Triennial Report of the ICO to IUPAP

for 2008-2011

Introduction:

The International Commission for Optics (ICO) was created in 1947. It is an Affiliated Commission of the International Union of Pure and Applied Physics (IUPAP), and a Scientific Associate of the International Council for Science (ICSU) since 2005. As it is clear from its name, its objective is to contribute, on an international basis, to the progress and diffusion of knowledge in the field of optics and photonics. ICO activities concentrate in educational and scientific events, traveling lecturers, periodical publications and reports, awards and the corresponding honors. All these activities are addressed to the worldwide community in optics and photonics, academia, research institutions and industry, and with a particular emphasis in all initiatives in developing regions of the world.

The structural organization of ICO has an assembling operational basis led by the General Assembly, which is held every three years. The ICO General Assembly is constituted by the corresponding representatives of the ICO Territorial Committees. At the present state, ICO has a total of fifty one Territorial Committees, among which two of them are Associate Members. The geographical distribution of the Territorial Committees covers twenty seven European countries, three Northern American countries, six Southern American and Caribbean countries, eleven Asian-Pacific countries and four African countries. According to the assignment of units and votes, the Territorial Committees representativeness constitutes a total of one hundred and thirteen votes via the corresponding representatives of each territory. This extensive geographical representation inside ICO gives a very good wide international scope for the projection of its current activities in optics and photonics, in all the represented areas. However, an important effort is still needed to assure that this international projection be even more representative in critical areas of the world needing a clear input for progress and creation of local technologies, so as to avoid a dependence on external technologies that creates the obvious economical erosion.

In addition to the membership through the Territorial Committees, ICO has at present other members who are representatives of certain International Societies (IS). The approval of this new membership took place at the General Assembly is San Francisco (USA) in 1999. These IS have a total of six appointed Vice-Presidents representing: African Laser, Atomic and Molecular Physics Network (LAM), European Optical Society (EOS), IEEE Photonics Society, International Society on Optics Within Life Science (OWLS), Optical Society of America (OSA) and the International Society for Optics and Photonics (SPIE). The presence of these international societies in ICO assures at the time an important input for the presence of less represented areas, as it is the case of LAM as an African Network created in 1991 during the first international workshop on Lasers and Applications held in Dakar, Senegal, with the participation of more than twenty African countries. Moreover, much wider and far reaching insights on the current emerging topics in optics and photonics, related contacts with industries and entrepreneurship programs are connected with the particular initiatives of the IS and under the ICO umbrella coverage.

Ending with this brief description of ICO structure and in order to give a more strategic approach, one may define ICO as “The United Nations of Optics”, as it was stated by the former ICO President Anna Consortini.

As for the presence of ICO in other international bodies, the former is now having a place at the ICSU structure as an Associate Member. ICO was admitted as an ICSU Associate Member at the 28th ICSU General Assembly that was held in China in October 2005. The first attendance of ICO to ICSU General Assembly (GA) took place at the 29th one held in Maputo, Mozambique in October 2008. ICSU is an international body representing the world of science. It is headquartered in Paris, and is the largest non-governmental organization in world's scientific community and as such, it is linked to UN organization. The ICSU interests owed to many disciplines in the world of science, not necessarily restricted to fundamental science, and so they cover many interdisciplinary disciplines including science and humanities. This gives ICO an opportunity to connect with this diversified world of science and to assure the presence of the optics and photonics activities inside this complex universe of science and technology.

ICO activities 2008-2011

Prior to summarize the main activities of ICO during the term 2008-2011, and by including the most burning topics at this stage in the world of optics and photonics, I would like to focus your attention on a unique event that took place in the year 2010. This was the celebration of the 50th anniversary of the invention of the laser, which was first demonstrated by Theodore H. Maiman, in 1960 at Hughes Research Laboratories, in Malibu, California, USA. For the many activities that took place at this unique occasion, we have to mention the sum of joint efforts from three of the ICO IS members: OSA, IEEE Photonics and SPIE along with the American Physical Society (APS) under the LaserFest definition. Through a wide-range of events and activities, LaserFest has told the story of the pioneering development of the laser and has helped to explore how scientific research leads to technological innovation that can impact and transform all segments of society. LaserFest events and activities were designed for the general public, students, educators, and legislators and have contributed to the dissemination and divulgation of the world of optics all over many local and international forums. ICO has supported and endorsed activities inside this anniversary, the LaserFest and other similar activities, as organized by Territorial Committees and IS. ICO Newsletter published a series of articles with relevant contributions by pioneers in laser science.

To add a brighter color to this piece of art, the 2009 Nobel Prize in Physics was accorded to Charles Kuen Kao for groundbreaking achievements concerning the transmission of light in fibers for optical communication, and to Willard S. Boyle and George E. Smith for the invention of an imaging semiconductor circuit – the CCD sensor.

As part of the ICO activities and under the condition of an ICSU Scientific Associate, the President of ICO participated at the 29th ICSU Triennial GA that was held in Maputo, Mozambique, 13-25 October 2008. As mentioned above, this was the first occasion for ICO to attend an ICSU GA. As a proposed special activity, a poster containing the wide and general information on ICO and its organization and activities was displayed there.

During the triennium 2008-2011, ICO has worked, through its Territorial Committees and International Society Members, to promote optics and photonics in the different regions of the world on the basis of a variety of programs and activities. Perhaps the most visible events are the triennial Congresses of ICO that consist of a scientific conference and the General Assembly of the members. The ICO-21 Congress in Sydney, Australia in July 2008 was a very successful one, with more than six hundred participants. Sudan and Tunisia were admitted as new Members, making the total ICO membership count 49 Territorial Members and 2 Associate Members. With the admission of these two new members, the African Territorial Committees of ICO have increased up to a total of four, by including Ghana/West Africa, a member since 1993, and Morocco as an Associate Member. ICO has been looking for additional members, especially from developing regions, and it is likely that new members will be formally admitted in the next Congress (ICO-22) in August 2011 in Puebla, Mexico.

In the years between two successive General Congresses, the main ICO conferences are the Topical Meetings, normally also containing the annual ICO Bureau meeting. The ICO Topical Meeting on “Emerging Trends and Novel Materials in Photonics” was held in October 2009 in Delphi, making it the first large scale ICO conference in Greece, under the support of the Hellenic Optical Society (HELIOS). The conference combined also a number of special sessions and short-courses organized under the auspices of the European Science Foundation (ESF) COST MP0604 “Optical Micro-manipulation by Non-linear Nanophotonics” and MP0805 “Novel Gain Materials and Devices Based on III-V-N Compounds”. ICO is having among its priorities to promote new key topics that can be of interest for the forthcoming young researcher’s generation and to open new career curricula having industry connections in new technologies. With this intention an ICO/EOS Topical Meeting on Optics and Energy was held, as a first join venture with the European Optical Society. The meeting was held in Paris, 28-29 October 2010 and as part of the Topical Meetings shaping the Annual Meeting of the EOS (EOSAM). The ICO Bureau Annual Meeting took place at that occasion at the new location of the Institute d’Optique in Palaiseau, Paris region.

ICO is having among its general policy to enhance and support activities in Latin-America. For this purpose, ICO supported the VI Technolaser and II Optics, Life and Heritage 2009 meeting, join together for the first time and held in April 2009 in La Havana, Cuba. At that occasion an international exhibition in Holography took place under the lemma “The Holography in Science, Art and Heritage. In September 2010 ICO actively participated in the 7th Ibero-American Conference (RIAO) and 10th Latin-American Meeting on Optics, Lasers and Applications (OPTILAS). In that event, the Ibero-American Network for Optics (RIAO) was officially launched.

ICO is also actively involved in two topical conference series. One on them is the Information Photonics (IP; formerly Optics in Computing, OiC) series. A meeting of this series was held in 2008 in Hyogo, Japan, organized by the Information Photonics Group of the Optical Society of Japan (OSJ). The other conference series is Education and Training in Optics and Photonics (ETOP), the only truly bi-annual international conference series focusing entirely on optics and photonics education and training at all levels. ETOP is the international forum for leading educators in optics and photonics all over the world. Since IEEE-LEOS joined in as a new permanent sponsor (the original ones are ICO, SPIE, and OSA), a revised Memorandum of Understanding for the ETOP series was signed late in 2010. The 11th ETOP conference was organized in Saint Asaph, North Wales, United Kingdom, in July 2009. One of the remarkable agreements among ETOP partners is the feature that all ETOP conferences papers (of all meetings since its inception in 1988) are freely available online to everyone.

For the term 1st October 2008 to 2011 (update to the actual date April 2011), ICO has been involved in a total of 29 conferences, many of them in developing countries (a complete list is in the ICO Green Book, Part I). As a resume: 7 endorsed meetings without financial support (held as 3 in Europe, 3 in Asia and 1 in North-America); 9 endorsed meetings with financial support (2 in Europe, 3 in Asia, 1 in North-America, 2 in Latin-America and 1 in Australia; and 13 co-sponsored meetings (held as 7 in Europe, 1 in Africa, 2 in North-America and 3 in Latin-America). In all cases, the meetings were accomplishing the highest international standards.

Every year, in February, the Winter College on Optics was organized at the Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italy, with the subjects including nano-photonics for life sciences (2008), optics in environmental science (2009), optics and energy (2010) and optics in imaging science (2011). Through ICTP contact networks, the Winter Colleges reach efficiently students and researchers in developing regions. Preparatory schools were also organized prior to the actual Colleges. The so-called TSOSA (Trieste System of Optical Sciences and Applications) group, which combines local and international optics organizations and bodies, had every year an advisory meeting during the Winter College. The goal is to increase the ICTP in-house activities in optics, while maintaining the valuable initiatives (such as the sandwich doctoral programs) that benefit education and research of optics in developing regions. A related activity is the hands-on global ALOP (Active Learning in Optics and Photonics) program, spearheaded by Minella Alarcon of UNESCO and aimed at high school and university physics teachers. Since 2007, ICO also participates formally in this novel activity, with enhancing programs in Latin-America.

The development of optics and photonics in the term 2008-2011, and some comments toward the future

As an initial and labeling insight on this three years term, one may say that the world has experienced a critical period of economic crisis affecting all markets and geographical areas. However, despite this global economic crisis, the photonics market is continuing its rapid expansion with clear examples as those for energy-efficient lighting, renewable energies such as photovoltaic and solar cells, information and communications, optical components and systems, healthcare and life science, as fast, high-resolution imaging tool for clinical diagnostic systems (see Figure 1). Annual growth rate in the photonics market is expected through 2014. As a key technology, photonics is at home in many diversified industries and it is part of the future of global economy. In that future, technologies will benefit in a way or another the quality of life of young generations. As a determinant factor, the expected continuous growth and expansion will converge with the phenomenon of the world population growth.

To support the above statements, one may consider current statistics provided by UN and UNESCO, for world population and growth of the percentage of young people who will be in the future in a position to afford a professional career in technological fields. Thus, in 2050, the world most populous countries will be located in Eastern Asia, followed by some located in Sub-Saharan Africa and South-America. These indicators appear to confirm an analogous trend previously reflected by 2009 UNESCO data. As an overall panoramic, the world population growth is now almost entirely concentrated in poorer countries in the world. Together with these data, we may cite that the young population (with ages in the range between fifteen and twenty four years old) and calculated as an average of 1.2 billions, will continue to be concentrated in Africa and Asia. In this very large group of young population, one expects, in the near future, that some percentage will orient their professional careers towards the world of science, engineering and technological training. As an example, by assuming just that a 0.01% of this global young population be oriented towards science and technology, that will represent about 120,000 of young researchers and students in our field in 2050 located in Asia/Pacific, Africa and Latin America and Caribbean regions, to be compared to about 10,000 of young people located in more developed countries.

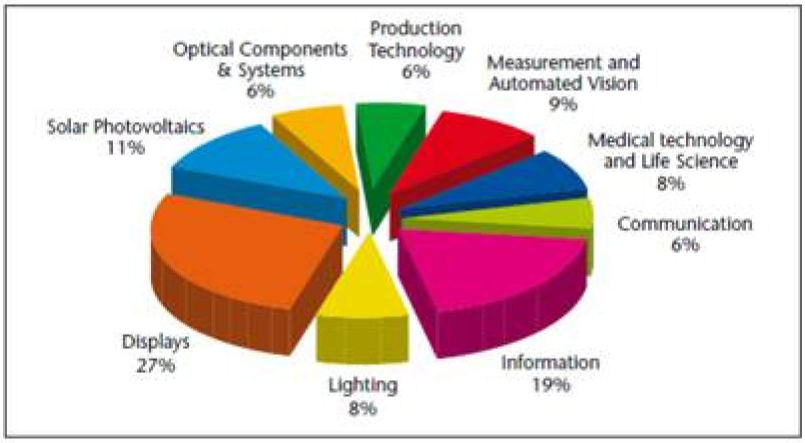

Figure 1.- Photonics World Market distribution for the year 2008. (Courtesy: OPTECH Consulting)

In the near future, it will be especially important for photonics companies and related industries, to maintain the edge in innovation and to uphold technological leadership and entrepreneurship in the field. For these key tasks, fundamental and applied research may be developed inside the current topics while other new emerging proposals will appear in the scene.

Let us review some current outstanding topics.

Classical and fundamental optics

Optics is certainly an ancient science. From a historical perspective its development throughout centuries was addressed to the needs of humans to recognize our environment, to perceive more and more small objects, needing lenses, mirrors and optical components and to better define distant objects. During the Renaissance, the optical sciences flourished. The great discovers of Kepler related to visual processes, "paved the way" for the creation of modern optics. Nowadays, the concept of optics touches a very broad range of phenomena involving the propagation of light and the interaction of light with matter. The development of optics in the 20th C. gave rise to new emerging fields determining the current vast applications. The latter are based upon fundamental concepts, which are key ones owing to the very nature of light. During the first decade of the 21st C., classical optics has seen contributions in the theoretical description for the spatio-temporal coherence of electromagnetic light, spatial and temporal characterization of light beams and luminous sources, polarization optics, light scattering, singular optics, interferometry, diffraction theory. These essential theoretical analysis concern practical applications such as radiometry and photometry, interaction of light with photonics devices, interaction of light with biological tissues, optical communications systems, atmospheric optics, metrology and sensor technologies, to give some relevant examples. The key conceptual aspect of these classical studies concerns the behavior of light as a random field and, therefore, is related to a statistical description of the electromagnetic waves. Then, we can consider that it associates the field of optics to those of physics and mathematics.

Optical Information Processing and Imaging Science

In reality, both the diffraction of light as well as the scattering of light arise essentially from the same phenomenon, basically described by the same laws contained in Maxwell's equations. Therefore, the distinction among them is in a certain sense mostly conventional or may be imposed for historical reasons linked to their observation and detection. In any case, the formulation of these phenomena leads to optical processing techniques and image formation in many contexts, from astronomy to diffractive tomography and diffused waves. The interpretation of the Fourier transform of an image has given a more general interpretation to the solution of the problems in this field. An important amount of research is done in subjects such as: Computing imaging, Wigner optics, imaging techniques for sensors, optical microscopy, super-resolution, ocular imaging and applications to adaptive optics, fluorescence image techniques, bases and applications to color displays, optical and digital holography, and many applications addressed to various fields in science and technology.

As a summary, optical interference phenomena are applied in many technologies such as communications, imaging and in ultra-fine measurement, and perhaps find their cleverest use in holography. Optics research combined with novel engineering continue to generate useful techniques as those mentioned above, which are benefiting fields as varied as medicine, astronomy and defense. The impact of the imaging science was demonstrated in 2009 by the Nobel Prize in Physics accorded to Williard S. Boyle and George E. Smith for the invention of an imaging semiconductor circuit– the CCD sensor. In these devices, there are three key technologies: semiconductor, silica and metal-oxide semiconductors (MOS). The use of CCD cameras is nowadays dramatically extended to the many diversified areas of science and technology. As an example of major applications, several well developed, Adaptive Optics (AO) technologies are now rapidly expanding into a host of other applications, from telescopes, microscopy and eye surgery to biometrics, DVD players, and even outside TV broadcasting.

Laser physics and laser technologies

The theoretical foundations of the laser emission were established by Albert Einstein in 1917 with the formulation and prediction of the stimulated emission of radiation. Experimentally, the first microwave amplification for stimulated emission of radiation was developed on the 1950s, and it was not until the 1980s that laser applications really took off. We can consider, for example, 1980 as starting the era of semiconductor lasers. The semiconductor-chip technology has been and continues to be a progressing and broadening technology leading to the fabrication of tiny, robust semiconductor lasers that are now ubiquitous – found in supermarket barcode readers, CD players and computer printers. Laser technology and applications continue to progress and broaden, as physicists and device engineers design ever more sophisticated semiconductor structures. Quantum cascade lasers (QCL) are among recent significant developments that look to have a variety of uses. One important physics tool is that the high intensity of laser light allows researchers to study extreme optical responses – so-called nonlinear effects. One of the first applications of QCLs has been in spectroscopy, in detecting trace amounts (less than one part per billion) of environmentally significant and polluting atmospheric gases.

As a resume, exploring and harnessing the behavior for future optical technologies continue to be a major goal in photonics research.

Lightning and displays

The new generations of organic light-emitting-diodes (OLED) has revolutionized the world of the lighting systems. The OLED is a display technology based on the use of organic polymers as the semiconductor materials in Light-Emitting Diodes (LED). The organic materials used in OLED may include “small” molecules or “macro” polymers.

Research and development in the field of OLEDs is proceeding rapidly and may lead to future applications in heads-up displays, automotive dashboards, billboard-type displays, home and office lighting and flexible displays. Moreover, OLED-based luminescent sensors for numerous potential applications, such as monitoring inorganic gases and biological compounds and organisms, are now under development. Much of the applied research being done in this area is focused on extending OLED lifetimes and improving the manufacturing processes to make them more competitive with standard LED technology.

<u>Optics communication and information technologies</u>

The Nobel Prize in Physics of the year 2009 was shared by the two previously mentioned scientists, W. S. Boyle and G. S. Smith and by Charles K. Kao. In the former article of Kao (co-authored with George Hockman) and published in 1966, it was demonstrated that the principal cause for radiation losses in the transmission of signals in an optical fiber was due to the presence of impurities in its structure. This cause was not strictly related to a physical property of the fiber as a transmission system. Kao and Hockman estimated the reduction of transmission losses when impurities are eliminated. The actual reduction could drop to 20 dB/Km (for λ = 850 nm), or even by zero. This discovery was the starting point for the 20th C. revolution of the optical communications technologies. With the combination of laser amplifiers, fiber optics revolutionized global telecommunications and ultimately made the internet possible. The association of optical communications and semiconductor devices suggested that light could be used not only to send signals but also to make fast optical processing possible. This aspect has given rise to optoelectronics. The optimization of these devices has led to new merging structures as the photonics crystals.

In the applications, one may include not only ultrafast optical communications and new imaging techniques, but also energy conversion and transmission and, further into the future, quantum information technology relying on controlling single photons of light.

<u>Optical materials</u>

The search for new structures with unique optical and physical properties, and, in a sense, connected with the research in photonic crystal has provided new class of materials with unique properties, namely the so-called metamaterials. The later belong to the class of composite materials designed, with features which show electric and magnetic responses to light analogous to those of atoms to produce bulk optical effects such as refraction. The remarkable property of metamaterials is that they can exhibit negative refraction, and so have the potential to control light in unexpected ways. Recently, metamaterials have been designed at the nanoscale, offering huge potential for optoelectronics and other technologies.

Another emerging research field connected to new nano-structured materials is related to plasmonic effects. The possibility for operate under a sub-wavelength structure condition provides a bridge for the 'scale-gap' between photonics and electronics.

The progress in the procedures for achieving optical data storage is connected with the progress in the obtention of new photomaterials, with large definitions inside inorganic-organic composites, with an interest for enlarging the wavelength range of operation, resolution limits and cost reductions.

Light-Matter interaction

Many advances have been achieved in this field due to the interaction of light with transparent media and modification of the speed of light. In the 1990s, the first experiments to put the brakes on light propagation were carried out. The principle behind slow light relates to the familiar concept of refraction. When light waves (electromagnetic radiation) pass through a transparent medium, interactions with the electrons cause the waves to spread out, or disperse, over a range of slightly different frequencies, each of which moves at a different 'phase' velocity. The different-frequency waves interfere with each other to create larger groups of waves that form an envelope, which travels more slowly and tends to bend in the directions that the individual slower phase-velocity waves are moving – hence light is slowed down and bent. Very promising applications in optical telecommunications, optoelectronic devices, optical networks, optical information processing and spectroscopy, as some of current interest are now enhancing the interest of this research subject.

As a general conclusion, optics and photonics are truly coming of age.

Maria L. Calvo
ICO President
Celebrating 50 years of the laser