

**16 MAY  
2021**



INTERNATIONAL  
DAY  
OF LIGHT

**RESEARCH  
BROCHURE**

ASTON INSTITUTE OF  
PHOTONIC TECHNOLOGIES

## The International Day of Light (IDL)

is a worldwide initiative that provides an annual focal point for the continued appreciation of light and the role it plays in science, culture and art, education and sustainable development, and in fields as diverse as medicine, communications and energy.



## Aston Institute of Photonic Technologies

coordinates eight Innovative Training Networks – **FORTE, WON, MEFISTA, REAL-NET, MOCCA, POST-DIGITAL, MONPLAS, MENTOR** and MSC Actions training programme COFUND **MULTIPLY**. This brochure celebrates the **International Day of Light 2021**. Our researchers will describe how their research relates to the concept of «light».

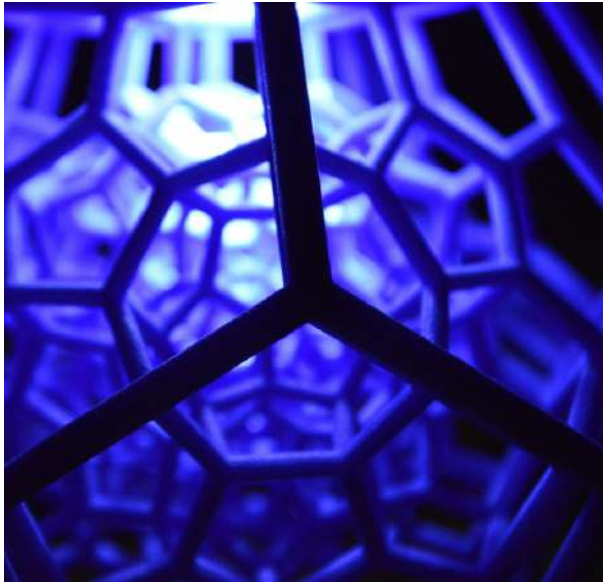
*"The International Day of Light gives people working in photonics a wonderful opportunity to think about what we are already doing in science, and what can be done beyond it. Photonics makes a difference by opening up new horizons for technology, by contributing to innovation, new products and economy, and by directly improving people's lives. Photonics is capable of changing places and lives. There are amazing examples of how photonics impacts communities around the world. It can help people who cannot read or study after sunset, generate emergency light from waste, plus many other astonishing examples. There are remarkable and fascinating applications of photonics in art and entertainment, and there will no doubt be many more developments and inventions in our lives, all thanks to photonics. After all, light is the only thing (that I know) that can dethrone darkness."*

Professor Sergei K. Turitsyn  
Director of the Aston Institute of Photonic  
Technologies

# COFUND MULTIPLY



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 713694.



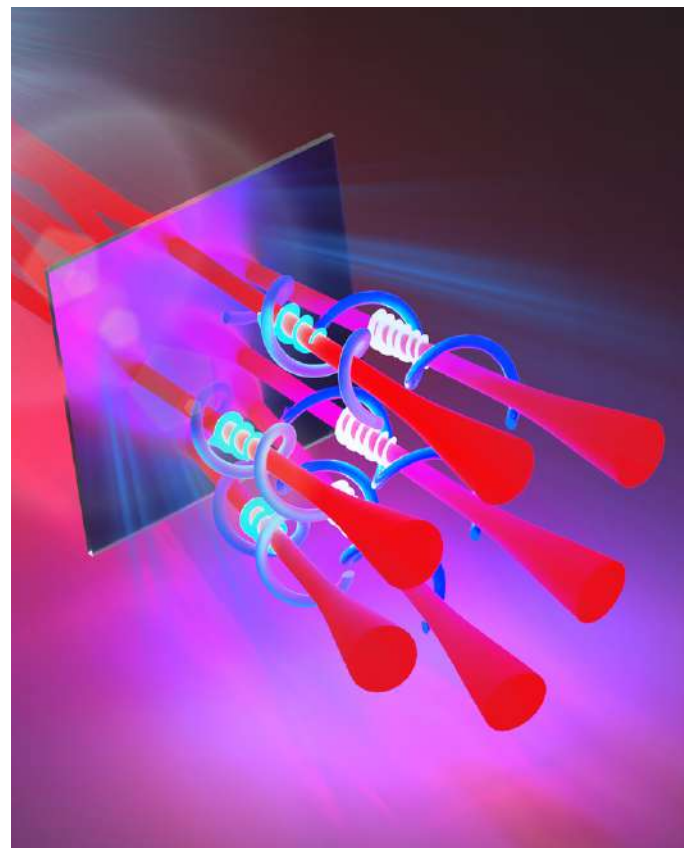
MULTIPLY is a 6 year Marie Skłodowska-Curie COFUND Action that offers interdisciplinary training for over 50 outstanding international experienced researchers in the areas of photonics science, technology and applications for the programme duration. The overall aim of the COFUND MULTIPLY project led by the Aston Institute of Photonic Technologies at Aston University is to assist in the career development of the next generation of photonics researchers and innovation leaders.

## RESEARCH HIGHLIGHTS

### Dr. Yijie Shen

Host Institution: ORC Southampton, UK

Tailoring light is much like tailoring cloth, cutting and snipping to turn a bland fabric into desired masterpieces. In the case of light, the tailoring is usually done in its spatial pattern and polarization. Now, structured light has been used to emulate quantum-like features akin to multi-particle quantum systems, pushing the limits of what classical light can do for quantum processes, and vice versa. This has opened the intriguing possibility to create high-dimensional classically entangled light in both spatial [Light: Sci. & Appl. 10, 50 (2021)] and spatiotemporal [Phys. Rev. Res. 3, 013236 (2021)] structures.

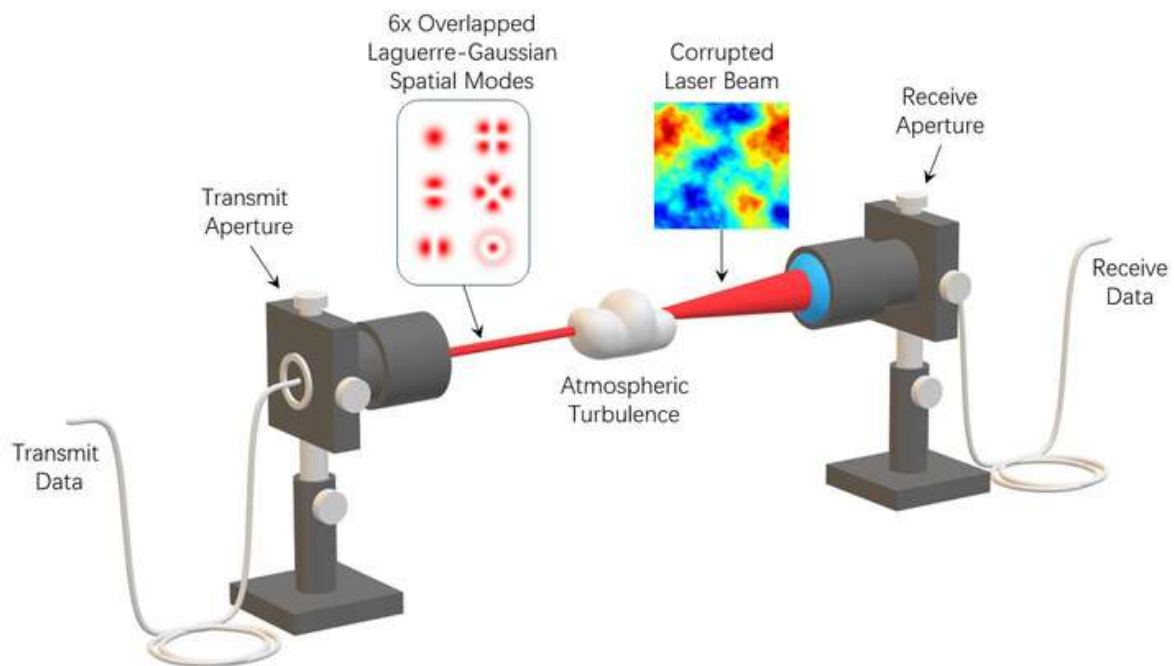




## Dr. Yiming Li

Host Institution: Aston University, UK

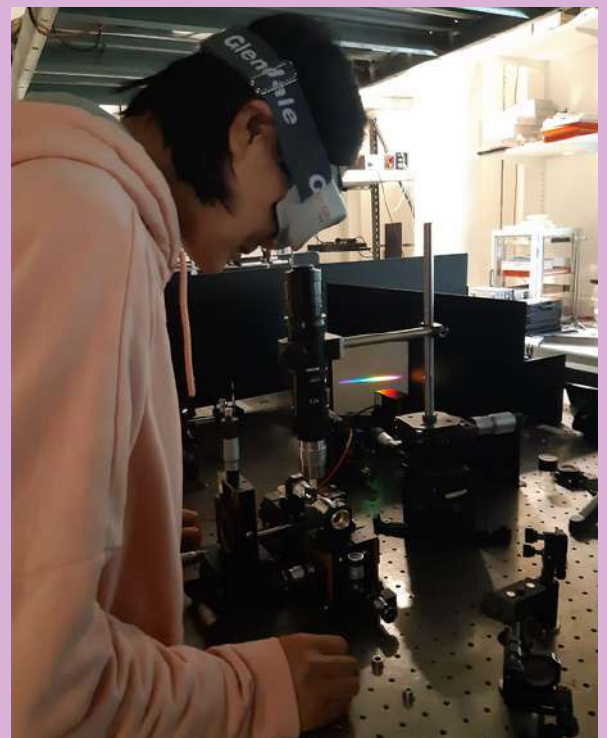
Light can be used to transmit information at tens of Gigabits per second. By exploiting the spatial distribution property of light, we can transmit independent information on different spatial modes and achieve an even faster speed! As is shown in the picture, we are now going forward to an impressive speed of 600 Gbit/s in free space channels (6 spatial channels with 100 Gbit/s information on each channel). This scheme will also reduce the cost of Internet deployment and improve the Internet quality in developing countries which have a lack of fibre connections.



## Dr. Xue Qi

Host Institution: Leibniz-IPHT, Germany

Supercontinuum, the ultimate white-light source, which is generated using ultrafast laser pulses propagating in solids, liquids, gases, and various designs of optical fibres, has many important applications in our life – imaging, communication, extremely accurate clock development et.al. We are devoted to generating a high-energy ultra-broad coherent supercontinuum in a hybrid waveguides (e.g. liquid/gas filled fibres) and demonstrating the fundamental physics about how fibre structure affects supercontinuum.



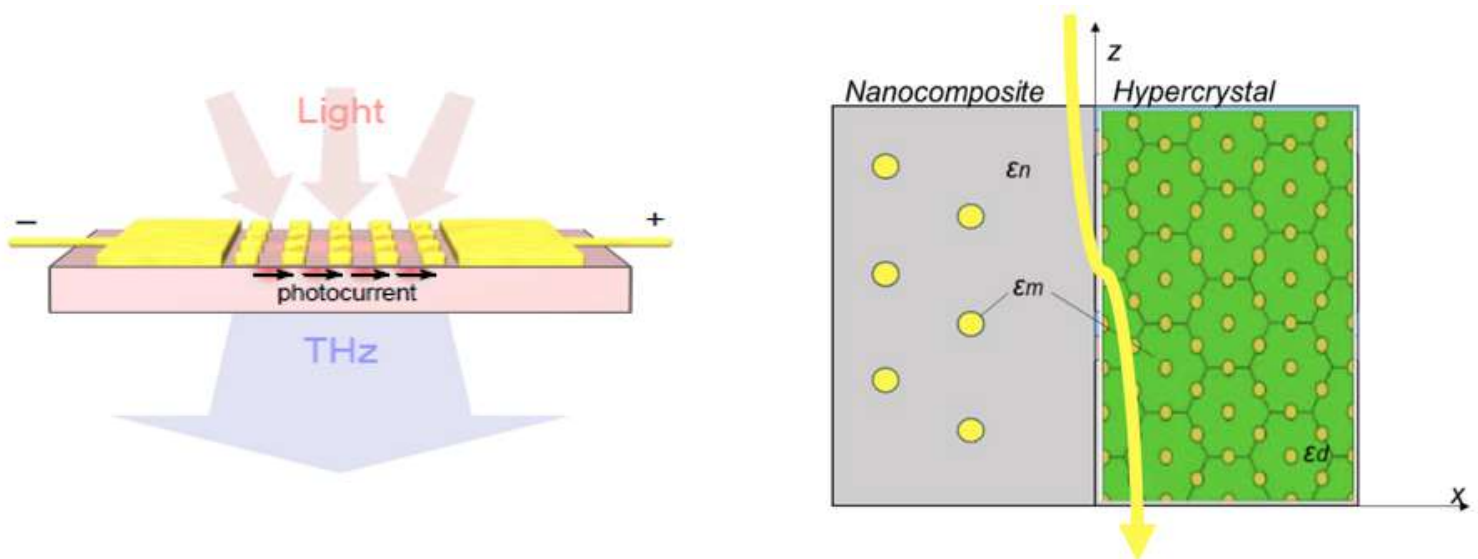
# Dr. Tatjana Gric

Host Institution: Aston University, UK

Controlling light, electricity and heat has made a tremendous impact in technological advancements throughout human history. Advances in electrical and electromagnetic technologies, wireless communications, lasers, and computers have all been made possible by challenging our understanding of how light and other energy forms naturally behave, and how it is possible to manipulate them.

Over the past 20 years, techniques for producing nanostructures have matured, resulting in a wide range of groundbreaking solutions that can control light and heat on a very small scale. Some of the areas of progress that have contributed to these techniques are photonic crystals, nanolithography, plasmonic phenomena and nanoparticle manipulation. From these moves forward, a new branch of material science has emerged – metamaterials. Metamaterials have, in the last few decades, inspired scientists and engineers to think about waves beyond traditional constraints imposed by materials in which they propagate, conceiving new functionalities, such as subwavelength imaging, invisibility cloaking and broadband ultraslow light. While mainly for ease of fabrication, many of the metamaterials concepts have initially been demonstrated at longer wavelengths and for microwaves, metamaterials have subsequently moved to photonic frequencies and the nanoscale. At the same time, metamaterials are being used to embed new quantum materials such as graphene, dielectric nanostructures and, as metasurfaces, surface geometries and surface waves while also embracing new functionalities such as nonlinearity, quantum gain and strong light-matter coupling.

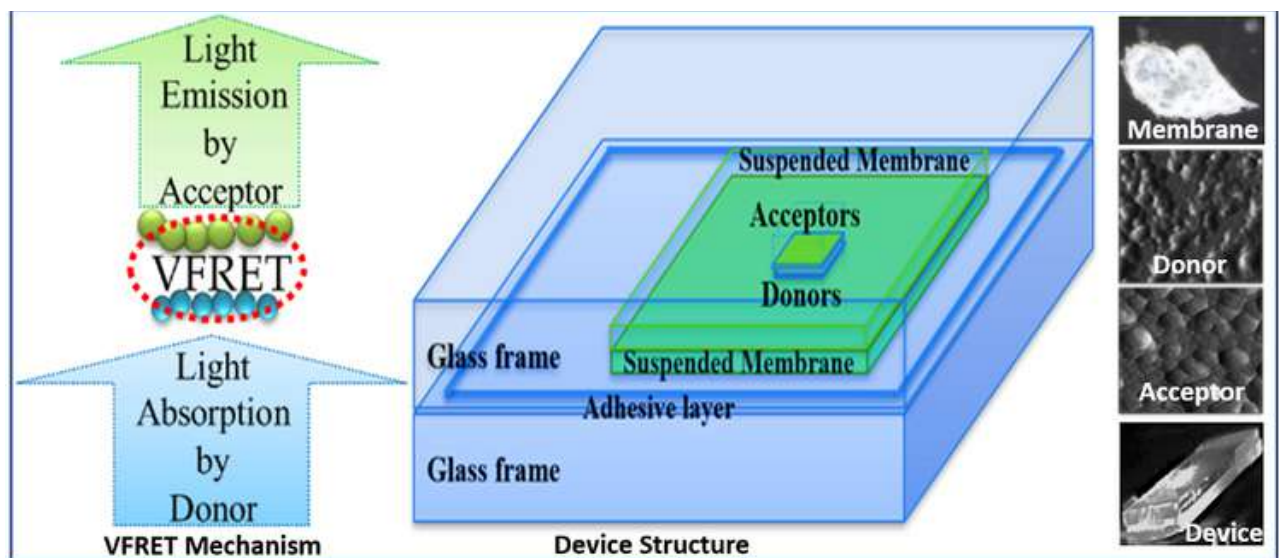
My project under the Multiply umbrella focuses on the design and fabrication of metamaterials and other functional materials. These are complex structures patterned in ways that perform a special function, such as transparently blocking a specific color of light, or invisibly heating a window in a car. These functions more generally include manipulating light, heat and electromagnetic waves in unusual ways.



## Dr. Gorkem Memisoglu

Host Institution: Basque Country University, Spain

In the “Resonance Energy Transfer in Graphene-Quantum Dots Systems for Nano-Photonics” project, Sound-to-Light transducers which are important for biomedical electronics, optic communication, and environmental science related industries, are fabricated and tested. Graphene-based nanomechanical membranes and quantum dot donor-acceptor fluorescent molecules are used in the Sound-to-Light transducer that works with the principles of the Vibrating Forster Resonance Energy Transfer (VFRET) under donor excitation light and acoustic excitations. With the help of graphene membrane vibration acoustically under donor excitation light, donor transfers its excitation energy non-radiatively to the nearest acceptor when there are less than 10 nm, acceptor emits light. The entire visible light region of the electromagnetic spectrum is important for this project.



## Dr. Mu-Chieh Lo

Host Institution: University College London

Data centres are continuously growing to match ever-increasing demand for cloud services, and optics is the only network connectivity cable that supports such faster data rates. However, most core technologies used today were conceived before the cloud existed. My MULTIPLY project is creating disruptive technologies through co-design and integration of electrically driven super-channel transceiver with analogue signal processing in photonic integrated circuit for data centre networks. This will open innovative opportunities in next-generation networks.

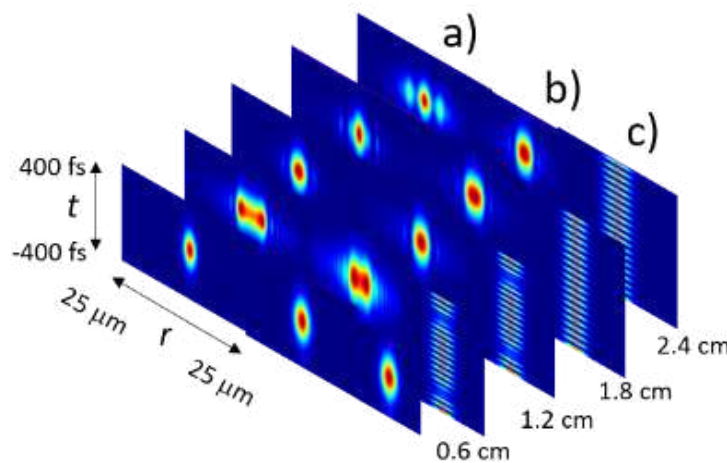


A compact, lightweight, and broadband photonic integrated circuit.

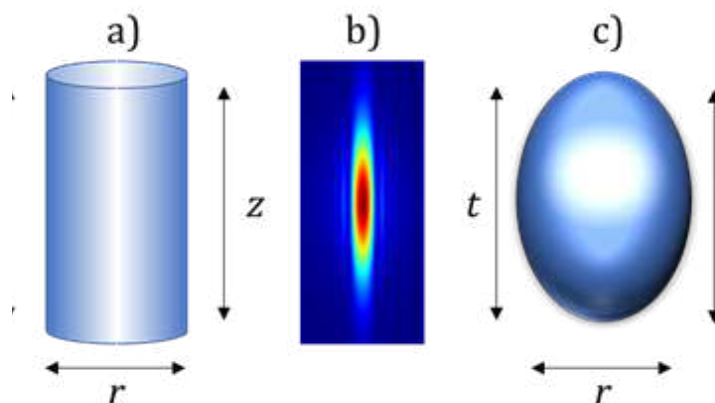
# Dr. Vladimir Kalashnikov

Host Institution: University Roma

The mastering of multidimensional nonlinear wave patterns has an interdisciplinary character and bridges different areas, ranging from nonlinear wave collapse and turbulence phenomena in plasmas, the formation of highly coherent structures, such as solitons in nonlinear optics (so-called “light bullets”), to liquid crystals and Bose-Einstein condensates (BEC). These soliton-like structures could provide unprecedented energy condensation and lead to a breakthrough in photonic networks' information capacity and multimode microresonators for optical comb generation. We demonstrated that multidimensional wave pattern stabilization can be substantially enhanced by introducing the graded dissipation in the multimode fibers (MMFs). The Figure below demonstrates the mode-cleaning of a femtosecond pulse in a short MMF without (a) and with (b, c) graded dissipation. (a): In a nondissipative fiber, a multitude of spatial modes is excited, so that mode cleaning can only be provided by propagating high-power pulses in a sufficiently long MMF. (b): In an actively doped MMF one may reach the mode cleaning in an extremely short fiber (z), without strong dependence on input pulse power and transverse beam size (r). (c): The control of a graded-index MMF characteristics results in a stable comb of multiple femtosecond pulses (Turing waves).



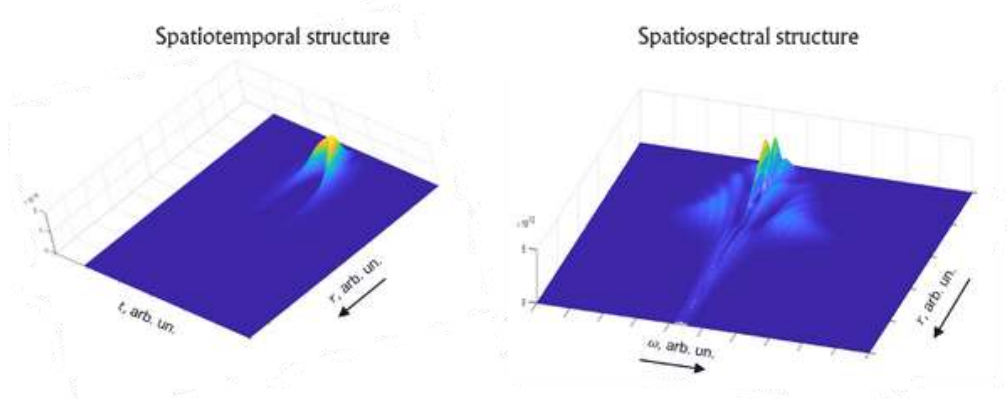
We analyzed the analogy between the stabilization of spatiotemporal patterns (solitons) in an MMF with a weakly-dissipative BEC confined by the cigar-shaped (a) and pancake-like (c) potentials. The  $t$ - and  $z$ -coordinates correspond to local time in photonics and longitudinal coordinate in BEC, respectively. We found that dissipative factors, such as graded dissipation, saturable gain, and kinetic cooling (spectral dissipation), play a crucial role in stabilizing the spatiotemporal solitons (b). In photonics, one can treat such a stabilization as a manifestation of mode-cleaning in an MMF, which is enhanced by dissipation and can be realized on extremely short propagation distances.





The main practical significance of the obtained results lies in the possibility of energy/mass scaling of coherent multidimensional photon/matter wave structures, and the demonstration of stable spatiotemporal mode-locking in MMF lasers.

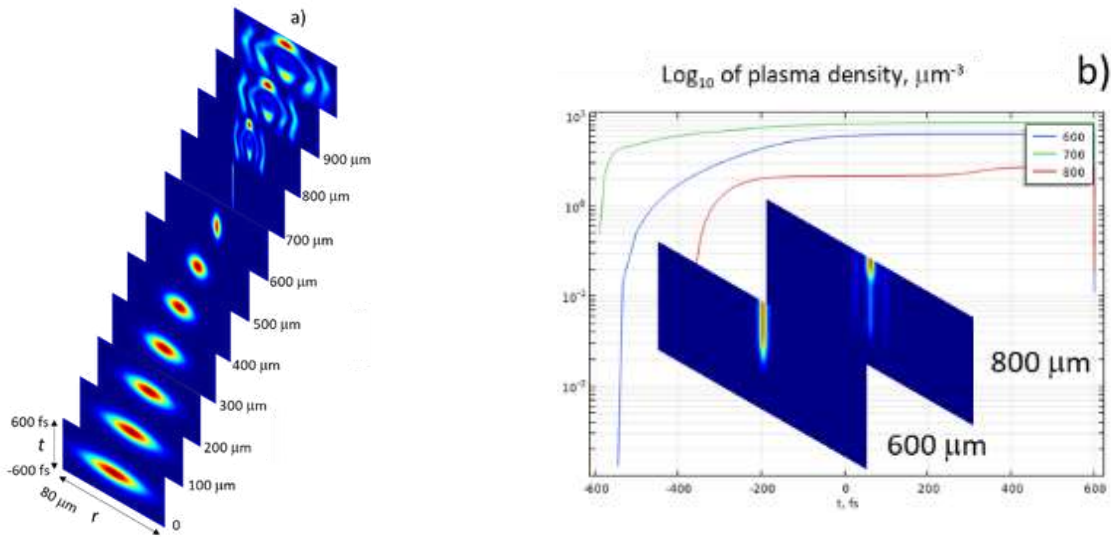
The nontrivial spatiotemporal and spatio-spectral dynamics is evident without mode-confinement in a bulk media, that can be used for the supercontinuum generation:



A new practical approach for generating multicolor spiral-shaped optical beams is demonstrated (so-called “Rainbow Archimedean spiral emission”). It makes use of a standard silica optical fiber, combined with a titled input laser beam. With appropriate control of the input laser coupling conditions, the colors of the spiral spatially self-organize in a rainbow distribution. Thus, standard optical fibers may be used for generating spiral beams in many applications, ranging from communications to optical tweezers and quantum optics:



We investigate the sub-surface modification of silicon using ultra-short pulsed lasers at wavelengths in the range of 1950–2400 nm for the pulse energy varying from 1  $\mu$ J to 1 mJ. We prove that the wavelengths between 2000 and 2200 nm are more favorable for creating sub-surface modifications in silicon (evolution of a pulse spatiotemporal profile (a) and a plasma density(b) is shown below).





## Dr. Katerina Pistiki

Host Institution: IPHT, Germany

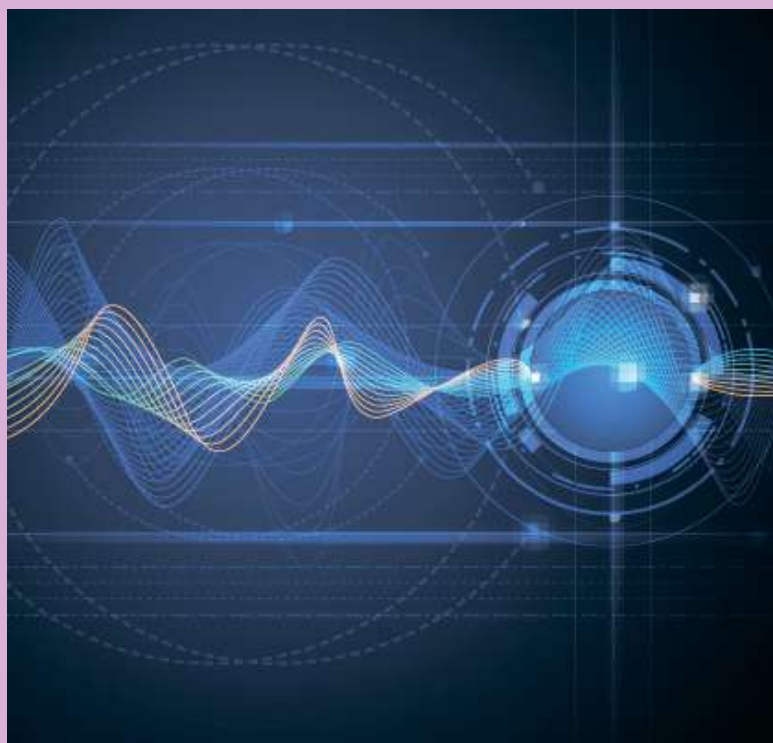
Raman spectroscopy is a fast, label-free and sensitive photonic technology that captures chemical information from biological samples after their excitation to a laser light. Over the past decade a large effort has been made to develop this technique for diagnostic purposes. In the Raman2Staph study, Raman spectroscopy will be applied on clinical Multi-drug resistant *Staphylococcus aureus* isolates aiming at the differentiation of Methicillin resistant (MRSA) from methicillin sensitive (MSSA) strains. This will enable a rapid and inexpensive detection of antibiotic resistant strains and can be applied for diagnostic as well epidemiological monitoring purposes in hospital settings.



## Dr. Xavier Porte-Parera

Host Institution: Femto-ST, France

Light carries information but, can it also help us to process it? This is the main question behind my scientific research as a Marie-Curie MULTIPLY fellow. In my project NEWRONS I want to develop our relationship with light and use it for efficient and ultrafast information processing. For this, I synergize neuroinspired methods and architectures with state-of-the-art optoelectronic devices. This effort is part of an effervescent multidisciplinary field with the ambitious goal of implementing advanced machine learning schemes into physical analogue systems.



## Dr. Lucas Souza

Host Institution: Aston University, UK

We are developing bismuth-containing bioactive glasses for photo-thermal therapy which has the potential to help treat residual metastatic bone cancers without the need for further invasive surgical procedures. This biomaterial combines the capacity to stimulate bone regeneration, very well described for bioactive glasses, with the photo-thermal conversion agent bismuth, which can absorb light in specific wavelengths and convert it into heat to induce cancer cell death by hyperthermia.

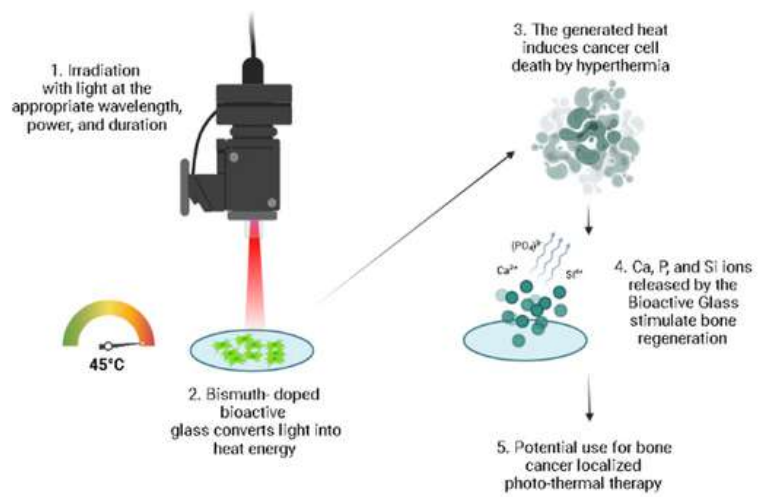
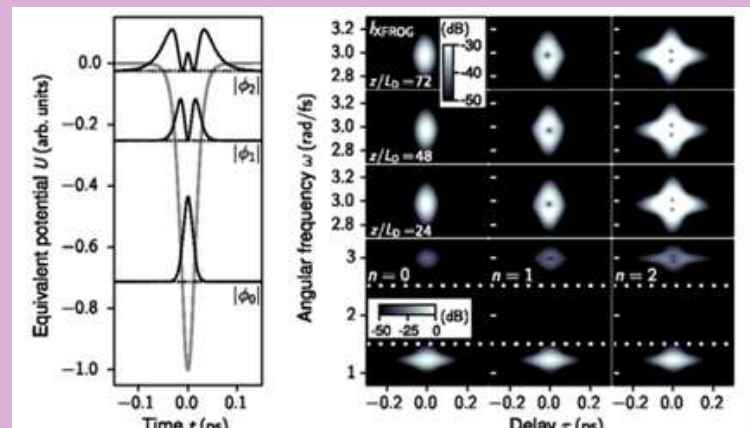


Figure 1. Multi-functional bismuth-containing bioactive glass for bone cancer therapy.

## Dr. Surajit Bose

Host Institution: Leibnitz University, Germany

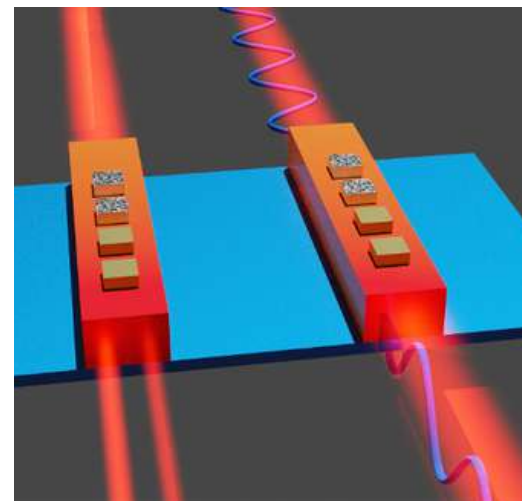
We explore the dynamics of a few-cycle soliton in the nonlinear waveguide to create light from visible to mid-infrared region. We discover that a few-cycle two-color soliton forms a robust molecule state of light. It can be interpreted as mutually trapped states (figure) and the conservation laws define binding energy. The new states described hold promise for applications, e.g., communication systems as information can be decoded in the frequency domain.



## Dr. Chao Meng

Host Institution: University of Southern Denmark

I am currently working on a very exciting project in which we attempt to reshape the light field with artificial sub-wavelength-thickness nanostructures, i.e., optical metasurfaces. These metasurfaces exhibit unprecedented capabilities for manipulating all the constituents of the light including amplitude, phase, and polarizations at will with a high spatial resolution as well as high efficiencies. It could be used not only with free-space propagating light, but also the optical modes propagating in the on-chip waveguides. Owing to their ultra-compact form fact and high design flexibility, we believed that the metasurfaces would be a promising technique for developing next-generation photonic components with ultracompact sizes, low power consumption as well as excellent performances.



# Dr. Judith Birkenfeld

Host Institution: IO-CSIC, Spain

At IO-CSIC (Visual Optics and Biophotonics Lab), we use light for the early detection of corneal diseases like keratoconus (KC). A recent example is 2-meridian corneal deformation imaging using Air-puff Optical Coherence Tomography. Here, we image the cornea in horizontal and vertical meridian while it is deformed under a low-pressure air pulse. We then analyze deformation asymmetries that are possibly due to biomechanical changes that happen in the early stages of keratoconus.

Patient-specific finite element models are used as a tool to get corneal material stiffness estimations by means of an inverse analysis procedure and simulation of the air-puff pressure. First results of our current patient study have been recently presented at the 2021 ARVO annual meeting (Association for Research in Vision and Ophthalmology).

Link to ARVO abstract: <https://arvo2021.arvo.org/meetings/virtual/vipKmEZFRNzdEC8LY>

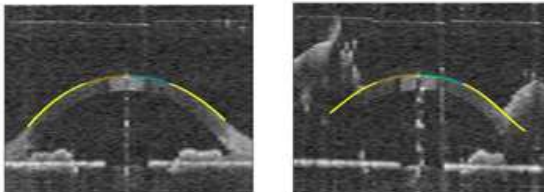
Link to VioBio website: <http://www.vision.csic.es/default.aspx>

Twitter, VioBio Lab: @VioBio\_Lab

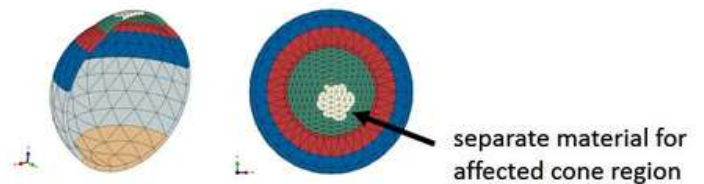
Twitter, J. Birkenfeld: @j\_birkenfeld

## Patient with mild KC

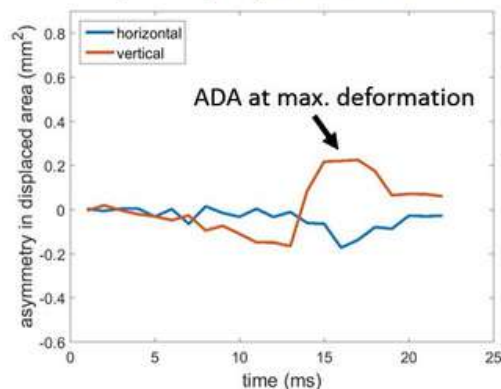
**horizontal meridian**  
**vertical meridian**  
**with segmented corneal surfaces before deformation**



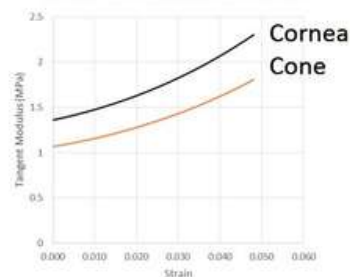
**FE models with patient-specific corneal geometry,**  
**IOP and age-related scleral material properties.**



**Asymmetry displaced area in time**



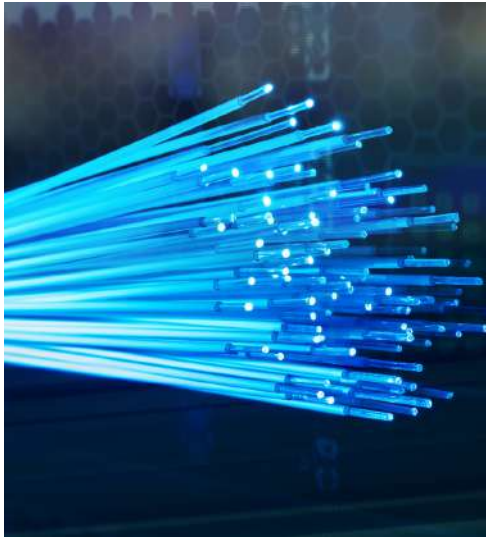
**Tangent modulus (Mpa) estimated**  
**from the inverse solver**







This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement No 766115



Optical fibre – thin flexible fibre with a glass core through which LIGHT signals can be sent – forms the backbone of communication systems. The exponential increase in data traffic is putting an escalating pressure on fibre-optic networks. Optical fibre is a nonlinear medium because its properties change with the signal intensity. It is well known that the fibre nonlinearity limits the achievable information rates of the conventional transmission methods in optical communication. The main objective of the FONTE is to develop communication and coding methods suitable for nonlinear optical fibre, and to increase the data rates of the future communication systems. In particular, the project aims to apply nonlinear Fourier transforms to address the limitation that the fibre nonlinearity sets on transmission rates.

## RESEARCH HIGHLIGHTS

### Vladislav Neskorniuk

Host Institution: Aston University and Nokia Bell Labs (Germany)

Optical fibres, the specific type of cable transmitting LIGHT between the two ends, are nowadays the main choice of media to provide an internet connection of all ranges (desired bandwidth and reach). We research the ways to apply the recently developed machine learning techniques to improve the long-haul fibre-optic communication links carrying the backbone internet traffic, notably, undersea between continents and on-ground between multi-million agglomerations. First, we develop novel methods of compensation the signal distortions arising in the links along with information transmission. Second, more generally, we apply machine learning to find the previously unknown ways of tuning the link to improve its performance and decrease the cost of operation.



Shutterstock: FlashMovie



## Stenio M. Ranzini

Host Institution: DTU-Technical University of Denmark and Nokia Bell Labs (Germany)

Every time you scroll pages on the internet, listening to online music, playing online games, or watching a movie in a stream environment - you are accessing information from a cloud. Cloud? What exactly is that? The Cloud is the place where all this information is stored. These are also called data centers and they are all around the world! Imagine how many data centers are out there, to store information from all content available on the internet. They need to be fast, so you can click at your home, request the information, and access it with an imaginable speed.



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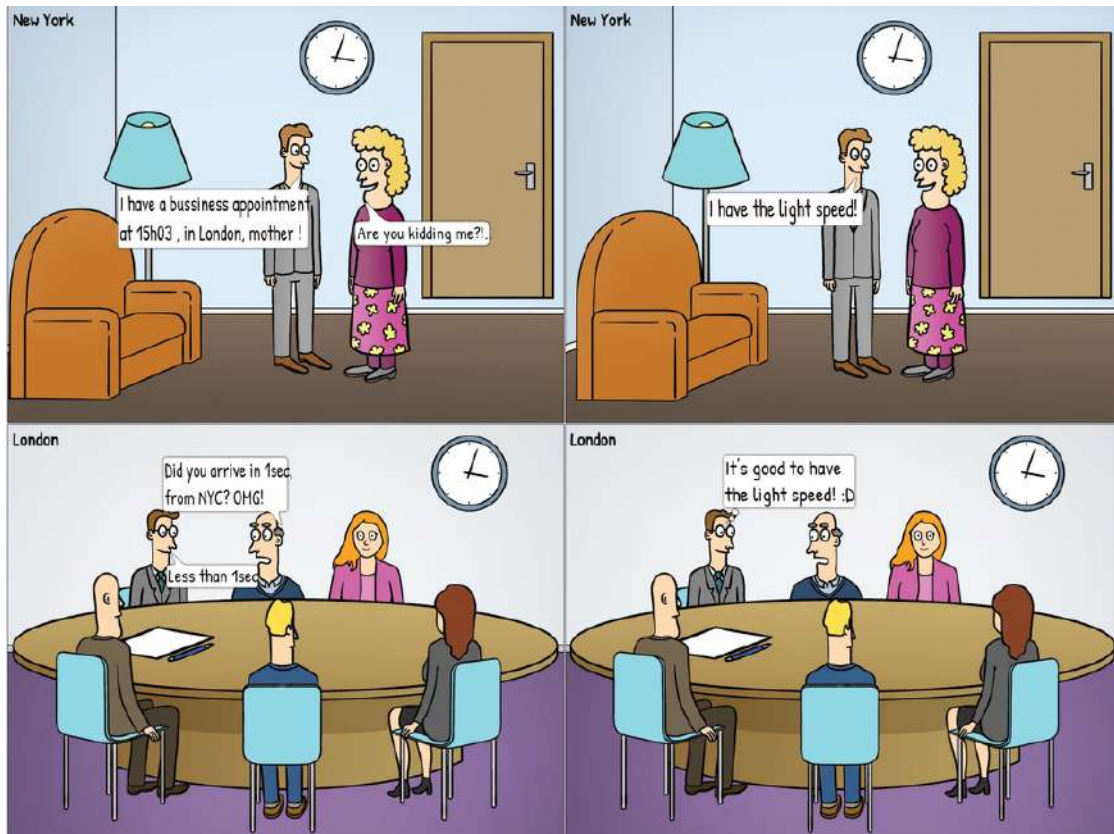
Only a few clicks! This information travels incredible distances, crossing all sorts of boundaries: mountains, countries, and even oceans! Have you ever thought that it only takes a few seconds to start enjoying your movie? How can that happen? The answer is LIGHT! All this information travels at the speed of light - nothing goes faster! The field that makes it possible is called optical communications systems, an area in which I am a researcher. My job is to make it possible to transmit as much information as possible - using LIGHT - in the most efficient way. For that, I am looking into advanced machine learning techniques to help me on this amazing quest! The technique that I am using to do this started with a model created to try to understand how the brain works. We are currently studying this technique for data processing for the next generations of transmitters and receivers inside the data centers. This technique will increase transmission distance by more than three-fold, without sacrificing communication speed. It is unreal how many different subjects can be intertwined together to improve a system!

## Abtin Shahkarami

Host Institution: TU Delft and Nokia Bell Labs (Germany)

You've probably wondered at least once in your life how great it would be if you could fly at the speed of LIGHT and travel to any location on the planet in less than a second. Unfortunately, this is not possible for objects, but it is possible for data you want to send or receive. This is made possible by the transmission of LIGHT waves bringing the data across optical fibres. However, the propagation of light waves in the optical fibre harms it. The LIGHT waves incur some damages (referred to as "distortion") when passing through the optical fibre. This is caused primarily by channel noise, dispersion, nonlinearity, and loss.

Our mission in EID-FONTE is to find solutions that mitigate distortion effects on the optical signal. In this direction, my own research is to investigate disruptive neural network-based solutions reversing the channel effects on the signal at the receiver, a process called equalization.



Created by Abtin Shahkarami

## Vinod Bajaj

Host Institution: TU Delft and Nokia Bell Labs (Germany)

Ever since humans started communicating, they improved their lifestyle at a much higher pace. They started communicating with the use of sign language and their voice, and then, to cover longer distances used runners and homing pigeons. Over the past two centuries, much more sophisticated systems were developed that were able to transmit information from one place to another, whether separated by a few kilometers or by transoceanic distances. Nowadays, we can access huge chunks of information from a distant part of the world.



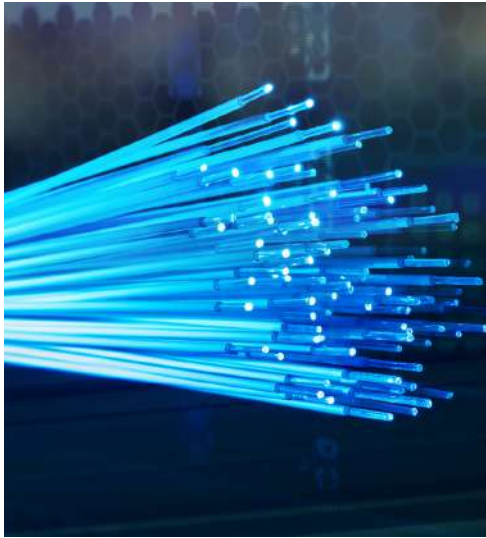
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The whole world is connected - the age of information has arrived. This is made possible by the use of LIGHT to carry information through optical fibres, very thin strands made from glass, collectively known as optical fibre communication systems. These systems are like information highway transmitting information in hundreds of Gigabits in a second. Despite having a huge capability, with the increase in the number of internet users and multimedia content e.g. audio and video, the capacity of these systems needs to be scaled up. The main limitations come from the devices used for transmitting and receiving information.

At FONTE, I work on applying machine techniques to mitigate the imperfection in the transmitter and the receivers. With the application of such techniques, we demonstrate the highest transmission speed through the fibre by using a single wavelength of light. We communicate at the speed of LIGHT as we use LIGHT to deliver our messages.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 861152.



An optical frequency comb is a very precise tool for measuring different frequencies of light. The technology, made possible by recent advances in ultrafast lasers, can accurately measure much higher frequencies than any other tool. Funded by the Marie Skłodowska Curie programme, the MEFISTA project will train six young researchers in the field. Researchers will conduct research on novel techniques for generating specialised laser waveforms, mid-infrared tuneable dual-comb sources, and manufacturing of mode-locked fibre lasers. Special focus will be placed on the use of frequency combs in laser radar/LIDAR in autonomous cars. The initiative will foster collaboration between academic and industrial partners, enriching EU research and innovation in optical frequency comb technologies.

## RESEARCH HIGHLIGHTS

### Alberto Rodriguez Cuevas

Host Institution: Aston University

Light does not only allow us to see, but it can be used in many ways. For example, we use light to measure distances with a technique called LIDAR. This technique consists of sending pulses of light to a target and counting the time until we receive pulses back. Since the velocity of light is close to 300000 km/s the overall process is very fast. Thus, we can send thousands of light pulses per second to different directions to obtain a 3D map of our surroundings. In that way, LIDAR can be used to give one type of artificial vision to robots and autonomous vehicles.

Light for high precision ranging



## Stefano Negrini

Host Institution: TU Delft

Light is fundamental for life, and also for technological developments! At the eve of the civilization, sun was used to measure time via the invention of a sundial. Light from fires was used to create a signal, along with lighthouses and beacons. Not as convenient or 'quick' as fibre optics and lasers, but for sure one of the first kind of artificial communication methods to use light as a medium.

I work in an international European project called MEFISTA. We don't use lighthouse or sunlight to develop our experiments anymore, but this is what I work on!



My role in this project is the study of the formation of frequency combs in a so-called optical cavity. This 'cavity' is a device that allows the interaction between the light which is injected and the light which is already inside it. If this interaction happens in a constructive way, frequencies are amplified and rise alongside the pump. So if the input spectrum is a single needle, at the output we will obtain a series of needles with constant spacing among each other: a comb! In order for this interaction to be constructive, we use a fairly new approach called "Gain-Through-Loss". The idea is to insert a localized loss inside the cavity to destabilize a precise frequency and thus control the spacing between every needle in the spectrum. This technique is quite new, thus, there are a lot of experiments to carry out. Things like frequency combs are applied in different technological fields, such as spectrometry and a range of applications (for example in LIDAR). We can say that art light is finally used as ruler too!

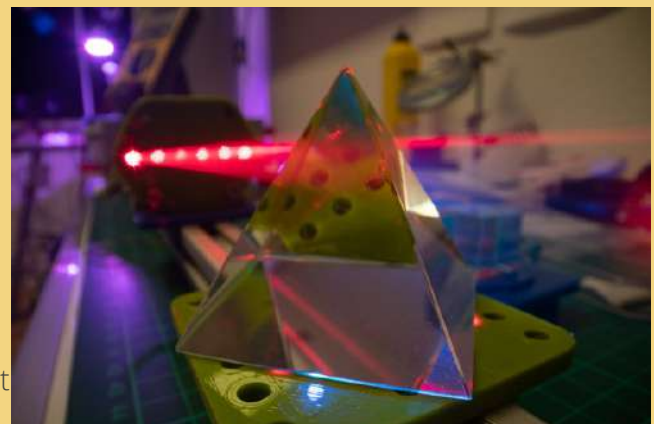
## Nayeem Akhter

Host Institution: Polytechnic University of Catalonia (UPC), Spain

The project "Novel mode locking techniques based on unconventional (non-hermitian) fibre structuring" aims to investigate new and unconventional physical concepts based on non-hermitian structuration of single and multi-mode fibres for generating dual-frequency combs (DFC).

The non-hermitian structuration of materials involves complex structures arising from the simultaneous refractive index and gain-loss modulations, leading to fascinating effects like the new concept of asymmetric coupling between the fibre modes.

By investigating unidirectionally-coupled transverse mode ensembles we can show phenomena like mode locking and beam self-cleaning. Mode locking is a group of techniques for generating ultrashort pulses. Beam self-cleaning is a magical phenomenon where light that is delivered as a random speckled beam at low powers is observed to evolve into a cleaned, almost Gaussian shaped beam at high power levels.





# EID REAL-NET



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 813144.



Within the exponential surge in the global data traffic, there is a clear need for the development of radically different methods for coding, transmission, and (pre & post) processing of information to mitigate nonlinearities and to estimate important network parameters. The training of a new generation of engineers with expertise in optical communications, nonlinear science methods, digital signal processing (DSP), and design of implementable algorithms is of high importance. From industry's perspective, the design of practical and implementable processing algorithms requires knowledge of ASICs and real-world conditions and restrictions. The multi-national & multi-interdisciplinary EID REAL-NET will provide timely doctoral training for six PhD students through industry relevant research in a fast-growing area of high practical relevance.

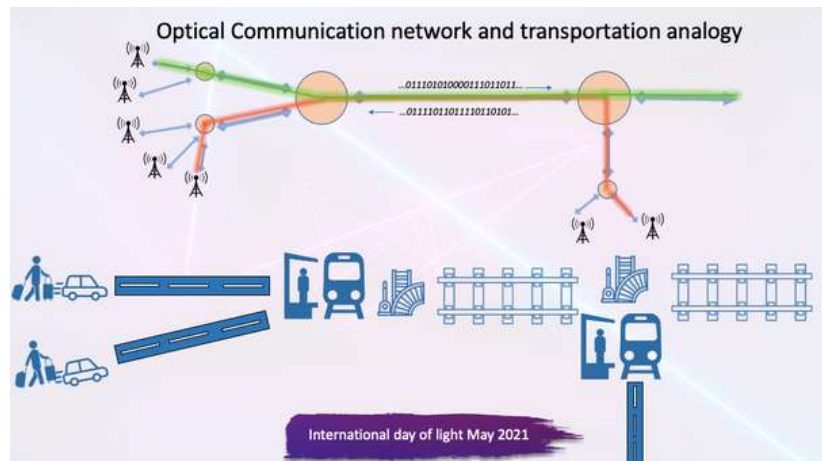
## RESEARCH HIGHLIGHTS

**Mohammad Mohammad Hosseini**

Host Institution: Aston University

As a Ph.D. student, nothing amazes me more than light. A vast amount of knowledge about light has been passed to us by great people like Newton, Maxwell, and Einstein. Now, we can bring light under control and use it to connect everywhere in the globe together. Light in optical communication networks is like vehicles in transportation systems. Cities of data centers, businesses, and people are connected with fast fibre railways.

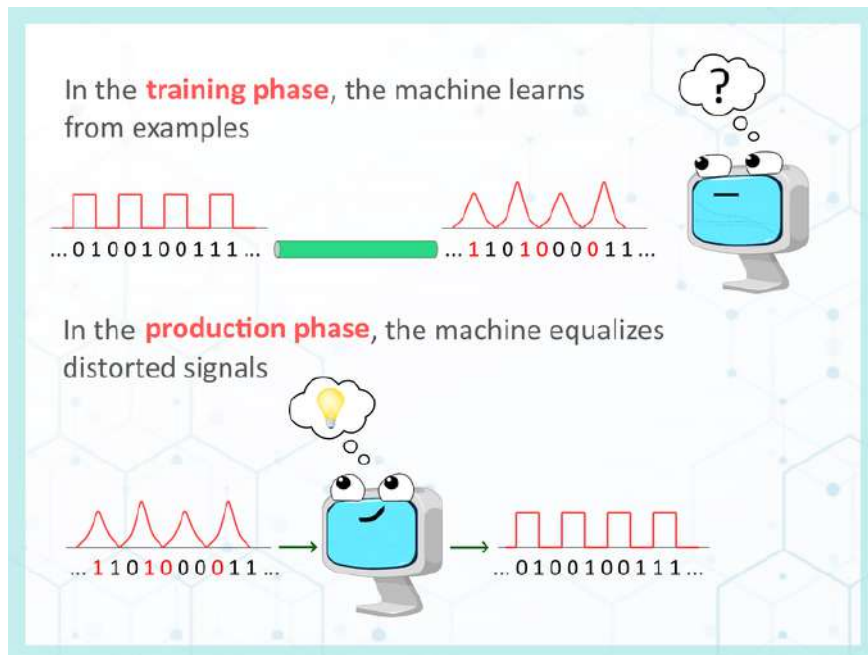
In the Real-Net project, I am optimizing optical networks to deliver more connections with minimum cost and decent reliability and quality of service.



## Mohannad Abu-Ronoh

Host Institution: Telecom Paris, France

Watching your favourite show in full HD means that you are roughly consuming 1.5 GB of data per hour. Luckily, with today's optical fibre standards, this amount of data can be transmitted in a fraction of a second. In fact, some submarine optical cables like FASTER are able to carry thousands of hours worth of full HD video across the Pacific in one second. That's a tremendous amount of data! This was made possible by the advancements in light technology that allowed us to send pulses of light through optical fibres at high speeds.

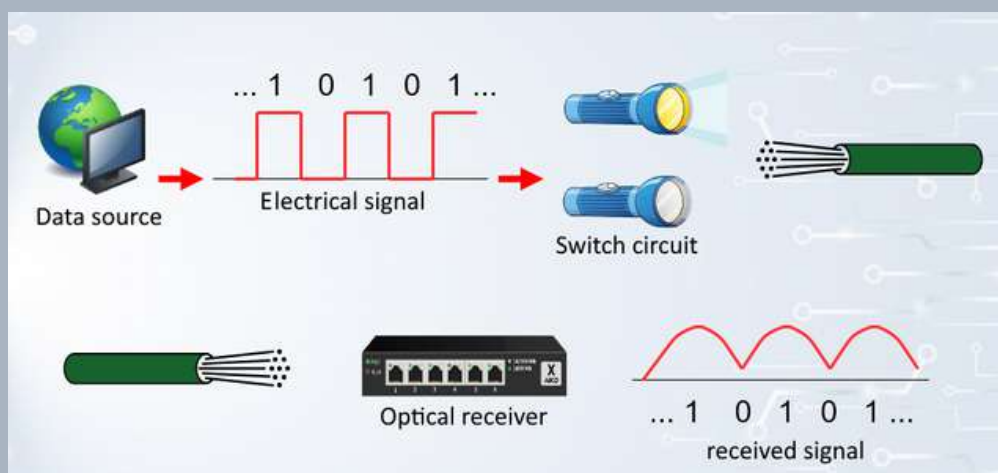


I work within the REAL-NET project to design smart ways using machine learning to equalize signal distortions and enhance the quality of the signal so you can always watch your favourite shows in the highest quality possible.

## Jamal Darweesh


Host Institution: Telecom Paris, France

Have you ever tried to communicate with a friend using a Morse code and a flashlight? The fascinating idea of encoding data into light pulses is the fundamental concept upon which optical fibre communication system is based. Generated electrical signals from multiple sources are transformed into light which propagates through a special type of channels known as the optical fibre. Optical fibres, are long, thin strands of carefully drawn glass about the diameter of a human hair which allow light to travel for long distances. In Real-net project (a project that is funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska Curie grant agreement), we work on finding efficient and low complexity algorithms to mitigate the distortions coming from the optical fibre in order to enhance data rates.





This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie grant agreement No 814147.

An abstract background on the left side of the page, consisting of a vertical strip with a blue and white geometric pattern of hexagons and octagons, creating a sense of depth and light refraction.

Growth of the Photonics market and great potential of Photonics in addressing global challenges creates a huge demand in innovative solutions and qualified experts with multidisciplinary skills in photonics and micro- and nano-technologies able to advance photonic technologies towards applications ranging from spectroscopy to LIDARs. EID MOCCA address challenges in huge demand of qualified experts by providing for 4 early-stage researchers a world-class advanced training programme which will bring them to the level of the next generation of leaders in the field of photonics and equip them with a unique knowledge base and skill set required to address the global challenges such as global warming, improving medical diagnostics and accuracy and precision in metrology and autonomous driving etc. that underpins innovative technological development across the range of photonics-based disciplines: laser physics and engineering, micro- and nano-photonic components and circuits. The unique Research Programme addresses demand in innovative solutions by developing a new generation of optical frequency comb (OFC) techniques, based on the expertise of world-leading academic and industrial partners. Research outcomes will result in new products, services and markets, based on advancing OFC generators with required characteristics in science, industry, and healthcare.

# RESEARCH HIGHLIGHTS

## Francesco Rinaldo Talenti

Host Institution: Sapienza University of Rome, Italy

Light propagation in space can be very chaotic and difficult to explain. For this reason, research in the field of optics frequently aims to find a simple and compact explanation of the interplay between matter and radiation. Once a physical system is consistently modelled, it is possible to perform interesting simulations of certain situations. The two figures show how light can be manipulated in practical applications: emerging from a chaotic regime, light evolution in space-time can be tracked precisely in an integrated device! Such manipulation of light is fundamental for many applications. Applications relevant to our work include communications and molecular spectroscopy.

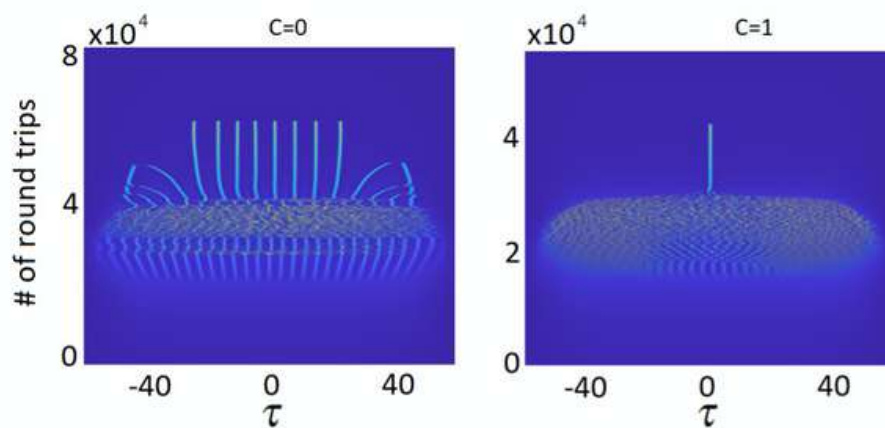


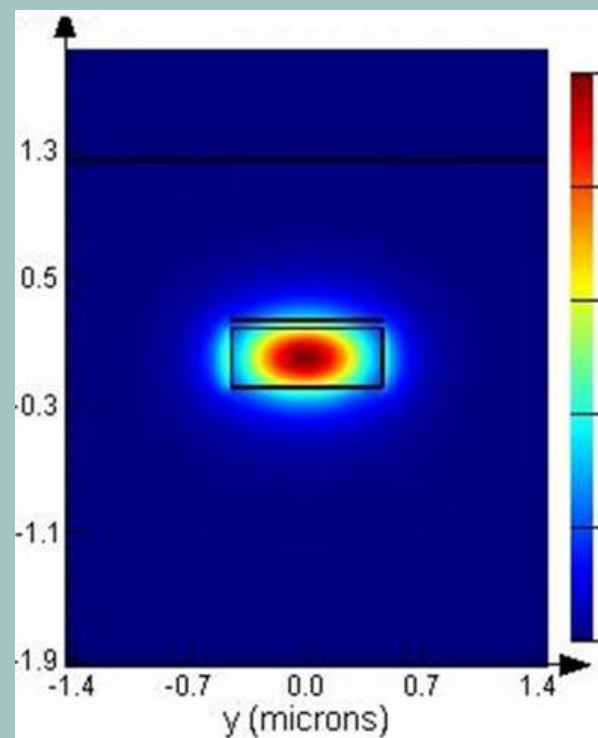
Figure from: F. R. Talenti, T. Hansson, and S. Wabnitz, "Control of Kerr Cavity Soliton Combs by Chirped Pumping," in OSA Advanced Photonics Congress (AP) 2020 (IPR, NP, NOMA, Networks, PVLED, PSC, SPPCom (Optical Society of America, 2020), paper JTu2D.4.

## Avinash Kumar

Host Institution: AMO GmbH, Aachen

My research within MOCCA focuses on generating "new" light colors via nonlinear wavelength conversion based on integrated nanophotonic circuits. The chips are based on the silicon photonic platform suitable for mass fabrication. The target of my research is to enhance the optical nonlinearity of this well-established material platform by introducing two-dimensional materials in the way shown above.

*Figure: Simulated optical mode, i.e. the cross section of the electric field profile of light confined on a nanophotonic chip, in a hybrid waveguide consisting of a silicon nitride (SiN) core embedded in silicon dioxide (SiO<sub>2</sub>). A very thin two-dimensional (2D) material is placed on the waveguide core to enhance the optical nonlinearity of the waveguide.*





# Victor Vassiliev

Host Institution: Aston University, UK

Almost everything we do in Photonics is closely related to light. My thesis aims to 'reshape' light in a very precise and controlled manner: we take a simple one frequency beam of light and transform it into a complex and wonderful tool, a 'frequency comb'.

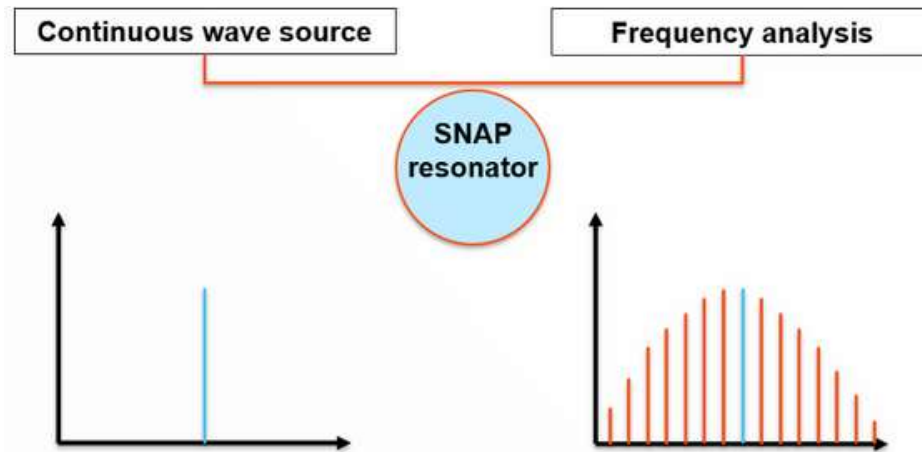


Figure: the creation of a frequency comb.

This transformation is made by taking advantage of the fascinating properties that light has when propagating inside a medium like glass: all the effects are carefully balanced in a small 'bottle' made from an optical fibre to split the initial frequency in a multitude of closely packed, equally spaced frequencies creating a very precise 'spectral ruler' that is used in many scientific fields.

Unfortunately, these transformations cannot be observed with a naked eye, but we have analysis and simulation tools which allow us to observe how light is reshaped inside of the resonator.

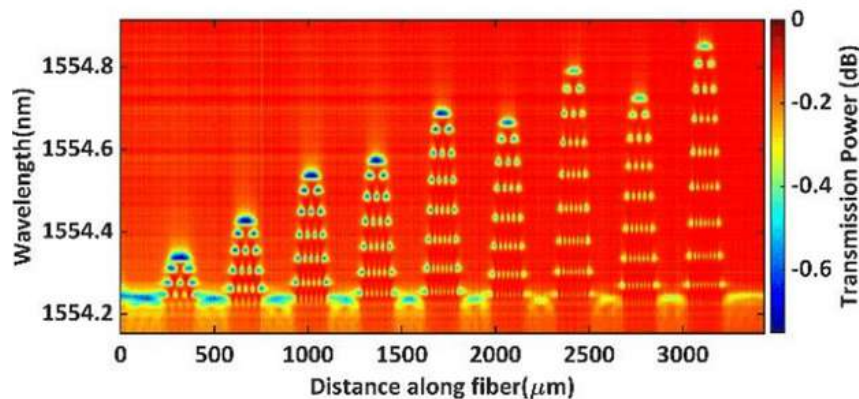


Figure: Example of spectrogram Image obtained with an Optical spectral analyser. We can see nine SNAP resonators and the Wavelengths of light resonating inside of it.

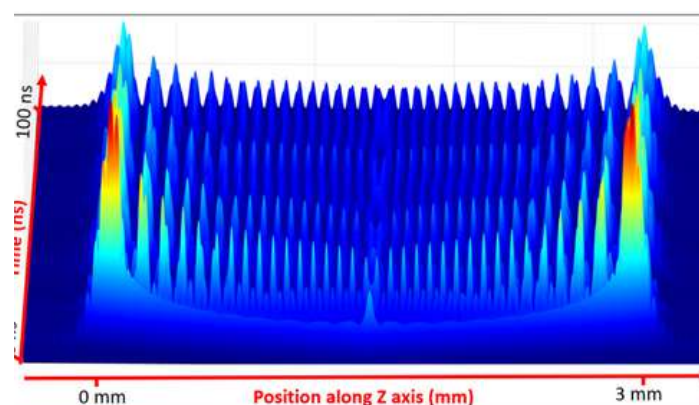
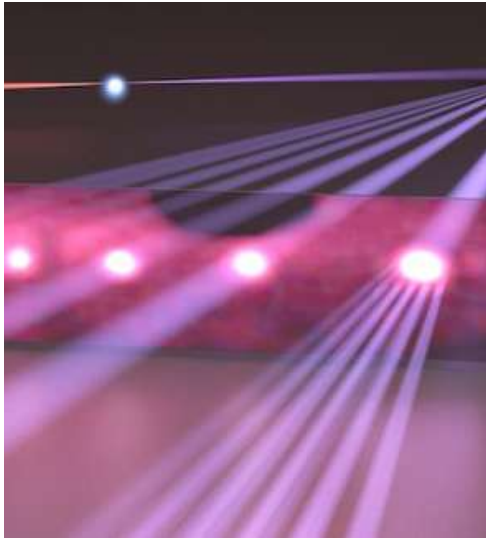


Figure: Example of Amplitude distribution inside of a SNAP bottle resonator obtained by numerical simulation.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 814276.



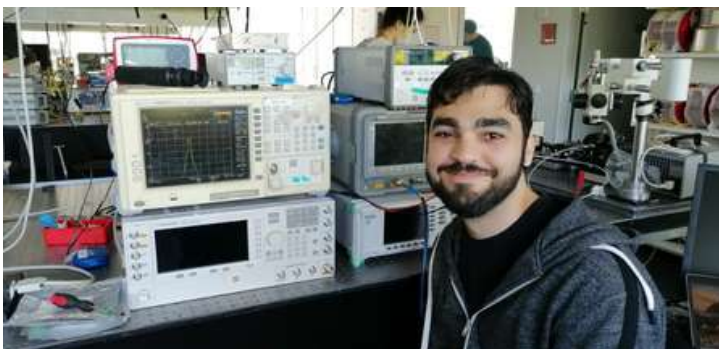
ETN WON "Wideband Optical Network" is a European Training Network funded by the European Union's Horizon 2020 research and innovation programme. Coordinated by Aston University, the WON Consortium unites 13 world leading groups working in the area of wideband optical networks and trains Early Stage Researchers (ESRs) in the unexploited area of wideband optical networks in three main areas: network management and control plane algorithms; design, prototyping and test of transceiver and in-line components; digital signal processing techniques and system modelling.

## RESEARCH HIGHLIGHTS

### Thyago Monteiro Sá Pinto

Host Institution: Danmarks Tekniske Universitet (DTU)

Optical Frequency Combs (OFC) can be seen as combs of Light since they correspond to a spectrum with equally spaced optical carriers (or lines). They are well known in the fields of metrology and spectroscopy, in the implementation of optical clocks and to study the interaction between light and matter, respectively. Recent advances regarding OFCs expanded their application over to telecommunication as an alternative for multi-carrier or multi-band systems. Therefore, the optimization of OFCs is necessary for these setups and, here at the Technical University of Denmark (DTU), working in particular on the ETN project WON, we are using machine learning tools to improve the many characteristics of these combs and their performance in optical communication systems.

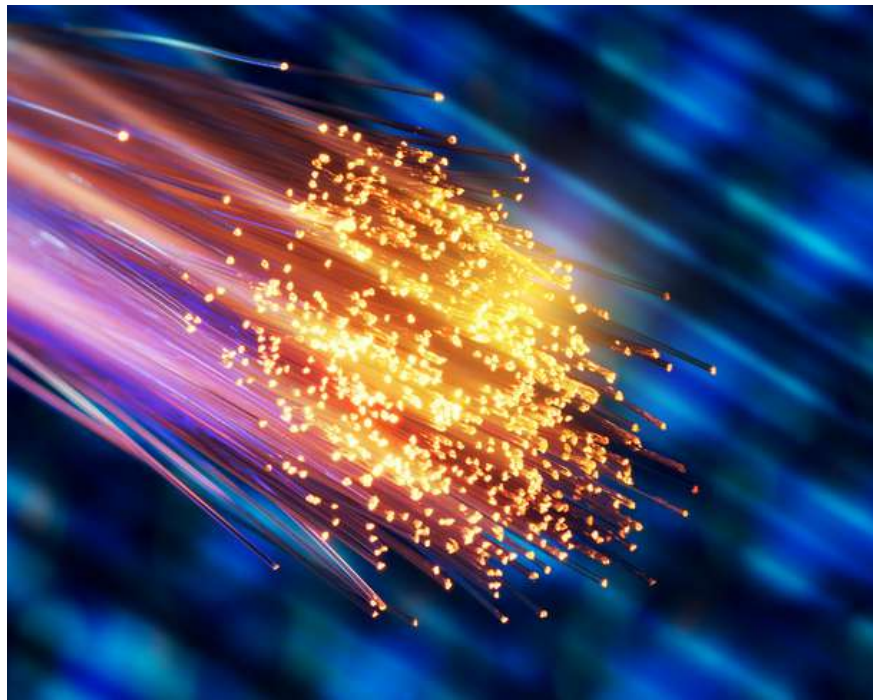


## Elliot London

Host Institution: Politecnico di Torino (PoliTo)

The internet has profoundly changed modern society in countless beneficial ways, and is made possible only through extensive networks of fibre-optic cables, each transmitting mind-boggling amounts of data every second at unparalleled speeds: through light!

As the number of internet users continues to grow, so too does the amount of data that we need to send over these networks to get the same (or better!) service, which is no simple feat. Naively, we could simply continue to install more and more optical fibres... but there are smarter approaches we can adopt.



One way is to extend the transmission bandwidth of the optical fibre, where data is sent over frequencies that are much noisier, giving a lower signal quality. Compensating for this reduction in signal quality in a wideband transmission scenario forms the foundation for my research; I use accurate, cutting-edge simulation tools to model the physical transmission of light through the fibres themselves – helping to piece together the puzzle that will allow mind-blowing future technologies such as fully integrated virtual reality!

## Gabriele Di Rosa

Host Institution: VPI photonics

Light is the medium carrying information through the backbone of the world network and allowed for the first time in history to create a global community sharing culture and knowledge on a mass scale. To sustain this ever-growing trend, the WON project aims at increasing the amount of information available on the existing fibre-optic infrastructure. In this context, the topic of my work is the efficient transformation of these enhanced capabilities of light as a communication medium.



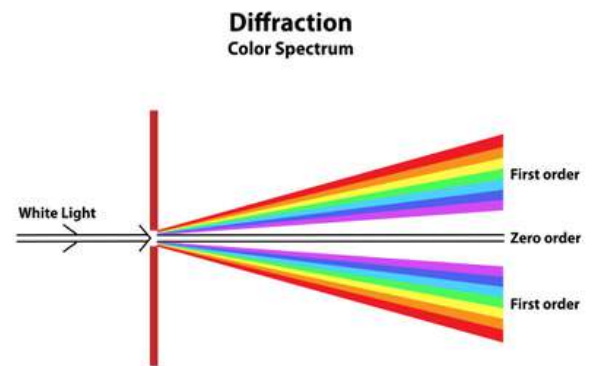


# Rafael Magalhães Gomes Kraemer

Host Institution: Eindhoven University of Technology (TU/e)

Light management in future optical networks.

As current optical network communication systems involve sending multiple colors of light through an optical fiber, separating these individual colors is an integral part of any modern optical communication system. My research focus is to come up with ways for managing and controlling these different colors of light as future wideband networks add more and more colors inside the optical fiber.



# Rasoul Sadeghi Yamchi

Host Institution: Politecnico Di Torino (PoliTo)

Light is the fastest thing in the world which is both a particle and a wave. With growing technologies and data centers like Youtube, Facebook, etc., the traffic of the networks increases, so the best solution to increase the networks capacity is to use wave characteristics of light. But how? Data can be carried on the light by using optical fibers. To use the whole capacity of optical fiber, it is good to increase the bandwidth of frequencies in an optical network. The aim of our project WON (Wideband-width Optical Network) is to investigate the advantages of this rise in the band (frequencies). My work as a researcher in WON is to analyse a whole network in regions like Germany, Europe, and the USA using wideband devices investigated by other team members.





## Bruno V. de A. Correia

Host Institution: Politecnico Di Torino (PoliTo)

With the goal of sustaining the continuous increase of Internet traffic over the next years, enhance traffic capacity of light transmission over optical fibres is crucial, as backbone optical networks are the main way to cope with such high demand. In this context, the Wideband Optical Networks (WON) project targets the possibility of light transmission over spectral portions of the fibre not used in today's systems.

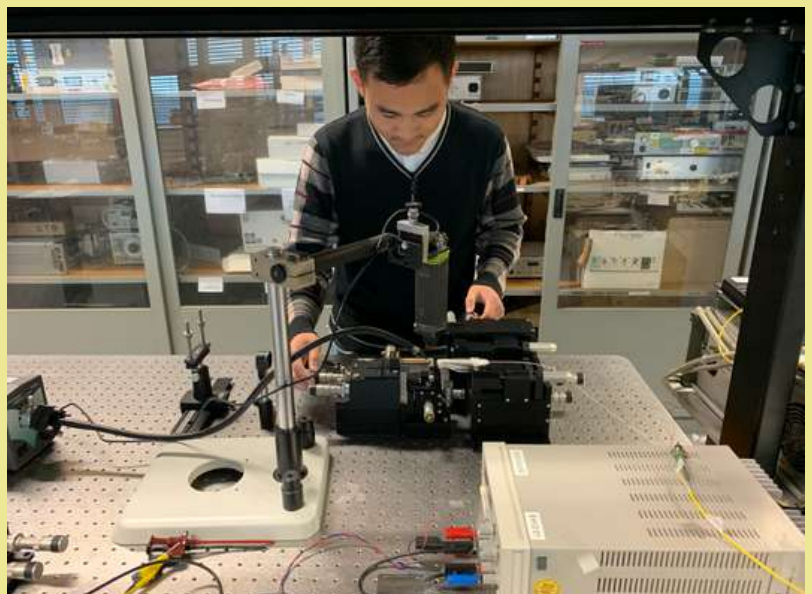
Specifically, my research aims the optimization of those systems in terms of quality of transmission, as we add more spectral portions to the current commercially available systems. Besides that, we evaluate the benefits of those transmissions in network scenarios. To perform that, we make use of advanced simulation tools, assessing both physical layer impairments and network capacity improvement.



## Yu Wang

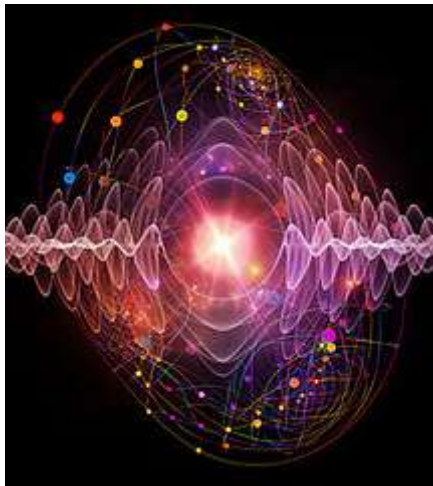
Host Institution: Eindhoven University of Technology (TU/e)

The optical fibre communication technology takes advantage of the light's speed and colour. Different colours of light carry different information for different purposes. The wavelength selective switch (WSS) can route the colourful light from any transmitters to any receivers. My research within the WON project focuses on investigating, designing, and assessing novel modular wideband WSS able to operate the light from 1260 nm to 1625 nm with low power loss, low crosstalk, and high channel number.





This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 860360.



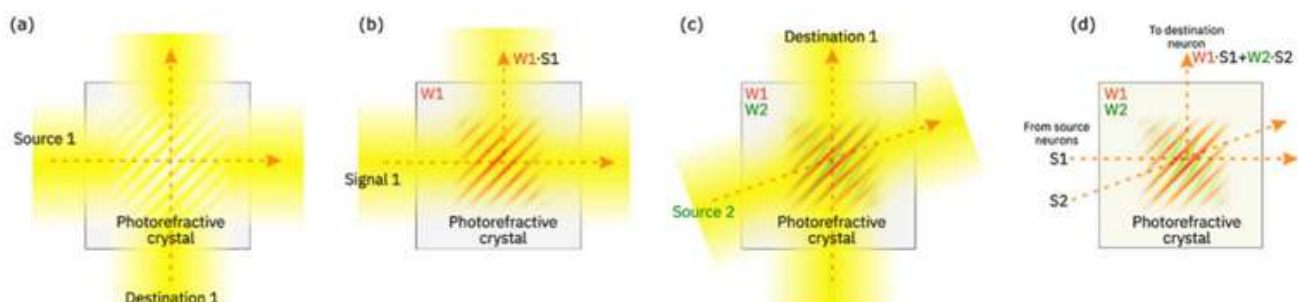
European Training Network on Post-Digital Computing is an interdisciplinary training network comprising internationally leading teams from academia, research centres and industry, including IBM, Thales and three highly reputed SMEs. POST-DIGITAL will provide a unique training opportunity to a cohort of 15 early stage researchers (ESRs) in the inter-disciplinary fields of emerging disruptive neuromorphic computational technologies and their applications. The strong industrial presence in the network will bridge the gap between early stage innovation and utilization, providing ESRs with the experience of practical applications and solutions beyond traditional digital methods. POST-DIGITAL has the ambition and the vision to create a new generation of scientific and industrial leaders that will greatly contribute to strengthening Europe's human resources and industry competitiveness in future digital and post digital economy and technology.

## RESEARCH HIGHLIGHTS

### Elger Vlieg

Host Institution: IBM, Switzerland

We are developing an analog optical processing unit that uses light to perform neural network calculations in a massively parallel manner. The larger compute effort in executing and training neural networks is in calculating the synaptic connections between the neurons. In our device, we achieve tunable optical synaptic connections by writing programmable reflective index gratings into a photorefractive crystal. The device is realized in silicon photonics technology, enabling a small form factor, and a scalable and stable implementation. Applying such a concept may enhance the power efficiency and performance of neuromorphic computing systems by several orders of magnitude compared to traditional computers.



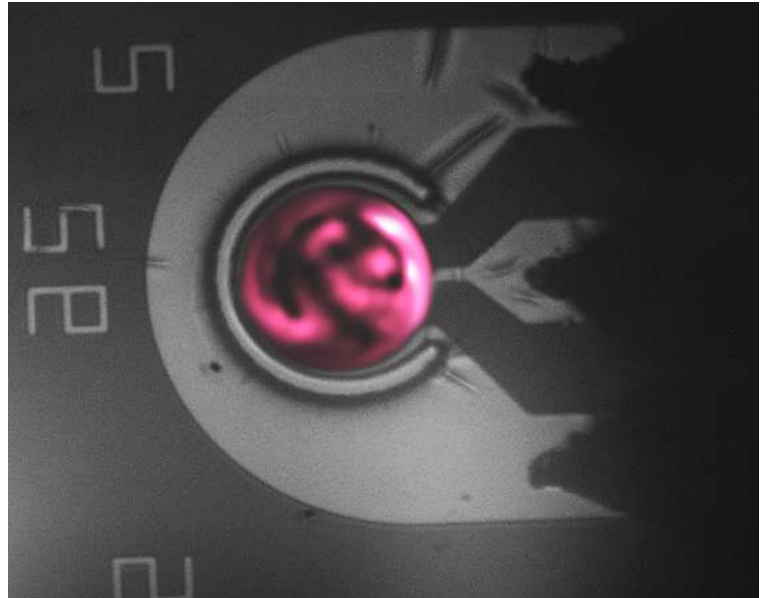
## Anas Skalli

Host Institution: Femto-ST, France

An optical neural network, using light for computation : Information encoded in spatial patterns is injected into a Vertical Cavity Surface Emitting Laser (VCSEL) emitting in the near-IR through a multimode fibre. The VCSEL then transforms the injected information non-linearly yielding the mode profile in the picture. This transformation is comparable to the action of a neural network: similar inputs result in very different VCSEL responses, and we can use the laser for pattern recognition.

The transformed mode profile is then imaged onto a micromirror array, whose mirrors constitute programable photonic connections. The system learns the best configuration to differentiate between different input patterns.

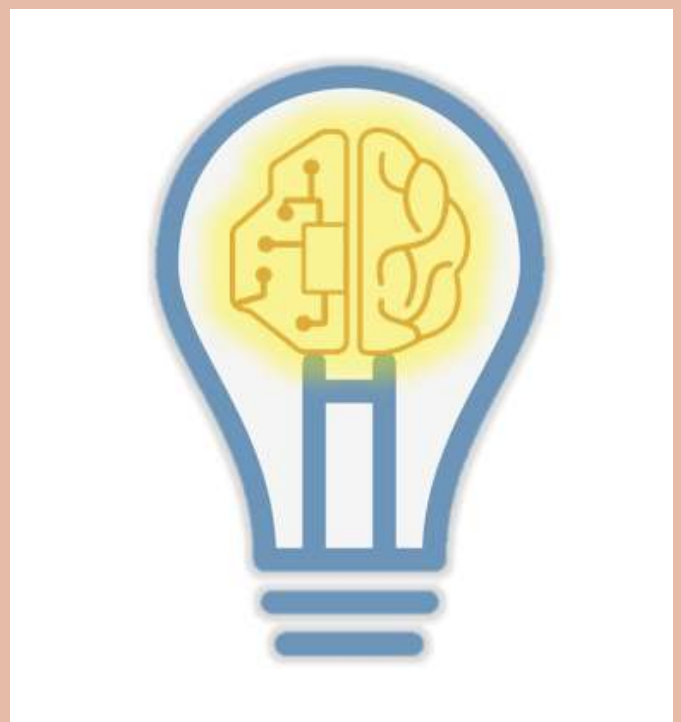
(<https://iopscience.iop.org/article/10.1088/2515-7647/abf6bd/meta> )



## Long Hoang Nguyen

Host Institution: Aston University

The high demand for artificial intelligence in many applications has requested the need for creating artificial neural networks that can mimic functional and biological characteristics of human brains. Photonic neuromorphic computing aims to meet that demand by developing a mechanism that manipulates information using light (rather than the conventional electron) in a way like our brains do. Using light instead of electrons may potentially help to exploit the benefits of higher bandwidth with less energy loss, then accelerating the potential of machine learning applications. One of them is my current research where I try to utilize light-based computing to compensate for distorted nonlinear optical signal in light-based communication.







This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 860775..



There is a growing concern about the potential health risks that micro and nanoplastics pose to us whether through ingesting the harmful bacteria they pick up when coming from wastewater plants, or just through injury and death of cells through contact, possibly through absorption of nanoplastics by cells.

MONPLAS is a four year Initial Training Network that consists of some of Europe's greatest experts who in collaboration with end-users and equipment manufacturers, will provide tomorrow's talent with the skills and knowledge to deliver technologies that will permit a robust, easy to use and low cost industrial instrument, whose measurements will correspond directly to the EC directive.

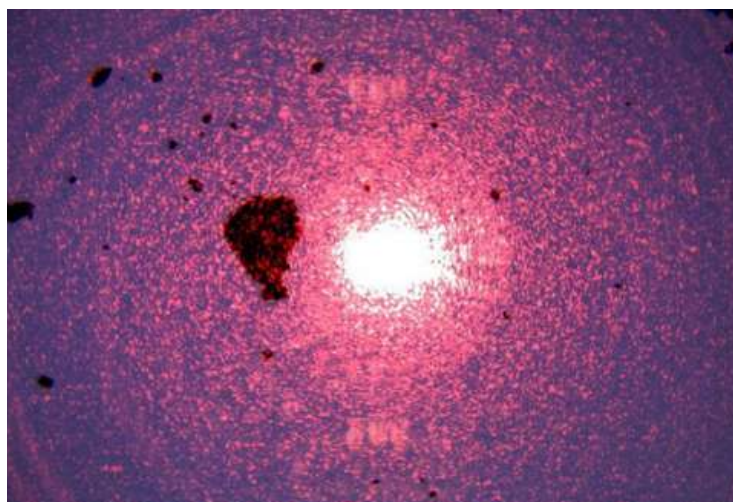
## RESEARCH HIGHLIGHTS

### Luca Maurizi

Host Institution: Aalborg University, Denmark

My PhD project focuses on micro- and nanoplastics in drinking waters. Since I am mainly making use of Raman microscopy, light allows me to assess chemical composition and number of particles in a sample.

This technique gains information from a special kind of diffused light, this being energetically different than the laser generating it. Below a picture showing a 633 nm laser impinging onto some particles. Don't they resemble a solar system?

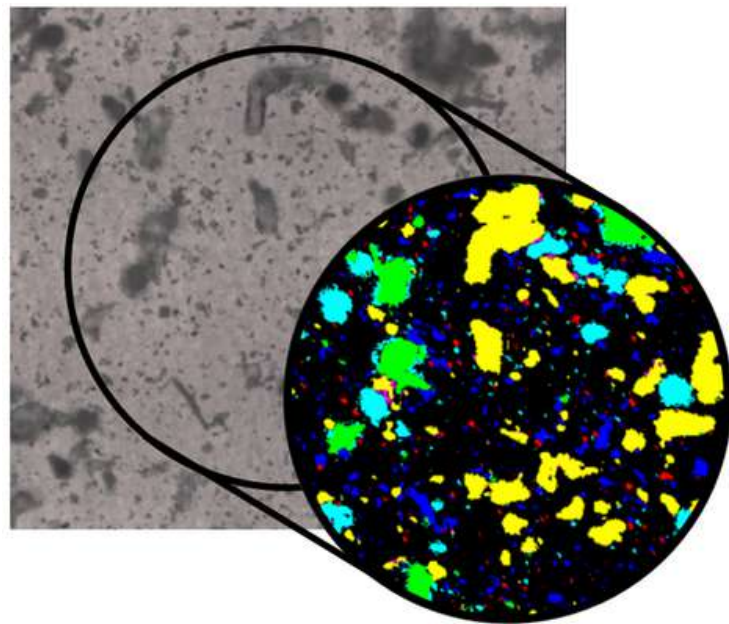




## Jordi Valls-Conesa

Host Institution: Bruker Optic

One of the many useful applications of light is to identify the materials composition through spectroscopy. IR light is particularly useful to identify carbon based materials, like plastics. Thus, using an IR microscope we can study plastics. The central focus of my research is to identify microplastics that are polluting water and food to make research on them easier for others.

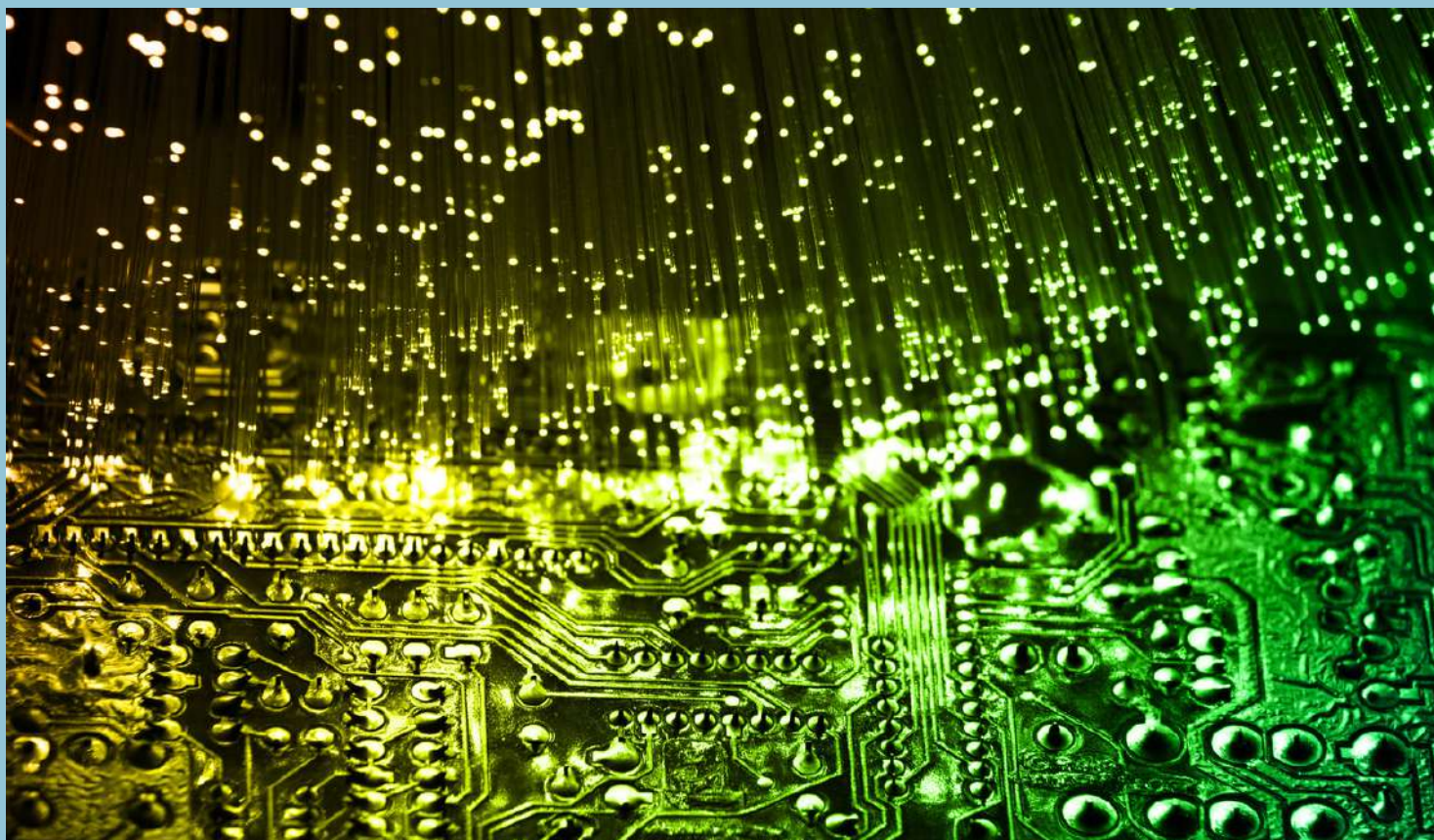


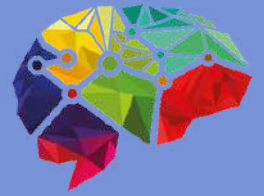
Visible image of MP (left) compared with the identification of MP using an IR microscope (right)

## Julia Sophie Böke

Host Institution: Leibniz-Institute of Photonic Technology, Germany

During my research project, I combine photonics, microfluidics and image processing. Therefore, I utilize the spectral properties of light to analyze the composition of microplastic particles inflow. Hopefully, this method will enable real-time and portable monitoring of microplastics in different liquids.





This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 956713.

We live in an age where we expect high speed internet and are online more and more. The number of glowing monitors and devices across the globe is only going to increase. The aim of Horizon 2020 project EID MENTOR (machine-learning in optical networks) is creating the next generation of high-capacity optical networks which will be a key enabler of global telecommunication infrastructure. Increasing demand (+20 % per year) means we need a boost in capacity. There is also a call for operators to reduce the cost per transmitted bit.

The search for a solution is leading researchers in the direction of machine-learning (ML) techniques. In fact, ML is the technique of choice for tackling this kind of complex, technical problem. This is where MENTOR's Early Stage Researchers come in. They will be working with experts in academia and industry to design crucial optical networks solutions that are robust enough for the future.

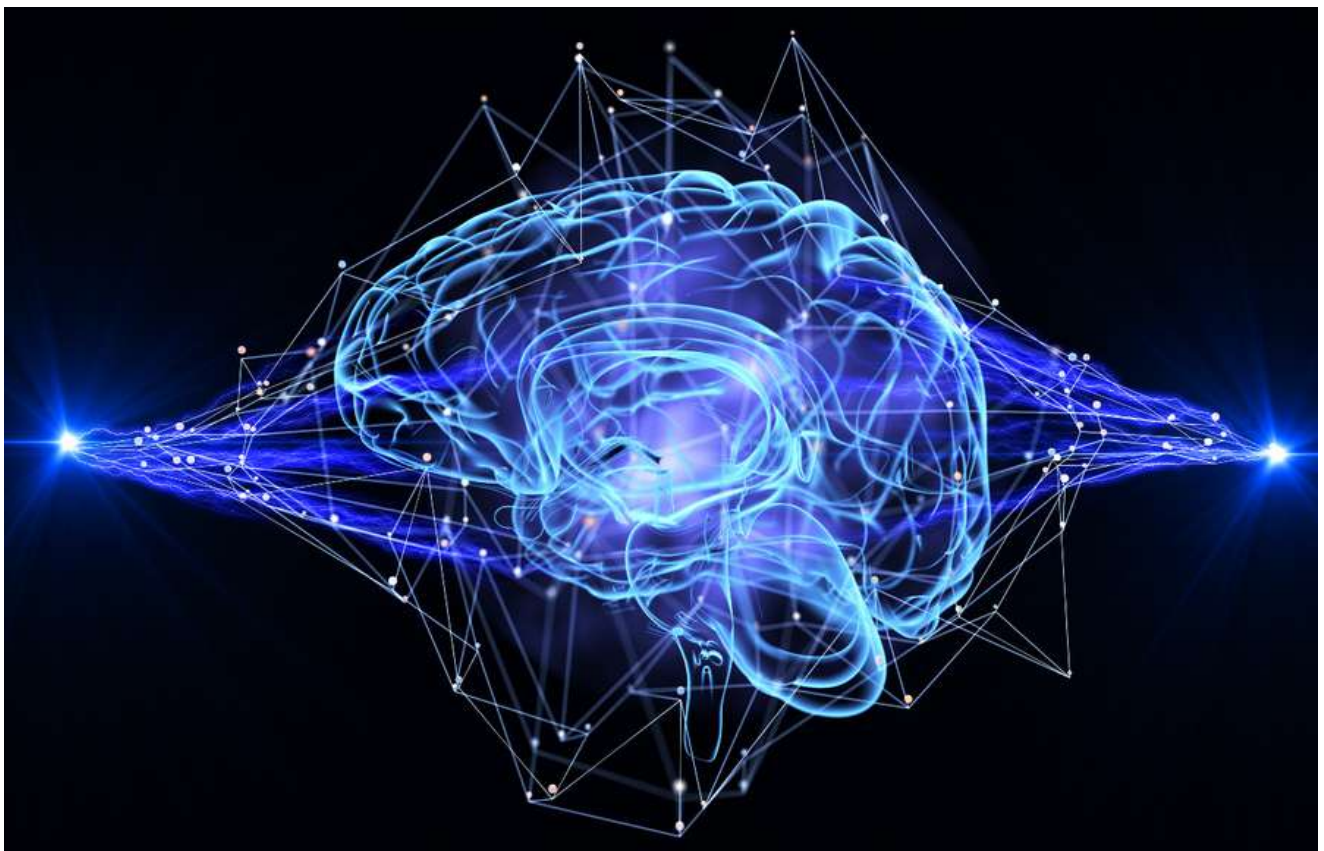


Photo by Tatiana Shepeleva



# MORE ABOUT THE INTERNATIONAL DAY OF LIGHT



## THE MAJOR GOALS OF THE IDL

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Improve the public understanding of how light and light-based technologies touch the daily lives of everybody, and are central to the future development of the global society.

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Build worldwide educational capacity through activities targeted on science for young people, addressing issues of gender balance, and focusing especially on developing countries and emerging economies.

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Highlight and explain the intimate link between light and art and culture, enhancing the role of optical technology to preserve cultural heritage.

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Improve the public understanding of how light and light-based technologies touch the daily lives of everybody, and are central to the future development of the global society.

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Enhance international cooperation by acting as a central information resource for activities coordinated by learned societies, NGOs, government agencies, educational establishments, industry, and other partners.

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Emphasise the importance of basic research in the fundamental science of light, the need for investment in light-based technology to develop new applications, and the global necessity to promote careers in science and engineering in these fields.

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Promote the importance of lighting technology and the need for access to light and energy infrastructure in sustainable development, and for improving quality of life in the developing world.

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Raise awareness that technologies and design can play an important role in the achievement of greater energy efficiency, in particular by limiting energy waste, and in the reduction of light pollution, which is key to the preservation of dark skies.

**The International Day of Light** is administered from the **International Basic Science Programme (IBSP) of UNESCO** by a Steering Committee that includes representatives from a broad range of international partners: *The American Institute of Physics (AIP), the American Physical Society (APS), Bosca, the China International Optoelectronic Exhibition (CIOE), Chinese Optical Society (COS), the European Centres for Outreach in Photonics (ECOP), the European Photonics Industry Consortium (EPIC), the European Physical Society (EPS), the Illuminating Engineering Society (IES), the International Centre for Theoretical Physics (ICTP), the IEEE Photonics Society (IPS), the International Commission on Illumination (CIE), [lightsources.org](http://lightsources.org) - the international network of accelerator based light sources, Light: Science and Applications, The Optical Society (OSA), SESAME, Signify, SPIE, the International Society for Optics and Photonics, Tampere University, Thorlabs, Transitions, the Université de Franche-Comté and Velux.*

For information about the International Day of Light, please visit [\*\*www.lightday.org\*\*](http://www.lightday.org)