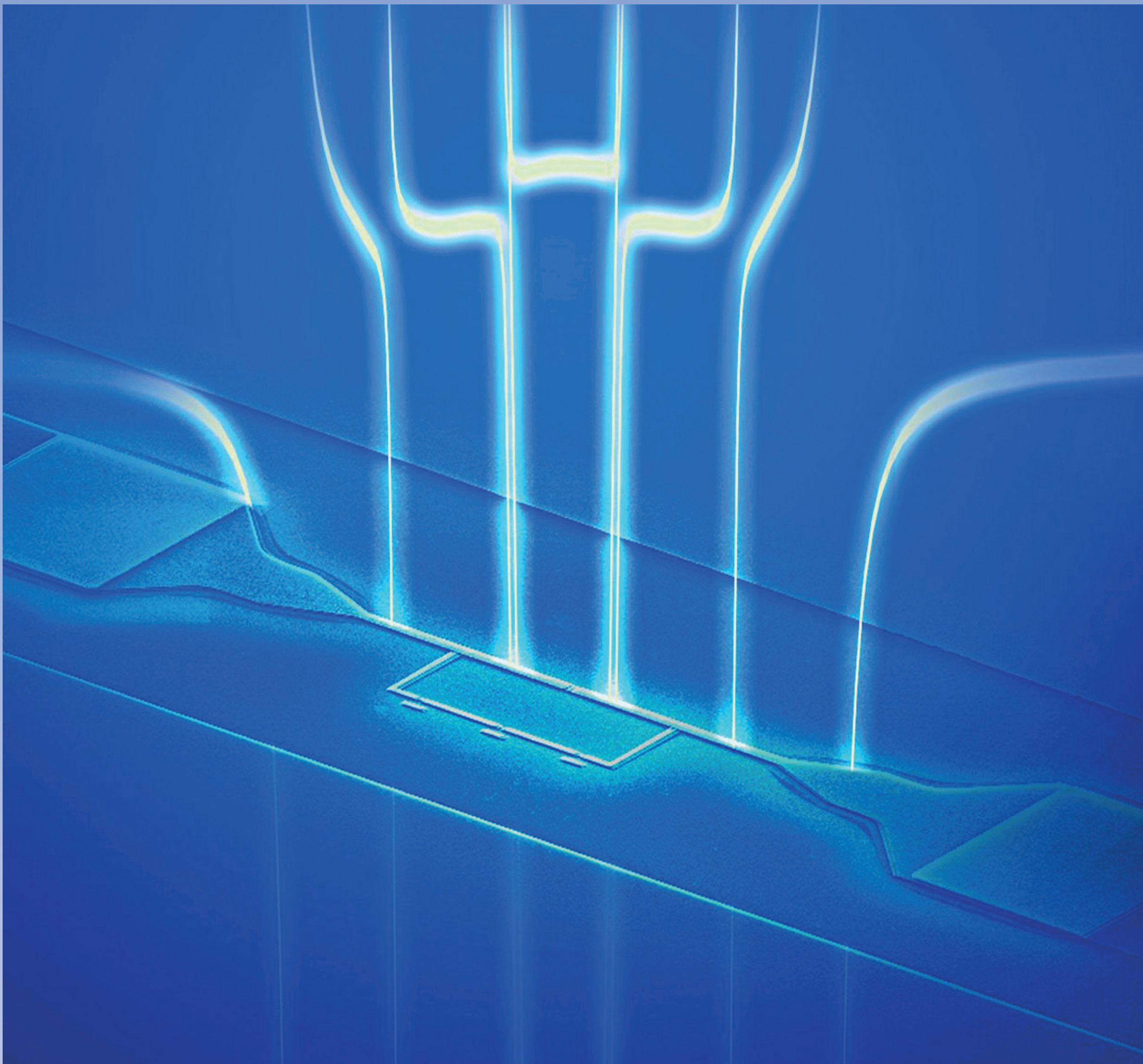

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(Madrid, Spain) 4-6 October 2015

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INTRODUCTION

The British Council in Spain, in collaboration with the Spanish National Research Council (CSIC) is organising a series of scientific workshops to provide opportunities for young researchers from the UK and Spain to meet face-to-face for the exchange of ideas, knowledge and information on priority topics and to explore future areas of research and collaboration.

This workshop on «Optical Technologies for Society» was the thirteenth in the series.

PRESENTATION

The workshop was divided in five sessions corresponding to optical technologies of great interest for society, whose impact in the near future is expected to be even greater: Nanophotonics, Optical Communications, Bio-photonics, High Power Lasers and Quantum Optics. Two key lectures given by senior researchers and two specific research topics related to each were presented in every session. Specific topics were presented by junior researchers working with the seniors. A total of 20 researchers in the field (10 seniors plus 10 juniors) preceded by a short welcome introduction by the British Council and CSIC representatives composed the programme.

Opportunities for dialogue were provided at the end of each session. In addition, the research topics were presented in a poster session where young researchers could directly interact with others.

The subject was selected to follow the celebration of the International Year of Light and light related Technologies proclaimed by the UN for 2015.

The workshop was coordinated by Professor *Keith Blow* and Doctor *Joaquín Campos*.

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PROGRAMME

MONDAY 5th OCTOBER	
9:00	**Welcome by British Council and CSIC representatives** **Andy Mackay**, Director of the British Council Spain **Paloma Tejedor**, Deputy Vice President for Internationalization of CSIC
Session 1. Nanophotonics (Chair, Dr. Joaquín Campos)	
9:20	Keynote, **Prof. Jeremy Baumberg** (University of Cambridge) «Seeing individual molecules by confining light to the nanoscale».
9:50	**Dr. Giuliana Di Martino** (University of Cambridge) «Growing nanowires by light».
10:00	Keynote, **Dr. Javier García de Abajo** (ICFO) «Pushing nanophotonics down to the atomic scale».
10:35	**Dr. José Ramón Martínez Saavedra** (ICFO) «Electron beams for nanophotonics in the atomic scale».
10:40	Discussion on the session presentations.
11:10	***Coffee break***
Session 2. Optical Communications (Chair, Prof. K. Blow)	
11:35	Keynote, **Dr. Juan D. Ania** (IO-CSIC) «Distributed Raman amplification and the capacity crunch in optical fiber transmission».
12:10	**Dr. Pawel Rosa** (IO-CSIC) «Raman amplification for nonlinear impairment compensation using optical phase conjugation».
12:15	Keynote, **Dr Robert Killey** (UCL) «Spectrally efficient optical transmission systems».
12:50	**Dr. Gabriel Saavedra Moncada** (UCL) «Wide-band amplification for increased capacity for optical transmission».
12:55	Discussion on the session presentations
13:30	***End of session***
Session 3. Bio-photonics (Chair, Dr. Joaquín Campos)	
14:45	Keynote, **Prof. Sergei Sokolovsky** (Aston University) «Cancer Photo- diagnostics and treatment».
15:20	**Mr. Ilya Rafailov** (Aston University) «Cross-sectional model to simulate and visualise the optical properties in urinary bladder».
15:25	Keynote, **Prof. Susana Marcos** (IO-CSIC) «Light for vision».
16:00	**Dr. Eduardo Martínez-Enríquez** (IO-CSIC) «Quantitative anterior segment optical coherence tomography».
16:05	General discussion on the session presentations
16:30	***Coffee break***
16:45	**Session: Posters display**
17:45	End of the day

TUESDAY 6th OCTOBER	
Session 4. High Power Lasers (Chair, Prof. K. Blow)	
9:00	**Welcome of the day**
9:10	Keynote, **Prof. Luis Roso** (Pulsed Lasers Centre, CLPU) «Extreme Lasers».
9:45	**Mr. Francisco Valle** (Pulsed Lasers Centre, CLPU) «Laser Generated X-rays».
9:50	Keynote, **Dr Shaiful Alam** (University of Southampton) «High power fiber lasers – harnessing the power of light».
10:25	**Dr. Lin Xu** (University of Southampton) «Compact High-Pulse-Energy Mid-IR Picosecond Optical Parametric Sources».
10:30	Discussion on the session presentations
11:00	***Coffee break***
Session 5. Quantum Optics (Chair, Dr. Joaquín Campos)	
11:30	Keynote, **Prof. Stephen Barnett** (University of Glasgow) «The strongly damped quantum harmonic oscillator».
12:05	**Dr. Rob Cameron** (Glasgow) «Chiral optical force».
12:10	Keynote, **Prof. Humberto Michinel** (University of Vigo) «Dark-Matter Optics».
12:45	**Dr. Ángel Paredes Galán** (University of Vigo) «On quantum corrections to ultra-intense laser propagation in vacuum».
12:50	General Discussion on session presentations
13:30	***End of session***
15:00	**Session: Posters display**
16:00	**Closing remarks**

SUMMARY OF DISCUSSIONS

In this workshop we celebrated the international year of light through the theme of «***Optical Technologies for Society***». The workshop consisted of five topics: Nanophotonics, Optical Communications, Biophotonics, High Power Lasers and Quantum Optics. These diverse topics have in common the potential for real impact on society from the short to the long term. Indeed, in some areas real impact has already been achieved.

■ **Session 1 (Nanophotonics)** started with a keynote talk by Jeremy Baumberg. He discussed a number of research directions including the use of nano gold particles to enhance local field strengths that can then be used as a probe of molecular properties. There was also a «bio» flavour to the work where lipid molecules can be studied. Giuliana Di Martino then followed with a presentation on the use of light to grow tailored gold nanowires. The second keynote talk, from Javier Garcia de Abajo, emphasized the potential of nanophotonics to approach physics on the atomic scale. This was followed by a presentation from Jose Ramon Martinez Saavedra on approaches to nanophotonics using electron beams. In a wide ranging discussion many potential applications of this technology were discussed.

■ **Session 2 (Optical Communications)** began with a keynote talk by Juan D. Ania on the potential applications of stimulated Raman scattering in optical communications systems. The need for these advanced amplification schemes in the future being driven by the present rate of increase of demand for capacity. There followed a presentation from Pawel Rosa on a specific application of Raman amplifiers in systems using optical phase conjugation. The second keynote talk from Robert Killey looked at the issue of enhancing spectral efficiency, again driven by what is now known as the «capacity crunch». This was followed by a presentation from Gabriel Saavedra Moncada on the use of wideband amplification schemes to open new parts of the spectrum for optical transmission. The discussion focussed on the necessity for advanced transmission schemes in fibre based communication systems. The conflict between the capacity crunch agenda and the green agenda was also considered.

■ **Session 3 (Bio-photonics)** began with a keynote talk by Sergei Sokolovsky entitled «Cancer Photo- diagnostics and Treatment». He presented how different photonics technologies are used to diagnose cancer, their advantages and limitations. Technology is ready not only for diagnosis but for photo-treatment as well. However some more research has to be done in molecular biology to distinguish cancerous cells from normal ones. Afterward Ilya Rafailov presented the work being done on a cross-sectional model to simulate and visualize the optical properties of the urinary bladder. The second keynote in this section was given by Susana Marcos who spoke about how optical technologies can be used to better understand vision and provide useful tools for visual corrections. Eduardo Martínez-Enríquez, presented the work «Quantitative anterior segment optical coherence tomography» as an example of the technologies used in this field. The discussion focused on the social impact of these techniques on the role of psychophysics in some experiments and on the challenges for cancer detection.

■ **Session 4 (High Power Lasers)** began with a keynote talk by Luis Roso on the topic of Extreme Lasers. In contrast to most laboratory based lasers, extreme lasers are typically the size of an entire building and consist of many amplification stages and lasers all coupled together. He discussed the new CLPU facility being built at the University of Salamanca and the expected operating parameters. Francisco Valle then discussed the methods for generating X-rays from a laser source. The second keynote talk by Shaif-ul Alam discussed the state of the art in optical fibre lasers. In particular he highlighted many applications of such lasers. Lin Xu then gave a presentation on recent work on high power mid-IR sources. Much of the discussion related to the new physics and applications that such sources would enable.

■ **Session 5 (Quantum Optics)** began with a keynote talk by Stephen Barnett who discussed the quantum physics of the strongly damped harmonic oscillator, a model that should have direct application in the nanophotonics area. He emphasized the need to look beyond traditional perturbation approaches. Rob Cameron then gave a presentation on chiral optical forces which offer the prospect of separating chiral molecules into their L and R forms. This would have immediate impact in the field of drug development. The second keynote talk by Humberto Michinel was devoted to dark matter, a topic of enormous current interest in astrophysics. He showed that some of the dark matter models have similar counterparts in optical physics. The final talk by Angel Paredes Galan was on quantum effects induced by ultra-intense lasers propagating in a vacuum. The discussion focused on the issue of quantum effects in nanophotonic systems.

New CLPU facility at the University of Salamanca.

ABSTRACTS

High Power Fibre Lasers: Harnessing the Power of Light

Dr. Shaif-ul Alam *(University of Southampton)*

Here we present a review on the recent progress of high power fibre lasers and their potential applications in different fields of science and industry. Tremendous advances have been made in fibre laser technology over the past decade to the extent that fibre lasers are displacing the existing solid state, gas and dye based laser systems in many application sectors. In terms of practical utility, the fully fiberized nature of the laser cavity allows for robust, reliable and compact designs with superior beam quality. Furthermore, the ultra-high efficiency offered by the fibre lasers will make them a technology of choice to meet the future green credentials.

Fibre lasers are renowned for their transparency to operate over a wide frequency range (Hz to GHz) and pulse widths (femtoseconds to continuous wave). In the continuous wave regime, tens of kilowatts average output power with diffraction limited beam quality and hundreds of kilowatts with slightly multimode beam have been demonstrated with the genuine possibility to scale those further. Furthermore, fibre lasers can operate over the entire 1-2 µm wavebands with hundreds of watts of output power making them attractive for numerous applications. In the pulsed regime, maximum average output power demonstrated to date is of the order of a kilowatt, significantly higher than those available from its solid state counterpart. Although energy extraction is somewhat limited due to the onset of deleterious nonlinear effects, however recent progresses made in the design of large mode area fibres, implementation of divide pulse amplifications in combination with chirped pulse amplifications and coherent combinations, it is envisaged that femtosecond pulses with tens of Joules pulse energy operating at tens of kilohertz repletion frequency is realistic from a fibre based system making them attractive for many scientific applications including laser assisted particle acceleration (Wakefield accelerator) and nuclear fusion. In short, fibre based laser systems are extremely versatile photon-engine.

The strongly damped quantum harmonic oscillator

Prof. Stephen Barnett *(University of Glasgow)*

We analyse the properties of a strongly-damped quantum harmonic oscillator by means of an exact diagonalisation of the full Hamiltonian, including both the oscillator and the reservoir degrees of freedom to which it is coupled. Many of the properties of the oscillator, including its steady-state properties and entanglement with the reservoir can be understood and quantified in terms of a simple probability density, which we may associate with the ground-state frequency spectrum of the oscillator.

Watching and controlling individual atoms and molecules by confining light to the nanoscale using plasmonics

Prof. Jeremy J. Baumberg *(University of Cambridge)*

How tightly can we confine light? For many years this was thought to be the optical wavelength, but new insights allow us to squeeze it down to a single cubic nanometre. This opens up a new regime where we can watch single molecules, and sculpt directly on the nanoscale using light. By combining metallic nano-objects at very close distances, we squeeze light into these tiny dimensions at resonant wavelengths whose colour depends exquisitely on the nanoscale geometry. Below 1nm gaps, we detect the influence of quantum mechanics in the optical signatures, at room temperature and ambient conditions. We also show how it is possible able to track single molecules, and discuss the implications for nano-chemistry and healthcare technologies.

(1) Nature 491, 574 (2012); Revealing the quantum regime in tunnelling plasmonics

(2) ACS Nano 5, 3878 (2011); Precise sub-nm plasmonic junctions within Au NP assemblies

(3) Nano Lett 13, 5033 (2013); Controlling sub-nm plasmonic gaps using graphene

(4) ACS Nano 9, 825 (2015); Monitoring Morphological Changes in 2D Monolayer Semiconductors

(5) Nano Letters 15, 669 (2015); Nano-optics of molecular-shunted plasmonic nanojunctions

(6) Science Reports 4, 5490 (2014); Watching individual molecules flex within lipid membranes

(7) Nature Comm. 5, 4568 (2014); Threading plasmonic nanoparticle strings with light

(8) Nature Comm. 5, 3448 (2014); DNA origami based assembly of Au nanoparticle dimers for SERS…

(9) Scientific Reports 4, 6785 (2014); Quantitative multiplexing with nano-self-assemblies in SERS…

(10) Nano Lett 13, 5985 (2013); In-situ SERS … of photochemistry within a nano-junction reactor

(11) Nano Letters 15, 2600 (2015); Demonstrating PL from Au is Electronic Inelastic Light Scattering

(12) JPCL 6, 1099 (2015); Plasmonic Nanogaps for Enhanced Photocatalytic Water Splitting

(13) ACS Nano 9, 825 (2015); Controllable Tuning Plasmonic Coupling with Nanoscale Oxidation

(14) PRA 92, 053811 (2015); Hybridization of plasmonic antenna and NPoM cavity modes

(15) Nano Letters 15, 7452 (2015); Controlling Nanowire Growth by Light

Chiral optical force

Robert P. Cameron *(University of Glasgow)*

Light carrying helicity in unusual ways can accelerate the opposite enantiomers of a chiral molecule in opposite directions; a remarkable phenomenon that may find use in a wealth of new applications. Stegosaurus exhibited exterior chirality.

Spectrally efficient optical transmission systems

Robert Killey *(University College London)*

The rapid growth in the volumes of data traffic is driving the need for spectrally efficient optical fibre transmission system technology. We investigated techniques to maximise spectral efficiency including high order quadrature amplitude modulation (QAM) and Nyquist-spaced wavelength division multiplexing. Using a recirculating fibre loop, we experimentally demonstrated polarisation multiplexed 16QAM and 64QAM Nyquist WDM transmission over long haul distances, with net information spectral densities of over 9 b/s/Hz, and compared the reach with analytical predictions based on the Gaussian noise model of nonlinear interference noise. We also assessed the performance gains that can be achieved through fibre nonlinearity compensation using multi-channel digital back-propagation.

Light for Vision

Susana Marcos *(Instituto de Óptica, CSIC)*

The eye is an incredible optical instrument capable of projecting images of the outsider world on the retina, and converting light into electrical signals that are interpreted in the brain, producing the visual impression. On the other hand, optical instruments allow us to quantify the structural and geometrical properties of the ocular components (cornea and lens), evaluate their optical quality, and manipulate the images that are projected on the retina to investigate visual function and neural adaptation to blur. In this conference, I will present novel optical imaging Technologies (optical coherence tomography, adaptive optics) that allow to investigate quantitatively the optical system of the normal and pathological eye, as well as eyes following optical or surgical treatment. These Technologies not only allow investigating the basic mechanisms of vision, but also the diagnostics and guiding of treatment, as well as advance in the development of new treatments of highly prevalent conditions in the population, such as presbyopia. Some of these technologies are trespassing the limits of laboratories to become instruments in the clinical practice, facilitating from the prescription of refractive error corrections to intraocular lenses for the correction of presbyopia.

Quantitative anterior segment optical coherence tomography

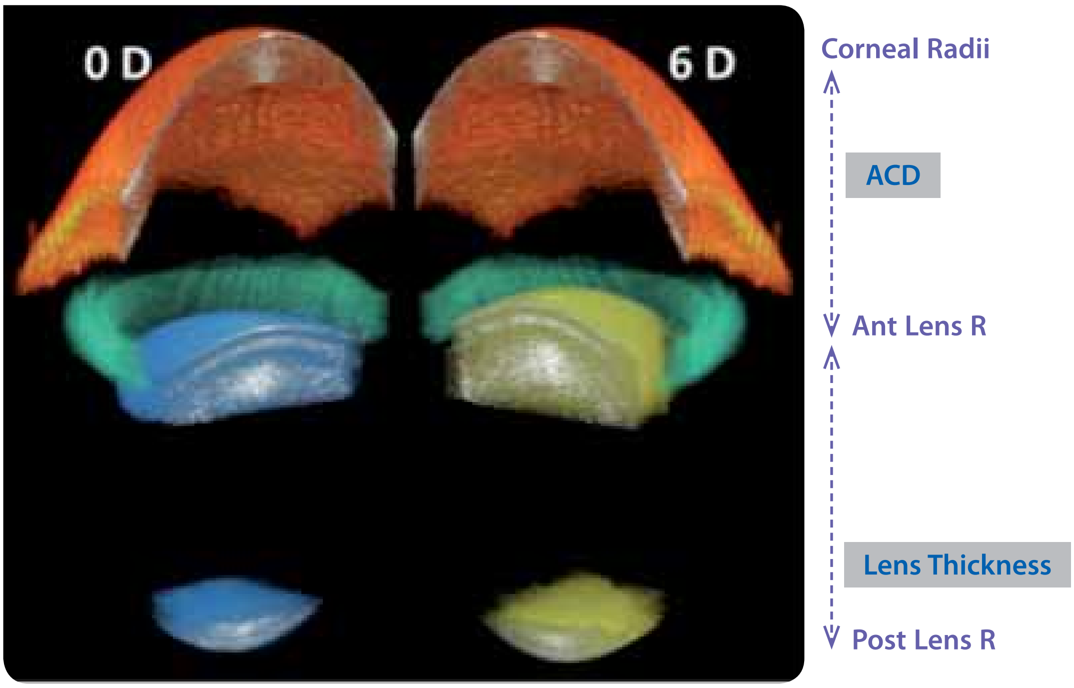
Eduardo Martínez-Enríquez, Mengchan Sun, Miriam Velasco-Ocaña, Pablo Pérez-Merino, Susana Marcos *(Instituto de Óptica, CSIC)*

Age-related cataract is a cause of blindness on a global scale (43% of worldwide blindness) due to biological aging, genetic, and environmental factors of the crystalline lens, which loses its transparency. Cataract surgery has become a routine surgical procedure, with a treatment rate of 4,000 to 6,000 operations per million population each year in economically developed countries. Traditionally, a foldable-monofocal and spherical intraocular lens (IOL) replaces the opacified crystalline lens. To optimize the visual quality after surgery, it is crucial to select the IOL power to be implanted for every individual patient, which is calculated by using few preoperative input data and statistical regression formulas obtained from a large population sample. However, the disadvantage of these approaches is that the formulas only work for the data set from which are derived, and thus can fail for a new «not seen» patient.

The current advances in imaging techniques have opened the possibility of research new approaches for providing a better IOL power calculation and for improving the IOL design for future customized IOLs. Modeling the optics of an individual patient´s eye and predicting the resulting optical performance addresses a current unmet need in visual optics.

In this work we present for first time the construction of customized anterior segment three-dimensional (3-D) models from Optical Coherence Tomography (OCT) technology. Given a set of OCT images,

Anterior segment 3-D models for two different accommodative states



3-D models are achieved by *(i)* automatic image processing algorithms to segment the surfaces of interest (iris, anterior and posterior surfaces of the cornea and of the crystalline lens or IOL) and *(ii)* distortion correction (fan distortion, that arise from the optical elements of the OCT; and optical distortion, due to refraction at the optical surfaces). Once we build accurate 3-D models from anatomical information of the patient, quantification is performed by fitting elevation data to parametric models or to Zernike polynomials.

Using these models and ray tracing analysis, the IOL power selection or even the IOL design can be optimized for an individual patient. Furthermore, they can be used for very different applications, and for discovering new knowledge about the eye, which will be essential to propose new corrections techniques for different diseases as presbyopia.

Growing nanowires by light

Dr. Giuliana Di Martino *(University of Cambridge)*

Individual Au catalyst nanoparticles are used for selective laser-induced chemical vapour deposition of single germanium nanowires. Dark-field scattering reveals in real time the optical signatures of all key constituent growth processes. The process is initially triggered by plasmonic absorption in the Au catalyst, whilst once nucleated the growing Ge nanowire supports magnetic and electric resonances which then dominate the laser interactions. This spectroscopic understanding allows real-time laser feedback which is crucial towards realizing the full potential of controlling nanomaterial growth by light.

Dark Matter Optics

Humberto Michinel and Ángel Paredes *(Universidad de Vigo)*

Recently, the first evidence of dark matter (DM) non-gravitational self-interaction has been reported for the Abell 3827 cluster, where a displacement of the luminous mass with respect to the maximum density of its DM halo has been observed, for some of the merging galaxies. A plausible explanation for this puzzling behavior is that local interactions with the cluster halo induce a drag force, which slows down the galactic DM distribution, while leaving the standard model sector unaffected. However, we have presented an alternative interpretation, considering that part or all of DM consists of Bose-Einstein condensed ultra-light axions that can form robust coherent solitons, which display interference properties that may be the cause of the offsets.

Thus, we present exhaustive numerical evidence supporting the idea that the detected shifts in position can come from the repulsion between coherent DM wave clouds in phase opposition, without any extra local interactions. This destructive interference behavior between robust wave lumps is well known in soliton systems, from nonlinear optics to atomic physics, where the mathematical description of the phenomena is similar to the theory of coherent DM waves.

Therefore, it is plausible that interference between dark waves can have observational consequences for galactic mergers and, in particular, it can explain the significant observations recently obtained. Even if present data do not allow for a detailed modelling, we have presented evidence, in simplified situations, showing that qualitative features can be reproduced in a rather robust way and that they are reminiscent of soliton repulsion in nonlinear optics and atomic matter waves. In fact, refined control of trapped atoms and optical media, including the introduction of gravity-like interactions, might allow for laboratory analogue simulators of galactic-scale phenomena.

Through future astrophysical observations, the scientific community will be able to discern the present scenario from models with explicit DM self-interactions. In our model, the force acting on DM is between galaxies and not between a galaxy and the cluster halo. Moreover, the outcome depends on the random value of the relative phase at the moment of the collision. Finally, we must point that the lack of observation of DM self-interaction for collisions at larger scales is expected because the coherent solitary waves are associated to independent galaxies but not to clusters.

Acknowledgements:

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On quantum corrections to ultra-intense laser propagation in vacuum

Ángel Paredes *(Universidad de Vigo)*

The classical propagation of light beams in vacuum is precisely described by Maxwell equations. Nevertheless, quantum effects related to the creation of real or virtual particle-antiparticle pairs introduce corrections to the classical result. Heuristically, we can think of the vacuum as a material whose nonlinear effects become important when the electric field approaches the Schwinger limit 1.3×1018 V/m. This phenomenon has been theoretically discussed since the thirties, but it has never been observed in spite of serious experimental efforts.

The rapid development of photonic technology may open the door to the study of this interesting question in the coming years. Here, we discuss the possibility of using ultra-intense lasers in this context. The creation of unprecedented extreme laboratory conditions can be useful for the exploration of fundamental physics, in a regime that is complementary to charged particle colliders. Pushing current experimental bounds might lead to the confirmation of the standard model in yet untested regions of parameter space or, even more interestingly, to hints of new physics.

In this contribution, we provide a partial overview of the status of present and near future facilities and of the literature concerning concrete proposals for experiments. This includes the search for effects as four-wave mixing, light-by-light diffraction, harmonic generation, pair production in a hohlraum, self-correction of intense beams and phase shifts for beams crossing in vacuum.

Acknowledgements:

Funded by MINECO through grant FIS2014-58117-P and by Xunta de Galicia through grant EM2013/002

Raman amplification for nonlinear impairment compensation using optical phase conjugation

Paweł Rosa, Giuseppe Rizzelli and Juan Diego Ania-Castañón
(Instituto de Óptica, CSIC)

The nonlinear-Shannon limit sets a cap to maximum capacity in single mode optical fibres. To combat fibre nonlinear effects, using mid-link or transmitter-based optical phase conjugation (OPC) enables real time compensation of all deterministic (signal × signal) nonlinear impairments. However, the degree of nonlinear compensation using mid-link OPC is related to the symmetry match of the conjugated and transmitted signal power evolution in the fibre. Meaningful performance improvement has only been demonstrated in Raman-based amplification optical links, thanks to the better control over signal symmetry provided by distributed amplification, as well as its improved noise performance. The key to maximise performance in OPC-assisted systems, lies in reducing signal power asymmetry within the periodic spans while ensuring a low impact of noise and non-deterministic nonlinear impairments in the over-all transmission link.

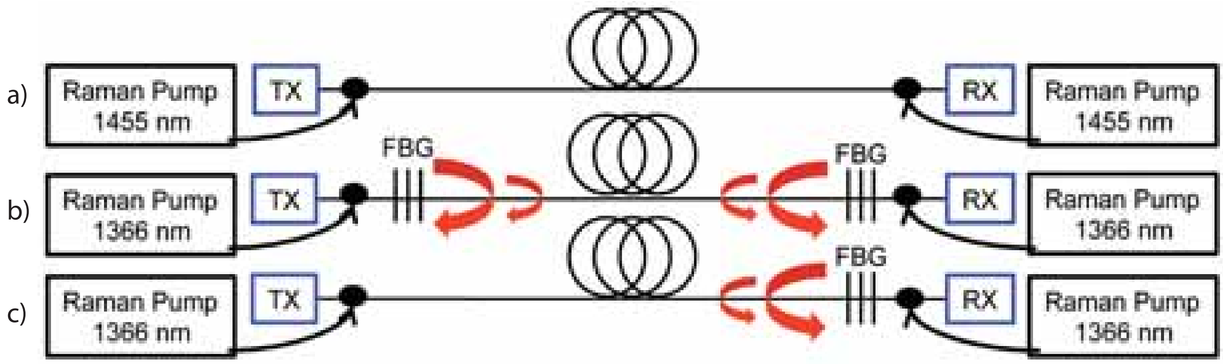


Figure 1. Schematic design of 1st order Raman (a), 2nd order URFL (b) and random DFB Raman laser amplifier (c).

In this letter, we demonstrate, using proven numerical models, that almost ideally symmetrical signal power evolution can be achieved in advanced distributed amplification schemes, with the best results obtained for half- open-cavity random distributed feedback (DFB) Raman laser amplifier with bidirectional 2nd order pumping. This setup allows to potentially reduce signal power evolution asymmetry inside the span with respect to its middle point to a mere 3% over a realistic span of length- 62 km SMF, which constitutes the highest level of symmetry achieved up to date on such a long span.

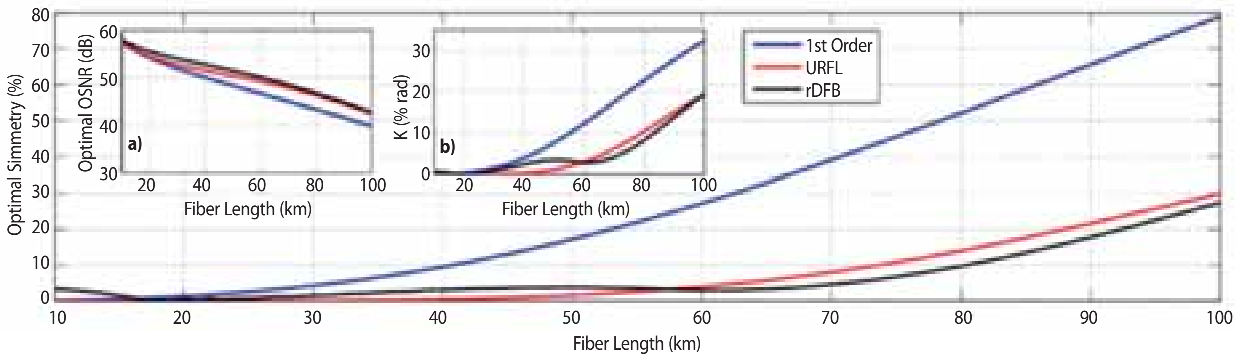


Figure 2. Lowest signal power asymmetry for a given length and amplification setup. Insets show the corresponding best OSNR (a) and the accumulated Residual Phase Shift (product of nonlinear phase shift and asymmetry) (b).

Cross-sectional model to simulate and visualise the optical properties in urinary bladder

I.E. Rafailov, L. Zang, S.G. Sokolovski, E.U. Rafailov, K.S. Litvinova *(Aston University, Birmingham)*, **V.V. Dremin, A.V. Dunaev** *(State University, Oryol)*

Urinary bladder cancer (UBC) is one of the top ten most common cancers worldwide. Due to the high rates of recurrence and progression, it has a considerable level of patient morbidity and is considered among the most expensive cancers to treat and monitor per patient. We aim to develop and describe a cross-sectional bladder optical property model based on the optical properties and autofluorescence data of biological tissue. It must be capable of visually representing the passage of photons through the tissue layers. The transmission coefficients (of scattering and absorption) were calculated from absorption, transmission and reflectance data gathered from male pig urinary bladder tissue using spectrophotometry. A «generic» cross-section optical property model was constructed using these calculated properties. Models of diagnostically important biomarkers were constructed through a combination of the Monte-Carlo method and the fluorescence spectra generated by UV and blue wavelengths. Further essential comparison data of pig bladder tissue was obtained in the form of fluorescence spectra by the «LAKK-M» system. The ultimate aim was to determine the effectiveness of photonics diagnostics devices by simulating effects of varying exciting radiation wavelengths. Further improvements to the model accuracy could lead to creating clinically relevant, reliable avenues for cancer and other early disease detection.

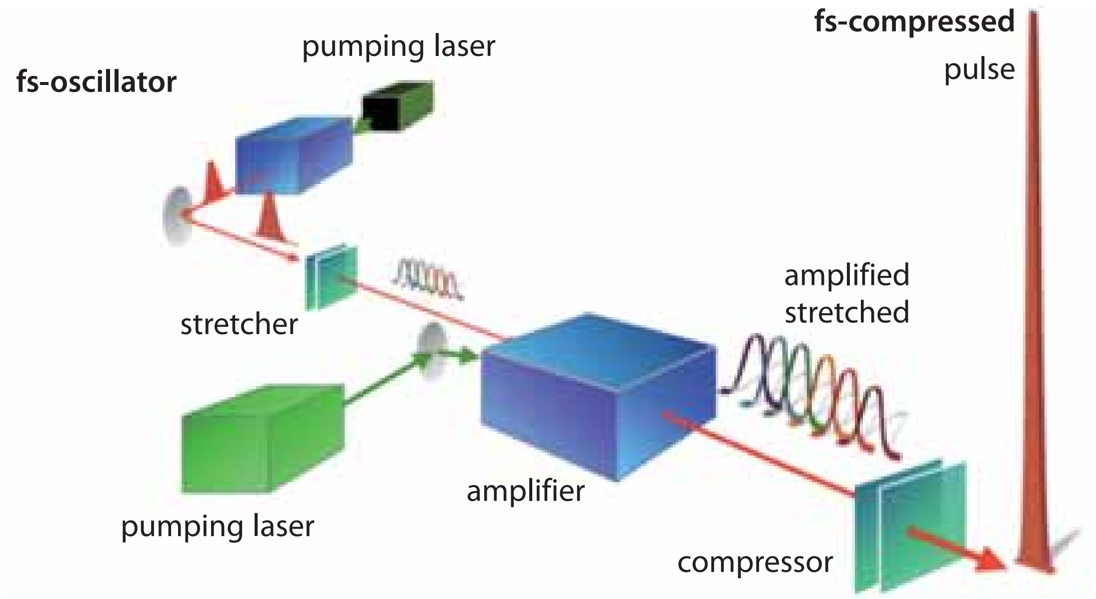
Extreme lasers

Luis Roso y Francisco Valle *(Centro de Láseres Pulsados, CLPU, Salamanca)*

Since the construction of the first laser in 1960 by Maiman, it was clear that lasers can lead to unexpected concentrations of radiant energy. Techniques such as Q-switching and particularly Mode-Locking soon broke all conceived intensity barriers. As more intensity was available, new phenomenology appeared and new physics was possible. Imagine, for example the tremendous advance in atomic and molecular spectroscopy that represented in the seventies the saturation spectroscopy techniques. So lasers and laser amplifiers where moving for higher and higher intensities. By early eighties it was realized that as the intensity increases the energy density inside the amplifier crystal rod was too high and an important risk of breaking down such amplifier. Is this a fundamental limit? Apparently yes, but science has been able to overpass it. Fortunately by mid-eighties, a group of researches at the Laser Laboratory at the University of Rochester (Rochester, NY), headed by Gerard Mourou, discovered a very clever trick to overcome this problem. This was the launching of the ultraintense laser technology.

If your amplifier gets enough pumping to amplify more and more a laser pulse, then the pulse will eventually be so intense that light will damage the own amplifier that created it. To reduce the energy density you can expand your laser in space and in time. Expansion in space means that you must have a cross section as big as possible (but this is difficult in general, because it implies wider optics and a much more complicated technology). The concept behind CPA is a scheme to increase the energy of a short pulse, while avoiding very high peak power in the laser amplification process itself. The clear fresh idea was to expand in time the pulse. A short pulse, because it is short in time, has a broad spectrum. When propagating through a dispersive medium it broadens since different frequency components propagate at different speeds. Once broadened, the pulse intensity is consequently reduced, and thus much amplification is possible. Once amplified, the long pulse can be recompressed with a pair of diffractive gratings, or with other optical systems, that compensate the dispersion from the stretcher of the beam, and the energy is concentrated in time ideally to the same pulse duration of the initial pulse. In other words, this technology allows the extraction of the energy from the amplifier crystal distributed in time. This technique is now called CPA (Chirped Pulse Amplification)

The application of CPA to lasers originated with the work of Mourou and his co-workers. This is done by lengthening the duration of the pulse being amplified in a reversible fashion, using the technique of optical pulse compression, developed by Treacy and Martínez. By lengthening the pulse in time, energy can be efficiently extracted from the laser gain medium, while avoiding damage to the optical amplifier. CPA is particularly useful for efficient utilization of solid-state laser media with high stored energy density (1 J/cm^2), where full energy extraction in a short pulse would lead to intensities above the damage threshold of the amplifier materials.



[1] Those lasers at the beginning where called T^3, from TTT i.e. Table Top Terawatt. It was a breakdown in the late eighties to achieve the Terawatt peak power jus over a more or less conventional optical table. Probably in the future the TTP, Table Top Petawatt, will be feasible.

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Wide-band amplification for increased capacity for optical transmission

Gabriel Saavedra *(University College London)*

Due to the exponential increase of data demand over the years it is necessary to achieve as much capacity as possible from existing infrastructure. One approach to achieve this is by maximising the use of available Bandwidth. Raman amplification presents several benefits over standard Erbium Doped Fibre Amplifiers (EDFA), one of them being the possibility to obtain Wide-band amplification by combining different pump frequencies. By pumping a separate fibre to obtain amplification, instead of the ones used for transmission, a discrete Raman amplifier is fabricated, avoiding this way the use of high pump optical powers travelling through the transmission system. Here we present the study of a discrete Raman amplifier analyzing, across the whole amplification bandwidth, the noise figure (NF) and net gain (G) for different fibre types and lengths. The results are compared with an EDFA, concluding that similar noise figures are achieved for the same net gain obtaining a bandwidth at least two times larger by using four pump frequencies in the Raman amplifier.

Wide-band amplification for increased capacity for optical transmission

Gabriel Saavedra *(University College London)*, **F. Javier García de Abajo** *(Instituto de Ciencias Fotónicas, ICFO)*

Due to the exponential increase of data demand over the years it is necessary to achieve as much capacity as possible from existing infrastructure. One approach to achieve this is by maximising the use of available Bandwidth. Raman amplification presents several benefits over standard Erbium Doped Fibre Amplifiers (EDFA), one of them being the possibility to obtain Wide-band amplification by combining different pump frequencies. By pumping a separate fibre to obtain amplification, instead of the ones used for transmission, a discrete Raman amplifier is fabricated, avoiding this way the use of high pump optical powers travelling through the transmission system. Here we present the study of a discrete Raman amplifier analysing, across the whole amplification bandwidth, the noise figure (NF) and net gain (G) for different fibre types and lengths. The results are compared with an EDFA, concluding that similar noise figures are achieved for the same net gain obtaining a bandwidth at least two times larger by using four pump frequencies in the Raman amplifier.

Electron Beams for Nanophotonics at the Atomic Scale

J.R.M. Saavedra and F. Javier García de Abajo
(Instituto de Ciencias Fotónicas, ICFO)

Electron beams are a valuable tool for nanophotonics thanks to their evanescent electric fields, which make electrons behave as spatially focused white light sources at optical frequencies. Indeed, electron-based spectroscopy techniques have better spatial resolution than optical microscopies for the same excitation energy, due to the smaller de Broglie wavelength of the electron compared to the photon, thus avoiding the diffraction limit at smaller scales (1).

Relying on these properties, we theoretically investigate the directional light emission from a particle array when it interacts with focused electron beams passing parallel to it (Smith-Purcell emission). We study the necessary conditions for Smith-Purcell emission by arbitrary arrays and conclude that SP radiation can appear not only in periodic structures but also in non-periodic structures (2).

In a different development, motivated by recent advancements in the energy and spatial resolutions of transmission electron microscopes (3), we explore the interaction of focused electron beams with the vibrational modes of carbon 2D nanocrystals. We find the electron energy-loss probability to mimic the density of vibrational states: both of these magnitudes evolve smoothly with cluster size towards the extended graphene limit. Our results support the use of phonons as long-lived, tightly-confined substitutes of plasmons (4).

Spatially-resolved excitation of phonons in triphenylene. We show an EELS spectrum (solid curve) calculated for 100 keV electrons focused at the position indicated by a vertical arrow in the density plot. The latter represents a 0.19 eV energy filtered map. Atomic displacements associated with one of the 4-fold degenerate 0.19 eV vibrational modes are shown by open arrows. The dashed curve represents the local density of vibrational states (LDVS) at the beam position.

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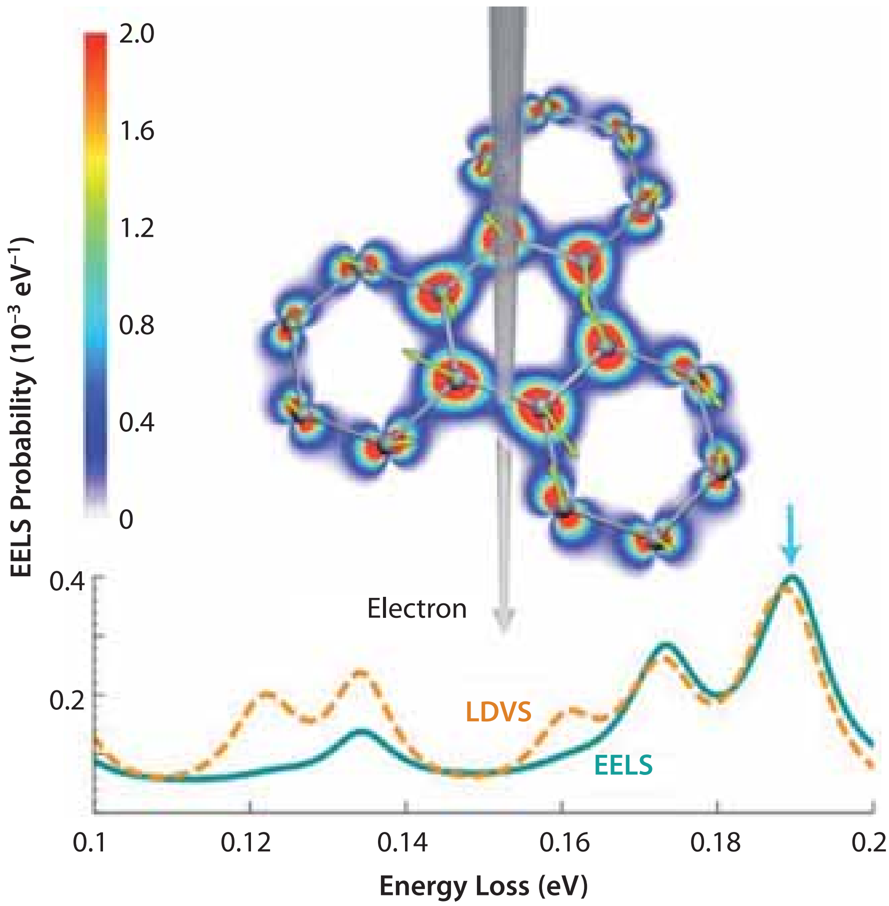
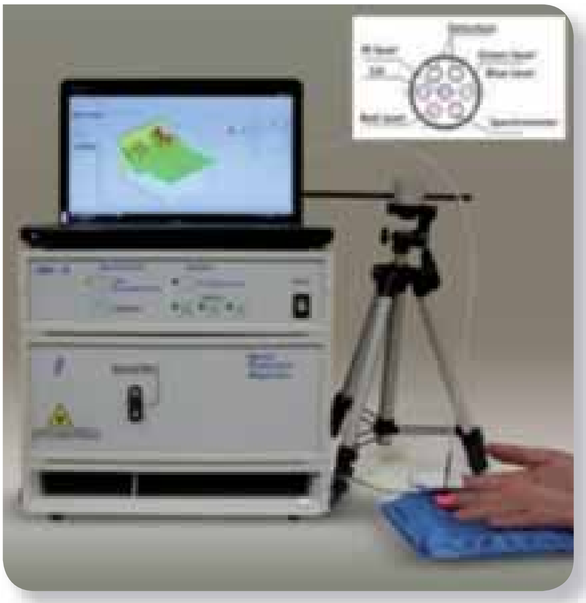


Cancer Photo-Diagnostics and Treatment

Sergei G. Sokolovski *(Aston University, Birmingham)*



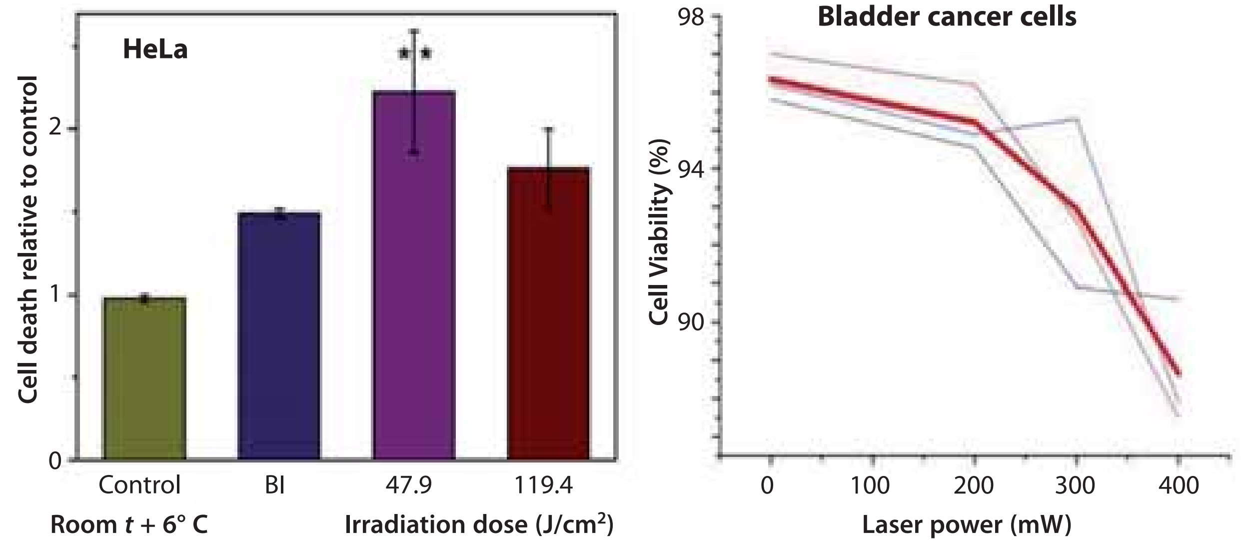
The fields of photonics and biophotonics have witnessed real progress and accomplishments. This has led to the development and introduction of novel and compact non-invasive optical diagnostic devices into biomedicine. The application of laser technology to diagnostic and therapeutic regimens across different medical fields has become widespread, encompassing diverse specialities ranging from ophthalmology to oncology. Accordingly to EU statistical analysis 7.6M deaths from cancers happened in 2008 and 13.1M are expected in 2030. However existing cancer photo-diagnostic approaches like golden standard biopsy, photodynamic diagnostics, OCT, MRI are very subjective and most promising issue Raman imaging/spectroscopy, multi-photon fluorescence spectroscopy are under development and still far from the implementation to the medical practice. Nevertheless the normal cell-to-cancer cell transformation and development malignant tumour change metabolic activity, oxygen consumption, alteration of the cell matrix and even developing its own vascular system. All these can be criteria in designing photonic diagnostic devises. The integration of various techniques in an instrument and methodological framework that combines them in a single device using integrating algorithms for multi-modal diagnostics is particularly promising. Multi-functional laser non-invasive diagnostic systems (see figure) are emerging laser Doppler flowmetry to detect tumour vascular system, reflectance oximetry for assessment of the cancer tissue oxygenation, and fluorescence spectroscopy which can reveal specific cancer biomarkers (porphyrins, collagen/elastin and redox ratios). All these can give comprehensive diagnostic information during even initial check in General Practice.

Existing photodynamic therapy (PDT) is a technique developed to treat the ever-increasing global incidence of cancer. PDT is based on the photodynamic effect (PDE) with resultant photosensitised cell damage (apoptosis) in the presence of light and oxygen. Photodynamic therapy is usually performed with use of a photosensitiser (PS), which is however absorbed both by healthy tissues and by the tumour. However, the PS is absorbed both by healthy tissues and by the tumour leading to in some cases prolong sensitivity of patients to intensive light. Due to this side effect, the low specificity of PSs to cancer types, and the cost of PS administration (for oesophageal carcinoma with post PDT period of 4-6 days £4370-6000), there is a need for further research in PDT methods for development of cancer phototherapy without the need for a PS.

The development of quantum-dot lase r diodes emitting in the highest absorption region (1268 nm) of triplet oxygen ($^3O_2$) presents the possibility of inducing apoptosis in tumour cells through direct $^3O_2$ to $^1O_2$ transition. Here we demonstrate that a single laser pulse triggers dose-dependent $^1O_2$ generation in both normal keratinocytes and cancer cells (HeLa and bladder) and show that tumour cells yield the highest $^1O_2$ far beyond the initial laser pulse exposure. Our modelling and experimental results support the development of direct infrared (IR) laser-induced tumour treatment as a promising approach in tumour PDT.

Laser generated X-rays

F. Valle Brozas, M. Huault, J. L. Sagredo Barcina, A. Peralta Conde and L. Roso *(Parque Científico Villamayor, Salamanca)*



Recently a laser based X-ray source has been developed in CLPU. This is the first based radioactive installation in Spain (License from the Spanish Nuclear Safety Council, IRA 3254). To generate the X-ray radiation, the laser is focalized on a metallic target (Copper) with intensities up to 10^{16} Wcm^{-2}. At these intensities, electrons are extracted, accelerated and reinjected in the target by the laser field producing the bremsstrahlung of these electrons and the K_α and K_β radiation coming from the shell of the target. X– ray and electron beam spectra have been obtained by using spectrometer and gafchromic films. The temperature of the electrons can be fitted to two Maxwell distributions (1) finding a temperature about 15 keV for hot electrons and 8 keV for cold electrons. This source has applications for radiography (2). The small x-ray focus allows to make radiographies with high definition (figure 2). Also the source has potentials applications in radiotherapy. The short radiation pulse opens the way to induce non-lineal damage in cells.

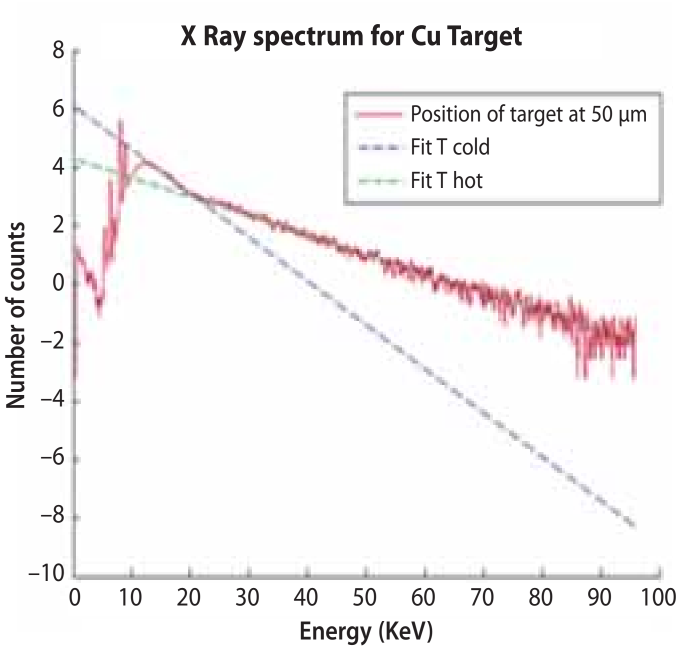


Figure 1. Spectrum of the x-ray source. The temperature of the electrons can be fitted to two Maxwell distributions (1).

Figure 2. Radiography of a bee made with our source.

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Compact High-Pulse-Energy Mid-IR Picosecond Optical Parametric Sources

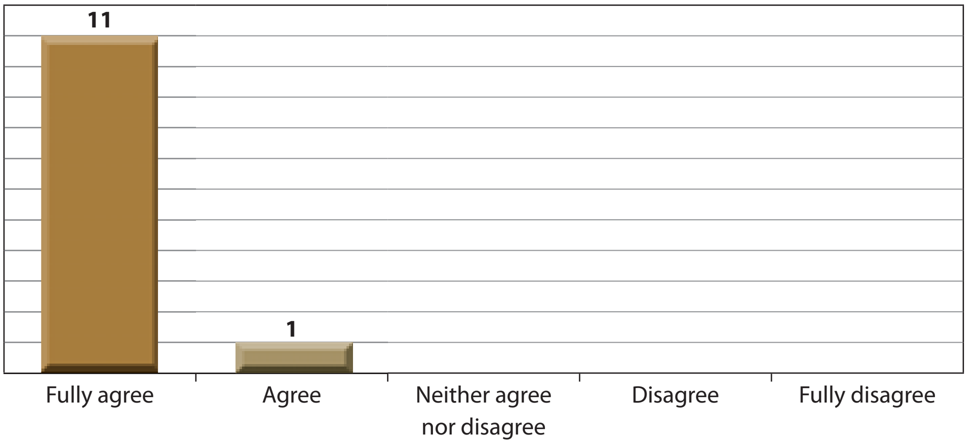
Lin Xu *(University of Southampton)*

We demonstrate high-energy picosecond mid-IR optical parametric generator/amplifier/oscillator (OPG/A/O) based on a MgO:PPLN crystal pumped by a fiber master-oscillator-power-amplifier (MOPA) employing direct amplification. An OPG tuning range of 1450-3615 nm is demonstrated with pulse energies as high as 2.6 µJ (signal) and 1.2 µJ (idler). When seeded with a narrow-linewidth, continuous-wave low power laser, maximum pulse energies of 3.8 µJ (signal) and 1.7 µJ (idler) are obtained at an overall conversion efficiency of 45%. We introduced a harmonic-cavity OPO that has a relatively compact cavity with a length that is a small fraction of that required to match the pump repetition rate. For a 1.554-m-long OPO cavity, resonating near-infrared signal pulses with a repetition rate that is the 193rd harmonic of the 1-MHz pump are demonstrated. The mid-IR idler output pulses, tunable from 2300 nm to 3500 nm, are generated at a 1-MHz repetition rate and have energies as high as 1.5 µJ.

EVALUATION QUESTIONNAIRE

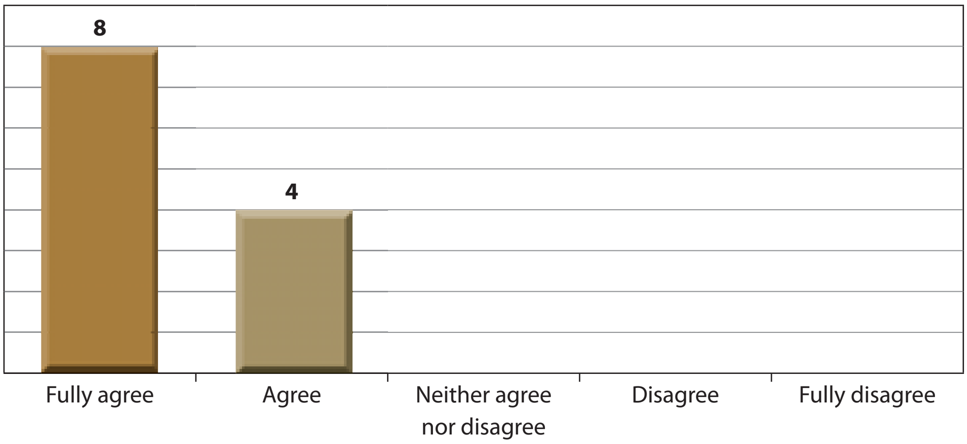
1. It was a well balanced programme

Fully agree	11
Agree	1
Neither agree nor disagree	
Disagree	
Fully disagree	



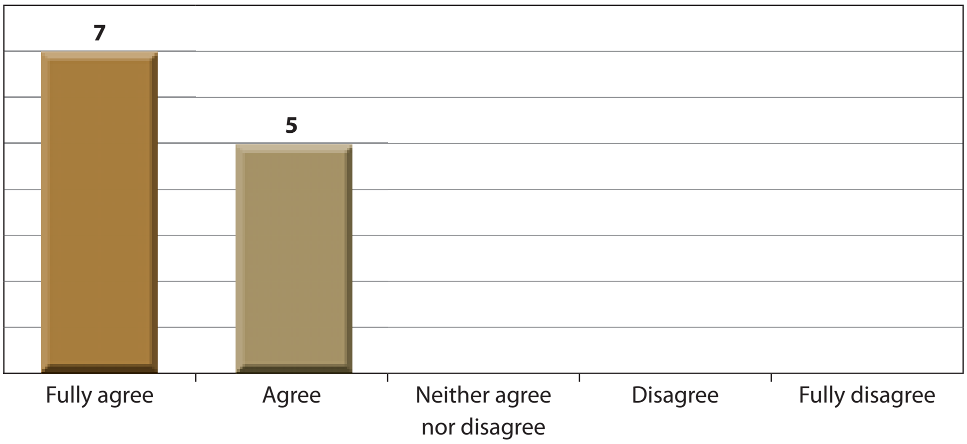
2. The discussion timing was right

Fully agree	8
Agree	4
Neither agree nor disagree	
Disagree	
Fully disagree	



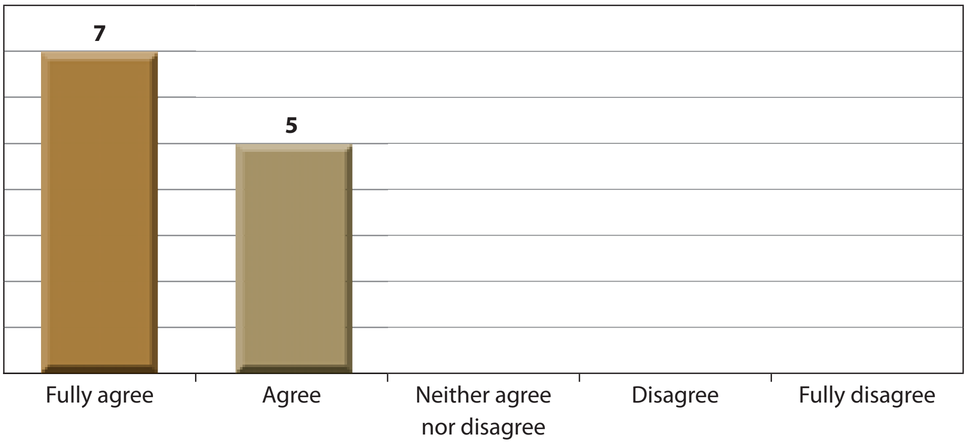
3. The length of the seminar was correct

Fuwlly agree	7
Agree	5
Neither agree nor disagree	
Disagree	
Fully disagree	



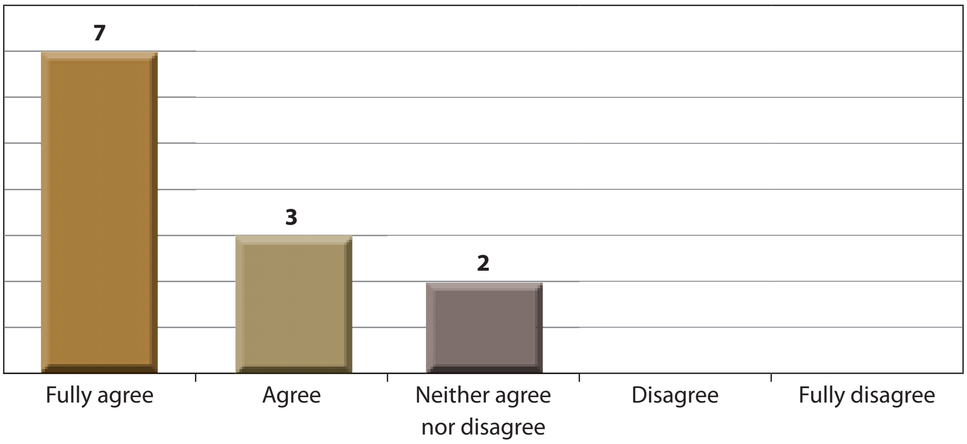
4. The mix of participants was right

Fully agree	7
Agree	5
Neither agree nor disagree	
Disagree	
Fully disagree	



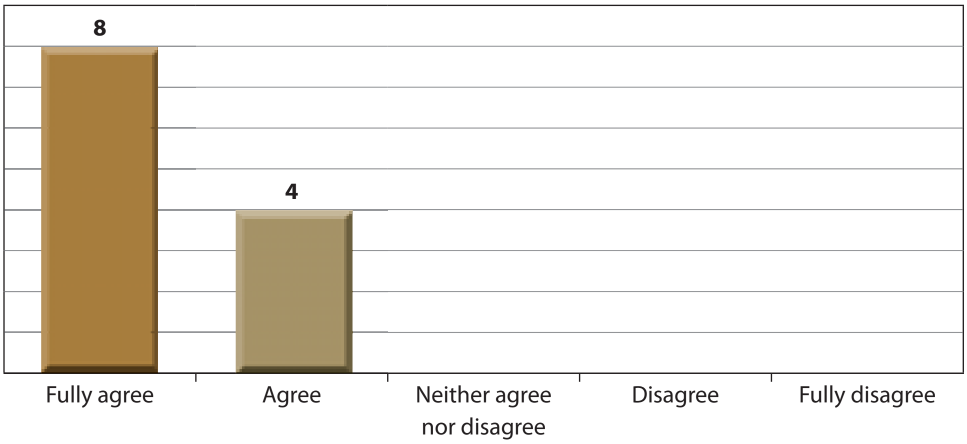
5. The conference facilities were good

Fuwlly agree	7
Agree	3
Neither agree nor disagree	2
Disagree	
Fully disagree	



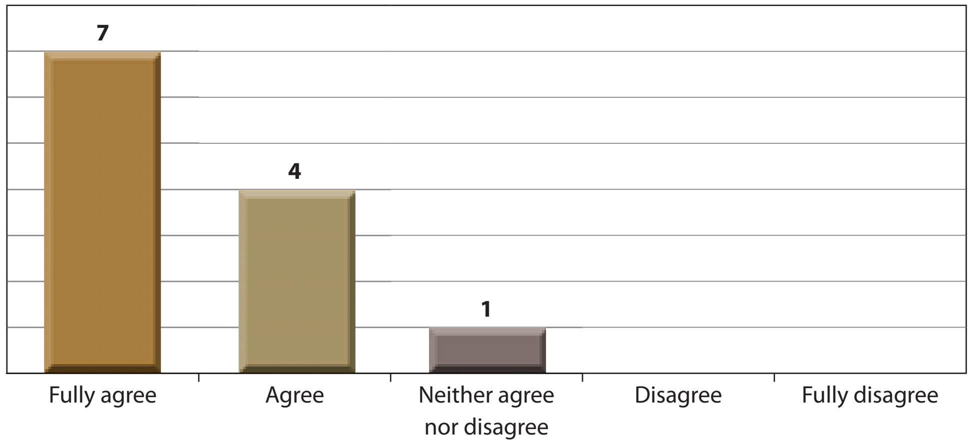
6. The standard of accommodation was good

Fully agree	8
Agree	4
Neither agree nor disagree	
Disagree	
Fully disagree	



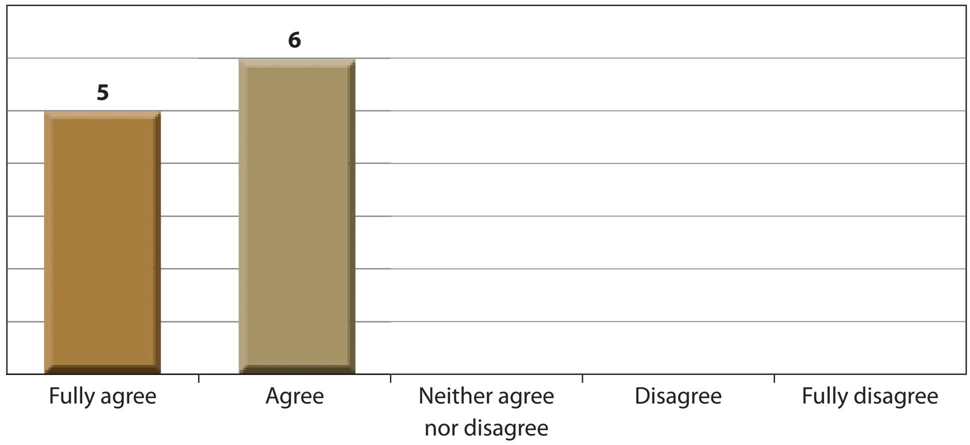
7. The food was good

Fuwlly agree	7
Agree	4
Neither agree nor disagree	1
Disagree	
Fully disagree	



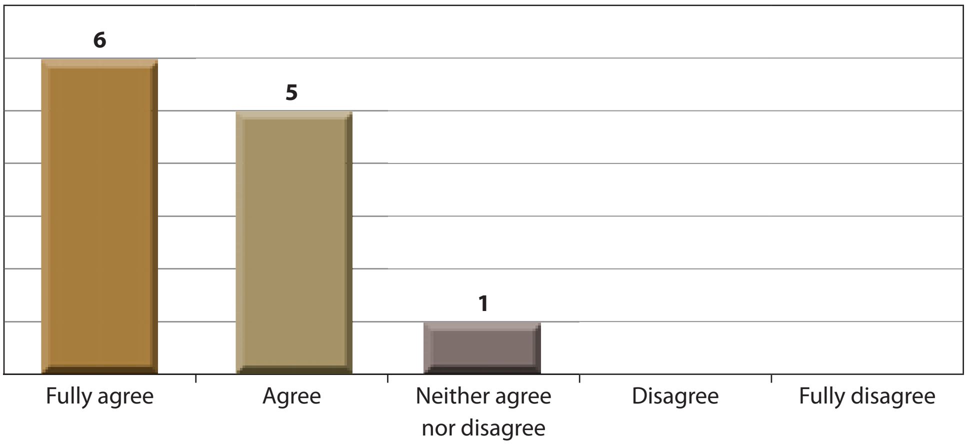
8. This seminar met my expectations

Fuwlly agree	5
Agree	6
Neither agree nor disagree	
Disagree	
Fully disagree	



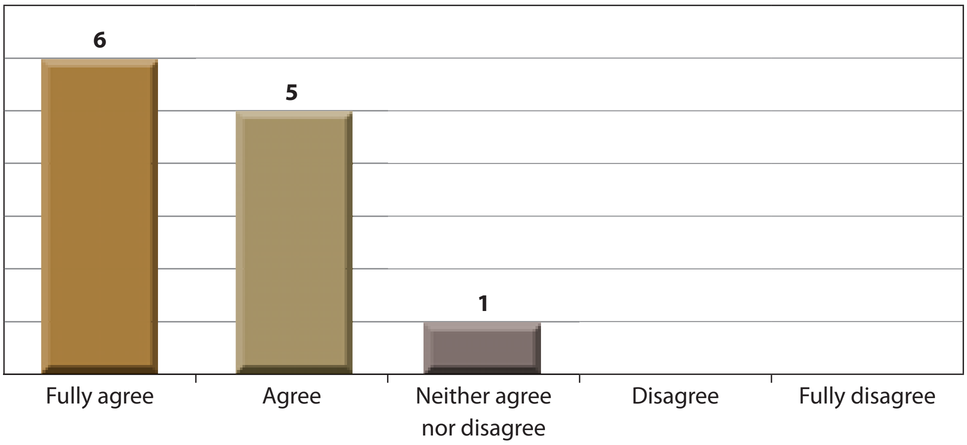
9. Overall, this was a high quality seminar

Fuwlly agree	6
Agree	5
Neither agree nor disagree	1
Disagree	
Fully disagree	



10. I have acquired new knowledge/or skills through this seminar

Fuwlly agree	6
Agree	5
Neither agree nor disagree	1
Disagree	
Fully disagree	



ACKNOWLEDGEMENTS

We would like to thank the British Council and the Consejo Superior de Investigaciones Científicas (CSIC) for organizing this series of scientific workshops, which provided a unique opportunity for young researchers from the UK and Spain to exchange ideas and explore potential collaborations. The meeting has provided many opportunities for dialogue and discussion, demonstrating the strength of our young scientists.
We would like to emphasize in particular the hard work and kindness of Belén Fortea (British Council) and Paloma Tejedor (CSIC), who made possible the success of the workshop, not only from the scientific point of view, but also providing a perfect framework for the necessary social interaction that this type of meeting requires, making it really enjoyable.


Further reading
Further reading

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