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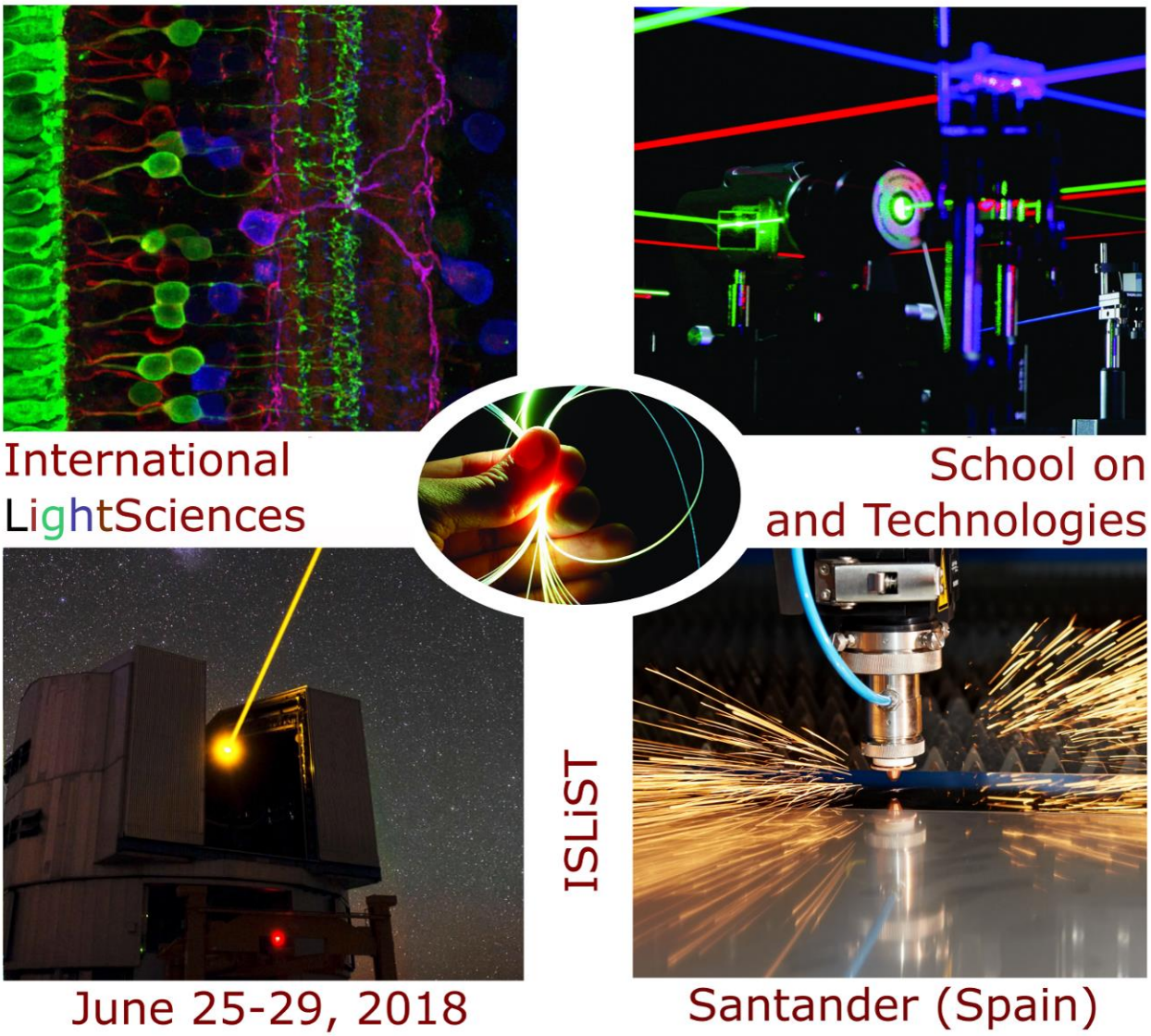

FINAL REPORT

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International School on Light Sciences and Technologies (ISLiST)

June 25-29, 2018, Santander, Spain

Core: ***Light in Communications and Sensing***

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1.- EXECUTIVE SUMMARY

This International School has been conceived as a great opportunity to review, actualize and improve the knowledge of *scientists, professionals and technicians*; to contribute to the education and to enhance the motivation of *PhD students*; to offer an ideal frame for *networking* and also to contribute to the education of common citizens. It is also a great opportunity to ensure that policymakers, entrepreneurs, and other key "actors" will be aware of the problem-solving potential of Photonics.

ISLIST is envisioned to be a worldwide top International forum (the third or fourth week of June of every year) on *Light Sciences and Technologies* in the framework of a *"special top university" that is recognized as the "university of universities"* and in a privileged environment "the Royal Magdalena Palace" in Santander, Cantabria, Spain. Each edition of this international school will have an intensification or main core in a specific application area and additional current hot topics. *Light in Communications and Sensing* was the core of this 2018 edition.

81 attendees from 18 different nationalities all around the world received knowledge and shared experiences with the seventeen (17) highly renowned professors and researchers from the most prestigious worldwide institutions of Europe, USA and Australia, as well as presidents of the most reputed international Photonic Organizations. Sponsored by the Santander Council (Ayuntamiento de Santander), the ISLIST attendees enjoyed the Santander Council Reception, a great opportunity to share experiences and an optimum occasion for networking.

Figure 1.- General View of the Royal Palace of the Magdalena, venue of ISLIST.

Seventeen Invited Talks and two round tables took place along the week. The first round table was focused on challenges in Light in Communications. The second one was on challenges in Light in Communications.

ISLIST-2018 included a very special session on Photonic Crystals with the participation of the two most well-known scientist on the subject: Prof. **Eli Yanoblowitch**, the father of the Photonics Crystal concept (University of California at Berkeley, USA) and Prof. **Philip Russell**, the inventor of the Photonic Crystal Fibers (Max Planck Institute for the Science of Light, University Erlangen-Nuremberg, Germany).

At the end of the closing ceremony, the next edition of this international school was announced. The fourth edition of ISLiST (June 17-23, 2019) will have the core on **Light in Sources, Health and Medicine**.

To be able to reach this 2018 ambitious program, this International School of UIMP was supported by several sponsors: Gobierno de Cantabria, Fundación ACS, the Optical Society, OSA and Equipos Nucleares S.A. (ENSA) and Prysmian.

It has also been supported by several collaborators such as: Santander Council, AMBAR Telecomunicaciones, B-Phot Brussels Photonic Team, SPIE-the International Society for Optics and Photonics, SEDOPTICA; OZ Optics, INNOVA Scientific, Grupo Alava, ERZIA, Semicrol, Hotel Santemar and the Photonics Engineering Group of the University of Cantabria. Without these Sponsors and collaborators, this top quality school and the grants for international students would not have been possible. The UIMP, the direction of this event and the scientific community using Light are grateful with the generosity of all these Organizations and all the Invited Speakers. Thank you so much!

Santander, November 5, 2018.

Prof. José Miguel López-Higuera
Director ISLIST at UIMP

2.- ISLIST-2018: A SUCCESSFUL AND TRULY INTERNATIONAL SCHOOL

ISLIST at UIMP has been acknowledged as a high standard international meeting by the invited scientists and professionals and as well as by the attendees. It has been considered as an edition with an excellent organization, where high quality services were offered, where cutting-edge ideas and technologies were presented and discussed and where networking and interchange of experiences were also successfully carried out (see satisfaction-survey).

The participants of this first edition of the ISLIST at UIMP in Santander, Spain, enjoyed the Seventeen (17) invited talks and two round tables by highly renowned professors and researchers from the most prestigious worldwide institutions of Europe, USA, and Australia, as well, presidents of the most reputed international Photonic Scientific Organizations. The hot topic of *Light in Communications and Sensing* was the core of this 2018 edition.

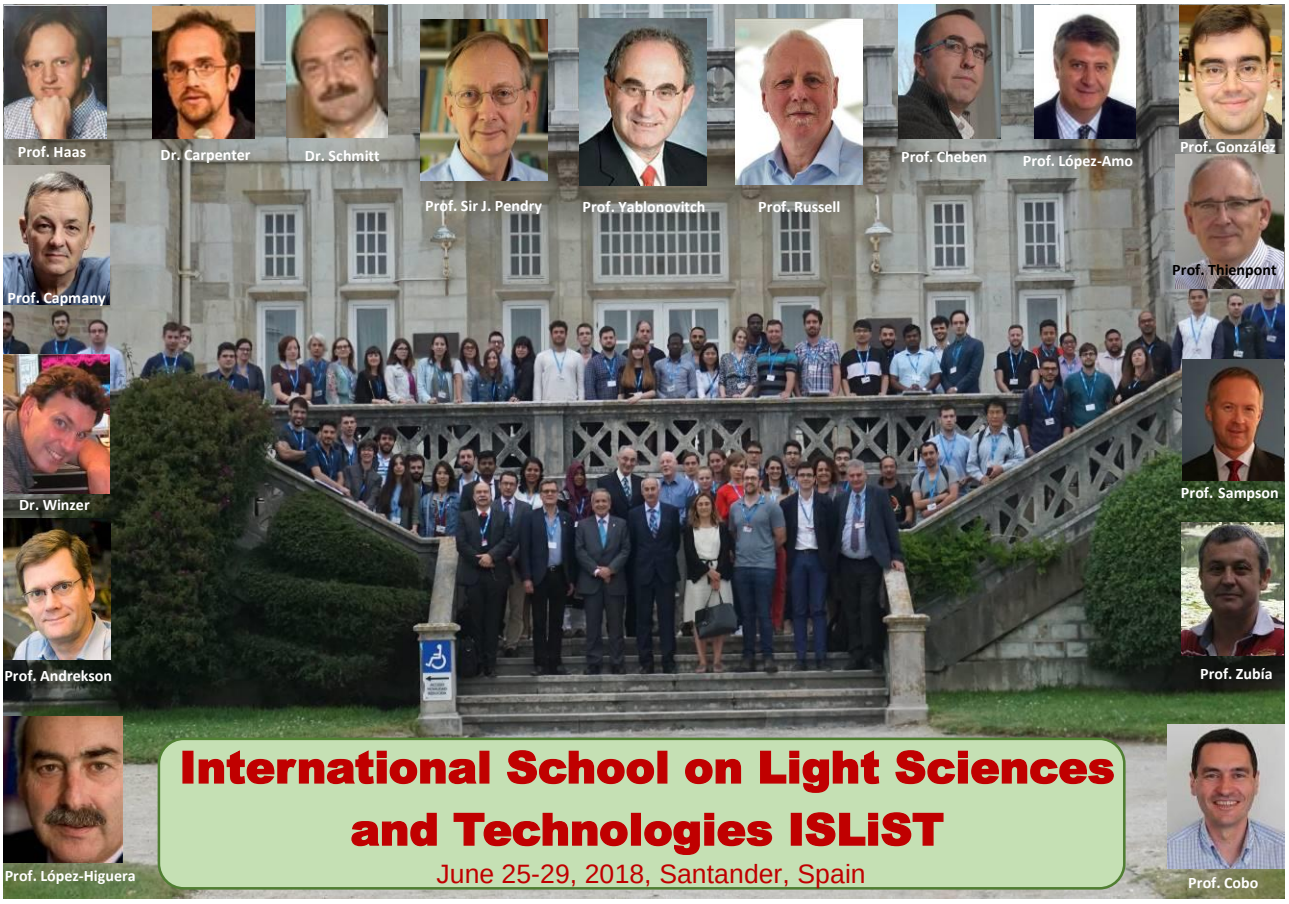

Figure 2. Family photo of the ISLIST-2018 participants. It was taken just before the Santander Council reception. Invited Speakers and organizers.

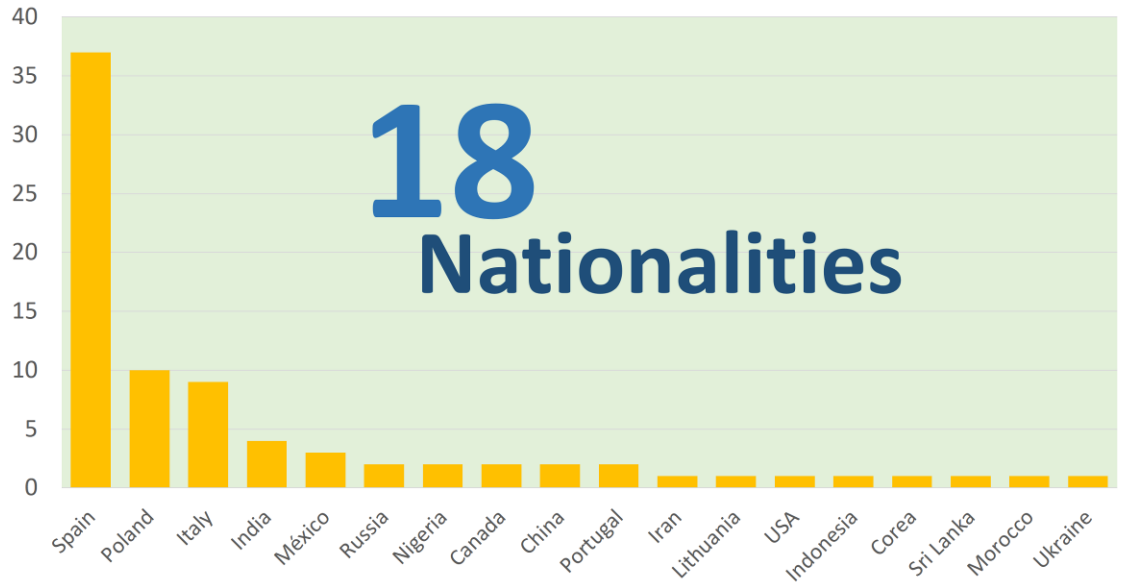

Figure 3.- ISLIST attendees by countries from Europe, Asia, America and Africa.

81 attendees form 18 different nationalities (from over 35 different places) participated in this meeting. As shown in the geographical breakdown in Figure 3, 37 participants came from Spain, 10 from Poland, 9 from Italy, four from India, 3 from Mexico, 2 from Russia, Nigeria, Canada, China and Portugal; 1 form Iran, Lithuania, USA, Indonesia, Corea, Sri Lanka, Morocco and Ukraine participated in the School.

Eighty-five per cent (85%), seven (10%) and six (6%) of participants were from education institutions (Universities), R&D centers and companies, respectively.

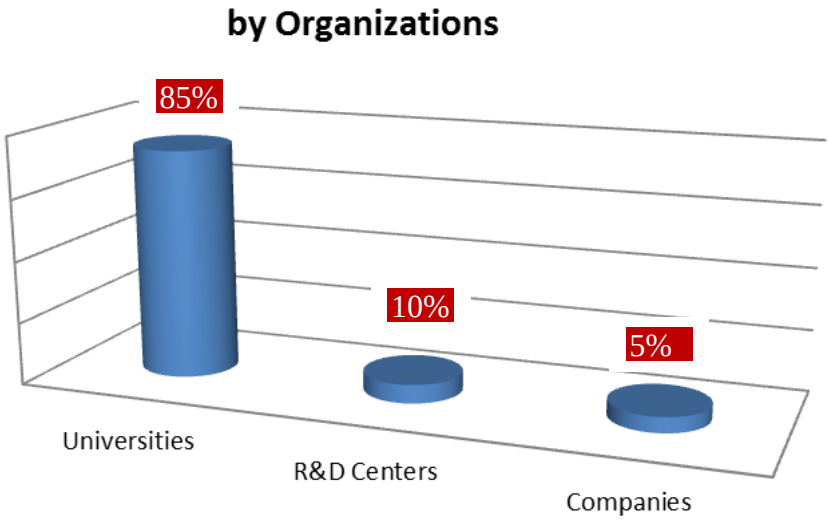

Figure 4.-Attendees by Organizations.

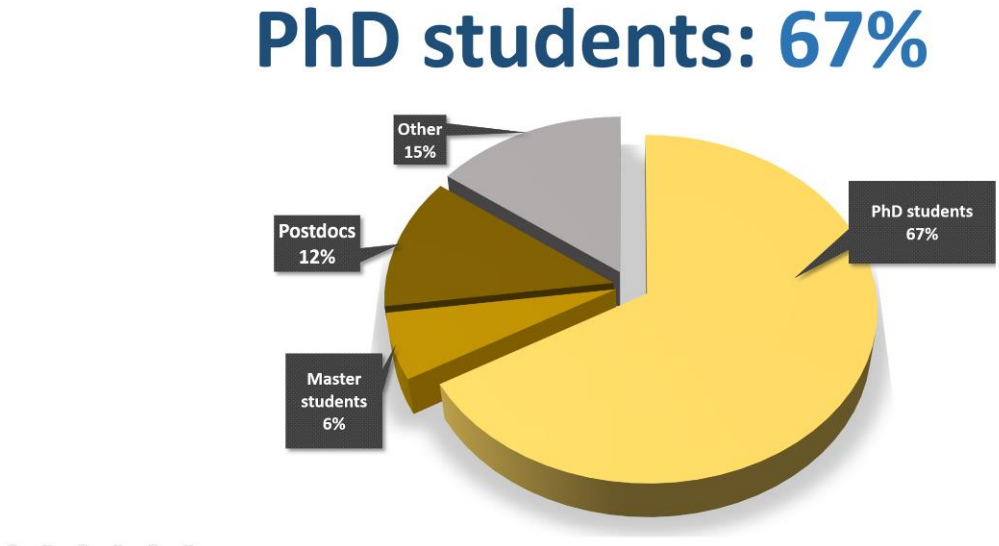

Figure 5.-ISLIST attendees by education

Regarding the previously mentioned students: 67% were PhD students, 12% were PhD (Dr), 6% were Master Students.

In terms of the participants age: 79% of the attendees were in the range from 20 to 30 years, which is in correlation with the fact of the education period working towards PhD degrees and also in Post-docs. This fact suggests the very good acceptance of this top quality school and its positive potential impact on the education of very good researchers and professionals in the early stages of their careers. This fact will be key issue for the near future of our globalized world in which this key technology (Photonics) will play as relevant roll as Electronics played in the last XX Century. 10% were attendees of more than 41 years old.

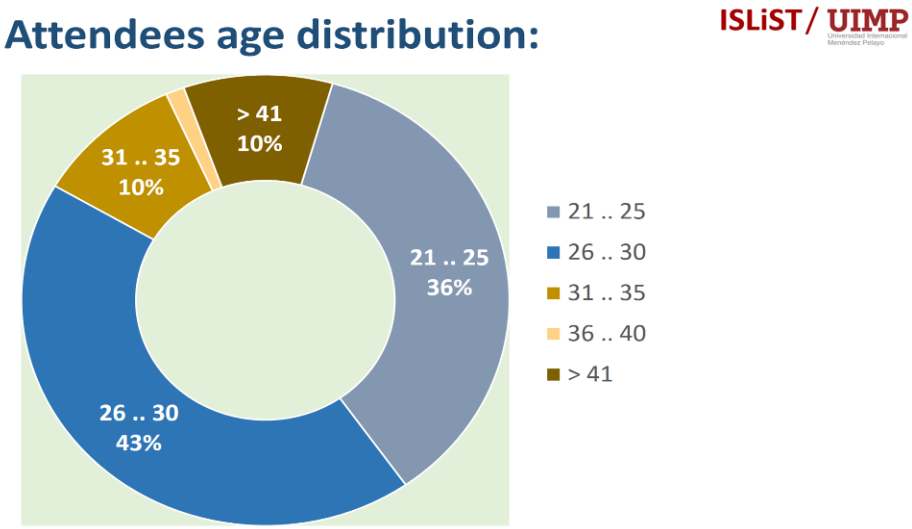

Figure 6.-ISLIST attendees by age.

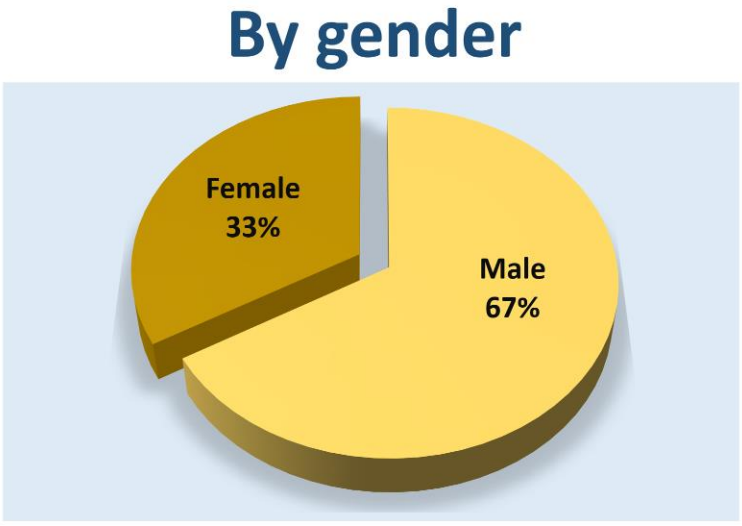

Figure 7.- ISLIST attendees by gender

Analyzing the gender distribution, the 67% of the attendees were men and the 33% women, that in comparison with the gender distribution of the previous ISLIST 2017 (74% attendees were men and 26% women) represents a decrease of the gender gap. This is in same way in correlation with the real situation in many countries in technical professions. Taking in consideration the number of women as students in grade levels of the current education institutions, these numbers will be progressively change towards a more homogeneous distribution without the need of any specific policy, just fighting against any kind of discrimination. In any case, what really will help to decrease this gap are policies facilitating the familiar real conciliation lives of the families with very special emphasis in the youngers ones.

For Spanish Students or Students of any nationality but working/studying in Spanish institutions, UIMP offers grants with funds provided by Spanish State. However, UIMP is not able to offer grants for any other international Students. Thanks to the sponsors and collaborators, ISLIST was able to offer grants for **international** students from non-Spanish institutions. http://www.teisa.unican.es/ISLiST/index.php/grants

Figure 8.-ISLIST Student Grants distribution

A call for applications was opened for two kinds of student grants: i) Registration Grants or ii) Full Grants that cover course registration, accommodation and living expenses.

A total of 60 grants were allocated (25 funded by the Spanish state and 35 using the funds form the sponsors and collaborators). 50 were complete or full grants (35 for international students) and 10 covered only the school registration fee.

As it happened in the previous editions of ISLiST, the offer of scholarships to students from any institution around the world, has significantly contributed to the achievement of the recognition of ISLiST as a top international forum, what is "inscribed in the genes" of this very special **University of Universities** (the International University Menendez Pelayo, UIMP).

3.- PROGRAM AND ITS DEVELOPMENT

The School Programme was designed and published in the meeting web site. The program and Notebook and a Handbook was printed and included in the bag of all the ISLIST participants: https://www.teisa.unican.es/ISLiST/images/2018/ISLIST-2018-UIMP-Program.pdf

The general Schedule of ISLIST-2018 was programmed and developed as shown in figure 9.

General Schedule

Time	Monday 25th	Tuesday 26th	Wednesday 27th	Thursday 28th	Friday 29th
9:30		Prof. **Sir John Pendry** **Inventor of the Metamaterials** Imperial College London, UK	Prof. **JM López Higuera** **Head,** Photonic Engineering Group University of Cantabria, Spain	Prof. **Hugo Thienpont** **Director** of Brussels Photonics, Vrije University, Belgium	Photonic Crystal´s Special Session Prof. **Eli Yablonovitch** **Director,** NSF Center for Energy Efficient Electronics Science Univ. of California, Berkeley, USA
10:15	**Opening Remarks**				
10:40	**Coffee Break**	**Coffee Break**	**Coffee Break**	**Coffee Break**	**Coffee Break**
11:00	**Opening talk** Prof. **Sir John Pendry** **Inventor of the Metamaterials** Imperial College London, UK	Prof. **Harald Haas** **Director,** LIFI Research Development Centre, Scotland, UK	Dr. **Nikolaus P. Schmitt** **Senior Researcher,** Airbus Group Innovations Muenchen, Germany	Prof. **David D. Sampson** **Vice-Provost,** Research& Innov. University of Surrey, UK **Head,** OBEL, University of Western Australia.	Photonic Crystal´s Special Session Prof. **Philip Russell** **Director,** Max Planck Institute for the Science of Light, Erlangen, Germany
12:10	Prof. **Peter Andrekson** **Director** FORCE, Chalmers University of Technology, Sweden	Dr. **Joel Carpenter** University of Queensland, Australia	Prof. **Pavel Cheben** **Principal Researcher** National Research Council of Canada	Prof. **Joseba Zubía** **Head,** POF Sensing Group, Univ. of the Basque Country Spain	12:30 Closing remarks, ISLiST2019 announcement and **Diploma Delivery**
13:30 15:00	**Lunch**	**Lunch**	**Lunch**	**Lunch**	
15:30	Dr. **Peter Winzer** **Chair,** Optical Transmission Systems and Networks Bell Labs, USA	**Round Table I** **Optical communications challenges** *Peter. Winzer* *Peter Andrekson* *José Capmany* *Harald Haas* *Eli Yablonovitch* Moderator: **JM López-Higuera**	Prof. **Manuel López-Amo** **Head,** Optical Communications Group of Public University of Navarre, Spain	**Round Table II** **Photonic sensing challenges** *Hugo Thienpont* *David Sampson* *N.P. Schmitt* *Pavel Cheben* Moderator: **JM López-Higuera**	
16:40	Prof. **José Capmany** **Head,** Photonics Research Labs Technical University of Valencia, Spain		Prof. **Miguel González** **Head,** Photonics Engineering Group of Univ. of Alcalá de Henares, Spain		
17:55			**Family Photo** **Santander City Council Reception**		

Figure 9.-ISLIST-2018 General Schedule

The ISLIST-2018 Speakers are also shown the figure 10.

Figure 10.-ISLIST-2018 Speakers (by apparition order).

3.1 Invited Talks and Round Tables in the frame of ISLIST-2018

After the Opening Ceremony, from June 25 to June 29, 2018, 17 keynotes and invited talks and two Round Tables were developed.

3.1 Invited Talks and RoundTable on Communications

After the opening speech by the Professor *Pendry* of the University of Ghent, Belgium, key issues on communications were addressed by the invited recognized researchers and directors of R&D centres and corporations.

During his opening talk, Prof. Pendry spoke about the Science of Invisibility Cloaks and Metamaterials. He told how on Electromagnetism rests our ability to deploy materials that can control the components of the electric and magnetic field. How a new class of materials has created some extraordinary possibilities such as a negative refractive index, and lenses whose resolution is limited only by the precision with which we can manufacture them. These new materials, named metamaterials, offer properties determined as much by their internal physical structure as by their chemical composition and the radical new properties to which they give access promise to transform our ability to control much of the electromagnetic spectrum. Prof. Pendry also spoke about how the cloaks have been designed and built that hide objects within them, but remain completely invisible to external observers.

Figure 11.-Moment of the Opening Invited Keynote by Prof. Sir J. Pendry (Imperial College of London, UK).

Prof. *Andrekson* delivered a comprehensive review on the current, limitations, challenges, and opportunities in optical communication. One highlight was the use of phase-sensitive amplifiers. He mentioned that these amplifiers are not only capable to amplify light with lowest possible noise figure (0 dB quantum limit, 1 dB reported) but can also simultaneously mitigate transmission fiber nonlinearity impairments, a result of the coherent superposition of the signal and idler waves in the amplifier.

Figure 12.-Prof. Andrekson (Director of FORCE -Fiber Optic Communications Research Centre) *during his Invited Lecture*

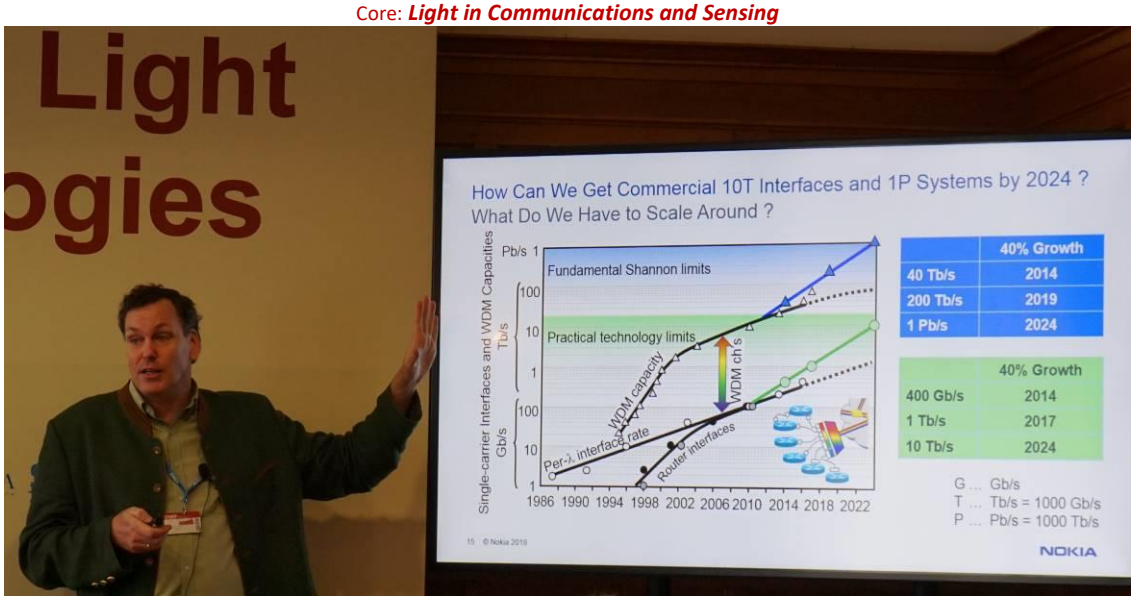

Figure 13.-Dr. Winzer (Chair of Optical Transmission Systems and Networks Bell Labs, USA and Editor-in-Chief of IEEE/OSA Journal of Lightwave Technology, JLT) *in a moment of his Invited Lecture*

Dr. Winzer during his fantastic lecture spoke about the new possibilities in ultra-fast digital electronic signal processing, coupled with our increasing abilities to digitally electronically control the full optical field across all its physical dimensions, including its spatial mode content, allow not only for new ways of optical communications but opening up a new era in optical instrumentation far beyond telecom.

Prof. Capmany addressed the basic principles behind Analog Photonics.

Figure 14.-Prof. Capmany (Head Photonics Research Labs at iTEAM Institute, Technical University of Valencia, Spain and Editor-in-Chief of IEEE Journal of Selected Topics in Quantum Electronics) *answering a question from an attendee after his Invited Lecture.*

Prof. Capmany reviewed the recent advances, paying special attention to developments in integrated optic chips and Space Division Multiplexing Access techniques. During his top level talk he also addressed the potential applications in emerging application fields, such as neurophotonics, quantum communications and programmable multifunctional photonic systems.

Figure 15.- Prof. Pendry in a moment of his second Invited Keynote.

Prof. Pendry in a second spectacular lecture spoke about how the new concept of transformation optics that manipulates electric and magnetic fields can provide an equally intuitive understanding of sub wavelength phenomena and at the same time be an exact description at the level of Maxwell equations and also how the concept is applied to a wide number of plasmonic structures.

Figure 16.- Prof. Pendry chatting with attendees during a coffee break after his Keynote

Figure 16.- Prof. Haas (Director of LIFI Research Development Centre, Scotland, UK) *in a moment of his Invited Lecture.*

Prof. Haas after stated the scene by motivating the need for new wireless spectrum and by providing a general background on the subject of optical wireless communications then, discussed about the relationship between VLC and LiFi, then spoke about the major advantages of VLC and LiFi and discussed the existing challenges. He gave an overview of recent standardization activities– primarily focusing on the new IEEE 80211 LC (light communication) Study Group activities and concluded on commercialization challenges of this disruptive technology.

Dr. Joel Carpenter delivered his talk by using a spectacular visual material on how can be measured and manipulated light's spatial properties. He spoke about the creation of 'pre-scattered' light states which can propagate through a scattering media, only to form a desired image on the other side and, as well on the creation of devices capable of splitting a light beam up into the spatial modes it is composed of, a functionality for the spatial domain that is analogous to how a dispersive prism splits white light up into its constituent colours.

Figure 17.- Dr. Carperter (School of Information Technology, University of Queensland, Australia) *in a moment of his Invited Lecture.*

Figure 18.- Round Table in Challenges on Communications: The panelists during the preliminary words from the ISLIST Director.

To conclude the optical communications part of the core, during two and half hours Challenges to face on Light based Communications by means the format of a round table Challenges to face Light based Communications were discussed under the moderation of the ISLIST Director. The panelists and topics were: Prof. José Capmany, Challenges on Analog and RF Communications; Dr. Peter Winzer, Challenges on Digital Communications; Prof. Peter Andrekson Challenges on Fiber Nonlinearities and their use in mixed Photonic-Digital Systems; Prof. Harald Haas, Challenges on LIFI Communications. From the previous statements, the very animated and deep discussions both among the panellists and with the attendees, very interesting and useful conclusions were extracted.

Figure 19.- The five panelists during moments of their interventions.

3.2 Invited Talks and second Round Table in sensing

Eight invited talks on sensing, two invited keynotes and the second round table were developed. Six were focused on key sensing technologies using light based approaches, two in useful topics both for communications and sensing and the two keynotes was in the frame of the very special session on Photonic Crystals key technology in the field of photonics on which are based a wide set of phenomena in nature and in many photonic devices. The second round table was focused on Challenges on sensing.

Prof. López-Higuera briefly introduced Photonics (the new field of knowledge and technique that in the currents Photonics is considered a Key Enabling or Essential technology) in order to clearly stated the doctrinal conception of the very relevant area of Sensing using Light, which is understood as any sensing approach that employs light sciences and technologies. Then he clearly stated what must be understood, properly, by Photonic/Optical/ fiber optic sensors, Smart Light Sensors and a wide set of sensing concepts. Then before the conclusions he did a "flight" over 23 significant cases using different techniques and in a wide number of sector application.

The ISLiST attendees experienced the pleasure of listening and discussing with Dr. Nikolaus P. Schmitt about LIDAR and approaches used in Aircraft sector. After stated that measurement of air data is vital to control an aircraft and that since decades it has been done using fluid flow pressure sensors he mentioned that recent optical air data sensors (OADS) based on backscatter Laser Doppler LIDAR provide a unique technology to precisely measure the air flow vector even remotely outside the aircraft boundary layer. Beside air flow, laser backscatter further allows for remote measurement of air temperature and density as well.

Figure 20.- Prof. López-Higuera (Universidad de Cantabria, CIBER-BBN and IDIVAL) during his lecture.

*Figure 21.-Dr. Shmitt (*Senior Expert Optronic Systems at Airbus, formerly EADS, and chairman of the AIRBUS Research Technology Group on Optics, Muenchen, Germany up to June 2018) *during his invited Lecture.*

Dr. Schmitt also mentioned that the optical remote sensing of airflow at larger distances ahead of an aircraft enables additional future new functionalities such as real-time feed-forward of signals to the flight control, based on 3D measured air flow disturbances before the aircraft reaches them, reducing their impact on the aircraft.

The ISLiST attendees had also the privilege of listening, dialoguing and discussing with Prof. Pavel Cheven. He lectured on advanced Silicon Photonics for Communications and Sensing subject relevant for both key photonic areas. During his presentation he did overview of this emerging field, including the fundamental principles, recent advances and applications.

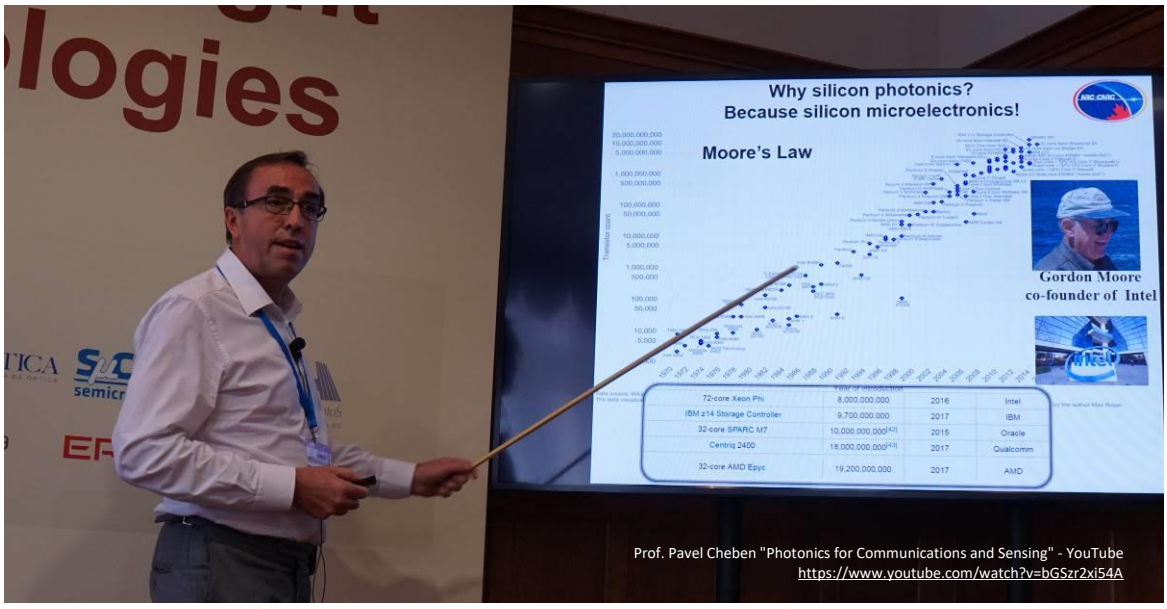

*Figure 22.-Prof. Pavel Cheben (*Principal Research Officer, National Research Council, Canada) *during his invited Lecture.*

Prof. Cheben stated that by locally engineering of the refractive index of silicon (by forming a pattern of holes at the subwavelength scale), it is possible to manipulate the flow of light in silicon photonic integrated circuits. He mentioned that by using this powerful concept has resulted in a plethora of advanced integrated photonic devices with unprecedented performance for applications in optical interconnects, telecommunications and sensing. His subwavelength engineered silicon waveguide structures are likely to become the key building blocks for the next generation of integrated photonic circuits.

Prof. Manuel López-Amo in the introduction of his lecture stated that one of the main goals in fiber optic sensor technology is its capability of including multiple measuring points by multiplexing together a high number of sensors in the same network. During his comprehensive presentation he was focussed on multiplexing networks for point and quasi-distributed optical fiber sensors, and also explained the reasons for what and why they are. Then he when deepen into the principles of these systems and defined broad categories based on the measurand and the underlying physics. After that he described and compared different kind of multiplexing networks for optical sensors including the ones using optical amplification and, also, lasing. Prof. López-Amo concluded his lecture by describing selected application examples of such networks.

*Figure 23.-Prof. López-Amo (*head of the Optical Communications Group of Public University of Navarre, Pamplona, Spain) *answering a question to an attendee after his comprehensive Invited Lecture on* State of the art and trends on Optical fiber Sensor Networks.

*Figure 24.-Prof. González Herráez (*Head of Photonics Engineering Group of Univ. of Alcalá de Henares, Madrid, Spain) in his Invited Lecture on Optical fiber Distributed Sensors.

Prof. Miguel González Herraez explained that in Distributed optical fibre sensors the entire length of the optical fibre is used both as sensing and transmission element, and that a large number of physical variables (strain, temperature, vibration, pressure, etc.) can be monitored at each point along the fibre. He also mentioned that the behaviour of these fibre sensors also offers additional advantages which makes it an appealing option for very harsh environments. Then he reviewed the basic principles and limitations of these sensors, when into several very significant examples and provided a roadmap to consider by the experts in future developments.

Figure 25.-Prof. Adolfo Cobo (ISLiST´s Secretary) chairing the session.

Prof. Thienpont (recognized by his relevant contributions to Photonics in research, in transference and also in education), in his enthusiastic and outstanding presentation defended the key role of the Photonics, in general terms, for the advance of the new world in this XXI century. He illustrated his statement with very representative examples in which the Science and technology of the Light is playing and, what is more important will play, essential roles for the advance of the societies both for the advanced and also for the developing nations of our globalized world. He identified the major roadblocks that is needed to overcome to bridge this innovation valley-of-death, and also the best practices on how to transition fundamental research results to industrial innovation with European companies. He also illustrated the approach with a variety of success stories in different industry sectors. He supported his arguments with a wide set of including several very representative examples developed or being developed in the frame of his very large R&D group. Especial emphasis was devoted to the case of shorting foods in line.

Figure 26.-Moments of the Invited Keynote by Prof. Hugo Thienpont (Chair of Department of Applied Physics and Photonics, Director of Research, Brussels Photonics Team Vrije Universiteit Brussel, Brussels Belgium). Collaborator of ISLIST for international Student Grants

Figure 27.-Prof. David Sampson (Vice-Provost of Research and Innovation at University of Surrey, UK; Head of Optical & Biomedical Engineering Laboratory, OBEL, University of Western Australia, Australia) answering one question after his Invited Lecture).

Prof. Sampson is his Invited Lecture on Biomedical optical sensors and imaging, after providing a brief perspective on the past, focused on contemporary technologies and applications. He also described prospects, issues and opportunities for contemporary biomedical fibre-optic sensors research. He argued that the ones based on optical fibre technology, encompassing imaging devices, continue to make great inroads into medical and biological applications and remain a topic of intense research. He continued mentioning that in medical applications that require in situ measurement, optical sensing via hypodermic needles, catheters and endoscopes provides access to the huge diversity of optical methods at locations that are otherwise inaccessible to optics. He also stated that elsewhere in bioscience and technology, the advantages of sensing via optical fibres are not so clear cut, but profound examples and new opportunities exist and are waiting for people to identify and to develop the appropriate devices and systems.

Prof. Zubía developed a complete overview on Fiber Optic Sensors based on Plastic materials (POF Sensors) with a special focus on the ones for Aircraft Structural and Engine Health Monitoring. He argued that aircraft structures and engines require periodic, scheduled inspection and maintenance operations and that such kind of operations are time consuming, labor intensive and a cost factor to the operations of commercial and defence aircraft fleets. He mentioned that structural health monitoring (SHM) is a cost-effective approach to meet operational requirements, and to reduce maintenance costs in aircrafts. Prof. Zubia then offered several examples including the ones developed in his R&D Group. He concluded arguing that polymer fiber optic sensor (PFOS) technology is a mature technology that provides advantages over traditional sensors and can be used to monitor physical parameters not only of wing surfaces and fuselage sections but also of the engines themselves.

Figure 28.- Invited Lecture by Prof. Joseba Zubía (Head, POF based sensors Group University of the Basque Country Spain).

Figure 29.- The four panelists during the round table on Challenges in Sensing using LightTechnology: Prof. Sampson, Dr Schmitt, Profs. Cheben, Thienpont and López-Higuera (round table coordinator).

During the Round Table II on Challenges in Sensing Using Light both the attendees and the invitees lived a very interesting round table with very actives participations from both sides. After the presentation by the moderator each of the invited panellists presented their brief statement on their previously allocated topic: Prof. Hugo Thienpont on *General Challenges on Photonic Sensing to face on XXI century;* Prof. Pavel Cheben on *Challenges on Silicon Photonics for Communications and Sensing;* Dr. Nikolaus P. Schmitt on Challenges on Photonic sensing for the aerospace; Prof. D. Sampson on *Challenges on Biomedical Optical Sensors.*

Then, each member of the panel took the opportunity to debate different aspects among the panelists. After that, attendees asked different questions, in an open and fully-freedom-environment, and a very interesting debate took place inside the room. Numerous interactions were carried out among the panelists and from the attendees and also discussions were established from both sides. After two and half hours, the round table concluded with several open questions and also with very interesting and useful thoughts and conclusions.

Figure 30.- The panelists and coordinator during moments of their interventions.

3.3 Especial Session on Photonic Crystals

The ISLIST attendees had the privilege of participate in a very special session by the fathers of Photonic Crystal and Photonic Crystal Fibers. Prof. Yablonovitch and Prof. Russell contributions represent outstanding advances that have together led to the creation of the field of photonic crystals. Very few people have had the opportunity to see, heard and discuss with this two eminent scientists and engineers in the same session. It was only a privilege of two or three International meetings included ISLIST at UIMP in 2018.

The contributions of both Profs. Yablonovitch and Russell to photonics, have been essential to understand and identify a structure and also to conceive and to develop revolutionary devices that are being extensively used and have benefitted mankind through their wide-range impact in science, technology and the quality of human life.

Today, photonic crystals appear in many areas of science, technology, medicine, and in nature in the biological world as well, including, silicon photonic integrated circuits; to improve the output of light emitting diodes; to improve the efficiency of solar cells; to suppress undesirable electromagnetic modes in particle accelerators; in specialty optical fibres; in optical fibres that are used for cancer therapy; in white light or wavelength-tuneable, ultra-bright optical fibre-based sources; as a naturally occurring phenomenon in diverse biological organisms, such as peacocks, parrots, butterflies, beetles, and sea horses.

Prof. Yablonovitch (Director NSF Center for Energy Efficient Electronics Science, University of California, Berkeley, USA, Doctor Honoris Causa by the Hong Kong University of Science & Technology) delivered his invited Keynote on the Birth of the Photonic Bandgap Concept and its Application in Technology, as well as in Nature. He argued that photonic crystals are also part of everyday technological life in opto-electronic telecommunication devices that provide us with internet, cloud storage, and email. But photonic crystals have also been identified in Nature, in the coloration of peacocks, parrots, chameleons, butterflies and many other species. In spite of its broad applicability, the original motivation of photonic crystals was to create a “bandgap” in which the spontaneous emission of light would be inhibited. Conversely, the opposite is now possible. The “optical antenna” can accelerate spontaneous emission.

Prof. Russel (Director Max Planck Institute for the Science of Light, Erlangen, Germany; Doctor Honoris Causa by the Universidad Internacional Menéndez Pelayo in Santander, Spain.) devotes his Invited Keynote to speak on the birth of photonic crystal fibre and its many scientific and technical applications. He mentioned that the idea to realise a fibre with a two-dimensional periodic array of microscopic features running along its entire length first emerged in 1991 and also that the first working PCF left the drawing tower in 1995 and now, after many breakthroughs, PCF has already moved into real world applications. Among the large number of examples of the use of PCF he mentioned that solid-core PCFs are being used commercially to convert infrared pulses into white light supercontinua 10 million times brighter than an arc lamp, and hollow core PCF filled with gases is underpinning a range of extremely bright sources of tuneable deep and vacuum ultraviolet light, driven by ultrashort pulses of infrared light.

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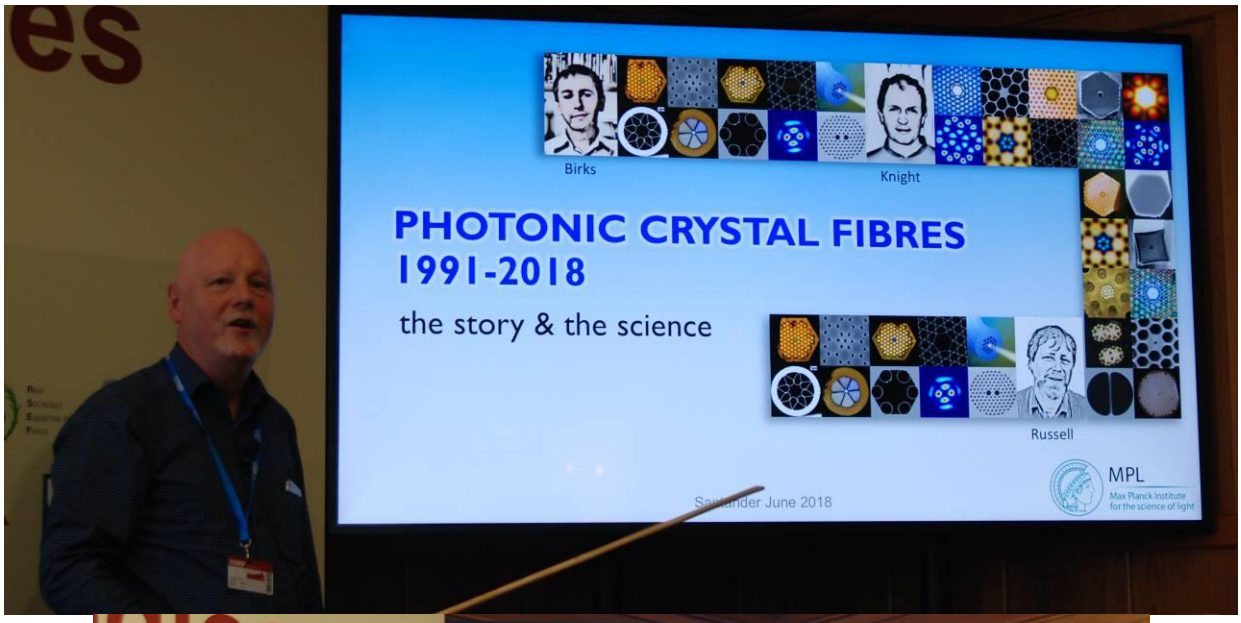
Figure 31.- Two moments of the Prof. Yablonovitch´s Invited Keynote and a moment hearing the question from an attendee.



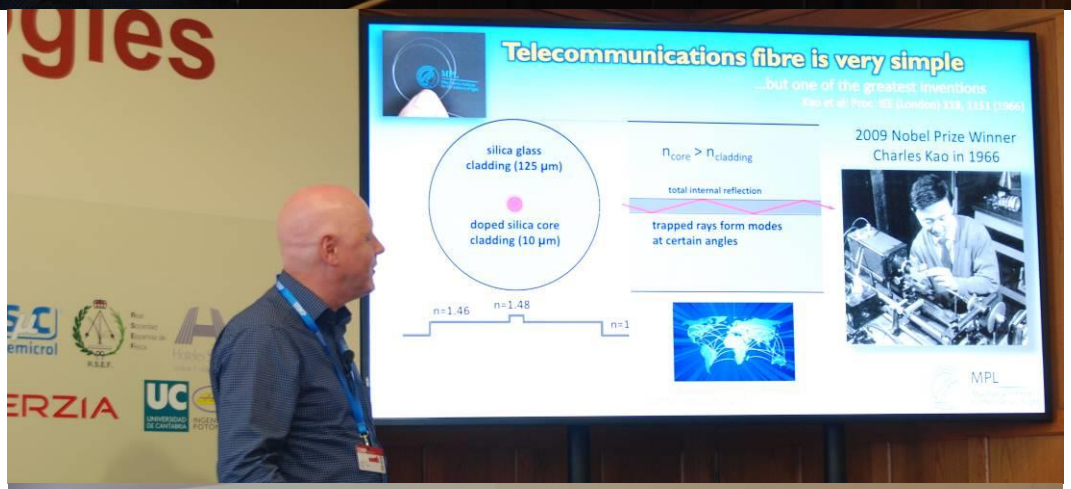


Figure 32.- Two moments of the Prof. Russell´s Invited Keynote and a moment hearing the question from an attendee.

Figure 34.- Profs. Russell, Thienpont and Yablonovitch after the Especial Session on Photonic Crystals. ISLIST, Santander, June 29, 2018

3.4 Some moments during the talks and free times

Figure 35.- Attendees during the talks.

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Figure 36.- Four moments during the coffee-break and free time .

4 Special Events

Within the frame of ISLiST, three special events were allocated and developed: The Santander Council Reception, and two interviews.

4.1 Santander Council (Ayuntamiento de Santander) Reception

The Santander Council was very pleased to offer to ISLIST attendees a special Reception. It was a great opportunity to chat, to do networking and to share experiences, enjoying with snacks and drinks inside an incredible nice environment in the Dining Room of the Royal Magdalena Palace.

Figure 37.- General view of ISLIST Attendees in the Dining Room in the Royal Palace, Ms. Maria Tejerina (Vice-Chancellor of Santander Council), welcoming the ISLIST participants and Prof. López-Higuera (Director of the event) addressing some acknowledging to the Santander Council for their collaboration to reach the objectives of this International School.

Figure 38.- ISLIST participants on a corridor of the Royal Palace moments before to start the Santander City Council Reception.

Figure 39.- ISLIST participants enjoying moments of socialization and networking during the Santander City Council Reception.

Figure 40.- ISLIST participants enjoying moments of socialization and networking during the Santander City Council Reception.

4.2 Two Interviews

During the ISLIST at UIMP, two interviews were performed. One to **Prof. Sir John Pendry**, father of the metamaterial field and worldwide recognized by his outstanding contribution to physics through seminal research in surface science, and photonics. Another one to the Fathers of the Photonic Crystal´s **Profs. Eli Yablonovitch and Philip Russell**. Both interviews were conducted and realized by the Director of the even. The results (just the answers from the interviewed) of both interviews can be checked by visiting YouTube:

Prof. Pendry interview:

https://www.youtube.com/watch?v=Ibggw7Tu9LY

Profs. Yablonovitch and Russell interview:

https://www.youtube.com/watch?v=799maf0FA9w

Figure 41.- Profs. Pendry, Russell, Yablonovitch and López-Higuera after the interviews in the Family Saloon at the Magdalena Royal Palace in Santander, June 25 and June 28, 2018.

5.- Opening, Closing remarks and Diploma Delivery

The opening ceremony was presided by the Vice-Chancelor of the UIMP Prof. Paqui Caballero, who welcomed all participants to the event and stated that ISLIST international School is envisioned to be a worldwide top International forum (**every fourth week of June**) on *Light Sciences and Technologies* in Santander, Spain.

He also added that ISLIST has been conceived as a great opportunity to review and actualize knowledge in this Key or Essential science and technology for the development of nations. It offers a great opportunity to contribute to the education of citizens and to ensure also that policymakers are made aware of the problem-solving potential of Photonics.

The ISLIST director explained how the School was planned to be developed along the week including the special and exceptional events included in the programme. He presented also the statistics concerning the participants on the school and concluded with acknowledgement words for the Sponsors and Collaborators with special thanks to all the 16 Invited Speakers selected among the world-wide leader authorities in their respective matters. He added special mentions to the secretary of the course Adolfo and to his secretary Maria, both at University and to Margarita Montes, to the Vicerrector Rodrigo Martinez and the Rector Emilio Lora Tamayo at the UIMP for their understanding, support and facilities offered during the organization of the event. Very special words of Acknowledgement were pronounced by the Director of the even about the key role played by the former UIMP Rector Prof. César Nombela in the creation of the ISLIST as a fully international event in UIMP every year.

Figure 42.-The UIMP Vice-chancellor and ISLIST Director during the Opening Ceremony

The Closing Ceremony was presided by the Vice-Chancellor of the UIMP Prof. Montaña Cámara who remarked the UIMP satisfaction for the high quality of the ISLIST international school and its splendid development, concluding his Closing Speech with the confirmation of the continuation of this international School in next years.

Prof. López-Higuera announced that the Fourth International School on Light Sciences and Technologies next year will have the Main Core on **Light on Sources, Health and Medicine**. It will be developed during the week of **June 17-21, 2019**. The ISLIST director announced also that several invitations were, at that time, submitted.

Figure 43.-The UIMP Vice-chancellor (Prof. Motaña Cámara) and the School Director during the Concluding Remark and announcement of the ISLIST 2019.

At the time to conclude this report it is fully confirmed the participation of several top and worldwide well-known researchers including Profs. Aydogan Ozcan (**Head of the** Bio-and Nano-Photonics Laboratory, Associate Director of California NanoSystems Institute, CNSI, University of California los Angeles, UCLA), Susana Marcos (Director of theVisual Optics and Biophotonics Lab. Instituto de Optica, Consejo Superior de Investigaciones Cientificas ,IO-CSIC, Madrid, Spain), Kishan Dholakia (School of Physics& Astronomy University of St Andrews, UK) and Dr. Jan Denneman (External Relations / Past President - the Global Lighting Association, Netherlands) have had confiremed his peticipation on ISLIST -2019. Many other very well known Profesors and Profesionals (included several Nobel Laureates) are also been invited.

After the closing ceremony a personalized Official Diploma was delivered to the participants that attended the school.

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Figure 44.-The ISLIST-2018 attendees that fulfilled the UIMP requirements, receiving the diploma from four ISLIST professors and the Vice-chancellor of UIMP.

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Figure 45.- The ISLIST-2018 attendees that fulfilled the UIMP requirements, receiving the diploma from four ISLIST professors and the Vice-chancellor of UIMP.

6.- QUALITY: SATISFACTION SURVEY

To have an objective index of quality, after closing the ISLIST international School a brief and anonymous survey was carried out online by the participants. The questions asked were:

***Q1**-Please indicate your overall opinion regarding the quality of the invited speakers*

0 - Very Poor
1 - Poor
2 - Average
3 - Good
4 - Very good
5 - Excellent!

***Q2**-Please indicate your overall opinion regarding the topics of the talks*

0 - Extremely uninteresting
1 - Not very interesting
2 - Average
3 - Interesting
4 - Very Interesting
5 - Really what I was looking for!

***Q3**-Please indicate your overall opinion regarding the ORGANIZATION of the school*

0 - Very Poor
1 - Poor
2 - Average
3 - Good
4 - Very good
5 - Excellent!

***Q4**-Please indicate your overall opinion regarding the INFORMATION that you received before attending the school*

0 - Very Poor
1 - Poor
2 - Average
3 - Good
4 - Very good
5 - Excellent!

***Q5**-Would you attend future editions if possible?*

0 - Not at all
1 - Not very likely
2 - Maybe
3 - If the main core suits me
4 - Probably
5 - I would love to come again to Santander and attend ISLiST-XX

***Q6**-Would you recommend ISLiST to other colleagues?*

0 - Not at all
1 - Not very likely
2 - Maybe
3 - If the main core suits him/her
4 - Probably
5 - Absolutely!

***Q7**-Finally, did the school meet your expectations?*

0 - No, it was a complete disappointment
1 - Not really
2 - Only partially
3- Yes, but it might have been better
4 - Yes, absolutely
5 - It was even better than I expected!

***Q8**-Please, tell us about the best things of the school (what we should go on considering in future editions)*

***Q9**-Please, tell us about the worst things of the school (what we should NOT consider in future editions)*

***Q10**-Do you have any suggestions, comments ...?*

After receiving the responses, the overall results of the survey are graphically summarized as follows:

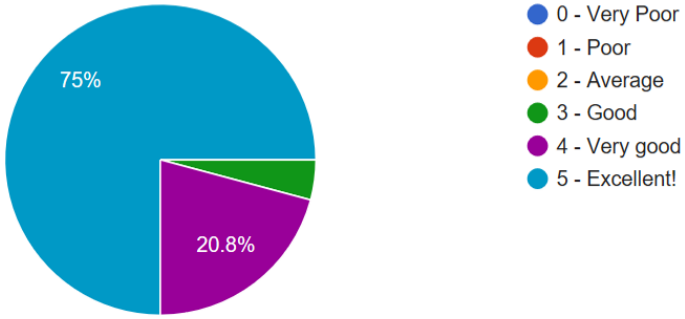

*Figure 46.-Regarding the **quality of the invited speakers** (Q1), the 75 %, the 20.8 % of the participants considered that they were excellent, very good and good respectively. There were no answers qualified as average, poor or very poor.*

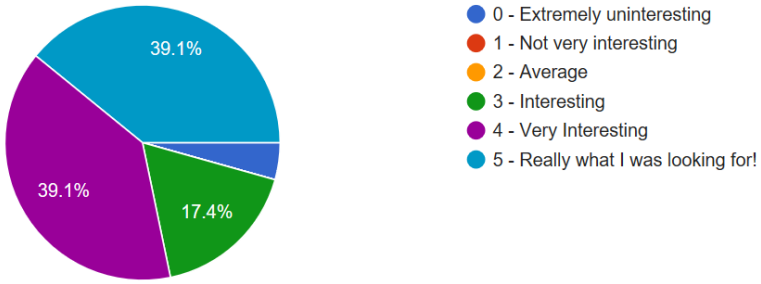

*Figure 47.- Regarding the **topics of the talks** (Q2), the39,1%, the 39.1% and the 17.4%% and of the participants considered that they were Really it was what I was looking for, very interesting and interesting respectively.*

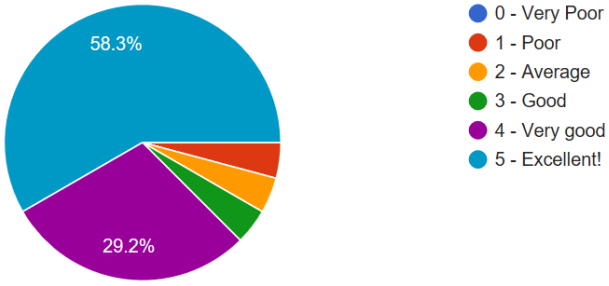

*Figure 48.-Regarding the **organization of the School** (Q3), the 58,3 %, the 29.2 % and the 4.16 % of the participants considered that they were excellent, very good and good respectively. There were no answers qualified as average, poor or very poor.*

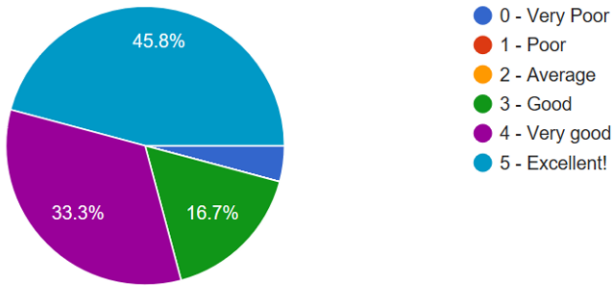

*Figure 49.- Regarding the **information received before attending the School** (Q4), the 45.8 %, the 33.3 % and the 16.7 % of the participants considered that they were excellent, very good and good respectively.*

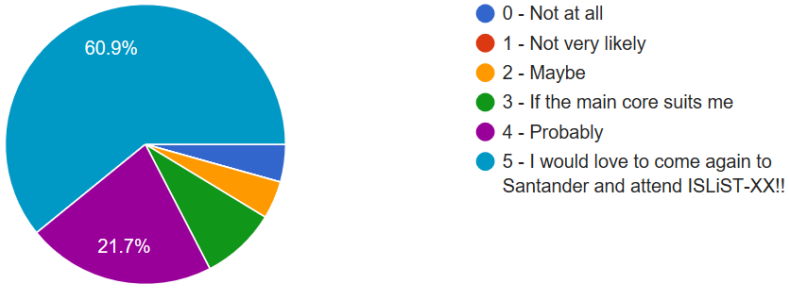

*Figure 50.-Regarding the **possibility of attending the next edition of the School** (Q5), the 60.9 %, the 21.7% and the 8.5 % of the participants considered that they were that they would love to come again, If the main core suit they, probably, and maybe (4.2 %) respectively.*

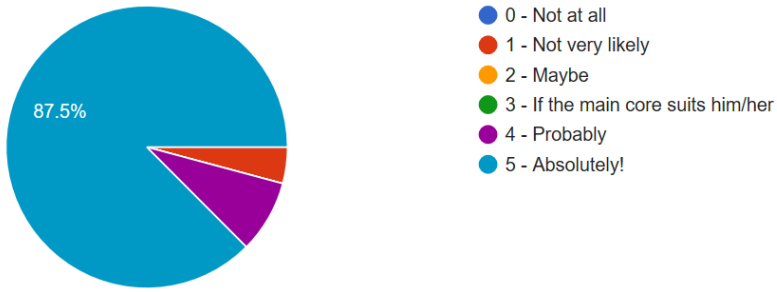

*Figure 51.-Concerning **if they would recommend ISLIST to other colleagues** (Q6), the 87.5 %, and the 8,5 % of the participants considered that they will absolutely and probably respectively will recommend the school to other colleagues.*

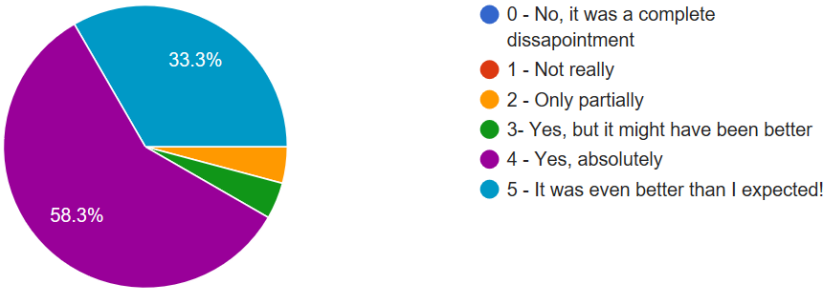

*Figure 52.-Concerning **if the ISLIST meet your expectations** (Q7), the 58.3%, the 33.3%, and the 4,5% of the participants considered that: yes absolutely,* it was even better than they expected *and* yes, but it might have been better *respectively the school meet their expectations.*

Concerning the three additional questions (Q8, Q9 and Q10), we have received the following (**they are as they have been received**):

Q8-Please, tell us about the best things of the school (what we should go on considering in future editions):

The selection of the **speakers** was excellent. Great experts in the field that taught us a lot.
The presentation by the **speakers** were exciting and insightful
The quality of the invited **speakers**.
The **speakers**
Very good and charismatic **speakers**, and inspiring lectures. Nice balance of science, engineering and technology industry insight. The venue and accommodation is also very special.
Punctuality, that was the best
Everything was excellent! **Speakers**, food, venue! Throughly enjoyed it. For me, everythng was good. Can't pick a single aspect
Great place, invited **speaker** at top level
The **speakers** selection was excellent.
Fooding is best
Not compromising with the quality of **speaker**
The best things of the school were organization (talks/hotel/meals), flavour of the meals and the kind support of all the staff of the event.
Round tables were great and the talks that we're not really following the core of the edition were really good.
The school is conducted at a high level. I liked everything.
the place where it was kept and the attencion received by the organizers

Q9-Please, tell us about the worst things of the school (what we should NOT consider in future editions)

It is not about the school itself, but the accommodation of those of us who had a national grant could have been better located. Any other location closer to the palace would have been a better choice... It is the only thing I can think about that could be improved.
There was no transportation after the school to the residence.

I hope to see more selective and enthusiastic participants. I saw several participants who constantly played on their phones during sessions. In future editions, it would be good to have poster session from participating students to provide for benchmark for level of participation. Also good for networking.

Try to contact and have women as invited speakers

Poor social meeting - it should be at the begining of the summer school

Too much hours in a very unconfortable chairs

Try to give travelling support with other grants to students of PhD

Not as such

The worst things of the school were some issues with other assistants for example 1) To separate or do not talk or share time with people outside of Europe, 2) Leave the talks before they finished, 3) Spend the time inside the room but playing or drawing...

can't think of any

Maybe general schedule because it's a short time to get to know each other among students

Q10-Do you have any suggestions, comments ...?

I would suggest that a platform for interaction between students should be added probably like a group discussion on one of the topics discussed and a presentation of the discussed subject should be made briefly. i would also suggest a guided tour around the city probably to the museum and other places

I would suggest free coffee at coffe breaks, if possible.

I would suggest to have shorter lunch breaks in order to finish earlier. In addition, I would suggest to introduce breaks between the lessons (about 5 or 10min) to recover

Thank you very much for the opportunity.

Send the slides of the speakers as soon as the summer school finishes so it is easier for us to remember the important things and refer back.

The get-together was planned for too late into the school. It would be much better to meet each other at the very beginning of the event, to network better.

Try to give travelling support with other grants to students of PhD

You can have some project or quiz on the last day to see get people more involved. Like in "Astrobiology" summer school, they had to do group project. This will improve the networking among attendees more. Looking forward to next year summer school.

I would like to have a meeting or an opening party in order to integrate all the assistants and promoted the friendship of all of them, probably go for a trip (Faro de Cabo Mayor), at the beach or a museum with all the assistants in order to show the beautiful places of Santander. On the other hand, could be useful give more free time between talks or increase the days of the school and decrease the time of the talks in order to keep the attention of the audience. Last, it had been perfect if the assistants have the afternoon to walk and visit Santander or have one day without scholar activities and half-paying that night in the hotel by the local organisers.

I'd love the main core being holography.

7.- CONCLUSIONS

Sixty-eight (81) people from 18 different nationalities from all around the world participated on ISLiST-2018. During the development of the programme, they received knowledge and shared experiences with sixteen (16) highly renowned professors and researchers from the most prestigious worldwide institutions of Europe, USA and Asia. They also enjoyed the Santander Council Reception, where they took advantage of the great opportunities to do networking on matters of their interest.

Very special moments were lived during several talks and interventions during the Round Tables. Special emphasis must be devoted to the two Invited keynotes by Prof. Pendry and also the one delivered by Prof. Thienpont.

The ISLIST attendees had the privilege to participate in a very special session by the fathers of Photonic Crystal and Photonic Crystal Fibers. Profs. Yablonovitch and Russell. Very few people in world have had the opportunity to see, heard and discuss with these two eminent scientists in the same session. It was only a privilege of two or three International meetings included ISLIST at UIMP in 2018.

Unforgettable were also the fresh and enthusiastic questions and discussions among the participants and the panellists of the two round tables.

To continue with the ISLIST mission to educate people (all around the world) on Light Sciences and Technologies even after the event, the slides used by the invited speakers can be observed on PDF format on the website of event: https://www.teisa.unican.es/ISLiST/index.php/presentations .

Videos of eight invited talks (as they were) can be found in YouTube: https://www.youtube.com/playlist?list=PLIBKO1S3QiNr-6zoKjb-jmpnrnA3vU2Og

To contribute with above mentioned mission of ISLIST, two interviews were also performed: One to **Prof. Sir John Pendry**, father of the metamaterial field and another one to the Fathers of the Photonic Crystal´s **Profs. Eli Yablonovitch and Philip Russell**. They can be checked by visiting also YouTube: https://www.youtube.com/watch?v=lbggw7Tu9LY ; https://www.youtube.com/watch?v=799maf0FA9w (Warm thanks are given to the Invited speakers for their generosity given the corresponding permissions that enabled these open access).

Thanks to the Santander Council Reception, the attendees and the invited speakers had the opportunity to share thoughts, experience and to do networking inside an unparalleled place, the Royal Palace of Magdalena, and having snacks and drinks. Thank you for that opportunity to Ayuntamiento de Santander.

According to the post-ISLiST survey, the quality of the program, of the speakers, of the complementary events, of the facilities offered, can be considered at the top level worldwide. ISLIST has met their expectations. As numeric indicators it can be consider that 75% of the attendees agreed with the excellence of the invited speakers, the 87,5% of the attendees very happy to recommend ISLIST to other colleagues and about the 60.9% indicating their interesting in participating again in next editions of the ISLiST School.

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Core: ***Light in Communications and Sensing***

ANEX

ISLiST-2018 PROGRAMME

Monday, 25

Why Light matters for Communications and Sensing?

10:15 h

Opening Ceremony

10:40 h / **Break**

11:00 h / Opening Invited Talk

The Science of Invisibility Cloaks and Metamaterials

Prof. Sir John Pendry

Inventor of the Metamaterials. The Blackett Laboratory, **Imperial College London**, UK.

12:10 h / Invited Talk

Optical fiber communication: Challenges and opportunities

Prof. Peter Andrekson

Director FORCE, Laboratory at the Microtechnology and Nanoscience Department Chalmers University of Technology, Sweden

13:30-15:00 h / **Lunch Time**

Afternoon: **Light in Communications**

15:30 h / Invited Talk

Breaking the Optical Fiber Shannon Limit Through Full Control of the Optical Field

Prof. Peter Winzer

Chair Optical Transmission Systems and Networks Bell-Nokya Labs, USA

16:40 h / Invited Talk

Advances in Analog and RF Photonics

Prof. José Capmany

Head Photonics Research Labs at iTEAM Institute, Technical University of Valencia, Spain

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Core: ***Light in Communications and Sensing***

Tuesday, 26

Morning: **Light in the nanoscale and Communications**

9:30 h / Invited Keynote

Controlling Light on the Nanoscale

Prof. Sir John Pendry

Inventor of the Metamaterials. The Blackett Laboratory, **Imperial College London**, UK.

10:40 h **/ Break**

11:00 h / Invited Talk

LiFi-High Speed Wireless Networking using Nano-Metre Waves

Prof. Harald Haas

Director of LIFI Research Development Centre, Scotland, UK

12:10 h / Invited Talk

Spatial mode manipulation in communications and imaging

Dr. Joel Carpenter

School of Information Technology, University of Queensland, Australia.

13:30-15:00 h / **Lunch Time**

Afternoon*:* **Challenges on Communications**

15:30 h- 17:45 / Round Table I

Light on Communications: Challenges to face

Prof. José Capmany, **Head** Photonics Research Labs at iTEAM Instutute, Technical University of Valencia, Spain

Challenges on Analog and RF Communications

Dr. Peter Winzer, **Director** Optical Transmission Systems and Metworks Research Dept, Bell-Nokya Labs in Holmdel, USA

Challenges on Digital Communications

Prof. Peter Andrekson, **Director** FORCE, Chalmers University of Technology, Sweden.

Challenges on Fiber Nonlinearities and their use in mixed Photonic-Digital Systems

Prof. Eli Yablonovitch, **Director** NSF Center for Energy Efficient Electronics Science, University of California, Berkeley, US.

Silicon Photonics and other forms of Optical Communications

Prof. JM López-Higuera, Director ISLiST, **Moderator**

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Core: ***Light in Communications and Sensing***

Wednesday, 27

Morning: **Light in Silicon Photonics and Sensing**

9:30 h / Invited Talk

Smart Light based Sensors

Prof. JM López-Higuera
Head, Photonic Engineering Group of University of Cantabria, CIBER-BBN and IDIVAL, Spain.

10:40 h / **Break**

11:00 h / Invited Talk

Forward-looking LIDAR for aircraft: research results, lessons learned and trends

Dr. Nikolaus P. Schmitt
Past **Senior Expert, Optronic Systems,** Airbus Group Innovations, Muenchen, Germany.

12:10 h / Invited Talk

Advanced Silicon Photonics for Communications and Sensing

Prof. Pavel Cheben
Principal Researcher, National Research Council of Canada, Canada.

13:30 -15:00h / **Lunch Time**

Afternoon: **Light on fiber based Sensors**

15:30 h / Invited Talk

Optical fiber Sensor Networks: State of the art and trends

Prof. Manuel López-Amo
Head, Optical Communications Group of Public University of Navarre, Pamplona, Spain.

16:40 h / Invited Talk

Optical fiber Distributed Sensors

Prof. Miguel González Herráez
Head, Photonics Engineering Group of Univ. of Alcalá de Henares, Madrid, Spain

17:55 h ISLiST Family Photo

18:05 h / Special Event

Santander Council Reception

The Santander City Council will offer to ISLiST attendees a special reception that, in addition, will be an optimum time to share experiences and promote networking.

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Core: ***Light in Communications and Sensing***

Thursday, 28

Morning: **Light based sensors**

9:30 h / Invited Talk

Photonics as a key-enabling technology: From disruptive research to successful innovation with societal impact

Prof. Hugo Thienpont

Director, Brussels Photonics Team Vrije Universiteit Brussel, Brussels, Belgium.

10:40 h / **Break**

11:00 h / Invited Talk

Biomedical Optical Sensors

Prof. David D. Sampson

Vice-Provost, Research&Innovation, University of Surrey, UK; **Head,** OBEL, University of Western Australia.

12:10 h / **POF Sensors for Aircraft Structural and Engine Health Monitoring**

Prof. Joseba Zubía

Head, POF based Sensors Group, University of the Basque country, Spain

13:30-15:00 h / **Lunch Time**

Afternoon: **Challenges in Sensing**

15:30h- 17:45 / Round Table II

Challenges in Sensing Using Light

Prof. Hugo Thienpont, Director of Research, Brussels Photonics Team Vrije Universiteit Brussel, Brussels Belgium

General Challenges on Photonic Sensing to face on XXI century

Prof. Pavel Cheben, Principal R. Officer, National, Research Council (NRC), 1200 Montreal Rd., Ottawa, Canada

Challenges on Silicon Photonics for Communications and Sensing

Dr. Nikolaus P. Schmitt, Past Senior Researcher of Airbus Group Innovations, Muenchen, Germany

Challenges to face on Photonic sensing for the aerospace

Prof. David Sampson, Vice-Provost, Research & Innovation, University of Surrey, UK

Challenges on Biomedical Optical Sensors

Prof. JM López-Higuera, Director ISLiST, **Moderator**

Friday, 29

Special Session on Photonic Crystals

9:30 /Invited keynote I

The birth of the Photonic Bandgap Concept and its Application in Technology, as well as in Nature

Prof. Eli Yablonovitch

Inventor of Photonic Crystal

Director, NSF Center for Energy Efficient Electronics Science, University of California, Berkeley, USA

10:40 h / **Break**

11:00 /Invited keynote II

The birth of Photonic Crystal Fibre and its many scientific and technical applications

Prof. Philip Russell

Inventor of Photonic Crystal Fibers

Director, Max Planck Institute for the Science of Light, Erlangen, Germany. **2015 OSA President.**

12:30 h

Closing Remarks, Announcement of ISLiST 2018 and Diploma Delivery

The UIMP official diploma will be delivery to each attendee by very well-known ISLIST Professors.