



Chalcogenide glass lasers on silicon substrate integrated photonics

**Clara Dimas
MASDAR INSTITUTE OF SCIENCE & TECHNOLOGY - MIST**

**07/08/2016
Final Report**

DISTRIBUTION A: Distribution approved for public release.

REPORT DOCUMENTATION PAGE				<i>Form Approved</i> OMB No. 0704-0188	
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services, Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.</p>					
1. REPORT DATE (DD-MM-YYYY) 08-07-2016		2. REPORT TYPE Final		3. DATES COVERED (From - To) 01 Sep 2014 to 31 Aug 2015	
4. TITLE AND SUBTITLE Chalcogenide glass lasers on silicon substrate integrated photonics				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER FA9550-14-1-0225	
				5c. PROGRAM ELEMENT NUMBER 61102F	
6. AUTHOR(S) Clara Dimas				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) MASDAR INSTITUTE OF SCIENCE & TECHNOLOGY - MIST Opposite Presidential Flight Abu Dhabi, 54224 AE				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) EOARD Unit 4515 APO AE 09421-4515				10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/AFOSR IOE	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-AFOSR-UK-TR-2016-0013	
12. DISTRIBUTION/AVAILABILITY STATEMENT A DISTRIBUTION UNLIMITED: PB Public Release					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The grant has been accomplished.					
15. SUBJECT TERMS chalcogenide laser, integrated photonics, glass on silicon chip, EOARD					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 47	19a. NAME OF RESPONSIBLE PERSON CUMMINGS, RUSSELL
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (Include area code) 011-44-1895-616021

Chalcogenide glass lasers on silicon substrate integrated photonics

Final Report

Principal Investigator: Masdar Institute Professor Clara E. Dimas

Period of Performance: 12 months

Research Project Start Date: September 1, 2014

Table of Contents

Introduction	3
Impact	3
Objectives.....	3
Results & Discussion	4
Patterning with Focused Ion Beam	4
Patterning with Lift-Off	4
Doped Film Simulations	5
Photoluminescence.....	6
Conclusion.....	7
References	8

INTRODUCTION

On-chip mid infrared (mid-IR) optical sources are a vital building blocks for many fully integrated photonic systems for sensing, imaging, communications, and signal processing applications. Passive, active and nonlinear mid-IR devices have been explored recently in several research efforts [2]. Lasers have been developed in visible region (380 to 750nm) and near infrared region (750 to 1800 nm). Light generation in mid-IR (2 to 20 um) has been a less explored territory in integrated photonics. A unified mid-IR photonic system can enable new capabilities in sensing, signal processing and communication by reducing coupling losses, chip size, energy requirements and manufacturing cost. Chalcogenide glass (ChG) light sources doped with rare earth metals have been simulated in previous work [1] to be feasible for laser emission in mid-IR spectra. Demonstrated rare earth ChG bulk and fiber lasers exist in research and industry respectively. This aim of this project is to work towards a rare earth doped ChG laser on a chip.

Quantum cascade lasers provide an alternate method of generating light in mid-IR region. But III-V materials required make quantum cascade lasers are incompatible with silicon manufacturing process. Chalcogenide deposition on the other hand can be achieved at far lower temperatures and it can take advantage of already matured Si mass manufacturing process to reduce production cost considerably. Si compatible laser device is also viable for inter-chip optical data transfer links and on chip optical communication applications.

Rare earth doped optical fibers are also used for laser generation in mid-IR range. Erbium doped Silica fiber laser for 2 um and chalcogenide glass fiber lasers for 3 um and beyond have been demonstrated successfully in [2-18].Fiber lasers are bulky and they are not suitable for compact on chip applications. Fiber to chip coupling losses are also a drawback of using fiber laser. ChG are a suitable host to transfer this fiber technology to planer on-chip laser as their refractive index is high and they are nonhygroscopic and nontoxic. They also exhibit a wide transparency window in mid-IR range and low photon energy and low non-radiative decay rate. [2] An on chip laser source will overcome the coupling losses to photonic devices and would also reduce the device size significantly.

IMPACT

Low-cost deployable infrared (IR) sensor systems are needed for gas and chemical identification. Benchtop tools suffer from bulky and or expensive IR lasers. Current semiconductor lasers are composed of epitaxial films which require high temperature depositions and are difficult to integrate with other photonic and electronic components. Chalcogenide glass provides a path towards integrating on a low-cost substrate. Therefore one can leverage having flexibility in substrate (i.e. non-lattice matched substrate) to integrate with other photonic material platforms and integrated circuits. In addition, the optical pump can be a low-cost portable telecom laser. The eventual integration into deployable sensors could be wearable short wave infrared (SWIR) laser and sensor which currently do not exist because of the cost and material challenge to emit at SWIR wavelengths.

OBJECTIVES

The objectives of the work entailed process and device development using ChG material. In addition test setups for characterization of materials and devices were also involved for carrying out testing and validating the fabrication processes. The goal was to advance the study of ChG processing and materials in order to work towards the realization of the first ChG laser on chip.

RESULTS & DISCUSSION

Patterning with Focused Ion Beam

Focused Ion Beam was investigated in order to produce patterns (such as a microdisk resonator) with minimum roughness. Roughness causes scatter points and therefore can hinder optical gain needed for a laser. The main challenge is re-sputtering on edge and sidewall of resonator. After varying the etch depth, speed and pattern options, minimal re-sputtering and side wall roughness was found using 30 nPa of ion beam, serpentine clean scan using an FEI Quanta 3D tool. The tradeoff for lower roughness is the slower etch speed due to the low ion energy. Therefore a practical use of FIB of ChG will be in conjunction with UV lithography.

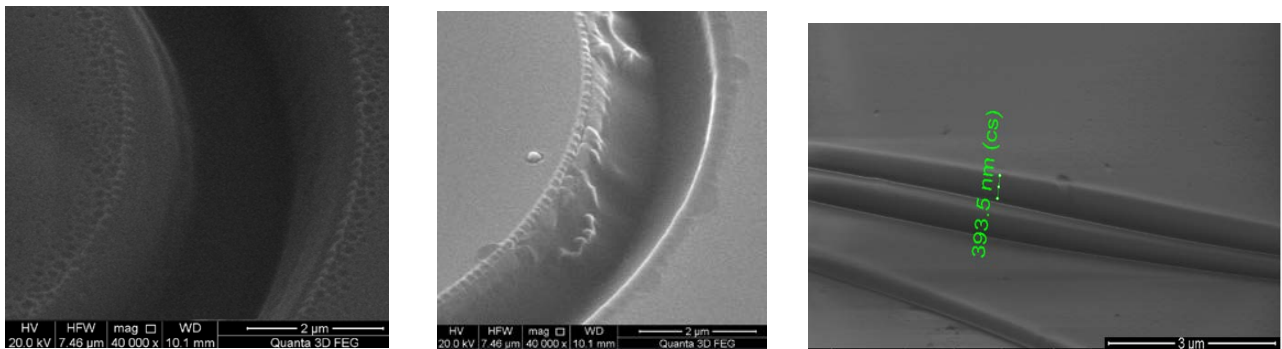


Figure 1. Focused Ion beam (FIB) patterns of GLS using 30 nPa (Left) and 50 nPa (center) of energy. Significant side wall roughness and re-sputtering causing an edge scallop effect is evident with the higher energy etch. (right) FIB of waveguides showing smooth sidewalls.

Patterning with Lift-Off

Two generations of lift-off processes have been developed. High loss ChG waveguides were fabricated using an available recipe for negative resist. As the sidewalls were not optimized, both roughness and dangling material caused significant scatter points, further demonstrating that for photonic structures fabrication processes need to be tailored. Therefore a significant amount of time was spent developing a new process using AZ5214 and image reversal photoresist. Challenges include the cleanroom at Masdar Institute (MI) not having clean de-ionized water and therefore dilution of developer and cleaning of samples introduces contaminants. Another significant challenge was the spin coater in the MI cleanroom. The weakened (clogged) tubing of the spin coaters inhibited the spinning of 6 inch wafers and smaller chucks sizes were very limited and also did not hold often well samples resulting in having to repeat spin coating and cleaning of samples. In summary the second generation lift-off samples used the process specs found to be optimal in terms of side wall roughness and negative side-wall profile include: exposure of 14 seconds at constant power; develop time (in 1:4 diluted developer) of 38 seconds; spin coating of 3000 rpm for 30 secs ; image reversal bake is performed at 115C for 45 secs; flood exposure for 60 seconds.

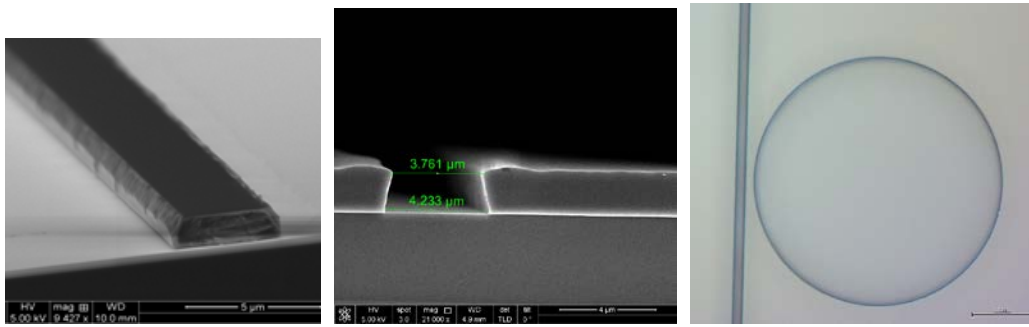


Figure 2: (left) GLS waveguides fabricated using the first generation lift-off recipe. (center) SEM and optical microscopy (right) images of 5214 photoresist (generation 2) which was optimized for sidewall roughness and negative sidewall profiles.

Doped Film Simulations

One avenue for obtaining rare earth doped films is using ion implantation. Films were doped under the quenching concentration for two ChG films (GLS and As₂S₃) as well as for an SiO₂ thin film sample. Table 1 shows the expected ion projected range and concentration. The open source software of SRIM (Stopping and Range of Ions in Matter) was used to simulate the ion concentration profile and projected range as a function of the dosage amount and thin film material. Table 1 and Figure 3 show these parameters per film. Expected concentrations are equal or less than documented quenching concentrations. The simulated Ion concentration profile show the distribution within the thin film with the projected range with 50% of the thickness for the ChG films. Samples are therefore expected to be optically activated after some heat treatment and therefore ions area expected to remain in the thin film as opposed to gravitating towards the substrate.

Er Ion Energy	Material	Thin Film Thickness (nm)	Projected Range wrt thickness %	Er Concentration Quenching (ions/cm ³)	Concentration given dosage (ions/cm ³)
400 kEv	SiO ₂	200	76%	1.00E+22	1.30E+20
400 kEv	As ₂ S ₃	200	55%	Lower than GLS, not specified	1.00E+20
1200 kEv	GLS	600	53%	2.80E+20	2.80E+20

Table 1. Per thin film, projected range with respect to thickness and expected concentration extracted from a SRIM simulation.

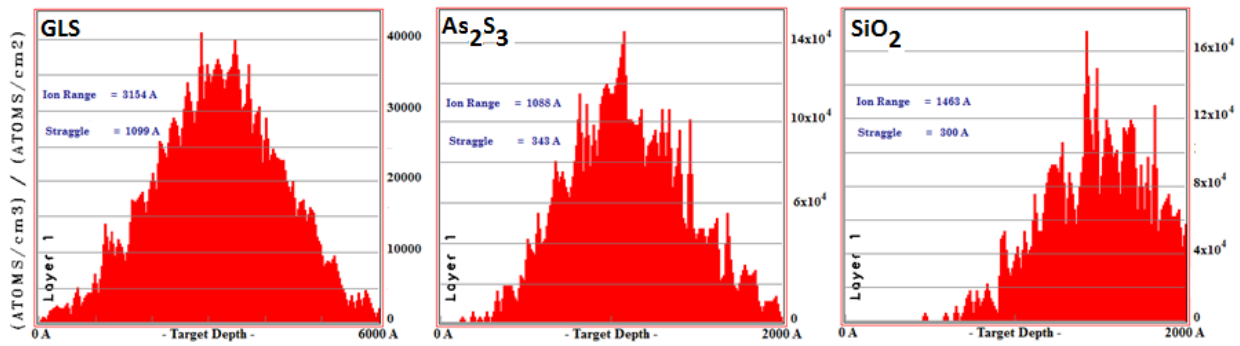


Figure 3. SRIM simulation results of the thin films which were ion doped with Er+.

Photoluminescence

The main characterization setup is a unique photoluminescence measurement testbed which has been designed to accept several pump wavelengths in the visible and NIR as well as detect from thin films NIR and mid IR wavelengths. The pump light comes from a fiber attached to a laser diode of 660 nm. The light passes through a beam splitter and gets coupled into a multimode fiber (MMF). Sample is placed on the other end of this MMF. Sample is dipped into liquid nitrogen at the time of measurement to decrease the temperature of the sample to 77 K. The pump excites electrons in Er³⁺ ions to ⁴F_{9/2} which produce 2μm radiation on decay. This light is captured by MMF and is coupled into a Monochromator after passing through FC2, beam splitter, chopper, and coupling lens.

A Merlin lock in amplifier unit drives the chopper and the PbS detector attached to the Monochromator output. TraqBasic software running on a PC controls Monochromator and Lock in amplifier simultaneous while performing a wavelength scan on the emitted light.

To manufacture a low loss microdisk cavity, ChG will be deposited on Si substrate with a thick layer of SiO₂. A negative resist is being used to pattern the device. The resist patterning process is engineered to produce a negative sidewall which is ideal for lift off and produces minimum sidewall roughness. AZ5214E is the resist being used for patterning.

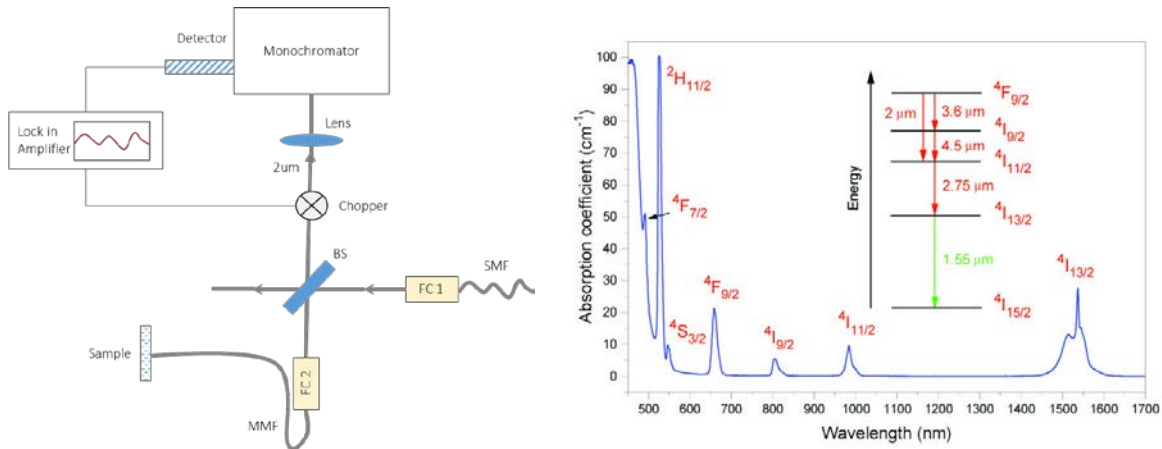


Figure 4. (left) PL setup showing a combination of free space and fiber components. (right, [3]) the expected energy levels and PL given a high energy pump source.

CONCLUSION

In conclusion, the work carried out has laid a foundation for developing ChG photonic devices such as light sources since the following was achieved:

- Carried out ion implantation simulation and doping of ChG films
- Developing FIB process of ChG waveguides and resonators, minimizing re-sputtering and side wall roughness
- Optimized image reversal photoresist lift-off process in order to yield lift-off and low loss photonic devices
- Setup Photoluminescent measurement testbed

Further work will entail optically activating ion implanted devices through a series of rapid thermal anneal treatment optimization and PL measurements. Waveguide loss measurements will also follow the lift-off patterning of ChG thin films. Both measurements is expected to demonstrate respectively high gain and low loss using the same process steps. Past work from other groups have demonstrated high gain but using a process that is not compatible with low loss patterning. While other groups have demonstrated low-loss ChG structures but only in undoped materials. By overcoming this tradeoff, ChG are on the path to achieving laser emission on a chip.

REFERENCES

- [1] Al Tal, Faleh, et al. "Simulation of an erbium-doped chalcogenide micro-disk mid-infrared laser source." *Optics express* 19.13 (2011): 11951-11962.
- [2] Han, Zhaohong, et al. "Integrated Midinfrared Laser Based on an Er-Doped Chalcogenide Microresonator." *Selected Topics in Quantum Electronics, IEEE Journal of* 21.1 (2015): 311-317.
- [3] Schweizer, T., Domink Brady, and Daniel William Hewak. "Fabrication and spectroscopy of erbium doped gallium lanthanum sulphide glass fibres for mid-infrared laser applications." *Optics Express* 1.4 (1997): 102-107.
- [4] Editorial, Nature Photonics. "Mid-infrared photonics", 2014
- [5] Stanley, Ross. "Plasmonics in the mid-infrared." *Nature Photonics* 6.7 (2012): 409-411.
- [6] Schliesser, Albert, Nathalie Picqué, and Theodor W. Hänsch. "Mid-infrared frequency combs." *Nature Photonics* 6.7 (2012): 440-449.
- [7] Yao, Yu, Anthony J. Hoffman, and Claire F. Gmachl. "Mid-infrared quantum cascade lasers." *Nature Photonics* 6.7 (2012): 432-439.
- [8] Jackson, Stuart D. "Towards high-power mid-infrared emission from a fibre laser." *Nature photonics* 6.7 (2012): 423-431.

PHOTONICS MIDDLE EAST 2015 PROGRAM – DAY 1



13 – 15 Dec. 2015, Texas A&M University at Qatar,
Student Center at Hamad Bin Khalifa University, Education City, Doha, Qatar



SUNDAY, 13. DECEMBER 2015	
8:30 – 9:00	Registration
9:00 - 9:15	Opening addresses: <i>M. Belic, I. Al-Qaradawi, M. Weichold</i>
9:15 - 9:30	Abdul Sattar Al-Taie: Qatar National Research Fund
9:30 - 10:30	Wolfgang Ketterle: <i>Ultracold atoms as quantum simulators for new materials – optical lattices, synthetic magnetic fields and topological phases</i>
10:30 - 10:45	Coffee Break
10:45 - 11:45	John M. Dudley: <i>A brief history of light</i>
11:45 - 12:45	Ferenc Krausz: <i>Tracking and steering electrons with light</i>
12:45 - 14:00	Lunch Break
14:00-14:15	L. Salvino: Office of Naval Research Global - Funding opportunities
Solitons	
14:15 - 14:45	G. Assanto: <i>Bifurcation, bistability and symmetry breaking with beams of light in nematics</i>
14:45 - 15:15	F. Mitschke: <i>Advanced optical telecommunications formats - soliton molecules for the long haul?</i>
15:15 - 15:45	A. Ferrando: <i>Nonlinear amplification of surface plasmon-polaritons via soliplasmon resonances</i>
15:45 - 16:15	Y. V. Kartashov: <i>Vortex solitons in partially-PT-symmetric potentials</i>
16:15 - 16:45	Coffee Break
Photonics applications	
16:45 - 17:15	A. Gaeta: <i>Chip-based optical frequency combs</i>
17:15 - 17:45	A. Fratalocchi: <i>Evolutionary photonics - a review of recent results</i>
17:45 - 18:15	B. M. Jelenkovic: <i>Controlling light interaction and propagation in nonlinear media – experiments in the Photonics Center of the Institute of Physics, Belgrade</i>
18:15 - 18:45	D. Wiersma: <i>Disordered Photonics</i>
18:45	End of Day 1

PHOTONICS MIDDLE EAST 2015 PROGRAM – DAY 2



13 – 15 Dec. 2015, Texas A&M University at Qatar,
Student Center at Hamad Bin Khalifa University, Education City, Doha, Qatar



MONDAY, 14. DECEMBER 2015	
9:00 - 10:00	Nail Akhmediev: <i>Extreme waves in conservative and dissipative systems</i>
10:00 - 11:00	Demetrios Christodoulides: <i>Parity-time and other symmetries in optics</i>
11:00 - 11:30	Coffee Break - Poster session
Fundamental studies and new concepts	
11:30 - 12:00	C. Denz: <i>Aperiodic nonlinear photonics</i>
12:00 - 12:30	H. Michinel: <i>ψ-dark-matter optics</i>
12:30 - 13:00	R. Carretero: <i>Small vortex clusters in Bose-Einstein condensates: Theory and experiments</i>
13:00 - 14:15	Lunch
14:15 - 14:30	Sponsor presentation: Quantel
Photonics applications	
14:30 - 15:00	M. S. Zubairy: <i>Sub-wavelength lithography and microscopy via Rabi oscillations</i>
15:00 - 15:30	F. Biancalana: <i>Interaction between positive and negative frequencies in nonlinear optics: new developments</i>
15:30 - 16:00	S. Tzortzakis: <i>Taming linear and nonlinear light wave packets</i>
16:00 - 16:30	Coffee Break - Poster Session
Optical media and materials	
16:30 - 17:00	E. van Stryland: <i>Separation of electronic and nuclear nonlinearities and modeling of organic materials</i>
17:00 - 17:30	N. Zheludev: <i>Electromagnetic toroidal moments, anapoles and flying doughnuts</i>
17:30 - 18:00	K. Neyts: <i>Liquid crystals, electrophoresis, electroluminescence</i>
18:00	End of Day 2
19:30	Dinner, Souq Waqif

PHOTONICS MIDDLE EAST 2015 PROGRAM – DAY 3



13 – 15 Dec. 2015, Texas A&M University at Qatar,
 Student Center at Hamad Bin Khalifa University, Education City, Doha, Qatar



TUESDAY, 15. DECEMBER 2015

9:00 - 10:00	Federico Capasso: <i>Metasurfaces - new frontiers in structured light and surface waves</i>
10:00 - 11:00	Yuri S. Kivshar: <i>All-dielectric nanophotonics and metasurfaces</i>
11:00 - 11:30	Coffee Break - Poster Session
Solitons	
11:30 - 12:00	T. Krauss: <i>Unconventional photonic crystals, chaos and rogue waves</i>
12:00 - 12:30	M. Trippenbach: <i>Ubiquitous phenomenon of four wave mixing</i>
12:30 - 13:00	M. Karpierz: <i>Dual diffraction and competing self-focusing in chiral nematic liquid crystals</i>
13:00 - 14:15	Lunch
14:15 - 14:30	Sponsor presentation: Coherent
Optical media and materials	
14:30 - 15:00	W. Krolikowski: <i>Optical trapping and manipulation of absorbing particles with tractor and bottle beams</i>
15:00 - 15:30	M. Belic: <i>Rogue waves and Talbot carpets</i>
15:30 - 16:00	M. Kauranen: <i>Second-order nonlinear optics of metal nanostructures</i>
16:00 - 16:30	Coffee Break - Poster Session
Fundamental studies and new concepts	
16:30 - 17:00	C. Conti: <i>Simulation of irreversible quantum mechanics and quantum gravity phenomenology in nonlocal nonlinear optics</i>
17:00 - 17:30	V. Zadkov: <i>Quantum optics of a quantum emitter in the vicinity of a plasmonic nanoparticle</i>
17:30 - 18:00	C. Lopez: <i>Modal and spectral characterization of random lasers' coupling</i>
18:00	End of PMEC



WEDNESDAY, 16. DECEMBER 2015

Ibn Al-Haytham Day

Chair Address

Photonics is the science of harnessing light. It plays a major role in driving economic growth and employment throughout the world, while solving important societal challenges in information and consumer technologies, renewable energy, health, manufacturing and security.

In 2013 the United Nations General Assembly proclaimed 2015 the International Year of Light and Light Technologies. The Science Program at Texas A&M University at Qatar and the Qatar Nonlinear Science Initiative welcomed the proclamation and joined celebrations of IYL by organizing the first Photonics Middle East Conference 2015 to be held at Hamad bin Khalifa University and Texas A&M at Qatar. In addition, people from Qatar University, Qatar National Research Fund, and SIDRA Medical and Research Center joined in the celebration by organizing Ibn Al-Haytham Days to take place in conjunction with the conference.

The aims of the conference are threefold: It is the first conference on photonics in Qatar. It is one of the last conferences to celebrate IYL. It aims to raise Qatar's visibility and international profile in photonics research, and it aims to produce impact on the status and direction of photonics research in Qatar in general — and at Qatar Foundation research institutes in particular.

More than 30 renowned researchers in photonics agreed to give talks on their favorite research topics and two high-level officials — Prof. J. M. Dudley, past president of the European Physical Society and Prof. P. Russell, president of the Optical Society of America — will present their views on the accomplishments of the International Year of Light. The distinguished lecture will be delivered by Prof. W. Ketterle, the winner of Nobel Prize in Physics in 2001.

PMEC 2015 and Ibn Al-Haytham Days represent capstone events in celebrating the International Year of Light 2015 and also an important first event in photonics in Qatar's scientific history.

I wish you pleasant stay in Doha and a very successful conference and concurrent activities.

Milivoj R. Belic

Chair, Photonics Middle East Conference 2015
Al Sraiya Holding Professor
Texas A&M University at Qatar

Dean Message

Photonics is the science of harnessing light. It plays a major role in driving economic growth and employment throughout the world, while solving important societal challenges in information and consumer technologies, renewable energy, health, manufacturing and security.

In 2013 the United Nations General Assembly proclaimed 2015 the International Year of Light and Light Technologies. The Science Program at Texas A&M University at Qatar and the Qatar Nonlinear Science Initiative welcomed the proclamation and joined celebrations of IYL by organizing the first P

Conference schedule

13–15 December 2015

Student Center Hamad bin Khalifa University

Sunday

9-9:15 a.m.	Welcome and opening addresses: M. Belic, I. , Al-Qaradawi, M. Weichold
9:15–9:30 a.m.	Abdul Sattar Al-Taie: Qatar National Research Fund
9:30-10:30 a.m.	Wolfgang Ketterle: Ultracold atoms as quantum simulators for new materials – optical lattices, synthetic magnetic fields and topological phases
10:30-10:45 a.m.	Coffee Break
10:45-11:45 a.m.	John M. Duddley: A brief history of light
11:45 a.m. – 12:45 p.m.	Ferenc Krausz: Tracking and steering electrons with light
12:45-2 p.m.	Lunch
2–2:15 p.m.	L. Salvino: Office of Naval Research Global-funding opportunities
Solitons 1	
2:15-2:45 p.m.	N. Akhmediev: Extreme waves in conservative and dissipative systems
2:45-3:15 p.m.	F. Mitschke: Advanced optical telecommunications formats: soliton molecules for the long haul?
3:15-3:45 p.m.	G. Assanto: Bifurcation, bistability and symmetry breaking with beams of light in nematics
3:45-4:15 p.m.	Y.V. Kartashov: Vortex solitons in partially-PT-symmetric potentials
4:15-4:45 p.m.	Coffee Break
Photonics applications	
4:45-5:15 p.m.	A. Gaeta: Chip-based optical frequency combs
5:15-5:45 p.m.	B. M. Jelenkovic: Controlling light interaction and propagation in nonlinear media — experiments in the Photonics Center of the Institute of Physics, Belgrade
5:45-6:15 p.m.	D. Wiersma: Disordered photonics
6:15-6:45 p.m.	A. Fratalocchi: Evolutionary photonics - a review of recent results
7:45 p.m.	End of Day 1

Monday

9-10 a.m.	Philip Russell: Intense light-matter interactions in photonic crystal and microstructured fibres
10-11 a.m.	Demetrios Christodoulides: Parity-time and other symmetries in optics
11-11:30 a.m.	Coffee Break - Poster session
Fundamental concepts	
11:30 a.m. – noon	C. Denz: Aperiodic nonlinear photonics
Noon – 12:30 p.m.	H. Michinel: Psi-dark-matter optics
12:30-1:30 p.m.	R. Carretero: Small vortex clusters in Bose-Einstein condensates: Theory and experiments
1-2:15 p.m.	Lunch
2:15-2:30 p.m.	Sponsor presentation: Quantel
2:30-3 p.m.	M. S. Zubairy: Sub-wavelength lithography and microscopy via Rabi oscillations
3-3:30 p.m.	F. Biancalana: Interaction between positive and negative frequencies in nonlinear optics: new developments
3:30-4 p.m.	S. Tzortzakis: Taming linear and nonlinear light wave packets
4-4:30 p.m.	Coffee Break - Poster Session
Optical materials	
4:30-5 p.m.	E. van Stryland: Separation of electronic and nuclear nonlinearities and modeling of organic materials
5-5:30 p.m.	N.I. Zheludev: Randomly accessible reconfigurable photonic metamaterials
5:30-6 p.m.	K. Neyts: Liquid crystals, electrophoresis, electroluminescence
7:30 p.m.	Dinner, Souq Waqif

Tuesday

9-10 a.m.	Federico Capasso: Metasurfaces - new frontiers in structured light and surface waves
10-11 a.m.	Yuri S. Kivshar: All-dielectric nanophotonics and metasurfaces
11-11:30 a.m.	Coffee Break - Poster Session
Solitons 2	
11:30 a.m. – noon	T. Krauss: Unconventional photonic crystals, chaos and rogue waves
Noon – 12:30 p.m.	M. Trippenbach: Ubiquitous phenomenon of four wave mixing
12:30-1:30 p.m.	M. Karpierz: Dual diffraction and competing self-focusing in chiral nematic liquid crystals
1-2:15 p.m.	Lunch
2:15-2:30 p.m.	Sponsor presentation: Coherent
2:30-3 p.m.	W. Krolikowski: Optical trapping and manipulation of absorbing particles with tractor and bottle beams
3-3:30 p.m.	W. Blau: Nanocarbon as versatile materials platform for photonics
3:30-4 p.m.	M. Kauranen: Second-order nonlinear optics of metal nanostructures
4-4:30 p.m.	Coffee Break - Poster Session
Fundamental concepts	
4:30-5 p.m.	C. Conti: Simulation of irreversible quantum mechanics and quantum gravity phenomenology in nonlocal nonlinear optics
5-5:30 p.m.	V.N. Zhadkov: Quantum optics of a quantum emitter in the vicinity of a plasmonic nanoparticle
5:30-6 p.m.	C. Lopez: Modal and spectral characterization of random lasers' coupling
6 p.m.	End of P MEC
Wednesday: Ibn Al Haytham Day	

Plenary speakers

Metasurfaces: New frontiers in structured light and surface waves

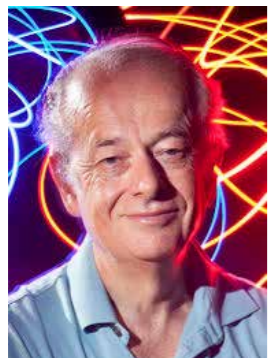
Federico Capasso

Harvard University, USA

Summary:

Patterning surfaces with subwavelength spaced metallo-dielectric features (metasurfaces) allows one to locally control the amplitude, phase and polarization of the scattered light, allowing one to generate complex wavefronts such as optical vortices of different topological charge and dislocated wavefronts. Recent results on achromatic metasurfaces will be presented including lenses and collimators. Metasurfaces have also become a powerful tool to shape surface plasmon polaritons (SPPs) and more generally surface waves. I will present new experiments on imaging SPP that have revealed the formation of Cherenkov SPP wakes and demonstrated polarization sensitive light couplers that control the directionality of SPP and lenses, which demultiplex focused SPP beams depending on their wavelength and polarization.

Bio:



Capasso received his doctorate in physics (cum laude) from University of Rome in 1973. After a postdoctoral stint at Fondazione Bordini in Italy, he was associated with Bell Labs in Murray Hill, N.J., USA, for most of his scientific career. Through the years, he progressed from a visiting scientist (1976-1977) to the vice president of physical research (2000-2002). Since January 2003 he has been the Robert Wallace Professor of Applied Physics and Vinton Hayes Senior Research Fellow in

Electrical Engineering at the School of Engineering and Applied Sciences at Harvard University. He is the recipient of numerous awards, including the Gold Medal of SPIE, EPS Quantum Electronics and Optics Award, Humboldt Research Award, Galileo Galilei Medal, Julius Springer Prize, King Faisal International Prize, Gold Medal of the President of Italy for meritorious achievement in science, Edison Medal from IEEE and the Arthur Shawlow Prize from APS. He is a foreign member of Academia dei Lincei; member of both the National

Academy of Sciences and National Academy of Engineering; and a fellow of AAAS, the Institute of Physics, SPIE, IEEE, OSA and APS. He has received honorary doctorates from the University Paris Diderot, Lund University in Sweden, University Roma III and University of Bologna. He is a Commendatore of the Italian Republic.

Capasso's scientific interests span most of photonics. He is author of many books, book chapters and hundreds of papers in leading journals in physics and engineering. According to Google Scholar, his citation count is more than 43,000 and h-index more than 100. His Science paper on Quantum Cascade Laser is cited more than 4,000 times. His i10-index stands at 500, which means that 500 of his papers are cited at least 10 times (and more than 100 of his papers are cited more than 100 times).

A brief history of light

John Dudley

International Year of Light Steering Committee and
CNRS-Université de Franche-Comté Institute FEMTO-ST,
France

Summary:

The United Nations (UN) has declared the year 2015 the International Year of Light and Light-based Technologies. In declaring this International Year, the UN has recognized the centrality of how the fundamental study and applications of light impact on virtually all areas of science, and how light-based technologies can promote sustainable development and provide solutions to global challenges in energy, education, agriculture, health and well-being. The year 2015 has been selected for this celebration as it commemorates a remarkable series of important milestones in the history of the physics of light: the early work on optics by the Islamic scholar Ibn Al-Haytham in 1015; the mathematical theory of the wave nature of light proposed by Fresnel in 1815; the electromagnetic theory of light propagation proposed by Maxwell in 1865; Einstein's embedding of light in cosmology through general relativity in 1915; the discovery of the cosmic microwave background by Penzias and Wilson in 1965; and Charles Kao's achievements in 1965 concerning the transmission of light in fibers for optical communication. In this talk, we will briefly review the general aims and objectives of the International Year of Light, but we will mainly focus on providing a survey of recent developments in optics that relate closely to the anniversaries celebrated in 2015. Amongst topics that will be covered include the experimental study of novel localized structures, the physics of accelerating beams and their applications, and examples in linear and nonlinear systems where optics can yield insights into other physical systems including gravity analogues and extreme events.

Bio:



John Dudley is a professor of physics working at the CNRS Research Institute FEMTO-ST in Besancon, France. His research covers broad areas of optical science and he has published more than 500 contributions in journals and conference proceedings, and delivered more than 120 invited talks at major conferences. He regularly speaks on topics including his own research, current research trends in photonics, extreme events in nature, public outreach and education, and career development. He has won numerous awards and fellowships, including the Médaille d'Argent of the national French research agency CNRS, the SPIE President's Award and the Hopkins Leadership Award of the Optical Society OSA. He was president of the European Physical Society for a two-year term from April 2013 to March 2015. In 2009, he initiated the International Year of Light and Light-based Technologies 2015 and currently serves as chair of its international steering committee.

Ultracold atoms as quantum simulators for new materials — Optical lattices, synthetic magnetic fields and topological phases

Wolfgang Ketterle

Massachusetts Institute of Technology, USA

Summary:

When atoms are cooled to nanokelvin temperatures, they can easily be confined and manipulated with laser beams. Their interactions can be tuned with the help of magnetic fields, making them strongly or weakly interacting, repulsive or attractive. Crystalline materials are simulated by placing the atoms into an optical lattice, a periodic interference pattern of laser beams. Recently, synthetic magnetic fields have been realized. With the help of laser beams, neutral atoms move around in the same way as charged particles subject to the magnetic Lorentz force. These developments should allow the realization of quantum Hall systems and topological insulators with ultracold atoms.

Bio:



Wolfgang Ketterle has been the John D. MacArthur professor of physics at MIT since 1998. He leads a research group exploring new forms of matter of ultracold atoms — in particular, novel aspects of superfluidity, coherence and correlations in many-body systems. His observation of Bose-Einstein condensation in a gas in 1995 and the first realization of an atom laser in 1997 were recognized with the Nobel Prize in Physics in 2001 (with E.A. Cornell and C.E. Wieman). He received a

diploma (equivalent to master's degree) from the Technical University of Munich (1982) and the Ph.D. in physics from the University of Munich (1986). He did postdoctoral work at the Max-Planck Institute for Quantum Optics in Garching and at the University of Heidelberg in molecular spectroscopy and combustion diagnostics. In 1990, he came to MIT as a postdoc and joined the physics faculty in 1993. Since 2006, he has been the director of the Center of Ultracold Atoms, an NSF-funded research center, and associate director of the Research Laboratory of Electronics.

His honors include the Rabi Prize of the American Physical Society (1997), the Gustav-Hertz Prize of the German Physical Society (1997), the Fritz London Prize in Low Temperature Physics (1999), the Dannie-Heineman Prize of the Academy of Sciences, Göttingen, Germany (1999), the Benjamin Franklin Medal in Physics (2000), the Knight Commander's Cross (Badge and Star) of the Order of Merit of the Federal Republic of Germany (2002), the MIT Killian Award (2004), a Humboldt research award (2009) and memberships in several Academies of Sciences. He holds honorary degrees from Gustavus Adolphus College, St. Peter (2005), the University of Connecticut (2007), Ohio State University (2007) and Strathclyde University (2011), and an honorary professorship at Northwestern Polytechnical University in Xian, China (2014).

All-dielectric nanophotonics and metasurfaces

Yuri S. Kivshar

Nonlinear Physics Center, Australian National University,
Australia

Summary:

Rapid progress in the fields of plasmonics and metamaterials is driven by their ability to enhance near-field effects with subwavelength localization of light, and a majority of such effects is usually associated with metallic nanoscale structures ("meta-atoms" and "meta-molecules"). Recently, we observe the emergence of a new branch of nanophotonics aiming at the manipulation of strong optically induced electric and magnetic Mie-type resonances in dielectric and semiconductor nanostructures with high refractive index. Unique advantages of dielectric resonant nanostructures over their metallic counterparts are low dissipative losses and the enhancement of both electric and magnetic fields that provide competitive alternatives for metal-based plasmonic structures, including nanoantennas, nanoparticle sensors and metasurfaces. In this talk, we review the new emerging field of nanophotonics and metamaterials, and demonstrate that Mie-type resonances in dielectric nanoparticles and subwavelength-patterned dielectric structures can be exploited to boost performance of many nanophotonic metadevices. In addition, the coexistence of strong electric and magnetic resonances and resonant enhancement of magnetic field in dielectric nanoparticles bring new physics and entirely novel functionalities to simple geometries not much explored in plasmonic structures, especially in the nonlinear regime.

Bio:



Yuri S. Kivshar received a Ph.D. in theoretical physics in 1984 from the Institute for Low Temperature Physics and Engineering (Ukraine). From 1988 to 1993 he worked at research centers in USA, France, Spain and Germany, and in 1993 he moved to Australia where later he established Nonlinear Physics Center at the Australian National University and where he is currently head of the center and distinguished professor. His research interests include nonlinear photonics, optical solitons, nanophotonics, and metamaterials. He is a fellow of the Australian Academy of Science, the Optical Society of America, the American Physical Society and the Institute of Physics (UK), as well as deputy director of the Center of Excellence for Ultrahigh-bandwidth Devices for Optical Systems CUDOS (Australia) and research director of Metamaterial Laboratory (Russia). He has received many prestigious awards, including the International Pnevmatikos Prize in Nonlinear Science (Greece), the Lyle Medal (Australia), the State Prize in Science and Technology (Ukraine) and the Harrie Massey Medal of the Institute of Physics (UK).

Intense light-matter interactions in photonic crystal and microstructured fibers

Philip. Russell

Max Planck Institute for the Science of Light, Germany

Summary:

The well-controlled guided modes and long path-lengths offered by photonic crystal fibres (PCFs) permit remarkable enhancements (and in some cases reductions) in many kinds of light-matter interaction. Recent examples include the solid core PCFs widely used in generation of bright broad-band supercontinuum light; twisted PCFs that support modes carrying orbital angular momentum; effective light-driven optoacoustic devices that permit stable GHz mode-locking of fiber ring lasers; bright deep and vacuum UV sources based on gas-filled hollow core PCF; and nanoscale glass structures that self-pulsate optomechanically when pumped with only a few mW of continuous wave laser light. After introducing PCF itself, I will discuss a selection of recent results in the talk.

Bio:



Philip Russell is a founding director at the Max-Planck Institute for the Science of Light, a position he has held since January 2009. He obtained his D. Phil. (1979) at the University of Oxford. His interests currently focus on scientific applications of photonic crystal fibers. He is a Fellow of the Royal Society and the Optical Society of America (OSA) and has won several awards including the 2000 OSA Joseph Fraunhofer Award/Robert M. Burley Prize, the 2005 Thomas Young Prize of the IOP, the 2005 Körber Prize for European Science, the 2013 EPS Prize for Research into the Science of Light, the 2014 Berthold Leibinger Zukunftspreis and the 2015 IEEE Photonics Award. He is OSA's president in 2015, the International Year of Light.

Parity-time and other symmetries in optics

Demetrios Christodoulides

CREOL, University of Central Florida, USA

Summary:

Parity-time (PT)-symmetric photonic structures utilize gain and loss in a balanced fashion in order to achieve a desired functionality. Here we review recent developments in the newly emerging fields of PT-symmetric and supersymmetric optics.

Bio:



Demetri Christodoulides is the Cobb Family Endowed Chair and Pegasus Professor of Optics at CREOL, the College of Optics and Photonics of the University of Central Florida. He received his Ph.D. from Johns Hopkins University in 1986 and he subsequently joined Bellcore as a postdoctoral fellow at Murray Hill. Between 1988 and 2002 he was with the faculty of the Department of Electrical Engineering at Lehigh University. His research interests include linear and nonlinear

optical beam interactions, synthetic optical materials, optical solitons and quantum electronics. He has been author or co-author of more than 250 papers. He is a Fellow of the Optical Society of America and the American Physical Society. In 2011 he received the R.W. Wood Prize of OSA.

Tracking and steering electrons with light

Ferenc Krausz

Max Planck Institute for Quantum Optics, Germany

Summary:

Electronic motions in atomic systems trigger and steer chemical reactions, affect biological function, change physical properties relevant to processing information and hence are fundamental to physical and life sciences as well as modern technologies. Electron dynamics and light wave oscillations (being mutually the cause of each other) typically evolve on the time scale of tens to thousands of attoseconds. The new millennium has spawned controlled (few-cycle) laser light and attosecond extreme ultraviolet pulses, giving rise to the birth of attosecond science. They have permitted — for the first time in the history of science — real-time access to the fastest motions outside the atomic core and insight into previously inaccessible phenomena. Next-generation technology is expected to open the door towards capturing electronic motions with picometer resolution in space and attosecond resolution in time, providing unprecedented insight into dynamic changes at the atomic scale.

Bio:



Ferenc Krausz earned an M.Sc. from Budapest University of Technology in Hungary in 1986 and a Ph.D. from the Vienna University of Technology in Austria in 1991. From 1998-2004 he was a faculty member at the Vienna University of Technology. In 2003 he became director of the Max Planck Institute for Quantum Optics in Garching, Germany. In 2004 he also became professor at Ludwig-Maximilians-Universität München and in 2006 director of the Munich-Centre for Advanced Photonics. Krausz's research includes ultrashort-

pulse lasers, ultrafast spectroscopy, high-field physics, attosecond physics: control and real-time observation of the atomic-scale motion of electrons, development of light sources and measurement techniques for medical applications.

Invited speakers

Bifurcation, bistability and symmetry breaking with beams of light in nematics

Gaetano Assanto

NooEL, Department of Engineering, University Roma Tre, Italy and Optics Lab, Department of Physics, Tampere University of Technology, Finland

Summary:

Light self-localization in liquid reorientational media such as nematic liquid crystals supports the formation of spatial optical solitons. These nonlocal solitons are stable and robust even in the presence of perturbations, collisions, interactions. When the optic axis of the uniaxial medium is orthogonal to the electric field of the propagating light beam, the nonlinear optical response features an abrupt change versus excitation and a power threshold, the so-called optical Freedericks transition, with a nonlinear bifurcation via symmetry breaking. Optical wavepackets and inherent noise, in fact, can alter the initial symmetry and turn into self-trapped beams with opposite transverse velocities. We demonstrate that such system can give rise to optical bistability versus input power, with hysteretic switching between a soliton state and a diffractive state of the beam. Owing to light-assisted symmetry breaking, a bistable loop can also be obtained at fixed excitation when varying the incidence angle.

Bio:



Gaetano Assanto received his M.Sc. in electronic engineering at the University of Palermo in 1981. Having finished his Ph.D. in electronic and computer engineering, Assanto became a research associate at the Optical Sciences Center at the University of Arizona and then research scientist at the Center for Research in Electro-Optics and Lasers at the University of Central Florida. In November 1992 he joined the University of Rome "Roma Tre," where he is the head of the Nonlinear Optics and OptoElectronics Lab (NooEL). He is an

OSA and an IEEE fellow, serves on the editorial boards of Optics Letters, Laser Physics Review, Research Letters in Optics, International Journal of Optics, Journal of Nonlinear Optics Physics and Materials, Photonics Letters Poland, Journal of Optics and Nature Scientific Reports. He ranks 74th among the top Italian scientists. From September 2014 (until August 2018) he is a Finnish distinguished professor with Tampere University of Technology.

Interaction between positive and negative frequencies in nonlinear optics: new developments

Fabio Biancalana

School of Engineering & Physical Sciences, Heriot-Watt University, EH14 4AS Edinburgh, UK

Summary:

I show that new surprising nonlinear phenomena can be predicted by using a propagation equation that correctly includes the nonlinear interactions between the positive and negative frequencies of an ultrashort pulse. I support my claims with experimental results and with accurate numerical simulations of the forward wave equation. I will show recent surprising phenomena in the fields of cavity solitons and nonlinear fiber optics.

Bio:



Prof. Fabio Biancalana obtained his 'Laurea' degree in Theoretical Particle Physics in 2001 at the University of Roma III, Italy. His PhD project at the University of Bath (UK) was about the theoretical and numerical understanding of supercontinuum generation and various nonlinear effects in photonic crystal fibres. Fabio is the recipient of the 15th and last Deryck Chesterman Medal (Univ. of Bath, 2005), for outstanding research in physics. He spent 2 years at the Tyndall National Institute in

Cork (Ireland), working on the solitonic sector of the coherent semiconductor Bloch equations, and on the dynamical propagation of pulses in spatiotemporal photonic crystals. At the Tyndall Institute he was awarded an IRCSET Postdoctoral Fellowship (2006). After that he moved to Cardiff University (UK) where he holds an EPSRC Fellowship in Theoretical Physics (2007), working on the project Nonlinear Resonant Optical Phenomena And Solitons In Polaritonic Photonic Crystals. Fabio joined Heriot-Watt in 2012, at the same time leading the Max Planck Research Group on "Nonlinear Photonic Nanostructures" at the Max Planck Institute for the Science of Light in Erlangen, Germany.

Nanocarbon as versatile materials platform for photonics

Werner J. Blau

Center for Research on Adaptive Nanostructures and Nanodevices (CRANN), Trinity College Dublin, Ireland

Summary:

Nanocarbon materials are attractive building blocks for future nanoelectronic and nanooptic devices because they allow achieving new degrees of both performance and functionality, a combination unachievable by most conventional materials. They possess a variety of nearly ideal, low-dimensional nanostructures with unique properties across a range of physical phenomena ranging from mechanics, thermal physics and electrochemistry to optics. These, in turn, make them ideal not only for a wide range of applications but as a test bed for fundamental science. Their specific properties are chiefly governed by quantum physics and/or surface effects, and are significantly different from equivalent macroscopic objects.

Nanocarbon occurs in six different basic forms: graphene, graphite, fullerenes, nanodiamond, nanotubes and nanocones. Recent linear and nonlinear spectroscopic and optoelectronic results prove that they have much to offer in the photonics arena. A primary objective is to develop a new, environmentally friendly and yet versatile materials technology platform for photonic and optoelectronic devices based on polymer composites of tailored Nanocarbons, targeted specifically to the eye-safe 2 mm near-infrared region, with enormous potential in industrial processing, free-space communications and medical procedures. In this lecture, I will review selected target application demonstrations, such as light-trapping structures for improved photovoltaic devices; near-infrared (NIR) photoemitting structures to demonstrate NIR OLEDs and possible NIR lasers; nonlinear optical applications, including broadband optical limiters and modelockers; and ultrafast all-optical switches.

Bio:



Werner J. Blau is professor of physics of advanced materials at Trinity College Dublin. In addition he is honorary professor at CAS Shanghai Institute for Optics and Mechanics, East China University of Science and Technology and Northwest University Xi'an. He is well known for his original work in molecular and polymer engineering. For more than two decades, Blau's research has addressed the fundamental issue of structure-property relationships and made significant contributions

towards understanding and application these in several areas, especially in optically active nanostructures and polymers and in carbon nanotube composite areas. His group has become initiators of and international leaders in a number of related research fields, most notably in the area of information and communications technology hardware. According to the ISI Web of Science, Blau has published 469 peer-reviewed original papers that have been cited 16,450 times to date. His h-index is 62. In addition, he has also obtained 14 patents, published approximately 110 refereed papers in conference proceedings, and edited 14 books, book chapters and special issues.

Small vortex clusters in Bose–Einstein condensates: Theory and experiments

Ricardo Carretero

San Diego State University, USA

Summary:

Motivated by recent experiments studying the dynamics of configurations bearing a small number of vortices in atomic Bose–Einstein condensates (BECs). We illustrate that, by considering these vortices as quasi-particles, such systems can be accurately described by reduced models of coupled ordinary differential equations on the vortex positions. We study in detail the dynamics and stability of vortex configurations bearing a small number of vortices in harmonically trapped BECs. Periodic and quasi-periodic solutions, and their stability, are studied and compared favorably with experimental observations. Symmetry-breaking bifurcations for regular vortex configurations are identified and matched to experimental observations. The case of increasingly large number of vortices and its coarse-grained continuum limit description is also considered.

Bio:



Ricardo Carretero holds a summa cum laude B.Sc. in physics from the Universidad Nacional Autónoma de México, UNAM (1992) and a Ph.D. in applied mathematics and computation from Queen Mary College, University of London, UK (1997). He spent two postdoctoral years at the Centre for Nonlinear Dynamics at the University College London, UK, and was a PIMS Postdoctoral Research Fellow for another two years at the Department of Mathematics and Statistics at Simon Fraser University in Vancouver, Canada. He

started as an assistant professor in applied mathematics at San Diego State University in 2002, and was promoted to associate professor in 2006 and to professor in 2009. His research focuses in spatio-temporal dynamical systems, nonlinear waves and their applications. He is the co-founder and co-director of the Nonlinear Dynamical Systems group at San Diego State. He has received multiple NSF grants, published more than 100 peer-reviewed publications and has been co-author or co-editor on three books. An active advocate of the dissemination of science, he continuously delivers engaging presentations at local high schools and science festivals, and helps designing museum exhibits.

Extreme waves in conservative and dissipative systems

Nail Akhmediev

Australia National University, Australia

Summary:

We consider a few examples of extreme waves of integrable equations describing waves in optical fibers and the complex Ginzburg-Landau type of equations describing dissipative systems such as passively mode-locked lasers. Extreme waves in these cases have different origin and different behavior. In each case, they can appear regularly and chaotically. Individual extreme waves admit analytical treatment. The extreme waves that appear chaotically are known as rogue waves. Statistical analysis is required to calculate probability of their generation.

Bio:



Nail Akhmediev is one of the leading researchers in theoretical nonlinear optics internationally. He is a fellow of the Optical Society of America in recognition of his work on nonlinear guided optics. He is a winner of prestigious Alexander von Humboldt Award for his pioneering contributions to nonlinear dynamics, the theory of dissipative solitons and rogue waves. He is chair and a member of scientific program committees for many international conferences in optics and

nonlinear dynamics. He has published more than 300 papers in refereed international journals; more than 150 conference papers; several books, including *Solitons, Nonlinear Pulses and Beams*, published by Chapman and Hall, London (1997) with Dr. Ankiewicz; and several chapters in books.

Aperiodic nonlinear photonics

Cornelia Denz

Institute of Applied Physics and Center for Nonlinear Science,
University of Muenster, Germany

Summary:

Artificial photonic materials with a deterministic aperiodic structure of its refractive index exhibit distinctive band gap properties that are different from well-known periodic as well as recently studied random photonic refractive index structures. This is due to the fact that aperiodic structures provide long-range order without translational periodicity and short-range disorder. Aperiodic structures include quasi-crystals, Fibonacci-based structures, aperiodic spiral lattices as well as structures with random Fourier spectrum. Due to their unique, adaptive, and tunable light transport and localization features, aperiodic lattices are highly attractive candidates for applications in nonlinear optical information processing.

In our presentation, we will introduce a paradigm shift in the fabrication design of these photonic lattices by introducing a holographic optical induction method based on spatially scanning single-site non-diffracting Bessel beams as the basic unit of a complex photonic lattice. This technique allows realizing a huge variety of two- and three-dimensional photonic structures, including deterministic aperiodic golden-angle Vogel spirals or Fibonacci lattices. We will demonstrate light propagation in these structures and compare them to complex periodic lattices, superlattices, accelerating lattices, defect-bearing lattices and controlled random lattices

Bio:



Cornelia Denz is a professor of physics at the University of Muenster in Germany. She obtained her Ph.D. from Darmstadt University of Technology in Germany in 1992. Since 2001, she has been head of the nonlinear photonics group at the University of Muenster in Germany, leading a group of about 30 scientists. Since 2003, she has been a director of the Institute of Applied Physics and board member of the Center for Nonlinear Science, which she founded in 2006. Since 2010 she has been vice

rector for international affairs and young researchers. She is an author of more than 220 peer-reviewed publications, three books and numerous book chapters. Denz's main research interests are in the application of nonlinear optics and photonics in information technology and life sciences. She also fosters pupils' interests in STEM in a science lab for young scholars. She has received a number of honors and awards. Among them, she received the 1993 Lise Meitner-Award and the 1999 Adolf-Messer-Award for her work in optical neural networks and nonlinear dynamic phase contrast microscopy. In 2010, she was elected "Professor of the Year" in natural sciences and medicine in Germany. Denz is a fellow of the Optical Society of America and the European Optical Society. She is board member of the European Optical Society and the German Society for Applied Optics, and member of the editorial board of a number of journals.

Evolutionary photonics: a review of recent results

Andrea Fratalocchi

PRIMALIGHT, King Abdullah University of Science and Technology, Saudi Arabia

Summary:

Evolutionary photonics takes inspiration from natural systems and phenomena such as chaos and unpredictability, creating new technologies in material science, energy harvesting and nanomedicine. In this invited talk, I summarize my research activity in the field, discussing recent results including chaotic energy harvesting, the control of subwavelength and ultrafast rogue waves, the development of disordered sensors for early-stage cancer detection, and finally a new generation of high-performing photovoltaic cells and black-body metamaterial "lasers."

Bio:



Dr. Andrea Fratalocchi (laurea degree magna cum laude in 2013, Ph.D. in 2007, h-factor 22, f-factor 2.2) is an assistant professor in the Computer, Electrical and Mathematical Sciences and Engineering Division in King Abdullah University of Science and Technology (KAUST). He joined KAUST in January 2011. Before joining KAUST, Fratalocchi was a KAUST research fellow, working at Sapienza University under the KAUST Fellowship Award. From 2007 to 2009, Fratalocchi worked as a postdoctoral researcher at Sapienza University under a grant from the Enrico Fermi research center. Fratalocchi has long-standing expertise as a referee of the highest impact-factor journals, including Nature and Physical Review Letters, as well as writing international projects and organizing conferences. In 2012, he was appointed editor of Nature Scientific Report, the newest journal of Nature Publishing Group. He is a member of the complex-energy consortium, an international group of six universities from the United States and Europe and two private institutions aimed at developing a new disruptive technology for solar energy production. He collaborates with researchers at Cambridge University, Harvard University, University of St. Andrews, EPFL, Australia National University, Sapienza University, Birmingham University, University of Ferrara and University of Toronto.

Dual diffraction and competing self-focusing in chiral nematic liquid crystals

Mirosław A. Karpierz

Warsaw University of Technology, Poland

Summary:

Chiral nematic liquid crystals (ChNLC) are media with a very strong nonlocal nonlinearity due to the intensity dependent reorientational effect. It causes that spatial solitons (called nematicons) with a width of a few micrometers are observed for mW input powers over several millimeters propagation distance. Nematicons can be routing by changing light power, polarization, by external electric or magnetic fields as well as due to the interaction with other beams or nematicons. Additionally, ChNLCs create layered structures with periodically changed refractive index. Such a structure can be treated as an array of planar waveguides and depending on the refractive index variation the light can be guided in the individual waveguide or can be coupled between them. It results in dual diffraction in two planes, i.e. discrete and continuous diffraction existing simultaneously in two orthogonal planes. While the discrete diffraction depends on the refractive index distribution, the continuous diffraction depends on the initial beam width. This causes that modifications of the diffraction angle in both planes are independent. In this work, we present numerical and experimental results showing dual diffraction in ChNLCs and the way the self-focusing effects in both directions lead to the beam self-trapping.

Bio:



Mirosław Karpierz is a professor of physics at the Warsaw University of Technology (WUT). He received an M.Sc. in applied physics from the Faculty of Applied Physics and Mathematics in 1987, Ph.D. in physics from the Institute of Physics in 1990, and D.Sc. (habilitation) in physics from the Faculty of Physics in 2000. He is the dean of the Faculty of Physics WUT and the head of the Nonlinear Optics Laboratory. His research activity includes nonlinear optics and photonics: nonlinear

optics of liquid crystals (nematicons, liquid crystalline waveguides, and measurements of liquid crystalline parameters); nonlinear guided-wave phenomena (optical solitons, nonlinear optical couplers, nonlinear interaction of guided modes); photonic systems and devices. He is organizing international workshops on nonlinear optics applications (every two years since 1992) and is an editor of Photonics Letters of Poland (<http://photonics.pl/PLP/>).

Vortex solitons in partially PT-symmetric potentials

Yaroslav V. Kartashov

ICFO-Institut de Ciències Fotoniques, Spain
Institute of Spectroscopy, Russian Academy of Sciences,
Russia

Summary:

The evolution of nonlinear waves carrying topological phase dislocations is a physical problem of fundamental importance attracting attention in various areas of physics. This evolution becomes especially intriguing in the presence of transverse refractive index modulations of the nonlinear media. Such modulation not only modifies shape of self-sustained nonlinear excitations, but also suppress collapse and azimuthal instabilities, destructive for solitons in many uniform materials and especially in cubic media. Many types of conservative potentials, such as square and Bessel lattices, created by the modulation of real part of the refractive index, were shown to support stable vortex solitons. The common feature of such conservative potentials is the equivalence of two azimuthal directions, manifested in the identical parameters of vortex solitons with opposite topological charge.

A different class of non-conservative parity-time-symmetric potentials, introduced in the context of quantum mechanics, attracts now considerable attention in optics, due to specific ability of such potentials to switch from entirely real to complex spectrum with increase of the depth of the imaginary part of the structure. While PT-symmetric potentials may support stationary solitons with symmetric intensity distributions in nonlinear medium, there always exists certain selected direction in them, defined by the local currents from amplifying to absorbing domains. In my presentation I will show how this property can be used to construct partially PT-symmetric azimuthal potentials from fully PT-symmetric cells placed on a ring, where two azimuthal directions become nonequivalent.

Bio:



Yaroslav V. Kartashov was born in 1976 in Moscow, Russia. He received his Ph.D. degree from Moscow State University in 2002. Currently he holds the position of leading researcher in the Institute of Spectroscopy in Russia and visiting professor position in ICFO-The Institute of Photonic Sciences in Spain. Kartashov is a co-author of more than 250 papers in leading optical journals.

Second-order nonlinear optics of metal nanostructures

Martti Kauranen

Tampere University of Technology, Finland

Summary:

The optical properties of metal nanoparticles are dominated by the localized surface plasmon resonances of the conduction electrons. The resonances depend on the size and shape of the particles as well as their dielectric environment, thereby allowing for broad tunability of the resonance wavelengths. The resonances are associated with strong local fields (hot spots) near the particles, which can enhance optical interactions. Such local-field enhancement is particularly important for nonlinear optical effects. In this Paper, we summarize our recent results on second-harmonic generation (SHG) from metal nanostructures. SHG requires non-centrosymmetric structures and is also otherwise sensitive to the sample symmetry. In our case, the symmetry is broken using either L or T-shaped nanoparticles ordered in a two-dimensional square array. On the other hand, symmetry-breaking defects of the particles can play a prominent role in the SHG response, which can be interpreted in terms of higher-multipolar (magnetic, quadrupolar) contributions to the effective response. Recent advances in sample quality, however, have allowed the electric-dipole limit of the effective response to be reached, providing a basis for any further engineering of the nonlinear response by sample features. We have subsequently pursued several novel ideas in enhancing the SHG response. In the first approach, we have shown that the SHG response can depend strongly on subtle details of particle ordering in the array. In addition, we have shown that the nonlinear response of SHG-active particles can be enhanced by centrosymmetric SHG-passive particles. Both examples arise from interaction between the particles through the lattice. We have also addressed the role of plasmon resonances in the SHG response. In contrast, to interpretations that emphasize the role of the resonance at the fundamental wavelength, we have shown that particle geometry and associated local-field distributions may play an even more prominent role. Finally, by studying the dependence of SHG on the angle of incidence, we are entering a new regime where interplay between the SHG radiation pattern and surface-lattice resonances leads to completely new features.

Bio:



Martti Kauranen is a professor of physics at the Tampere University of Technology in Finland. He received an M.Sc. in engineering physics from the Helsinki University of Technology in Espoo, Finland, in 1985 and a Ph.D. in optics from the University of Rochester in Rochester, N.Y., in 1992. From 1993 to 1999, he worked at the University of Leuven in Belgium. His research covers the nonlinear optical properties of surfaces, thin films and nanostructured materials, including multipolar contributions to their nonlinear response, as well as new nonlinear measurement techniques based on polarization effects. He has been author of about 140 articles in scientific journals and given more than 250 presentations at international conferences. He is a fellow of the Optical Society of America. He was an associate editor of *Optics Express* from 2008 to 2011 and has been an associate editor of *Optica* since the launch of the journal in 2014. He is presently a general co-chair of the European Quantum Electronics Conference 2015 and of the OSA Nonlinear Optics Meeting 2015.

Unconventional photonic crystals, chaos and rogue waves

Thomas F. Krauss

University of York, UK

Summary:

The ability of photonic crystals to strongly confine light in high Q cavities and in slow light waveguides is well known. These structures are highly ordered and built with great precision. By abandoning the premise of highly ordered and “perfect” structures, we can explore new ways of confining light. For example, light can assume chaotic trajectories and we have shown that these afford enhanced energy storage compared to regular cavities, which I will discuss in the context of resonant absorption in solar cells. Similar cavities also allow us to observe rare events (“rogue waves”) via the suitable control of phase space.

Bio:



Thomas Krauss is professor of photonics in the Department of Physics at the University of York. His research focuses on understanding and controlling the light-matter interaction in photonic nanostructures, and building functional devices that make use of this understanding. Krauss is particularly interested in the development of photonic crystals, and his activity spans the study of fundamental concepts such as nonlinearity and enhanced light emission, to more

applied areas such as nanolasers, optical switches, biosensors and solar cells. Following a Ph.D. in semiconductor ring lasers at the University of Glasgow, Krauss initiated research on planar photonic crystals in 1993. His work on fundamental concepts in photonic crystals, including his 1996 paper in *Nature*, was pivotal in transforming photonic crystals from a scientific curiosity to the essential building block in photonics that they are today. He became a professor at the University of St. Andrews in 2000, where he established a 15-20-strong research group and a nanofabrication laboratory. He developed the “slow light” concept in photonic crystal waveguides and conducted a number of seminal experiments, including work on ultrasmall switches and efficient nonlinear effects. Following 12 years of successful research at St. Andrews, including a stint as head of school from 2009 to 2012, he relocated with his group to York in early 2013 and established a new suite of nanophotonics fabrication and characterisation laboratories. Krauss is a fellow of the Institute of Physics, the Royal Society of Edinburgh and the Optical Society of America. He has led several large UK and EU research projects, and gives invited presentations at numerous international conferences each year.

Chip-based optical frequency combs

Alexander Gaeta

Columbia University in the City of New York, USA

Summary:

Optical frequency combs are having and will have enormous impact on many areas of science and technology, including time and frequency metrology, precision measurement, telecommunications and astronomy. I will describe our recent research on a novel type of frequency comb that is based on parametric nonlinear optical processes in silicon-based microresonators. The dynamical behavior of how combs are generated in such a system is complex and include phase transitions, mode locking and synchronization, and femtosecond pulse generation. Ultimately, such chip-based combs offer great promise for creating devices that are highly integrated and stable and can operate from the visible to mid-infrared regimes.

Bio:



Alex Gaeta received his Ph.D. in optics in 1991 from the University of Rochester. From 1992 until 2015 he was a member of the faculty in the School of Applied and Engineering Physics at Cornell University. In 2015 he joined the faculty at Columbia University in the Department of Applied Physics and Applied Mathematics where he is currently the David M. Rickey Professor of Optical Communications. He has published more than 190 papers in areas of ultrafast nonlinear optics, all-

optical signal processing, nanophotonics and quantum effects in nonlinear optics. He co-founded PicoLuz Inc. along with Michal Lipson and Alex Cable. He is the founding editor-in-chief of *Optica* and a fellow of the Optical Society of America and of the American Physical Society.

Optical trapping and manipulation of absorbing particles with tractor and bottle beams

Wieslaw Krolikowski

Texas A&M University at Qatar, Qatar
Laser Physics Centre, Australian National University, Australia

Summary:

When an incident light heats non-uniformly, a surface of absorbing particle, gas molecules rebound off the surface with different velocities, thus creating an integrated (photophoretic) force acting upon a particle. In this talk we demonstrate that by employing the photophoretic force and spatially shaped optical beam it is possible to create an "optical bottle" to efficiently trap and manipulate micron-size particles in gaseous environment. Moreover, by using the hollow laser beam (i.e., a beam with a dark core), one can realize a "tractor beam" for transporting and delivering particles over large distances.

Bio:



Wieslaw Krolikowski received the Ph.D. in physics from the Institute of Physics of the Polish Academy of Sciences in Warsaw, Poland, in 1988, and the D. Sc. (habilitation) degree in physics from the Warsaw University of Technology in 2001. From 1988 to 1991 he was a research associate at Tufts University in the United States. Since 1992 he has been with the Laser Physics Centre at the Australian National University in Canberra. In 2014 Krolikowski joined the Science Program at Texas

A&M University at Qatar where he is a professor of physics. His research interests include experimental and theoretical aspects of light localization and optical solitons, parametric processes, nonlinear dynamics, photorefractive nonlinear optics, fiber and integrated optics, laser trapping and laser matter interaction. Krolikowski is a member of the Australian Optical Society and a fellow of Optical Society (OSA). In 2013 Krolikowski received an honorary doctorate (doctor honoris causa) from the Technical University of Denmark for his contributions to soliton physics.

Modal and spectral characterization of random lasers' coupling

Cefe López

Instituto de Ciencia de Materiales de Madrid, Spain

Summary:

Random lasers are very attractive devices both for photonics applications, due to their simple fabrication possibilities, and for basic research on the physics of light-matter interaction. So far, theoretical and experimental approaches have focused on single, independent resonators, where the cavity is defined by the ensemble of scattering centres or by the pump spatial extension. However, just as standard lasers, random resonators can be coupled together by mutual injection of light. By shaping the spatial beam of the pump source we succeeded in exciting millimetres distant random resonators simultaneously, thus inducing strong mutual coupling. Surprisingly, we observe that the same frequencies are activated in different resonators. This is in contrast to what would be expected because, given the pumping conditions, the spectral signature of a random laser is intrinsically unique, as it is related to the random spatial distribution of the scattering centres in its cavity. We perform spectral measurements and spatial characterization of the emission from a coupled pair of random resonators and observe strong mode competition as a function of the pumping conditions and coupling strength. Extending the reported results to a network of coupled random lasers could open the way to a complete new range of applications.

Bio:



Cefe López's alma mater is the Universidad Autónoma de Madrid where he graduated in physics and received his Ph.D. After a postdoctoral period at the University of Oxford and a teaching stint at the Universidad Carlos III de Madrid he gained tenure in the Spanish Scientific Research Council. His main research interest focuses on self-assembled photonic structures and related systems. In particular, his multidisciplinary group covers synthesis and processing of materials — such as photonic crystals and photonic glasses, composites, nanoparticles, and quantum dots — as well as the study of light transport, generation, and interference in ordered and disordered dielectric structures.

Advanced optical telecommunications formats: Soliton molecules for the long haul?

Fedor Mitschke

Universität Rostock, Germany
Institut für Physik, Germany

Summary:

At an ever-increasing rate, vast amounts of data are transmitted around the globe through fiber-optic cables. The conventional on-off keying (for logical 1 or 0, respectively) has reached its limit; it becomes urgent to find more efficient coding. Multiplexing of wavelength is routine now; of polarization, phase and amplitude is explored. While such schemes allow high data volumes, they unfortunately have reduced reach and are thus not fully capable of going the long haul distance. Recent suggestions like spatial or modal multiplexing require special fibers and are incompatible with the existing immense worldwide fiber network, but it certainly is economically preferable to pursue technology that works with legacy fibers.

All schemes mentioned so far avoid the fiber's inherent nonlinearity and related problems by keeping the transmitted power low. At somewhat higher powers there exist solitons, pulses of a special shape that possess a unique robustness to perturbations: a beneficial consequence of nonlinearity. While solitons have been established for commercial data transmission, they were universally understood to provide on-off keying (the binary format) only. We have recently demonstrated that solitons can be used for a quaternary format (and more, by implication). Our proposal invokes interactions between adjacent solitons, originally thought of as a nuisance: here they are exploited to provide stable soliton compounds which we call soliton molecules. Conditions exist under which such molecules of two or three solitons are stable enough to allow successful data transmission. Formats involving soliton molecules seem particularly suited for the long haul as they suffer less from noise than all "linear" schemes.

Bio:



Fedor Mitschke obtained his Ph.D. at Hannover University in Germany, then joined AT&T Bell Laboratories (Holmdel, USA) in 1985-1986. After returning to Germany he held positions at Hannover University (where he obtained his habilitation, or second doctorate), LMU University Munich and the University of Muenster. Since 1997 he has been professor for "Experimental Physics: Optics" at Rostock University in Germany. His research interests have been optical bistability, optical chaos, laser modelocking mechanisms and nonlinear fiber optics. He is author or co-author of approximately 130 peer-reviewed publications, and author of a textbook on fiber optics.

“ Ψ -dark-matter optics “

Humberto Michinel

Universidade de Vigo, Spain

Summary:

We propose a computational model for describing the dynamics of ultralight axionic dark matter (DM) based on two conjectures: that ultralight axions are the fundamental particles of dark matter and they exist in our universe in a Bose–Einstein condensed state. Under these assumptions, the dynamics of dark matter seems to be analogous to some well-known coherent optical and matter wave systems. Our numerical calculations could explain some intriguing cosmological features like the surprising repulsive interaction of dark matter after galactic collisions, recently observed. Our final conclusion is that the underlying dynamics of DM reminds well-known features of nonlinear optical systems, paving the way for a novel approach to understanding this fundamental problem of Physics.

Bio:



Humberto Michinel is currently professor in the optics laboratory of the Applied Physics Department at the University of Vigo in Ourense, Spain, where he leads the Physical Optics research group. He has also been director of the master's degree in photonics of the three universities in Galicia, Spain, since 2006. He studied physics at the universities Complutense de Madrid and Santiago de Compostela (Spain). Much of his scientific activity has been focused on the study of nonlinear

coherent wave propagation in different systems mainly in optics and ultracold atoms, but also includes contributions in other topics like singular beams, nonlinear optical materials or quantum effects in atomic systems, among other fields. Michinel has also organized numerous scientific conferences, the most recent being the 23rd General Meeting of the International Commission for Optics in Santiago de Compostela where he was re-elected vice president of ICO. Recently, he co-founded the company ERH-ILLUMNIA in the field of solid-state lighting, a spinoff from the University of Vigo.

Liquid crystals, electrophoresis, electroluminescence

Kristiaan Neyts

Ghent University, Belgium

Summary:

The last decade has seen a tremendous advance in electronic display applications. Different technologies have been competing to provide devices with large size, high resolution, high brightness, high color saturation and low power. For displays, liquid crystals are currently the preferred material, but OLEDs provide better color saturation and electrophoretic ink displays lower power.

In this presentation we consider recent advances in applications that are based on the material development that has been accomplished in display research. Liquid crystals can be used to produce tunable color filters, tunable resonators, wavelength tunable lasers or beam steering. Electrophoresis serves as a tool to measure the charge, size and refractive index of microscopic particles. For lighting applications, the outcoupling of light from an OLED stack can be increased by introducing structures that avoid the limitations due to total internal reflection. All these photonic applications require a detailed knowledge of the optical behavior.

Bio:



Kristiaan Neyts is research professor at Ghent University in the Electronics and Information Systems (ELIS) department of the faculty of Engineering Sciences and Architecture. He obtained his Ph.D. in 1992 at Ghent University on thin film electroluminescence and held a postdoctoral position at the University of California, Berkeley, USA, from 1997 to 1998. Now he is heading the Liquid Crystals and Photonics group that is conducting research in the fields of

liquid crystals, OLEDs and electrophoresis. This group of 20 researchers has expertise in device technology, numerical simulation and electro-optical characterization. Neyts is co-author of five patents and more than 180 papers listed in the core collection of the Web of Science. Since 2004 he has been the promoter of 15 completed Ph.D.s.

Taming linear and nonlinear light wave packets

Stelios Tzortzakis

Texas A&M University at Qatar, Qatar
IESL-FORTH and University of Crete, Greece

Summary:

The nonlinear propagation of ultrashort laser pulses in the form of solitons, filaments and light bullets is an exciting research field. Beyond the basic studies on the complex physical phenomena involved, the field is driven significantly by the numerous applications. Here we will discuss our recent results on the tailored propagation of linear and nonlinear waves using Gaussian or appropriately engineered waves propagating either in isotropic or periodically modulated media. We show that an appropriate periodic modulation of the index of refraction of the medium offers a very robust way of tailoring the propagation of high intensity laser beams. We also explore tailor-made media presenting strong non-uniformity as well as scattering properties. In the latter case we find conditions under which extreme events are observed. Finally, we propose a way to deliver very high intensities at remote distances overcoming the intensity clamping limit.

Bio:



Stelios Tzortzakis received his Ph.D. from the Ecole Polytechnique (France) in 2001 in nonlinear optics. Presently he is a physics professor at the Texas A&M University at Qatar, while he is also an affiliated professor at the University of Crete and the IESL-FORTH research institute in Greece. He has worked in many research laboratories in France and Greece, and since 2003 he has held a CNRS position at the Ecole Polytechnique. In 2006 he was the recipient of a European Union Marie Curie

Excellence Grant with which he founded and leads the UNIS research group at IESL-FORTH. He is a recognised expert in nonlinear laser propagation phenomena and has created the filamentation.org website, a unique information resource for the related scientific community. His research experience and expertise is around the topics of nonlinear interactions of intense femtosecond laser pulses with matter, nonlinear laser propagation phenomena, ultrafast spectroscopy, hot/warm and dense plasma physics, photonic structuring in transparent solid materials, dynamical metamaterials, photonic lattices, and strong field THz science.

Separation of electronic and nuclear nonlinearities and modeling of organic materials

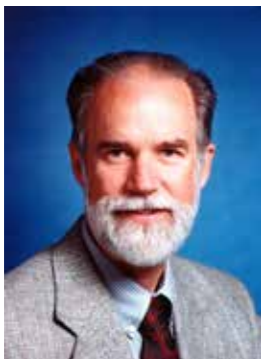
Eric Van Stryland

CREOL, The College of Optics and Photonics, University of Central Florida, Florida

Summary:

Our new nonlinear beam deflection technique allows unambiguous separation of slow and fast nonlinearities and allows testing of models, e.g. gas phase vs. liquid phase to test local field correction factors. Combining results from our recently developed dual-arm Z-scan method, we test a quasi 3-level model for several organic materials that gives surprisingly good results for nonlinear refraction knowing only the linear and 2-photon absorption spectra. From these data we can obtain the wavelength dependence of the standard figure-of-merit for all-optical-switching, which is proportional to the ratio of nonlinear refraction to nonlinear absorption.

Bio:



Eric Van Stryland received his physics Ph.D. working in the Optical Sciences Center at the University of Arizona in 1976 and joined the University of North Texas. He joined the start of CREOL in The College of Optics and Photonics at the University of Central Florida in 1987, became CREOL director in 1999 and its first dean in 2004. He is past president and a fellow of OSA, and a winner of the R.W. Wood Prize. He is a fellow of SPIE, IEEE and APS, and a past board member of

LIA. He has graduated 37 Ph.D.s, published more than 300 papers primarily in the field of nonlinear optics (e.g. Z-scan, nonlinear Kramers-Kronig, cascaded second-order nonlinearities), and is Pegasus Professor and Trustee Chair at the University of Central Florida.

Disordered photonics

Diederik Wiersma

European Laboratory for Non-linear Spectroscopy (LENS),
Università di Firenze, Italy

Summary:

There has been a lot of interest in recent years in disordered photonic media in which the spatial arrangement of scattering elements goes beyond a simple Gaussian distribution. Examples include photonic quasi-crystals, hyper-uniform structures, random lasers, and structures in which the distribution is inhomogeneous. We will discuss recent developments in the field and in particular go into the case of self-similar random systems and Lévy flights, and show how dynamic optical measurements can be used to determine the fractal dimension of an optical random walk. Also we will discuss optical structures found in nature (which can sometimes outperform those created by researchers), and go into real-life applications in the field of lighting and solar energy.

Bio:



Diederik Wiersma received his master's degree cum laude and his Ph.D. from the University of Amsterdam in 1995. He is a professor in the department of physics at the University of Florence and in charge of the micro- and nano-photonics research area at the European Laboratory for Non-linear Spectroscopy (LENS). His research interests lie in the fundamental optical properties of micro- and nano-photonics materials, in particular with periodic, random or amorphous

structure, and their applications in lighting and solar energy. He has recently started a new research line on microrobotics and photonics, supported by the European Research Council.

Quantum optics of a quantum emitter in the vicinity of a plasmonic nanoparticle

Victor N. Zadkov

International Laser Center, M.V. Lomonosov Moscow State University, Russia

Summary:

Control of the near-field in the proximity of plasmonic nanostructures is a key to shaping the spatial intensity of light and its polarization distribution at the nanoscale. Near-field being formed by the interference of the incident electromagnetic field with the local field of the nanoparticle strongly depends both on polarization of the incident field and aspect ratio of the prolate nanospheroid. Dependence of the near-field intensity distribution on these parameters has been studied in detail and it was shown that plasmon oscillations in the nanoparticle excited by the incident electromagnetic field could lead to a significant (up to the tens or even hundreds of times) enhancement of the near-field. Such plasmonic nanoparticles are able not only to efficiently convert incident optical radiation into a highly localized near-field, but also vice versa. Plasmon oscillations in the metal nanoparticle excited by the incident electromagnetic field affect also the spontaneous relaxation rate of a quantum emitter (atom, molecule, quantum dot) located in close proximity of the nanoparticle. Most attention, both experimentally and theoretically, has been paid to controlling the properties of the spontaneous fluorescence of quantum emitters in the vicinity of a metal nanoparticle and, recently, to the resonance fluorescence spectrum.

The properties of a quantum emitter near a nanoantenna are determined by the position of the emitter relative to the nanoantenna and both, the amplitude and polarization of the near-field at the point where the emitter is located. Taking into account the actual polarization at the emitter's location is crucial for the interaction of the nanoparticle with the quantum emitter. However, despite this demanding request, how the near-field polarization distribution depends on the frequency and polarization of the incident electromagnetic field still remains largely a challenging question and related works are just at start. In this work, we present the results of detailed theoretical study that reveals how the near-field polarization

distribution of a metal nanoparticle (prolate nanospheroid) interacting with a plane electromagnetic wave depends on the polarization and frequency of the incident field. Using these results we also analyze the resonance fluorescence of a two-level quantum emitter in the vicinity of a plasmonic nanoparticle, effects of bunching/antibunching and squeezing of photons from resonance fluorescence, as well as study their photon number statistics.

Bio:



Victor Zadkov is with the Department of Physics at M.V. Lomonosov Moscow State University. He received his M.S., Ph.D. and Dr.Sci. degrees in physics from the same university. Since 1991 he is a vice director of the International Laser Center and since 2000 a vice dean of physics. Zadkov's current research interests are in the field of laser physics, interaction of laser radiation with matter, laser applications in life sciences, nanophotonics, quantum optics and foundations of quantum

information. He is an author of more than 150 refereed publications, including a book, and an editor of various collections and special issues of journals. Zadkov is a member of the EPS and has also served for many years as an associate member and member of the Quantum Electronics and Optics Division Board of the EPS and as a jury member for the Prize on Research into the Science of Light, Fresnel Prizes and QEOD Thesis Prizes. In 2015 he was elected a member of the EPS Council. He is also a member of the OSA, and appointed a member of the OSA International Council for 2014-2016 and a member of the OSA Hopkins Leadership Award Committee for 2013-2015. In 2009 he was elected a member of the C-17 commission of the IUPAP and in 2011 a chair of this commission. Zadkov is a member of the international steering committee for the International Year of Light 2015. He is also in the roots of several collaboration projects in between Russia and Germany, France and China. Zadkov serves on the editorial boards of the European Physical Journal D, Journal of Quantum Computers and Quantum Computing and the Moscow University Physics Bulletin, and is a program committee and international advisory board member for many international conferences and symposia.

Sub-wavelength lithography and microscopy via Rabi oscillations

M. Suhail Zubairy

Institute for Quantum Science and Engineering (IQSE), Texas A&M University, USA

Summary:

In optical lithography, the feature size in which scientists can write the circuits is limited to half the wavelength of the light by something called the diffraction limit. Many attempts have been made to advance this field beyond the current limit set by the wavelength of the laser used. In this talk, I shall review these methods and then present a method for optical sub-wavelength lithography based on Rabi oscillations that is only a single preparation step away from the currently implemented lithographic process. This method allows, in principle, to write a pattern with an accuracy better than a millionth of the wavelength of the light used. We shall discuss the experimental realization of this scheme. Another high-resolution method, the structured illumination microscopy (SIM) has been of special interest in high precision imaging in recent years. Linear SIM has been realized nearly 20 years ago but with resolution limitation. Since these years, nonlinear SIM has become a widely used method to get a high-resolution image. In this talk we will discuss how the nonlinearity associated with Rabi oscillations can be used for precision imaging.

Bio:



M. Suhail Zubairy is a University Distinguished Professor of Physics and the holder of the Munneryn-Heep Chair in Quantum Optics at the Texas A&M University. He received his Ph.D. from the University of Rochester in 1978. He served as professor of electronics and the founding chairman of the Department of Electronics at the Quaid-i-Azam University before joining Texas A&M University in 2000. Zubairy's research interests include quantum optics and laser physics. He has published more than 300 research papers on topics such as precision microscopy and lithography, quantum computing, noise-free amplification, and atomic coherence effects. He is the co-author of two books, one on quantum optics and the other on quantum computing devices. He has received many honors, including the Willis E. Lamb Award for Laser Science and Quantum Optics, Alexander von Humboldt Research Prize, the Outstanding Physicist Award from the Organization of Islamic Countries, the Abdus Salam Prize in Physics, the International Khwarizmi Award from the president of Iran, the Orders of Hilal-e-Imtiaz and Sitara-e-Imtiaz from the president of Pakistan, and the George H. W. Bush Award for Excellence in International Research. He is an elected member of the Pakistan Academy of Sciences and a fellow of the American Physical Society and the Optical Society.

Electromagnetic toroidal moments, anapoles and flying doughnuts

Nikolay I. Zheludev

Optoelectronics Research Centre, University of Southampton, UK

The Photonics Institute & Centre for Disruptive Photonics technologies, NTU, Singapore

Summary:

We review recent progress in toroidal electrodynamics that has been possible with artificial metamaterials. The toroidal dipole is a localized electromagnetic excitation independent from the familiar magnetic and electric dipoles. While the electric dipole can be understood as separated opposite charges and the magnetic dipole as a current loop, the toroidal dipole introduced by Y.B. Zaldovich in 1958 corresponds to currents flowing on the surface of a torus. Resonant interactions of induced toroidal dipoles with electromagnetic waves have recently been observed in metamaterial structures at microwave, terahertz and optical frequencies. They provide distinct and physically significant contributions to the basic characteristics of matter, including absorption, dispersion and optical activity, the origin of which cannot be comprehensively interpreted in the context of standard multipoles alone. Interference of radiating induced toroidal and electric dipoles leads to transparency windows in artificial materials as a manifestation of the dynamic anapole. Toroidal excitations also exist in free space as spatially and temporally localized electromagnetic pulses propagating at the speed of light and interacting with matter.

Bio:



Nikolay Zheludev's research interests are in nanophotonics and metamaterials. He directs the Centre for Photonic Metamaterials at Southampton University, UK, and the Centre for Disruptive Photonic Technologies at Nanyang Technological University (NTU) in Singapore. He is also founding co-director of the Photonics Institute at NTU.

Simulation of irreversible quantum mechanics and quantum gravity phenomenology in nonlocal nonlinear optics

Claudio Conti

Sapienza University of Rome, Italy
Institute for Complex Systems, National Research Council (ISC-CNR), Italy

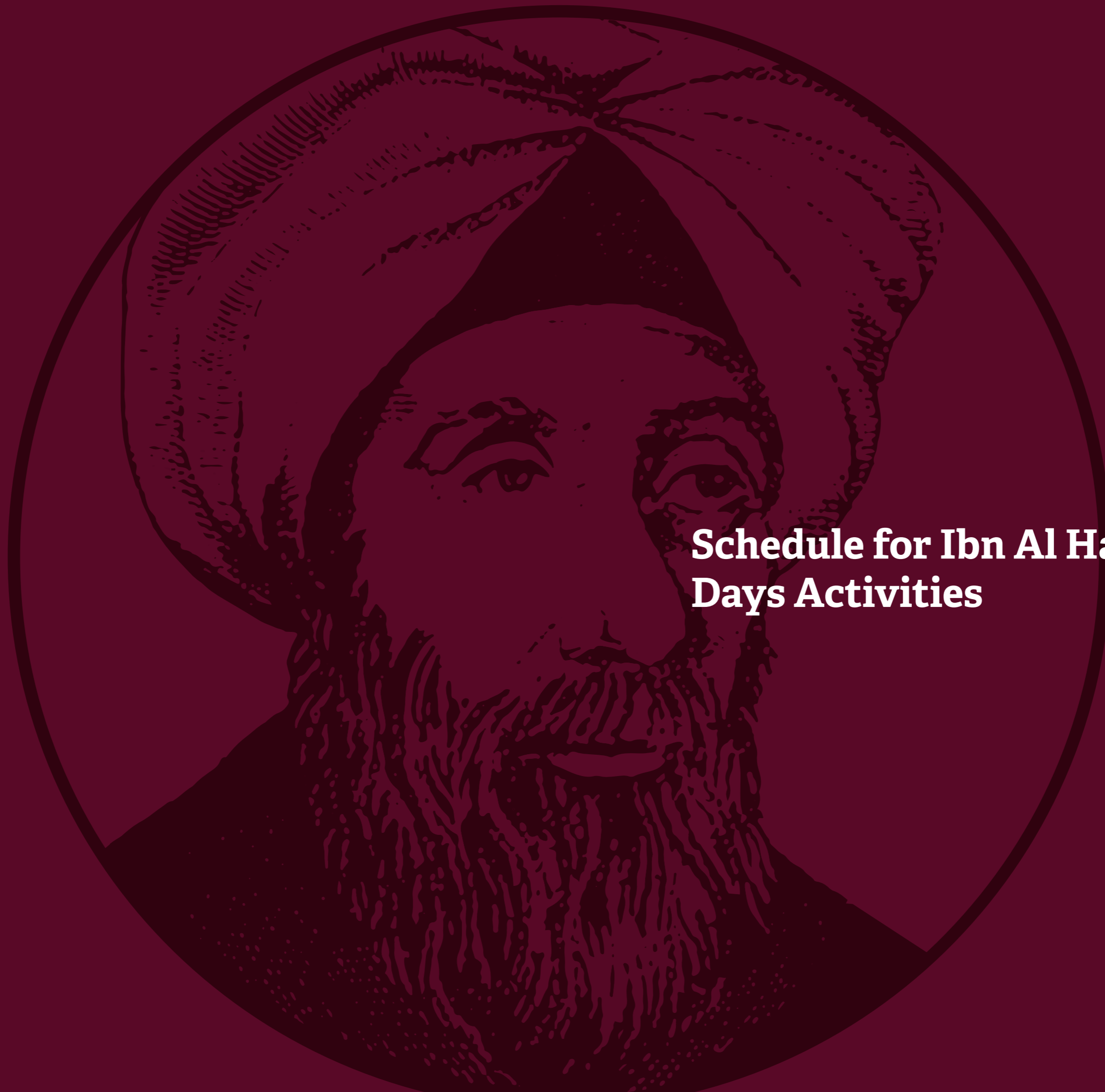
Summary:

We review some of our recent theoretical and experimental developments on the simulation of fundamental physical models by nonlocal nonlinear optics. Specifically, we first consider the case of a defocusing medium and show that it realizes the optical analog of a reversed harmonic oscillator in the highly nonlocal regime. In this analog, the evolution of an optical beam can be described in the terms of the so-called Gamow vectors that are commonly adopted in the Rigged Hilbert Space formulation of irreversible quantum mechanics. We also report on the experimental observation of these states, characterized by a quantized decay rate, and address the relation with dispersive shock waves. We then study the regime of non-paraxial nonlinear nonlocal optics and discuss links with generalizations of quantum mechanics that occur in quantum gravity theories with a generalized uncertainty principle.

Bio:



Claudio Conti (Ph.D. 2002) is director of the Institute for Complex Systems of the National Research Council (ISC-CNR) and associate professor in the Department of Physics of the Sapienza University of Rome. His research activity spans from experiments, to theory, to massive parallel computation in the fields of nonlinear physics, optics and photonics and the science of complexity.



Schedule for Ibn Al Haytham Days Activities

Tuesday, Dec 15th
Ibn Al Haytham Day One
On the Sides of the Photonics Middle East
Conference 2015
Ball Room – Student Center, HBKU (Education City)

Time	Activity	Facilitator
08:00 – 08:10	Brief Welcome	Dr. Abdullah al Kamali
08:10 – 08:30	Ibn Al Haytham Contributions	Prof. Ilham Al-Qaradawi
08:30 – 09:30	Demonstration Origins of light & color Application of light in the simple Laser Pointers	Mr. Thomas Altman
09:30 – 10:00	Student Activities I – Soap Bubbles	Mr. Thomas Altman
10:00 – 10:40	Student Activities II – Laser Optics	
10:40 – 11:20	Student Activities III – Build a Laser Show	
11:20 – 12:30	Lunch & Prayers	
12:30 – 13:30	Teacher Demonstration Lecture	
13:30 – 13:45	Closure	

Wednesday, Dec 16th
Ibn Al Haytham Day Two
On the Sides of the Photonics Middle East
Conference 2015
Ball Room – Student Center, HBKU (Education City)

Time	Activity	Facilitator
07:30 – 07:40	Brief Welcome	Dr. Abdullah Al Kamali
07:40 – 08:40	The coolest use of light – how to make the coldest matter in the universe	Prof. Wolfgang Ketterle, Nobel Prize Winner in Physics 2001
08:40 – 09:25	Demonstration Origins of light & color Application of light in the simple Laser Pointers	Mr. Thomas Altman
09:25 – 09:40	Break	
09:40 – 11:40	Students Presentations on Human Eye & Physics of Light 15 teams (5 teams x 3 school levels x 6 minutes each presentation = 90 minutes + 30 minutes)	Dr. David Cheng & Dr. Amine Jaouadi
11:40 – 12:10	Student Activities I – Soap Bubbles	Mr. Thomas Altman
	Student Activities II – Laser Optics	
	Student Activities III – Build a Laser Show	
12:10 – 12:30	Rewards	Dr. Abdul Sattar and VIPs
12:30 – 12:45	Closure	Prof Ilham Al-Qaradawi
12:45	Lunch	

The coolest use of light — how to make the coldest matter in the universe

Wolfgang Ketterle

Massachusetts Institute of Technology, USA

Summary:

Light has many important properties and applications. I will explain that light exerts forces on particles and objects. These forces deflect the tails of comets, they are used in the form of optical tweezers to manipulate cells and DNA in biological samples, and they allow the trapping of atoms. These forces are microscopically explained by the momentum of the photon, the quantum of light. Photons also have energy, which can be used to heat pellets to temperatures comparable to those inside the sun and enable nuclear fusion. However, laser light can also cool matter to temperatures close to absolute zero. In this regime, new materials with novel properties are observed.

Bio:

Wolfgang Ketterle has been the John D. MacArthur professor of physics at MIT since 1998. He leads a research group exploring new forms of matter of ultracold atoms, in particular novel aspects of superfluidity, coherence and correlations in many-body systems. His observation of Bose-Einstein condensation in a gas in 1995 and the first realization of an atom laser in 1997 were recognized with the Nobel Prize in Physics in 2001 (together with E.A. Cornell and C.E. Wieman). He received a diploma (equivalent to master's degree) from the Technical University of Munich (1982) and a Ph.D. in physics from the University of Munich (1986). He did postdoctoral work at the Max-Planck Institute for Quantum Optics in Garching and at the University of Heidelberg in molecular spectroscopy and combustion diagnostics. In 1990, he came to MIT as a postdoc and joined the physics faculty in 1993. Since 2006, he has been the director of the Center of Ultracold Atoms, an NSF-funded re-search center, and associate director of the Research Laboratory of Electronics.

His honors include the Rabi Prize of the American Physical Society (1997), the Gustav-Hertz Prize of the German Physical Society (1997), the Fritz London Prize in Low Temperature Physics (1999), the Dannie-Heineman Prize of the Academy of Sciences, Göttingen, Germany (1999), the Benjamin Franklin Medal in Physics (2000), the Knight Commander's Cross (Badge and Star) of the Order of Merit of the Federal Republic of Germany (2002), the MIT Killian Award (2004), a Humboldt research award (2009) and memberships in several Academies of Sciences. He holds honorary degrees from Gustavus Adolphus College, St. Peter (2005), the University of Connecticut (2007), Ohio State University (2007), and Strathclyde University (2011), and an honorary professorship at Northwestern Polytechnical University, Xian, China (2014).

