Optics & its applications

17-20 February 2018
Trento, Italy

SPIE. STUDENT CHAPTER
UNIVERSITY OF TRENTO

Hosts the 6th International Symposium in Optics and its Applications

within

SPIE.FOCUS

Symposium Abstract Book

Editors:
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6^{th} International Symposium in Optics and its Applications

SPIE Student Chapter of the University of Trento in collaboration with 14 other European SPIE and OSA Student Chapters will host the 6th International Symposium on Optics and its Applications (OPTICS-2018) on February 17-20, 2018 in Trento, Italy.

The goal of this symposium is to bring together experienced and young scientists from various countries working in the field of optics, and to provide a perfect setting for their discussions of the most recent developments in that area.

The Symposium will provide a good opportunity for contacts and information exchange between experts and students.

14 invited speakers from 10 European Research Institutions will present their talks on different research topics. During the Symposium, a special section will be dedicated to the professional development lectures from the academy and industry points of view. Students will have a chance to present their research with oral presentations as well as posters.

Conference Technical Topic

- Silicon photonics
- Strong field optics
- Optical properties of nanostructures
- Quantum optics
- Singular optics and its applications
- Laser spectroscopy
- Nonlinear & ultrafast optics
- Photonics & fiber optics
- Mathematical methods in optics

Location

The conference will be held in Sala "Luigi Stringa" and Fondazione Bruno Kessler (FBK) are located in Povo, via Sommarive, 18 - about three kilometers away from the city of Trento, in a mountainside of Marzola. The social dinner would be in MUSE ,Corso del Lavoro e della Scienza 3, is very close to the Trento city center, just 10 minutes away from Piazza del Duomo. To reach the Museum from the historical center, we suggest you use the pedestrian subway connecting via Madruzzo to MUSE.

Accommodation Grant

All co-organizer chapters received at least one accommodation grant for the chapter member who will present an oral presentation during the student talks and the chapter during the poster session. The grant covered 4 nights (17.02-21.02) at the hotel in Trento/Povo or the equivalent amount of money, if the participants will prefer to stay in other hotels. In addition to the grants for the chapter representatives, more accommodation grants are available. The applicants will be notified by the end of January.

Chapter Representatives

- Bordeaux Chapter, France - Nicolas Valero
- FEMTO-ST Chapter, France – Florent Behague
- Institute of Radiophysics and Electronics Chapter, Ukraine - Nataliia Mysko-Krutik
- Optics Students Karlsruhe (OSKar) Chapter, Germany - Badrinath Vadakkapattu
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University of Trento SPIE Student Chapter, Italy

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- Stefano Signorini (University of Trento, Italy)
- Alessandro Trenti (University of Trento, Italy)

Sponsors

SPIE FOCUS Conference Grant

The Federation of Optics College and University Students (FOCUS) Conference Grant since 2012 provides SPIE student chapter leaders with financial support to organize a regional student conference that features a significant, non-technical professional development opportunity. Applications for FOCUS Conference Grants are open twice a year and have a grant maximum of $7,000USD$ each.
Chapters are encouraged to collaborate in the organization of the conference. Common elements of a successful FOCUS conference are:

- Strong professional development program
- High quality invited speakers
- Student oral and poster presentations
- Student Best Paper Awards
- Career development
- Social program

15 student chapters from 11 European countries get together for realization of the 6 the edition of International Symposium in Optics and its Applications. 53 over 74 participants of OPTICS-2018 are SPIE members. 4 invited speakers of the symposium are members of the society. This internationality makes OPTICS-2018 the largest international FOCUS conference since 2012.

Others

Invited Speakers

SPIE Invited Lecturers

Michael Berry

University of Bristol, Bristol, United Kingdom

After graduating from Exeter and St Andrews, Michael Berry entered Bristol University, where he has been for twice as long as he has not. He is a physicist, focusing on the physics of the mathematics…of the physics.

Applications include the geometry of singularities (caustics on large scales, vortices on fine scales) in optics and other waves, connections between classical and quantum physics, and the physical asymptotics of divergent series.

He delights in finding the arcane in the mundane – abstract and subtle concepts in familiar or dramatic phenomena:

- Singularities of smooth gradient maps in rainbows and tsunamis
- The Laplace operator in oriental magic mirrors
- Elliptic integrals in the polarization pattern of the clear blue sky
- Geometry of twists and turns in quantum indistinguishability
- Matrix degeneracies in overhead-projector transparencies
- Gauss sums in the light beyond a humble diffraction grating

Superoscillations (faster than Fourier) (p)revisited: vorticulture, noise, fractals

Fine detail near optical phase singularities predated superoscillations, but appreciating the connection took some time. Superoscillation represents almost-destructive interference and is sensitive to noise; now there is a quantitative theory. In an extreme application, superoscillations can accurately represent fractals. A theoretical model explains how gamma radiation could emerge from a box containing only red light.

Magic mirrors and magic windows

Ancient oriental mirrors possess a property that seemed magical and was probably unintended by those who made them: the pattern embossed on the back of such a mirror appears in light reflected onto a screen from its apparently featureless front surface. In reality, the embossed pattern is reproduced on the front, in low relief invisible to direct observation, and analysis shows that the projected image results from pre-focal ray deviation. In this interesting regime of geometrical optics, the image intensity is given simply by the Laplacian of the height function of the relief. Observation confirms this 'Laplacian image' interpretation. Current research aims to create the transparent analogue of the magic mirror: 'magic windows', in which glass sheets, flat to unaided vision, concentrate light onto a screen with intensity reproducing any desired image. Laplacian image theory implies that the desired surface relief is obtained by solving Poisson's equation.

David L. Andrews

University of East Anglia, Norwich, United Kingdom

David Andrews is Professor of Chemical Physics at the University of East Anglia, where his group conducts research on fundamental photonics, optomechanical forces, optical vortices, nonlinear optics, energy harvesting and molecular energy transport. He has more than 20 books and over 360 research papers to his name.

David Andrews is a Fellow of the Institute of Physics, the Royal Society of Chemistry, the Optical Society of America, and SPIE - the international optics and photonics society in which he is an elected member of the Board of Directors.

Photons and Nanoscale Forces

It is well known that light has a capacity to generate forces – a principle already widely used in 'laser tweezers' for example. In the field of optofluidics, there are other applications that also involve a strong response to light, in microscale components. In fact, since each quantum of light conveys a momentum that can engage with matter, attention is increasingly being focused on pursuing these principles in the nanoscale regime, with nanoparticles and large molecules now in realistic prospect. Structured light offers many further avenues of application, with some studies raising the possibility of steering individual molecules, with a view to separating those of opposite chiral form. To understand such interactions is challenging, as quantum features emerge in both the matter and the light itself. This talk shows how photons can drive motion, and how at a deeply fundamental level, quantum fluctuations can also generate exotic nanoscale forces between particles of matter.

Mauro Fernandes Pereira

Department of Condensed Matter Theory, Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic

Prof. Mauro Fernandes Pereira obtained his PhD at the Optical Sciences Center, University of Arizona and has given important contributions to Nonequlibrium Greens Functions (NEGF) Many Body Theory of Transport and Optics of Semiconductor Materials and has been named SPIE Fellow in 2011 for his contributions to the Theory of Semiconductor Materials and Optics.

He created the TERA-MIR concept unifying THz and Mid Infrared Radiation and is the Chair of COST ACTION MP1204: TERA-MIR Radiation: Materials, Generation, Detection and Applications, Chair of the Series of NATO TERA-MIR Conferences (2009, 2012 and 2015).

He was a research associate at CBPF, Uni-Rostock and TU-Berlin, a visiting Lecturer at Bremen, Senior Researcher at Tyndall Institute, Chair of Theory of Semiconductor Materials and Optics at Sheffield Hallam University (2006-2017) and he is now Head of the Department of Condensed Matter Theory at the Institute of Physics of the Academy of Sciences of Czech Republic.

GHz-THz-Mid Infrared Devices: From Fundamental Theory and Simulations to Real World Applications

This talk starts by highlighting the main achievements of the TERA-MIR network [1] with a focus on the devices developed.

Next, my recent research is summarized: The α-factor of intersubband lasers was expected to be zero. However, values ranging from -0.5 to 3 have been found experimentally. This will be explained with a Nonequilibrium Green's Functions approach [2].

Analytical solutions for the evolution of peak luminescence with temperature will be presented as a numerical characterization tool for the MIR and NIR ranges [3-6].

Evolving from the MIR to THz-GHz, the talk introduces a concept to study nonlinear optics through controllable nonlinearities in semiconductor superlattices [7-8]. These results open the possibility of extending the whole field of nonlinear optics to the GHZ-THz range and the possibility of designing materials and devices for a large number of applications, including spectroscopy of biomolecules, which typically have GHz-THz resonances.

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Professional development speakers

Henk Leeuwis

LioniX International BV, Enschede, The Netherlands

Henk Leeuwis (m) (Senior Vice-President, Strategy and Innovation) obtained his MSc degree in Electrical Engineering at the University of Twente. He has been active in micro/nano system technology in general for over 35 years.

He has been project manager and department head including the responsibility for marketing and sales (Dutch Centre for Micro-Electronics (1984-87), 3T BV (1988 - 2001). Since January 2002 he has been Executive VP and Head Space Dept at LioniX BV (since 2016 LioniX International BV) and since 2012 he is responsible for integrated photonics based R&D project initiation in national, EU and NSO/ESA framework as Vice-President Strategy and Innovation. He has been active in European programs as project leader for RTD projects and as a proposal evaluator. He is Honorary Founder of the Dutch Micro/Nano Technology Association MinacNed and is involved in numerous governmental task forces and committees.

Academy-Industry collaboration connection with LioniX International B.V. example LioniX International BV, Enschede, The Netherlands

LioniX International is a leading global provider of customized microsystem solutions, in particular integrated photonics-based. We provide customized solutions for OEM's and System Integrators, from design to device, by vertical integration in scalable production volumes. LioniX International focuses on Photonic Integrated Circuits (PIC) enabled modules based on its proprietary waveguide technology (TriPleX^{TM}), in addition to its other core competences micro-fluidics, opto-fluidics and MEMS. Currently LioniX International employs nearly 50, highly educated people, and its management has experience in the micro/nano system technology for decades.
In order to build and maintain its technology leadership and a strong IP position, LioniX is very active in R&D collaborations with universities and institutes in national, EU and NSO/ESA framework, while for the development and production activities processes and equipment of the adjacent University of Twente / MESA+ Nanolab are being used ('facility sharing'). With its big role and experience in the innovation community, LioniX is one of the leading policy advisers in innovation strategy with a focus on disruptive technology issues.
In the presentation the activities of LioniX and the collaboration approach with academia will be exemplified. Next to this, the disruptive innovation chain in general, and the important position of (high) tech companies in particular, will be dealt with.

Mattia Mancinelli

Research Programs, SM Optics s.r.l., via John Fitzgerald Kennedy 2, Vimercate 20871, Italy

Mattia Mancinelli received his M.S degree in Physics in 2009 from the University of Trento, with a thesis in optoelectronics. In 2013 he obtained the Ph.D degree with a thesis on Linear and non-linear coupling effects in sequence of microresonators, within the NanoScience Laboratory of the University of Trento.

He became a post-dot within the NanoLab until April 2017. His activity covered the fields of Photonics, mainly focusing on silicon photonics, covering both experimental and theoretical study of optical integrated circuit, for both linear on nonlinear optics. He also worked on WDM and Telecom applications.

He was nominated as work-package leader for both the European project IRIS and the project SIQURO. The former concerns the realization of a revolutionary transponder aggregator in silicon photonics that contains hundreds of add-drop multiplexer. The latter concerns the generation of correlated photon pairs or single heralded photons exploiting a second order or third order parametric process in suitably designed silicon waveguides.

Since April 2017 he joined the R&D group of SM optics company to mainly performs transmissive tests on Optical Network and research on opto-electronic devices.

The working experience trained him on how to handle the *laboratory life* including the design and realization of an automated experimental set-up. Thanks to the experience of tutoring several PhD and master students, he has gained a great skill in working in a team and in stimulating the team to find the solution and reach the final goal.

The line between Academy and Industry

Be a researcher in an academic institution can be completely different from being a researcher in an industry.

The aim of this talk is the understanding of the main differences of the two world, and how the work requires the researchers to adapt to different situations.

Based on the personal experience, during the talk it would be underlined the most appropriate way to prepare ourselves to the changes and modify our approach to the work.

Finally, it would be analyze what is the best strategy to be a successful employee and to be able to make the difference in your work place.

Maurizio Sbetti

ADIGE S.P.A., BLM GROUP, Levico Terme, Italy

Degree in Physics from the University of Trento, Italy. Thesis in Optical Spectroscopy of doped glasses. Semiconductor Analyst by Dinamic Secondary Ion Mass Spectrometry for STMicrolectronics Italy Since 2000 in BLMGroup, Adige, Laser Tube Division.
Training, documentation, testing, product development and research have been the major activities in the time.

Today he manage the R&D team of Adige, with a personal specific interest in the laser technology evolution, laser safety, overall product and service development strategies, IP topics, research communities and organizations.

Careers for physicists in photonics-enabled industrial companies: a personal experience

An informal talk about one of the several paths a physicist can follow in an industrial organization , especially in the specific case of photonics and laser-enabled business.
The outline would be: A personal view of the evolution of the competencies, and the correlation between what the organization does and which are the skills needed for growing.
The map of the main industrial fields in applied photonics in the world, with a focus on material processing.
A view of the main research organizations and initiatives in photonics in Europe

Invited speakers

Mehr Ghulinyan

Functional Materials and Photonics Structures, Fondazione Bruno Kessler, Povo, Italy

M.S. in 1995 and Doctoral degree in physics in 1999 from the Yerevan State University. As a postdoc (2002 to 2006) at the University of Trento, his early-carrier research in Silicon Photonics – silicon-based Optical superlattices (OSL) – paved the way to the first-time demonstrations of fundamental phenomena: photonic Bloch oscillations [PRL-2003, cover story] and resonant Zener tunneling [PRL-2005-a], Anderson localization of light and observation of optical necklaces [PRL-2005-b], vapor control of photonic bands [PRB-2006] and optical switching using capillary condensation [Nat.Photon.-2007].

Currently, he is a senior researcher at the Centre for Materials and Microsystems (FBK) and holds a leading role in the development of FBK-CMM's capacities to perform optical engineering and fabrication of different micro/nano-optical components and circuitry. His interests are in the field of resonator optics, with a particular focus on monolithically integrated optically active and passive planar microresonators. Current research includes developments towards integrated Silicon Quantum Photonics and heterogeneously integrated active Silicon Photonics. Since 2012 holds the master's course of Photonics at the University of Trento as contract professor. He is a member of the Optical Society of America (OSA), author and editor of two book, several book-chapters, more than 120 research papers and inventor of 2 patents.

Integrated photonics research in FBK

We will present an overview of novel technological platforms for the realization of fully integrated microresonator structures for silicon photonics. A basic introduction to open resonators and their integration will be followed by an example. In particular, we will describe thin silicon nitride-based ultra-high-quality factor ring resonators monolithically integrated on a silicon chip. These devices are based on a strip-loaded configuration in which the absence of physically etched lateral boundaries in the guiding components leads to significantly reduced scattering losses. Consequently, Q's of 3,7×106 in the NIR (780nm) and up to 1×106 in the C-band (1550nm) were measured for very thin guiding material thickness of 80 nm and 115 nm, respectively. These developments are subject to further improvements that may allow employing strip-loaded devices in nonlinear frequency conversion or quantum computing schemes within the desired spectral range, provided by the material transparency. Current and future developments to bring the strip-loaded devices onto SOI platform will be also overviewed.

Fernando Ramiro-Manzano

Centro de Tecnologías Físicas, Instituto de Tecnología Química (CSIC-UPV), Valencia, Spain

Fernando Ramiro-Manzano received the Ph.D. degree in 2008 at the Polytechnic University of Valencia, Spain. At the beginning of his PhD studies, he worked on enhancing the efficiency of photo-electro-chemical solar cells exploring novel photonic structures based on self-assembled colloids, filling a patent. This project allowed him to create a new and successful research line in the laboratory: novel colloidal structures induced through confinement. After his PhD defense, he focused on photoluminescence enhancement effects appearing on novel porous-Si spherical microresonators with applications such as unique biomarkers.

Then, he won an IEF Marie Curie Project and moved to the University of Trento, Italy. He was involved in projects exploring novel light-injection, multimodal coupling strategies and non-linear effects in the frame of silicon-based planar-microresonators. Next, as a researcher associate of the University of Trento, he focused on bringing novel quantum phenomena to the market to enable planar Si technologies. He was the main instructor of Integrated Photonic Devices. He studied on-chip frequency conversion of Si-based materials as well as non-linear interferometry for Quantum Photonic applications and phenomena such as Quantum Fluids of Light. Next, he moved to the group Centro de Tecnologías Físicas inside of Instituto de Tecnologías Químicas-CSIC, Valencia (Spain) for working as a PI of a project related to resonators based on novel hybrid organic/inorganic materials for the light generation, manipulation and harvesting. He is an author or coauthor of 44 publications (of which 31 are peer-reviewed journal articles) holding an H-number of 14 according to Scopus.

Forward and backward photonic routes through integrated devices

The common strategy for designing a circuit is to assemble the inputs and outputs of building blocks and then concatenating transfer functions. The presence of a counter-propagating signal usually is considered as a spurious effect or a source of unwanted perturbation to eliminate. The optical microresonator, one of the main building blocks of integrated photonics, when is designed and fabricated for achieving a high Quality factor, usually presents performance-limiting back-reflections due to surface roughness. This generates a counter-propagating resonant light that coupled with the forward signal provokes mode splitting in the transmitted light. Anomalies in the balance of the splitting are attributed to external factors such as the waveguide coupling or nonlinear effects. Here, in this talk, we will show that the resonator itself could explain this effect and present a richness of counter-clockwise coupling possibilities. Moreover, we will present how to control them.

This could open the door to an additional degree of freedom of the photonic circuits, where the ports of the photonic components changes from in or out to duplex (in/out) in a dual signal processing. In particular, this talk will deal with advanced characterization techniques based on interferometry, implications of the time-reversal symmetry in numerical and analytical models, and non-linear optics.

Artur Aleksanyan

Laboratoire Photonique Numérique et Nanosciences (LP2N), Institut d'Optique d'Aquitaine, Talence, France

Artur Aleksanyan is currently a post-doctoral researcher at Institute d'Optique in Bordeaux. He graduated from Yerevan State University (Armenia) with the degree in Optics.

He was always fascinated with the universe, hence, once he got an offer to move to Bordeaux to be involved in a research connected with creating optical devices to find and explore celestial objects nearby bright sources, he took it without hesitation. Little did he know that he also liked wine... After a few years of active research in "effectively canceling undesired light sources", he now tries to apply his expertise from macro- to micro- or nano- world and find similarities between them. Artur is driving a bike at any weather, plays piano and listens to all sorts of music.

Natural adaptive approach towards optical vortex coronagraphy

In 1931, French astronomer Bernard Lyot suggested that placing a beam stop in the center of the Fou-rier plane of a telescope allows observing faint objects nearby on-axis bright sources. Particularly, he was using this tool to study the corona of the Sun, hence the name of this new astronomical imaging technique - coronagraphy. Since one decade, there is a growing interest in vortex phase masks that may efficiently reject on-axis light. The fabrication of these masks usually involves demanding proto-cols enabling precise material structuring down to the microscopic scale. Here we discuss how to get rid of machining techniques by benefiting from spontaneous topological structuring of matter under external fields. First, we show that spontaneously occurring liquid crystal topological defects offer a smart alternative to vortex phase masks [1]. We also address a simultaneous extinction of multiple bright sources on demand via adaptive liquid crystal light valve device used to generate on-demand multiple vortex masks [2]. Finally, we consider an alignment-free approach where the bright source itself creates its own vectorial vortex transmission mask via a photoelastic phenomenon [3]. In all the-se cases, laboratory demonstrations supported by simulations will be presented.

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David Blaschke

University of Wroclaw, Poland; JINR Dubna, Russia; MEPhI, Russia

David Blaschke is Professor for Theoretical Physics in the Institute for Theoretical Physics at the University of Wroclaw (Poland).

Born the 22nd of September 1959, he received his PhD in Physics in 1987 at the University of Rostock (Germany) where he habilitated in 1995 and became Private Docent in 1996. In 1998, he won the competition for a Professorship in Particle and Astrophysics at the University of Rostock, which was partly funded by the Max-Planck Society. In January 2001 he became elected Vice Director of the Bogoliubov Laboratory for Theoretical Physics (about 200 employees) at the Joint Institute for Nuclear Research Dubna (Russia); a position he held for 7 years, thereafter continuing as a leading scientist. In the period 2003 – 2006 he held guest professor positions at the Universities of Bielefeld, Rostock and Zagreb and a visiting scientist position at GSI Darmstadt. Since October 2006 he is Full Professor at the University of Wroclaw, where he teaches Quantum Field Theory, Statistical Physics, Matter under Extreme Conditions in Heavy-Ion Collisions and Compact Star Astrophysics and is leading a group of 10 people in the Department of Theoretical Particle Physics. He has supervised more than 15 PhD and more than 25 Diploma/Master theses. His research is centered around the problem of bound state formation and dissociation in strongly interacting matter at high densities, temperatures and field strengths, in thermodynamic equilibrium as well as nonequilibrium. In this field he is one of the worldwide recognized experts. He organized more than 60 international conferences, workshops and schools and is a frequently invited speaker. He manages several research projects, both national and international. Most notably he coordinates since more than 10 years the Helmholtz International Summer Schools (2 per year in different topics of the field “Structure of Matter”) at the JINR Dubna. He was co-speaker of the Virtual Institute on “Dense hadronic matter and QCD phase transitions” formed by 6 German Universities with GSI Darmstadt (2003 – 2006), Chair of the European Science Foundation Research Networking Programme on “The New Physics of Compact Stars” (2008 – 2013) and is presently Management Board member of the COST Actions MP1304 on “Exploring Fundamental Physics with Compact Stars (NewCompStar)”, CA15213 on "Theory of hot, dense matter in relativistic heavy-ion collisions (THOR)" and CA16214 on "Multi-messenger .physics and astrophysics of neutron stars (PHAROS)". He is a frequently invited reviewer, monitor or referee for several funding agencies and more than 20 scientific Journals. He is an author or co-author of more than 300 papers which earned him about 6000 citations and a Hirsch index h=41 according to INSPIRE; he co-edited more than 10 books. He is elected member of the Editorial Board of the European Journal of Physics A (Hadrons and Nuclei) where he is responsible for the Topical Issues on “Exotic Matter in Neutron Stars” and “The NICA White Paper”. In 2012 he became elected member of the Academia Europaea. In 2017 he was awarded the title honorary professor (Dr. h.c.) of the University of Dubna, Russia.

Dynamical Schwinger effect in strong, time-dependent external fields

Vacuum particle production by the Sauter-Schwinger effect under action of time-dependent strong fields of different nature possesses a number of general properties which on the qualitative level are independent of the nature of the concrete system. These are, e.g., the existence of the quasiparticle stage of the excitation during the period of the field action, the transient stage of fast oscillations in the period of the external field degradation, the change of symmetry of the system, and the emergence of a strong non-equilibrium out-state. Illustrating examples one can select from condensed matter physics, the physics of stongly correlated systems, the theory of relativistic phase transitions, early cosmology etc. The universal character of such phenomena allows to unify them in the rather general class of field induced phase transitions, a term adopted from the works [1,2,3]. The general foundation for this is the mathematical similarity of the corresponding kinetic equations describing the particle production processes.

In the present report we consider in detail an example from the strong field QED, where the kinetic equation is well known for the linearly polarized, spatially homogeneous, time-dependent external electric field model [4,5]. We give an outlook to applications of the approach in describing particle production in strong external fields provided by high-intensity lasers and nuclear collisions [6].

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Iacopo Carusotto

INO-CNR BEC Center, Povo, Italy

Iacopo Carusotto he has earned a PhD from SNS-Pisa (Italy) in 2000 working in the solid-state group of prof. La Rocca and Bassani and then made a post-doc in Yvan Castin's atomic physics group at LKB-ENS in Paris.

Since 2003 he works at the BEC Center in Trento where since 2009 he holds a “Senior Researcher” position and leads a group active in the many-body theory of quantum fluids of light and, more recently, synthetic magnetism and topological effects with light.

Quantum fluids of light

Light propagating in nonlinear photonic devices can be seen as an ensemble of photons showing collective fluid-like behaviours under the effect of the interactions induced by the Kerr nonlinearity.
I will start by reviewing key experiments demonstrating Bose-Einstein condensation and superfluidity features in quantum fluids of light. I will then present some among the most exciting research directions, with a particular attention on topological and quantum magnetism effects for light.

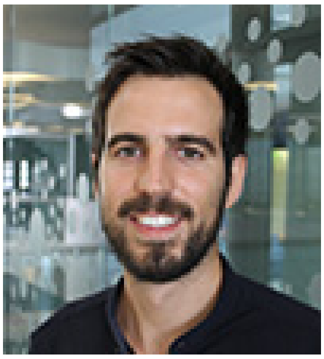
Giorgio Colangelo

ICFO - The Institute of Photonic Sciences The Barcelona Institute of Science and Technology, Barcelona, Spain

Giorgio Colangelo got the PhD at the ICFO - The institute of Photonic Sciences of Barcelona (Spain) in the group of prof. Morgan Mitchell where he worked in quantum metrology with cold atomic ensembles.

His researches where focused on the physics beyond Heisenberg principle to produce spin squeezed states and entangled states among macroscopic number of particles.

Currently he is working in the ICFO-Knowledge and Technology Transfer department, where he is developing a scientific program to promote scientific and technological education among young people.



Simultaneous measurements of non commuting observables in atomic interferometry

Continuous monitoring of a quantum system is essential to high-sensitivity measurement of time-varying quantities from biomagnetic fields to gravitational-wave strain.

Naive tracking strategies have limited sensitivity due to quantum back-action, in which measurement of one observable disturbs other, non-commuting observables. Quantum-aware strategies have shown back-action evasion, foregoing knowledge of one observable to precisely measure another.

Recent proposals suggest that back-action can be evaded even when tracking multiple, non-commuting observables, by employing negative-mass oscillators or zero-area Sagnac interferometers.

Here we show how simultaneous, back-action evading tracking of non-commuting observables can be achieved in a widely-used sensing technology, atomic interferometry. Using high-dynamic range dynamically-decoupled quantum non-demolition (QND) measurements on a precessing atomic spin ensemble, we track the collective spin angle and amplitude with negligible effects from back action, giving steady-state tracking sensitivity 2.9 dB beyond the standard quantum limit and 7.0 dB beyond Poisson statistics. The technique greatly extends the quantum limits for atomic sensors that track frequency, acceleration, rotation and gravity, magnetic fields, and physics beyond the standard model.

Massimo Borghi

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Massimo Borghi received the B.S. degree in physics from University of Modena and Reggio Emilia, Italy, in 2010, the M.S. degree in experimental physics from University of Trento, Italy, in 2012, and the Ph.D degree in physics from the University of Trento, Italy, in 2016.

He was a post-doc at the Nanoscience laboratory at University of Trento till 2017. From 2018, he is a research associate at the Quantum Engineering Technology labs at the University of Bristol. His research interests include passive integrated networks involving single and coupled resonators, nonlinear Silicon photonic devices for frequency up/down conversion, electro-optic effects in strained silicon devices, quantum optics in both free space and integrated Silicon On Insulator circuits.

Integrated quantum photonics

The first quantum revolution, occurred during the last turn of the century, enstablished the underpinning principles of quantum mechanics. The semiconductor technology, based on transistors, diodes and assemblages of them, was born after the first quantum revolution, which can be then considered as the father of the microelectronics. Since then, our understanding of the, somewhat weird, laws of quantum mechanics, such as quantum entanglement, superposition and wavefunction collapse, endlessy improved. We are now in the midst of the second quantum revolution, in which quantum technologies are starting to move from the laboratories to markets. Quantum technologies harness the unique law of quantum mechanics to beat what were tought to be the insurmountable limits of science and devices which are based on classical laws of mechanics and electromagnetism. Among these, silicon photonics integrated quantum circuits use photons as non-classical information carriers, and they have been demonstrated to be versatile devices capable of realizing a wide variety of tasks, such as quantum sensing, quantum computation and quantum simulation. The goal of this talk is to provide a general overview of the subject, take stock of the state of the art and to show the future directions.

Lorenzo Pavesi

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Lorenzo Pavesi is Professor of Experimental Physics and head of the Department of Physics at the University of Trento (Italy). Born the 21st of November 1961, he received his PhD in Physics in 1990 at the Ecole Polytechnique Federale of Lausanne (Switzerland). In 1990 he became Assistant Professor, an Associate Professor in 1999 and Full Professor in 2002 at the University of Trento.

He leads the Nanoscience Laboratory (25 people), teaches several classes at the Department of Physics of the University of Trento. He founded the research activity in semiconductor optoelectronics at the University of Trento. He has directed more than 30 PhD students and more than 30 Master thesis students. His research activity concerned the optical properties of semiconductors. During the last years, he concentrated on Silicon based photonics where he looks for the convergence between photonics and electronics. He is interested in active photonics devices which can be integrated in silicon by using optical nolinearities and modified material properties. His interests encompass also optical sensors or biosensors and solar cells. Recent development is toward integrated quantum photonics. He organized several international conferences, workshops and schools and is a frequently invited speaker. He manages several research projects, both national and international. He is a frequently invited reviewer, monitor or referee for photonics projects by several grant agencies. He is an author or co-author of more than 500 papers, author of several reviews, editor of more than 15 books, author of 2 books and holds 7 patents. He is chief speciality editor of the section Optics and Photonics of Frontiers in Materials and in the Editorial Advisory Board of APL Materials. Moreover he sits in the editorial board of the ETRI Journal. He is in the advisory board of Glass-to-Power and of Sybilla, two italian start-up. In 2001 he was awarded the title of Cavaliere by the Italian President for scientific merit. In 2010 and 2011 he was elected distinguished speaker of the IEEE- Photonics society. He is fellow of the IEEE and senior member of SPIE. He holds an H-number of 55 according to the web of science or Scopus and of 67 according to Google Scholar.

Classical and Quantum integrated Silicon Photonics

A review of the main concepts of linear, nonlinear and quantum photonics will be presented. Special emphasis will be placed on the use of integrated single and coupled microresonators as the single enabling building block where photon mode interactions, nonlinear optical effects and entangled photon generation can be achieved. Examples of applications of silicon photonics in biosensing for toxin in milk detection, on-chip optical switching matrix for next generation optical networks and quantum random number generator will be discussed.

Alessandro Tredicucci

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Prof. Alessandro Tredicucci is full professor of matter physics at the University of Pisa since 2014. He holds a Ph.D. in Physics from the Scuola Normale Superiore (1997), and was previously at Bell Labs, Scuola Normale Superiore, and CNR.

He is well known for having pioneered the development of THz quantum cascade lasers as well as the investigation of intersubband polaritons. His activity is now also focused on graphene photonics and THz optomechanics. He has co-authored more than 250 articles (h-index is 54), holds 15 international patents, and has about one hundred conference invited talks. He's the recipient of several awards, among which the Occhialini Medal of the Institute of Physics and Italian Physical Society, and the Nick Holonyak award of the Optical Society of America, of which he's also Fellow.

How to control light with light: perfect absorption and transparency through interference

Despite its apparent simplicity, the field of linear wave optics is still reserving surprises, with the emergence of unexpected physical phenomena that may prove of strong technological impact. One of these is coherent perfect absorption (CPA), which is essentially the time-reversal of lasing at threshold [1]. Together with its counterpart, i.e., coherent perfect transparency (CPT), these phenomena are expected to significantly impact all-optical signal processing techniques. Indeed, by CPA/CPT schemes it is possible to modulate the intensity of one optical beam by means of a second, possibly very weak, optical beam, without resorting to nonlinearities [2]. CPA/CPT schemes can be implemented in several systems, ranging from integrated optics [3, 4] to metasurface-based systems [5], where the added value of subwavelength footprint can also be achieved [6].
In this lecture I will discuss the fundamental aspects of these phenomena [7] as well as address relevant outstanding issues like the performance of passive optical switches in terms of compromise between insertion loss and extinction ratio [8].

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Oral Student Presentations

Additive manufacturing towards fabrication of next generation of optical fibres

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New generation of optical fibres faces the challenge of multiple step processes due to the need of producing fibres with complex geometries on single or multiple materials and dopants. Finding an alternative and novel fabrication method for optical preforms is the challenge in the production of this new generation of fibres. Conventional fabrication methods such as MCVD, OVD and VAD need to be complemented with post processes that reduce the repeatability of the fabrications process and endanger preforms. Additive Manufacturing processes were explored as a potential solution in a complex fabrication process of novel optical fibres. 3D printing methods such as selective laser sintering (SLS) for hard materials and fused deposition modelling (FDM) for soft materials were analysed in this work. A preliminary analysis concludes additive manufacturing processes can be a viable solution for the production of novel optical preforms for fibre fabrication.

Optical sensing of an interlacing yarn

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Interlacing is employed in textile industries to impart cohesion to multi-filament yarns. The geometry of an interlacer consists of an air jet nozzle and a yarn channel; as the continuous air jet impinges on a parallel yarn running through the channel, filaments are intermingled with each other, producing an interlaced yarn with periodic opening and tangling parts. These cohesion points, also called knots, are required since parallel multi-filament yarns can easily separate or break during post processing, such as winding, weaving and knitting [1]. The post processing of the interlaced yarn needs a high regularity in the distance between knots, in order to guarantee homogeneity in the appearance of the final fabric. Even if the process is periodic, not-interlaced segments occur without a clear reason. Therefore, an on-line counting technique is required in order to monitor the regularity of interlacing during yarn production. Furthermore, textile companies are interested in reducing the power consumption due to compressed air and hence the dynamics of knots formation needs to be further investigated.
An optical sensing approach allowed us to examine the yarn motion in an interlacer, by means of high speed videos. Through a quantitative analysis of the video, we identified the yarn width as a parameter that describes on-line the process and measures the knots distance and its distribution. Previous numerical simulations of the airflow pattern in the yarn channel indicate the formation of two twin vortexes in the yarn channel, ignoring the influence of the yarn [2]. The optical analysis of yarn motion let us suggest that the yarn-vortexes interaction plays a key role in the knots formation dynamics.

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Characterization of Optical Crosstalk in Vertically-integrated SPAD Arrays

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Optical crosstalk in silicon pixel detectors is a process characterized by the emission of photons in the p-n junction of a device and its successive detection in nearby pixels. Even if over the last two decades some works on optical crosstalk have been presented, its effect in SPAD arrays and integrated devices deserves further investigation, fostered by the increasing development of array detectors and 3D integration technologies.

In this study, measurements of intra-layer and inter-layer optical crosstalk of a two-tier silicon detector are reported and discussed. The vertically integrated prototype, designed for charged particle detection, is formed by two pixelated SPAD arrays connected by bump bonding. Each array is composed by an 8x48 sub-array of SPADs with a deep junction and an 8 x 48 sub-array of SPADs with a shallow junction. While the crosstalk coefficient is generally extracted from dark count rate measurements, in our study we performed direct crosstalk measurements by exploiting the coincidence detection circuits monolithically integrated in the prototype.

Intra-layer crosstalk was evaluated collecting measurements at different excess bias voltages and comparing the two different types of detectors. Samples with various substrate thicknesses (280 μm, 50μm and 25 μm) were analyzed. As the substrate thickness decreases the amplitude of the crosstalk coefficient increases highlighting the presence of guided-mode propagation within the silicon layer. Inter-layer crosstalk was investigated activating pairs of vertically-aligned detectors at different excess bias voltages.

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Ultrafast detection of IR photons by thermoelectric single-photon detector at the telecommunication wavelength

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Intense development of science and high technologies requires new generation of devices for precise measurements in different areas. Interest in quantum key distribution has recently dramatically increased due to developing of single-photon detectors (SPD) for the telecommunication wavelength at 1550 nm (0.8 eV) [1]. The count rate, dark count rate and efficiency of the detectors limit the range and bit generation rates that can be achieved in telecommunication systems. Different types of SPD can be used for infrared photon detection. However, to be useful as a SPD the photodiode must be surrounded with additional electronics; avalanche photodiodes have proven to be convenient and cost-effective devices, but their count rates are not high enough [2]. Superconducting SPD outperform semiconducting detectors in terms of the counting rate, detection efficiency, dark count rate and timing jitter [3]. In our previous works it is shown, that thermoelectric single-photon detectors (TSPD) with different construction of the detection pixel have high energy resolution, gigahertz count rate and thus can be a real competitor to superconducting detectors in a wide range of the electromagnetic spectrum [4, 5]. In this work the results of computer simulation of heat distribution processes in single-layer and multilayer detection pixels of TSPD after 0.8 eV energy photon absorption are presented. We have collected and analyzed the values of physical parameters of different materials at 0.5 K and 8 K and on this basis calculated the energy resolution and photon count rates of TSPD of different geometries. It is concluded that the TSPD can achieve higher specifications, as compared to the best SPD, for usage in telecommunication systems.

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Optical and microfluidic monolithic devices fabricated by femtosecond laser micromachining

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Femtosecond laser direct writing (FsLDW) [1] is a technique that enables material removal (ablation) and the local modification of a material's properties, without temperature buildup, in both absorptive and transparent materials. The local modification of a material's properties is very unique to this technique due to the non-linear photon absorption, and allows the fabrication of optical waveguides through increased/decreased refractive index and stress buildup in several types of materials, namely in polymers, glasses, and crystals [2]. In very specific substances, like fused silica, the modified region also shows the presence of nanogratings, aligned and periodical nanostructures composed by the hosting material and voids, enabling anisotropic etching of the exposed region for the fabrication of microchannels [3, 4].
In this work, the key abilities of FsLDW are optimized and explored for the fabrication of several optical and microfluidic devices. Ultimately, an optofluidic device, where optical and microfluidic components are combined, is manufactured and refractive index sensing of a fluid is demonstrated.

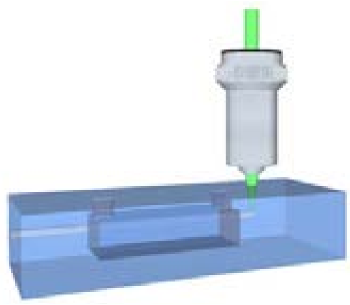

Figure 1: Fabrication scheme of an optofluidic device with FsLDW.

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Acknowledgments

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Nondiffracting femtosecond pulses and laser ablation

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Applications of laser-matter interaction quicklyfollowed the invention of the laser. The first laser cutting machine was designed in the Western Electric Engineerging Research Center to drill holes in diamond dies as early as in 1965 [1]. Since then, a number of advances have been made in this field, particulary since the development of ultrafast lasers, ie with picosecond or femtosecond pulse duration. The ultrashort pulse duration enables an extreme localization of laser-matter interaction.
We will overview the intense work performed by several groups in the recent years in the filed of ultrafast laser processing with shaped beams. Both the underlying physics and applications in terms of machining will be discussed, with a particular emphasis on mass fabrication and transparent materials processing (smartphones, microelectronics industry).
We will show that energy deposition is a critical step to control materials processing. The nonlinear propagation of intense ultrashort pulses inside transparent materials is rich and complex. It couples both nonlinear optics and plasma generation. However, it is hardly controllable for industrial applications. Recent advances in terms of beam shaping enable the control of the nonlinear propagation and energy deposition. This allows for instance to fabricate ultra-high aspect ratio nanochannels with a single laser pulse (see Fig. 1(a)). We will describe the phenomena at play, from ionization to shockwave emission pointing out new challenges in terms of physical modelling. In a second step, we will review challenging new applications enabled by this novel approach such as glass cutting at high speed, as exemplified in Fig 1(b).

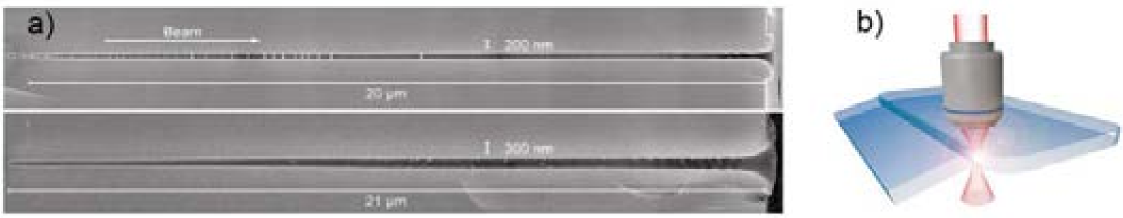

Figure 2: (a) High aspect ratio nanochannels processed in glass using single shot femtosecond Bessel beams from ref. [2] and (b) concept of their use for laser processing of glass from ref. [3].

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Correction of spatial light modulator – optical vortex dynamics criterion

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Number of Laser beam shaping related research have been exceedingly growing in past years. One of the most important devices used for both phase and amplitude modulation is Liquid Crystal on Silicon Spatial Light Modulator (SLM) which is widely used in many areas of modern optics, even on early experiment stage. Quality of produced SLMs is increasing year by year, but still there are some disadvantages, that can affect success of final experiment, for instance fill factor, reaction time, ghost order or SLM surface deviation from flatness. This deviation can have significant influence on quality of modulated laser beam. So far, several techniques and criteria, leading to correction of this deviation, have been presented, but still, researchers report further development in this case [1, 2].
Two methods such as interferometric surface measurement and iterative algorithm will be presented and examined using known criteria. Additionally, new criterion, based on optical vortex dynamics [3, 4] will be presented as well as new experimental results. These results show that there is still room for improvement, especially for SLM used in extremely precise measurements [5, 6].

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Investigation of Faraday Rotation effect using pressure-controlled thickness nanocell

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When plane-polarized light passes through a medium in a direction parallel to the applied magnetic field, the plane of polarization is rotated. The effect is discovered by Michael Faraday in 1845 and found many applications in optical isolators, telecommunications, optical current sensors, spectroscopy etc. Recently we have demonstrated, both experimentally and theoretically, Faraday Rotation (FR) of optical radiation (tuned to 133Cs D1 line transition) using a pressure-controlled thickness nano-cell placed up to 0.1 T longitudinal magnetic fields. Having a spectral width of 50 MHz FR resonances are frequency-resolved and despite the large number of transition components this allows one to investigate the behavior of an individual transition in strong magnetic fields.
The FR spectra recorded from nano-cell experience a strong modification, and it has been demonstrated in [1] that atomic lines are even narrower than in the case of transmission spectroscopy. Recently we have produced a new pressure-controlled nano-cell with variable thickness in the range of 170 nm - 1700 nm. The FR signals recorded for different thicknesses of the cell that differ with a step of $\lambda/2$ (λ being the resonant wavelength of the CW laser) show revival and collapse of coherent Dicke narrowing [2].
The theoretical FR model for strong magnetic fields has been elaborated using [3] and [4] and shows a good agreement with the experimental spectra.
The research was conducted in the scope of the International Associated Laboratory IRMAS (CNRSFrance & SCS-Armenia) and with the support of the SCS, MES of Armenia 15T-1C040. A. A. acknowledges the support of AGBU France and Philippossian & Pilossian foundation.

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Generation of surface electromagnetic waves propagating along cylindrical interface between two homogeneous media

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The interfaces between two media serve as useful tool to control the electromagnetic fields, including the radiation ones. The presence of separating boundaries gives rise to new types of phenomena in classical electrodynamics. One of the interesting effects is the generation of surface electromagnetic waves propagating along interfaces. These waves play an important role in a large number of physical problems and have important applications, in particular, in diagnostics of interfaces, in measurements of various characteristics of materials, in wireless energy transfer.
The problem of the generation of surface electromagnetic waves is exactly solvable for highly symmetric interfaces only. We have investigated the electromagnetic fields and radiation intensity for surface waves (propagating along the cylinder surface) emitted by a point charge rotating along a circular trajectory around a dielectric cylinder. This type of waves are emitted on the eigenmodes of the dielectric cylinder and exponentially decrease in outside region.
The radiation intensity at large distances from the cylinder is discussed in [1, 2]. The presence of the medium may essentially influence the spectral-angular distribution of the radiation intensity (see, for instance, [3–5] and references therein). It has been shown that, under the Cherenkov condition for the material of the cylinder and the charge velocity, in the corresponding angular distribution strong narrow peaks may appear. The angular density of the radiation intensity at those peaks exceeds the corresponding value in a homogeneous medium by several orders of magnitude. In addition to the radiation at large distances from the cylinder, the radiation can be present confined inside the dielectric cylinder. The corresponding energy flux through the cross section of the cylinder has been studied in [6]. Similar investigations for a charge rotating inside a dielectric cylindrical waveguide are presented in [7]-[10].

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Giant Magnetic Circular Dichroism exhibited using Derivative of Selective Reflection spectroscopy

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From the past decade, nanometric thickness cells have proven to be excellent spectroscopic tools allowing to achieve strong line narrowing on the recorded transmission spectra (up to 4 times narrower than the Doppler width). Recently, it was demonstrated that the derivative of Selective Reflection (dSR) technique allows the achievement of an even stronger line narrowing [1]. The dSRmethod being a linear technique, another of its advantages is the proportionality of the recorded signal to the atomic transition probabilities.
These benefits make the dSR-method convenient for the study of closely-spaced individual atomic transition components in a magnetic field. Hence, we have analyzed the Rb D2 line in an intermediate range of magnetic field (200 − 1000 G), with a σ_- polarized cw laser and we showed that atomic transitions verifying the selection rule $\Delta F = \pm 2$ are magneticaly induced and experience a strong enhancement [2]. Generalizing the previous work for both circular polarization, we demonstrate a giant asymmetric behavior reaching 1012 in transition intensity ratio between σ_- and σ_+, resulting in a strong circular dichroism [3].
These results find direct applications in linear and nonlinear Faraday Rotation-related fields, boosting optical magnetometry, tomography, narrowband atomic filtering, etc. Also, as suggested in [4] the Zeeman transitions are more suitable than hyperfine transitions for precise measurements of parity non-conservation induced by nuclear spin dependent interaction, and thus our study makes a significant step forward towards solving this outstanding problem.

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Second Harmonic Generation in strained silicon

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Centrosymmetry inhibits second order nonlinearities in centrosymmetric crystals, like silicon. However, the application of a stressing layer on top of a silicon waveguide has shown the capability to introduce second order nonlinearities. We have investigated the Second Harmonic Generation (SHG) process in a strained silicon waveguide engineered to achieve the multimodal phase-matching. In this way, we determined a second order nonlinear coefficient of about $0.3pm/V$. Nevertheless, the origin this non-linearity is still under debate. In fact, it can be due not only to a breaking of the silicon centrosymmetry caused by strain, but it can also have other origins, related for example to the field induced by trapped charges or to the generation in the silicon nitride cladding.

In order to remove these doubts, we are repeating the SHG experiments described so far using a sample holder equipped by a screw. In this way, a tunable mechanical strain is introduced in the waveguide. Studying the generation efficiency as a function of the applied load will provide a clear proof of the role that strain has on second order nonlinearities. Moreover, we will find a relationship between the strain-induced nonlinearity and the nonlinearity induced by other phenomena. Using a FEM software, we can determine the strain into the waveguide. The comparison of the simulations and the experiment will provide the relationship between strain and the strain-induced second order nonlinearity.

Wavelength conversion and generation via intermodal four wave mixing in silicon waveguides

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Four Wave Mixing (FWM) is a nonlinear optical process widely used in classical and quantum photonics in order to enable several functionalities at the chip scale. Among these functionalities, wavelength conversion and quantum states generation are at the heart of the development of technologies like on-chip gas sensing, mid infrared light detection and generation, quantum information and quantum computing. The FWM process involves two input pump photons that are converted into signal and idler photons of different frequencies. Usually, the waves involved in FWM excite only the first order waveguide mode. We studied the case of intermodal FWM, which exploits the dispersion of the higher order waveguide modes to control the phase matching condition. In this way, the spectral position of the intermodal phase matching can be easily tuned by engineering the waveguide cross-section, achieving also large detunings from the pump wavelength.
Our work report the first experimental demonstration of spontaneous and stimulated on-chip IMFWM, using Silicon-On- Insulator channel waveguides. Our measurements show the occurrence of discrete phase matched bands with a maximum distance between the signal and idler wavelengths of about 979.6 nm, with the pump wavelength at 1550 nm. We also investigated the tunability of the generated wavelengths as a function of the waveguide width. Several intermodal combinations have been studied, involving up to the third order waveguide mode.
The high tunability of the discrete phase matched bands, both in terms of spectral position and bandwidth, makes the IMFWM a suitable process for the on-chip development of wavelength conversion devices and heralded single photon sources. Moreover, the large spectral detuning that can be achieved with this process is of great interest for the developing field of mid infrared photonics.

Stimulated Emission Tomography of Hyperentangled States

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The generation and manipulation of entanglement in photonic systems is crucial in the development of quantum optical technologies. Particularly interesting is the entanglement in more than one of the degrees of freedom of the system, which include polarization, frequency, and spatial mode [1].
The analysis of such "hyperentangled" states through quantum state tomography (QST) [2] is usually quite challenging even in the case of a bipartite system, since the dimension of the Hilbert space can be very large [3].
In the case of photon pairs emitted by spontaneous parametric down-conversion (SPDC) or spontaneous four-wave mixing, the study of the quantum state of the generated pairs can also be done by exploiting the relation between stimulated and spontaneous emission rates to perform a stimulated emission tomography (SET) of the state that would be generated in the absence of the stimulating field [4].
For polarization encoded quantum states it has been demonstrated that QST and SET lead to the same result [5], with SET determining the polarization density matrix that would be achieved in the spontaneous regime in an approach free of coincidence experiments and with a very large signal-to- noise ratio, yealding considerable advantages in resolution and measurement time.
In this work we investigate the use of SET in the study of a source of hyperentangled states in which photons are entangled in polarization and path-energy. Unlike previous experimental realizations, in our implementation the source is pumped by a continuous-wave (cw) laser. The results are compared with those obtained by QST, demonstrating substantial agreement.

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Self focusing of laser beam into plasma

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Inertial Confinement Fusion [1] (ICF) consists in producing energy by fusing two light nuclei, deuterium (D) and tritium (T), through MJ/ns class laser facilities. The fully ionized gas, called plasma, is the natural fusion environment. Such a plasma is created by the strong heating of the DT target by laser beams. Once ionized, the produced ablated plasma can lead to very high pressure and temperature, up to hundreds of Mbar and106 Kelvin, in the target center hot spot, leading to the fusion reactions. Usual ICF lasers exhibit a power around 1012 W and intensity about 1014 W/cm2. Such an intensity create many nonlinear phenomena during the propagation of the laser in the ablated plasma, as beam self-focusing and hot electron production (energy in excess of the thermal equilibrium energy). These phenomena could jeopardize the whole fusion process, hence they have to be well understood and managed. Laser facilities have then been equipped with phase plates in order to reduce the laser intensity by producing a speckle pattern. In addition, temporal smoothing through spatial dispersion is introduced in order to smooth laser inhomogeneities.
In this talk, we will describe the physics related to the propagation of a high power laser in an underdense plasma and explain the main issues related to the success of the current inertial fusion programmes. We will focus on the nonlinear laser-plasma interaction induced by the ponderomotive force which consists in beam self-focusing [2]. Using the radiative hydrodynamics CHIC code [3], we have first investigated the propagation of a high intensity Gaussian beam into an underdense plasma. We compare our results with theoretical ones. We then show how optics techniques allow to reduce the ponderomotive effects, and so decrease the laser self-focusing.

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A novel cumulative photo-disruptive laser-skin interaction regime in dermatology: application to laser tattoo removal

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During the past decades, laser has always found new biomedical applications, as in dermatology and in aesthetics. At the cutaneous level, tissues indeed contain absorbing chromophores, including proteins, hemoglobin, water, melanin or even tattoo ink. Due to its unique features of wavelength, brightness, coherence and intensity, laser is considered as one of the best cure for many cutaneous anomalies, as well as a fantastic tool for tattoo removal. Both pigmentary disorders treatment and tattoo removal are based on selective photothermolysis [1] and photoablation [2]. The laser interaction with biological cells depends on the tissue absorption (Fig. 1) and therefore on the laser wavelength tunability [3]. Additional parameters such as the pulse duration, the total laser exposure and the power density are also key parameters to achieve the desired/targeted effects (photothermal, photoablative, photomechanical, photodisruptive).

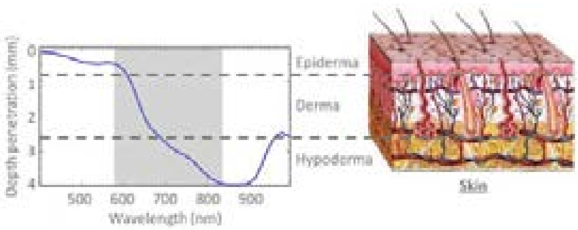

Figure 3: Light penetration in the skin as a function of the wavelength.

The present collaborative project PARACETAMOL between CELIA, IRISIOME, ALPhANOV and the University Hospital of Nice aims at: (i) providing an innovative solution consisting of a picosecond laser tunable in wavelength, repetition rate and pulse duration; (ii) demonstrating the efficiency of this solution for removing any tattoo ink (colored) with reduced pain on a wide variety of skin pigmentations. Hence, starting from the infrared wavelength tunable laser developed in a collaboration between the CELIA laboratory and the startup IRISIOME, we will transfer the tunability into the visible domain using degenerate four-wave mixing in non-linear fibers whose structure can be engineered to provide the desired range of tunability. In parallel to the laser development, we also focus on the laser-biological tissue interaction. We particularly investigate a novel cumulative photodisruptive effect on the tattoo induced by our ultrafast picosecond laser. In this context, tattoo removal protocols and medical treatments will be implemented through ex-vivo and in-vivo experiments.

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Integrated Microring Resonators for molecular interaction analyses

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Integrated photonic biosensors based on Mach-Zehnder Interferometers or microring resonators are widely used for food and drug monitoring and protein studies thanks to their properties such as high intrinsic sensitivity, easy integration, miniaturization, low cost. The goal of this study is to develop a system for performing fast and precise antibody interaction analysis using a photonic chip made by an array of six microring resonators (MRRs) based on TriPleX platform. The input light is provided by a Vertical Cavity Surface Emitting Laser (VCSEL) pigtailed to a single mode fiber operating at 850nm wavelength. The output signal is detected by PIN photodetectors placed in an optical signal read-out module.
Measured bulk sensitivity (Sb =104 ± 0.04 nm/RIU) and Limit of Detection (LOD = 2×10^{-6} RIU) are very similar for the six MRRs in the same chip [1], which is a good precondition for using the system for multianalyte detection.
Analyses of anti-biotin interaction with immobilized biotin by using different concentrations of anti-biotin antibody is performed. Dependence of resonance wavelength shift from antibody concentration, as well as association and dissociation rate constants were calculated. For the average dissociation constant (KD) of anti-biotin antibody toward immobilized biotin, a value of 2.310^{-7} M is achieved, that is in the same order of magnitude with published results in literature [2]. Furthermore, the specificity of the interaction was confirmed by using negative control antibodies. In addition, the functional surface of the sensors could be regenerated up to ten times by using 10 mM glycine/HCl pH 1.5.

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The orientational order and morphology of N2-CH4 solid solutions. Cluster approach

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Binary alloys of the N_2 and CH_4 molecular crystals are of considerable interest. Structural studies are very important for evaluating the optical properties of substances. Methane and nitrogen is known to exist in the planetary environments. Solid N_2 are formed by the linear molecules and CH_4 by the tetrahedral. Both the crystals have cubic lattice at the equilibrium vapor pressure. The character of the orientational ordering of particles in the matrix of molecular crystals is determined by the noncentral component of the intertiparticle interaction forces. Using the transmission electron diffraction technique the quench condensed $N_2 - CH_4$ films (CH_4 molar fraction below 40%) have been studied with the aim to understand how the introduction of CH_4 molecules affects the orientational order of the N_2 molecules. The samples were grown in situ by depositing gaseous mixtures on Al or C substrate at $T = 19K$. Measurements were made at temperatures from 5K to the sublimation temperature of nitrogen. The geometry of diffraction patterns for $\alpha - N_2$ based alloys corresponded to the Pa_3 symmetry characteristics for the low temperature phase of nitrogen. The morphology and obtained dependence of the lattice parameter on composition are analyzed within a cluster approach. The influence of pair and triple clusters on the lattice parameter and the orientational order of $N_2 - CH_4$ solutions has been studied. Information about orientational order was obtained from the analysis of the concentration dependence of the intensity of the superstructure diffraction peaks. The evaluation of the orientational order factor η requires the elimination of the η-independent component from the experimental data. This component was calculated independently.

Based on comparison between measured and calculated intensity of diffraction patterns the orientational order factor η was determined. With the increase of the CH_4 concentration η decreases rapidly to a value close to 0.91. It is found that in this system the transition to disorder phase occurs without changing the cubic symmetry of lattice. According to our estimates homogeneity starts deteriorating at CH_4 fraction of 6 mol$\%$ or even lower.

Multispectral Remote Sensing of Shallow Rivers

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Remote sensing techniques relying on analyses of spectral responses of earth surface can reveal significant information about our resources such as inland waters. Multispectral remote sensing could enable remarkable advances in characterizing rivers hydromorphology by providing spatially and temporally explicit information. Remote mapping of hydromorphology can play a decisive role in a wide range of river science and management applications including habitat modeling and river restoration [1]. High resolution satellite imagery (HRSI) has recently emerged as potentially powerful means of mapping riverine environments. In this research, we develop advanced methodologies for processing HRSI to map and quantify a set of key hydromorphological attributes including bathymetry and riverbed types and compositions. The techniques are built upon physical modeling interaction of light with different environments (i.e. atmosphere, water surface, water-column, and streambed) through its traveling pass from sun to reflecting back to the sensor. We have retrieved the bathymetry (i.e. water depth) and bed-types considering the attenuation effects of pure water and constituents (e.g. chlorophyll-a and suspended sediments). We have applied the techniques on the imagery acquired by WorldView-2 satellite sensor to extract the hydromorphological information of Sarca River located in Italian Alps.

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Poster Student Presentations

Nuclear γ-resonance time-domain interferometry as probe of slow dynamics in condensed matter

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The atomic and molecular motion at the Ångström length scale and in $ns - \mu s$ range is of great interest in order to understand the properties of various physical systems, such as supercooled liquids [1], metallic glasses, biological molecules, and polymers [2]. Accessing the slow dynamics at the microscopic length scale is experimentally challenging and only few techniques are available. Among them one of the most promising is the synchrotron radiation (SR) based technique known as nuclear γ-resonance time-domain interferometry (TDI) [3-4-5].
Here we present the main aspects of the technique and we show some of the latest results we obtained in the investigation of supercooled liquids approaching the glass transition region.

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Automatic alignment of photonic components of massive optical switch to ITU channels

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We demonstrate the automatic thermal alignment of photonic components within an integrated optical switch. The WDM optical switch involves switching elements, wavelength de-multiplexers, interleavers and monitors each one needing independent control. Our system manages rerouting of channels coming from four different directions, each carrying 12, 200GHz spaced, wavelengths into eight add/drop ports. The integrated device includes 12 interleavers, which can act either as optical de-interleavers to split the optical signal into odd and even channels or as optical interleavers that recombine the odd and even channels coming from the switching matrix. Integrated Ge photodiodes are placed in key positions within the photonic integrated circuit (PIC) are serve for monitoring. An electronic integrated circuit (EIC) drives the photonic elements by means of dedicated heating circuits (824 on-board heater control cells, 768 for the switching elements and 56 for the interleavers and the mux/de-mux) and reads out the Ge diodes photocurrent through TIAs. We applied a stochastic optimization algorithm to align the spectral response of the interleavers to the ITU grid. We exploit the thermo-optic effect to shift the interleavers pass-band in a desired spectral position. The interleavers are provided with dedicated metallic heaters that can be operated in order to tune the interleaver response, which is typically misaligned due to fabrication inaccuracies. The experimental setup is made of a tunable laser coupled with one input port of optical switch. The optimization algorithm is implemented via a software to drive the EIC till finding the best heating configuration (on the two branches of the interleaver) on the basis of the monitor diode-feedback. This way, the even and odd wavelengths input in the interleaver are directed toward the wanted lines within the switching matrix. Our method has been used for aligning the micro-ring based switching elements in the PIC as well. The algorithm, implemented in LabVIEW, converges over multiple instances and it is robust against stagnation. This work aims at enabling the automatic reconfiguration/restoration of the whole WDW optical switch.

Easy-plane ferroborates. Magnetopiezoelectric effects

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Rare-earth borates with formula $RFe_3(BO_3)_4$ (R = Y; La-Nd; Sm-Er) are popular object of study because they the materials which combine magnetically ordered and ferroelectric media properties. This is why ferroborates belong to the family of multiferroics[1]. Since ferroborates belong to noncentrosymmetric class 32, the direct piezoelectric effect (PE) is allowed in these crystals. We have investigated the piezoelectric properties of $SmFe_3(BO_3)_4$ and $NdFe_3(BO_3)_4$ single crystals using the acoustic method [2]. It was found that in those compounds, the value of the piezoelectric modulus e_{11} in the paraelectric phase ($\approx 1.4C/m^2$) was almost an order of magnitude higher than that of the α - quartz, and, therefore, such compounds may be recommended for technical applications.
In addition to the above-mentioned direct PE in multiferroics the indirect PE may exist. It consists in the joint action of the magnetoelastic and magnetoelectric mechanisms. Due to magnetoelasticity deformation changes the state of magnetic variables and through the magnetoelectric coupling excites the electric field (and vice versa). This effect was first discovered in samarium ferroborate [3].
In $NdFe_3(BO_3)_4$ direct renormalization of the piezoelectric interaction in a magnetically ordered phase is observed [4].

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Portable optical device for diagnostics of skin malformations

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Skin cancer is an increasing problem worldwide. An early stage, non-invasive diagnostic tool is essential for dermatologists and primary-care doctors. For this reason, an optical, non-invasive diagnostic device has been created.The setup consists of camera, LEDs arranged in a ring around the camera sensor and a computer for data processing (Figure 1). Light sources include three narrow bandwidth LEDs (525nm, 660nm and 940nm) for diffuse reflectance, as well as 405nm LED for photobleaching, to induce skin AF.[2],[3] There are significant changes of the structure, morphology and AF in collagen fibers in post-operative scars, it is expected that with time the AF intensity trend increases[4].

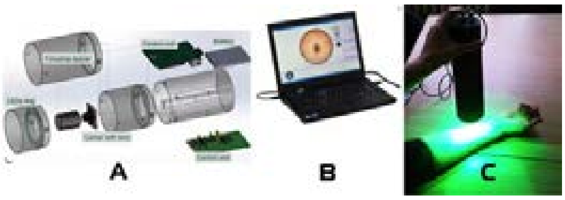

Figure 4: Diagnostic optical device: (A) Proposed system.[1] (B) Image of the skin malformation. (C) Device prototype in skin screening procedure.

After the acquisition of clinical images, the device is taking a set of images and transfers them to cloud based diagnostic service (scalable Matlab computing nodes). That allows virtually unlimited processing power for diagnosis calculations and the ability to access diagnosis through internet by using any PC or smartphone. In this study more than 15 seborrheic keratosis and more than 30 scars after cancer removal were evaluated in the age group 25-85; the range of the scars were from several months up to 20 years after the surgical procedure. With the proposed system it is possible to distinguish regular nevi and diagnose seborrheic keratosis and to evaluate the post-operative scars. The analysis is based on AF and p criterion – characterization of the proportion of hemoglobin and melanin in the skin sensitive for melanoma recognition from other pigmented skin formations[5].
This optical, non-invasive, low-cost and portable device has been successfully tested on a clinical setting; the algorithm is still being improved for more types of dermatological diseases to be distinguished for diagnostic screening purposes.

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Diffractive Coupling for Optical Neural Network

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Neural networks are inspired by the human brain. In a simplified interpretation, its neurons and their connectivities are the essential ingredients. We intend to recreate a neural network exploiting optical effects, see Fig1 (a). The required neuron connectivity can be established by diffractive coupling and the neurons are based on the pixels of a spatial light modulator(SLM). In this poster, the experimental scheme will be introduced and evaluated using numerical simulations. In our scheme, diffractive orders are created for each neuron via a diffractive optical element. We use the periodic distribution of the diffractive orders to couple individual optical neurons. Therefore, the diffraction's periodicity is essential and evaluated in detail, Fig 1(b). In experiments, we have successfully created neural network with 2025 photonic neurons. Our simulations show the validity of our concept for neural networks of up to 90,000 photonic neurons.

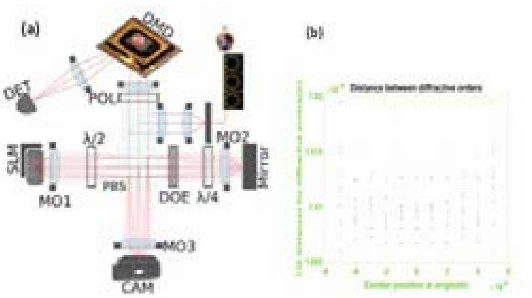

Figure 5: (a): experimental set up, (b): distance between diffractive orders (numerical result)

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Mid-Infrared Coincidence Measurements on twin photons at room temperature

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Nowadays it is growing the interest on the mid-infrared spectral region (MIR) in many area of science and technology for many reasons. Among these, for example, the MIR wavelength range allows for direct probing of the fundamental absorption bands of nearly all gas molecules, with the resulting appearance of a wide class of sensoristic applications. For this reason, it is becoming of great importance to have sensitive detection units in this spectral window. Already available for the near infrared range, where detection and manipulation of single photons are becoming a mature technology tool, detection systems for MIR still face many limitations. These are mainly due to the inherent sensitivity to unwanted incident black-body radiation. What we have proposed is a new approach to MIR detection by using frequency conversion. The idea is to up-convert the infrared radiation into the visible domain by means of the optical nonlinear effect known as Sum Frequency Generation (SFG). This results in the generation of visible light, which can be detected by any highly efficient and lownoise visible single photon detectors [1]. One the mayor feature of the proposed scheme relies on the fact that the up-conversion process inherently acts as a spectral and spatial filter to incoming light radiation, limiting the noise associated with the black body radiation. To demonstrate the capability of the detection unit, we measure the time correlation of MIR photon pairs by means of coincidence measurements. A clear peak of coincidences was observed [2]. What we have obtained is a key result, since coincidence measurement is the standard technique for photon pair detection, at the core of many quantum optics experiment. This demonstration opens the way to the extension of quantum optics experiment in the MIR.

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Design of Spin Coater and Characterization of Spin Coating Process

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Characterization of spin coating process done by roughness measuring instrument. Positive photoresist SPR3018 is used. Three different experiment are performed to determine the impact of spin speed, spin acceleration, and spin time to photoresist thickness and uniformity. Spin speed has impact on photoresist thickness. The faster the speed, the thinner the photoresist deployed. The thickness of the photoresistis inversely proportional to the square root of spin speed. Ramp-up acceleration has insignificant impact on photoresist thickness and uniformity while spin time has significant impact on photoresist uniformity. Longer spin coating time make the tendency toward concave surface increase.

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Nanosensor platform for metabolic profiling of breast cancer

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The increase in the life expectancy in Europe and the rest of the developed countries has brought the upsurge in the incidence of age-related diseases, such as neurodegenerative diseases (Alzheimer's, Parkinson's...), as well as a greater occurrence of cancer. A lot of scientific efforts are in place for the development of novel diagnostics tools and imaging strategies for drug discovery, early diagnostics, and treatment efficacy monitoring. These represent the major pillars for the progress towards personalized medicine. In the last five years, it has been demonstrated that the tumour metabolism is not an evolutionary cellular "accident", as classically postulated, but a process finely regulated, named metabolic tumour reprogramming.
Our goal is to unravel the crucial role of the metabolic reprogramming in cancer cell biology, taking as a first target cell lines of breast cancer, through the development of an imaging platform based on nanosensors. We are exploiting advanced imaging techniques, nanotechnology sensing, and ultrasensitive fluorescence detection to optimise a multiplex imaging platform, capable of performing cellular metabolic profiling.

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Nondestructive readout of Bessel-like photonic structures in an external magnetic field

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Materials with artificial refractive index modulation - photonic crystals and optically induced refractive lattices (photonic lattices) attract an increased interest and are promising for numerous applications. The nondiffracting beams [1] are of particular interest for optical induction of high-contrast micrometric scale refractive lattice structures in the photorefractive [2,3] and liquid [4] crystals providing unchanged lattice structure over the length of medium. One of the problems for practical applications of photonic lattice structures optically induced in photorefractive materials is erasure of holograms by homogeneous light during readout process. We report a novel method for non-destructive optical probing of photonic structures in photorefractive crystals in an external magnetic field.
Experiments were performed for Bessel-like lattices, which were recorded in Fe doped lithium niobate crystal. CW single mode laser beam at 532 nm and 17 mW power was used for formation of Bessel beam by an axicon. The probing of recorded photonic lattices was performed by diffraction of Gaussian beam at the same wavelength on the lattices. Directions of the magnetic field, C-axis of the crystal and the probe beam were mutually perpendicular. The stability of recorded lattices against erasure during readout was studied by measuring the time evolution of hologram diffraction efficiency for readout beam power of 17mW without and with application of external magnetic field of B = 0.85 Tesla.
Investigations showed an essential decrease of stored lattices erasure during readout in external magnetic field. The nearly exponential decrease of diffraction efficiencies η depending on erasure time for B=0 is modified when erasure was measured in the external magnetic field and shows slower decrease. Erasure constant for magnetic field assisted readout of stored hologram shows 2-3 times increase at η_{max}/e level for B = 0.85 Tesla due to magneto-photorefractive effect. The physical model describing the obtained results is presented.

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Second-Harmonic Generation in stressed Silicon microring resonators for octave spanning optical frequency comb generation

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Optical frequency combs (OFCs) are light sources whose spectrum contains thousands of equally spaced laser lines. They have revolutionized precise optical frequency measurements by allowing a direct link from any optical frequencies to a reference microwave clock. The self-referencing allowed by octave spanning OFCs [1,2] was even awarded with the Physics Nobel Prize in 2015. In the NEMO national project, we propose a new class of chip-based OFC sources, combining breakthrough technologies and theoretical understanding of the nonlinear dynamics for comb generation processes.
Recent experiments [3] have demonstrated that OFCs may arise entirely through second-order nonlinear optical effects, which potentially requires low pump power and intrinsically leads to multi-octave emission. Exploiting the technological versatility of Silicon, here we propose to develop on-Silicon chip-based OFC sources based on second order optical nonlinearity. To this aim, we induce a second order nonlinear susceptibility $\chi^{(2)}$ by applying an inhomogeneous strain to the silicon lattice to break its centro-symmetry. Specifically we study microring resonators of Silicon-on-Silica substrate, stressed by a Silicon Nitride layer [4].
In this work, we present the optimization of the microring parameters to enable second-harmonic generation in micro resonators (based on the work reported in [5]). We used a Finite Element Method (FEM) solver (COMSOL) to calculate the eigen modes of the resonators and adjust their sizes to fulfill the energy and the momentum conservations when the fundamental mode is polarized in the plane of the microring (TE-mode) and the second harmonic wave (SH) is polarized orthogonally to the plane (TM-mode). In order to avoid two-photon absorption, the pump wavelength is chosen around $2.4 \mu m$. Moreover the microring thickness is kept below the limit of stress relaxation by using a modal phase matching, ie. by generating the SH in a mode with a higher radial number than the fundamental one.

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Towards an all-optical optogenetic activation and readout system for insect brains

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We present our first steps to build an all-optical setup to perform two-photon calcium imaging on optogenetically activated neurons: the goal is to add optogenetics to our experimental two-photon imaging platform and apply this technique first to the fruit fly Drosophila melanogaster and subsequently to the honeybee Apis mellifera at the level of the primary olfactory processing brain centers, the antennal lobes.
Insect brains are an important model in neurobiology, thanks to their small sizes, tight structures, but rich performances. We use two-photon microscopy to image morphology and functions of the insect olfactory system in order to study various aspects of information coding [1][2]. We extended functional response studies beyond mapping out average activity: the role of the temporal dimension in stimulus coding is investigated by analyzing also the dynamics of neuronal activity.
Besides analyzing responses to natural odour stimuli, our objective is to develop an optogenetic toolbox to optically interfere with the honeybee brain with high temporal and spatial precision. Activating specific nodes of the first olfactory processing center, the antennal lobe, and imaging the propagation of activity in this brain region via two-photon microscopy, will allow to study connectivity in this neuronal network.
The required hardware for optical activation was integrated in our two-photon microscope: a 473 nm laser for opsin activation, overlapped with the infrared imaging beam, making both sources scannable with the same galvo mirror system. The key point is fast switching between the two light sources, allowing a fast transition between optogenetic activation and calcium imaging.

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Speaker Index

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