AC.1 (ICO) TRIENNIAL REPORT TO IUPAP FOR 2005-2008

Introduction

It was in 1997 that the International Commission for Optics (ICO) celebrated its 50th anniversary. The backbone of the ICO are the Territorial Committees that represent the members (countries or territories, as they are called) of the ICO and provide direct links to the scientific optics communities in all parts of the globe. The ICO has fulfilled, and continues to fulfill, its mission to contribute, on an international basis, to the progress of the science of optics and its applications through a variety of programs and activities in collaboration with the territorial optics communities. But the field of optics has changed dramatically over the recent years, and so has the world we live in. With the remarkable progress and developments, optics and photonics are now more exciting and promising than ever, not only as a field of science and technology but also as a stimulus for growth in economy and wellbeing. In accordance with its charter the ICO strives to ensure that not just the technologically advanced nations but also the developing regions of the world will be able to share in the profits.

Therefore, to be able to address the global challenges, the ICO has revised its structure and operations during the last three triennial periods, starting in 1999. First, the introduction of International Society members (IS) has put the ICO in direct contact with the optical sciences and engineering organizations worldwide. Currently the ICO has six IS members: the four original ones from 1999, i.e., OSA, SPIE, IEEE/LEOS, EOS, and two newer ones from 2002, viz., OWLS – Optics Within Life Sciences, and LAM – the African Laser, Atomic, Molecular, and Optical Physics Network. The OWLS society serves as an important link between the ICO and the rapidly expanding fields of biomedical engineering and life sciences. The LAM Network, on the other hand, with several nodes caters to all African scientists and also provides an extra seat in the ICO Bureau for the African optics community. Other topical or geographically based IS members could be envisioned and encouraged as well, e.g., those representing South and Central America or Far-East and South-East Asia.

In 2005 came the next big change in the ICO structure. Optics has its roots deeply in physics and since its foundation in 1947 the ICO has been an Affiliated Commission (specifically, AC. 1) of IUPAP, the International Union of Pure and Applied Physics. The collaboration between the ICO and IUPAP and its various Commissions has always worked very well and continues to be successful. However, optics is developing and acquires features that are not closely related to fundamental physics. In other words, optics is increasingly turning into a scientific discipline of its own. For this reason the ICO applied and was in October 2005 admitted as an International Scientific Associate into ICSU, the International Council for Science. This is an important step for optics and the ICO and I will say more about it later. Suffice it merely to point out now that being an ICSU member puts optics and the ICO directly in contact with the other disciplines and international bodies within science and technology that constitute ICSU. The ICO will naturally keep its status as an Affiliated Commission of IUPAP as well.

Before addressing the ICO triennial activities and the recent advancements within optics, I will briefly mention another important development in Europe. Prompted by the US National Research Council's study "Harnessing Light: Optical Science and Engineering for the 21st Century", which has led to similar evaluations and programs in other countries, a European Technology Platform Photonics21 was established in Brussels in December 2005. The strategic research agenda "Towards a Bright Future for Europe" was then completed early 2006, helping to place optics and photonics firmly into the European research framework programs. While these events concern mainly Europe, several ICO officials were involved in the process. These developments are yet another indication of the significance and impact of optics and photonics to our modern society, acknowledged even on the highest political level.

ICO activities, 2005-2008

The triennial period 2005-2008 was commenced with a banner year, the World Year of Physics 2005. The ICO participated actively in the celebrations, e.g., by introducing a special logo and announcing all ICO conferences that year as WYP events. These actions brought added global visibility to physics and highlighted the fundamental link of optics to physics. And as if icing on the cake, the 2005 Nobel Prize in physics was awarded to Roy J. Glauber, John L. Hall, and Theodor W. Hänsch for their pioneering and outstanding work in quantum optics and laser-based precision spectroscopy.

And, as I mentioned above, the year 2005 finished off with a bang. In their meeting in Suzhou, China the General Assembly of ICSU (formerly known as the International Council of Scientific Unions, from which the acronym stems) towards the end October 2005 admitted the ICO as an International Scientific Associate member in ICSU. ICSU is an independent international organization, working closely with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the Third World Academy of Sciences (TWAS). It represents all disciplines in science and promotes their interaction in interdisciplinary actions. ICSU has four types of members: International Unions (IUPAP being one of them), National Members, International Scientific Associates, and National Associates. The admittance of the ICO in ICSU will greatly enhance the overall visibility and recognition of optics as an own scientific discipline and, consequently, it will have a positive impact on optics education, on the funding of optical research, and on industrial applications of optics and photonics. The ICO will be able to interact with other international scientific bodies and actively take part in the global initiatives of ICSU, such as those on climate change and energy. The direct contacts between the ICO and IUPAP will continue as before. The new ICSU membership of the ICO was celebrated in February 2006 at the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, in connection with the ICO/ICTP Winter College on Optics, an occasion in which all the International Society members of the ICO were represented.

During the triennium 2005-2008 the ICO has worked, through its Territorial 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 the ICO that consist of a scientific conference and the General Assembly of the members. The ICO-20 Congress in

Changchun, China in August 2005 was the largest ever, with more than a thousand participants. Greece and Moldova were admitted as new Members, while Ecuador became an Associate Member, making the total ICO membership count 47 Territorial Members and 3 Associate Members. The ICO has been looking for additional members, especially from developing regions; as a result, Tunisia and Sudan were admitted as full ICO members at the ICO-21 Congress in July 2008 in Sydney, Australia.[(*)]

(*) New ICO Bureau was elected at ICO-21 Congress, which consists of: President Maria L. Calvo (Spain), Past President Ari T. Friberg (Finland), Secretary Angela M. Guzman (Colombia), Assoc. Secretary Gert von Bally (Germany), Treasurer James A. Harrington (USA), Elected Vice-Presidents Yasuhiko Arakawa (Japan), Zhou Bingkun (China), Zohra Ben Lakhdar (Tunisia), Hervé Lefèvre (France), Fernando Mendoza (Mexico), Duncan T. Moore (USA), Moshe Oron (Israel), Tomasz Szoplik (Poland), Appointed Vice-Presidents Roberta Ramponi (EOS), Iam-Choon Khoo (IEEE/LEOS), H. Philip Stahl (SPIE), Min Gu (OWLS), Ahmadou Wagyé (LAM), OSA and IUPAP representatives to be appointed. The ICO-22 Congress will be held in 2011 in Puebla, Mexico.

In the years between the Congresses the main ICO conferences are the Topical Meetings, normally also containing the annual ICO Bureau meeting. The ICO Topical Meeting on Optoinformatics was held in September 2006 in Saint Petersburg, making it the first ever major ICO conference in Russia. The ICO has long promoted optics and laser science in Africa and in line with these initiatives, the ICO Topical Meeting “OptoLaserMed 2007” was organized in Cape Coast, Ghana in November 2007. The acronym stands for “International Conference on Optics and Laser Applications in Medicine and Environmental Monitoring for Sustainable Development”. The conference, which was sponsored by IUPAP, combined also an OWLS meeting and a Workshop of the LAM Network, making it a highly successful and truly major African conference on optics, lasers, and biophotonics.

Besides the Topical Meetings, also the Regional Meetings are ICO major events. In October 2007, the 6th Ibero-American Conference on Optics (RIAO) and the 9th Latin-American Meeting on Optics, Lasers and Applications (OPTILAS) were arranged as an ICO Regional Meeting in Campinas, Brazil. The RIAO/OPTILAS conferences, held every three years, have a long association with the ICO and they represent the main showcase and forum for exchange of optics research and results in South and Central America.

The 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 which was co-located in 2006 with the Optoinformatics conference in Saint Petersburg. The other one is Education and Training in Optics and Photonics (ETOP), the only truly international conference series that focuses entirely on optics education and training at all levels. 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 2005. Two successful ETOP conferences, eighth and ninth in order, were organized in Marseille, France in October 2005 and in Ottawa, Canada in June 2007, respectively. An exceptional and most useful feature of the ETOP conferences is that all papers (of all meetings) are freely available to everyone on the net (at spie.org/etop/).

Between the triennial Congresses in 2005 and 2008 the ICO was involved in a total of 25 conferences, many of them in developing countries (a complete list is in the ICO Green Book, www.ico-optics.org). The participation of the ICO in these conferences may assume different levels (e.g., co-sponsorship or endorsement), but in all cases the meetings represent the highest international standard.

Every year, in February, the Winter College on Optics was organized at Abdus Salam ICTP in Trieste, Italy, with the subjects including classical and quantum information optics (2006), fiber optics and fiber lasers (2007), and nano-photonics for life sciences (2008). 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 Dr. Minella Alarcon of UNESCO and aimed at high school and university level physics teachers. Since 2007 the ICO also formally participates in this novel activity.

In addition to conferences and schools, the ICO has continued its policy of recognizing excellence in optical research. In particular, the ICO has awarded every year three prizes, namely: (i) the ICO Prize, which is the main award given out by the ICO, for outstanding work published before age 40; (ii) the Galileo Galilei Award, for significant contributions under comparatively unfavorable conditions; and (iii) the ICO/ICTP Award, for an outstanding young scientist from a developing country. A complete listing of all award winners is on the ICO website www.ico-optics.org. The ICO/ICTP Award, given every year at the Winter College, was in 2008 re-named the ICO/ICTP Gallieno Denardo Award, in recognition of the contributions of late Professor Denardo. A new IUPAP Young Scientist's Prize in optics is under consideration by the ICO Bureau.

During the triennial period 2005-2008 the ICO has continued its Proceedings Donation Program. The ICO has also awarded six Travelling Lecturer awards, for recognized experts in optics and photonics to lecture typically in two or three universities or research institutes in one or two developing countries. The ICO Long-Term Planning Committee has met twice, at the beginning of the Bureau meetings in Saint Petersburg (2006) and in Accra, Ghana (2007). The Regional Development Committee, which works in close collaboration with ICTP, LAM, and networks in South America, has separate sections for the ICO focus regions of Latin America, Africa, and South-East Asia. The Education Committee has been active e.g. on developing optics and photonics curricula at various levels as well as promoting optics kits and optics training and education in developing countries. Joint activities with ICSU have been explored and the cooperation with IUPAP has been continued; besides ICO Bureau contacts in Commissions C13 (physics development), C15 (atomic, molecular, and optical physics), and C17 (quantum electronics), the ICO now also is represented in the IUPAP Workgroup on Nanoscience. The ICO Standards Committee was terminated at the ICO-20 Congress in Changchun in 2005, since the subject was deemed to be out of the present scope of the ICO. Although the ICO statutes call for at least two members of the Bureau to be from industry, direct interaction between the ICO and industry is conspicuously missing from the ICO agenda. I feel that this should not really be so, especially now when optics and photonics enterprises of all types and levels abound throughout the world. One of the challenges for future trienniums may be activating entrepreneurship and arousing the interest of optics industries in the ICO programs. Guidance could be taken from the workshops on entrepreneurship for physicists and engineers from developing countries, which IUPAP has in recent years organized in collaboration with ICTP.

It has been a tradition with the ICO to produce every three years a book that highlights international trends in optics. Volume 6 in this series, titled "Advances in Information Optics and Photonics" and published by SPIE Press, came out just in time for the ICO-21 Congress in Sydney in July 2008. The volume contains 32 authoritative chapters from leading scientists or research groups worldwide. The editors are Ari T. Friberg and René Dändliker.

The ICO web site at www.ico-optics.org has additional information on the activities. It also contains the ICO Green Book "Towards ICO-21" and the quarterly published ICO Newsletters.

About optics in 2008, and beyond

The field of optics covers such a wide area and progresses so rapidly that any comprehensive survey of the state-of-the-art seems impossible. Only certain important sub-fields of optics and remarkable recent developments can be outlined. The grouping of subjects and choice of results are, of course, somewhat arbitrary and subjective. To the extent applicable I follow here delineations based on the workgroups of Photonics 21 and also address future research topics as identified by WG7 (www.photonics21.org).

Information and photonic communications

The progress in photonics systems, both optical core networks and access systems, has been steady, focusing on high-speed data transmission, all-optical switching, and interconnect applications.(**) Cost reduction of optical components is an important issue to ensure wide-band communication (> 10 Gb/s) everywhere. Emerging applications such as high-definition video transmission necessitate advances in mass storage. Secure communications is another interesting area, in which pre-commercial trials with quantum cryptography already are underway. Also quantum teleportation with entangled photons (and atoms) has recently been demonstrated. The phenomenon of slow light, likewise demonstrated, can be envisioned as a means for localized storage of photons in structures such as Bragg gratings, photonic crystals, and micro-cavities, providing chip-scale memories. Plasmonic technologies and engineered nano-structures (for example, wires, pillars, and dots) show great promise for light manipulation. First experiments on electromagnetically induced transparency (EIT) in quantum dots have been performed.

(**) It is of interest to mention that Emmanuel Desurvire, Randy Giles, and David Payne were finalists for the 2008 Millennium Technology Prize, a major bi-annual prize devoted to breakthroughs in technology, for their invention and development of erbium-doped fiber amplifier (EDFA) which enabled the high-capacity global optical fiber network.

Industrial manufacturing and quality

Laser processing systems, for example for cutting and welding of materials, are the main workhorse of industrial laser applications. Advances have taken place in process control, sensing methods, and beam delivery systems. Recent innovations in fiber-optical components for solid-state lasers, in particular for high-power fiber lasers, have led to have led to significantly increased power levels and beam quality. Shorter high-average power wavelengths in the ultraviolet regime for nano-, pico-, and femtosecond pulsed laser formats, as well as compact low-cost diode laser systems, are currently objects of interest in industrial production. On the opposite front, free electron lasers that are widely tunable and radiate even at ultraviolet and soft X-ray wavelengths, are actively planned for use in high-resolution materials characterization and processing, such as optical lithography.

Life sciences and health

Optical and other imaging techniques have had a major impact on medical diagnostics and care. Laser treatments based on absorption and controlled plasmonic resonances have advanced. Vision science has seen many breakthroughs. Stimulated emission depletion (STED) microscopy, which has demonstrated beating the Abbe diffraction barrier, is on the verge of commercialization for imaging cellular objects and mechanisms such as nerve communication. Optical tweezers are now used for molecular processes in biomaterials. Functional imaging combining metrology and analytical spectroscopy is implemented in “Lab-on-chip” devices. In the future, developments of hybrid photonic approaches are expected that allow gapless observation and manipulation, in living tissue, of structures and processes ranging from macro- and micro-levels down to nanoscopic and molecular scales.

Lighting and displays

Shuji Nakamura received the 2006 Millennium Technology Prize for his contributions towards the development of bright-blue, green, and white light emitting diodes (LEDs) and the blue diode laser. These light sources have been used for a range of applications. Intelligent light engines based on white LEDs are being developed for general lighting, both indoors and outdoors. Another major field of research and developments for displays are high efficiency, large area light sources based on organic light emitting diodes (OLEDs). As regards laser light, red-green-blue (RGB) and multi-primary laser sources and laser engines are being developed for laser engines for projection and lighting systems. Intelligent light management systems will lead to human well-being and considerable energy savings.

Imaging, detectors, and sources

Quantum imaging and quantum detection form a fundamental research field in photonics. For instance, on the molecular level single-photon counting imaging and statistics are often required. Entangled-state quantum (bi-photon) imaging and classical intensity correlation imaging have resulted in understanding of the non-locality of quantum systems. Three-dimensional imaging is related to human perception and can be applied in robot vision. Functional imaging and visualization methods (e.g., for real-time flow) appear highly potential for medical applications. Another major research field is near-field imaging; a variety of techniques lead to micro- and nanoscopy beyond the diffraction limit. Using metamaterials (a so-called hyperlens), sub-diffraction-limited objects can be imaged even in the far field. Tip-enhanced (plasmonic) nonlinear techniques have been used for high-resolution imaging and Raman spectroscopy, e.g., in carbon nanotubes. Polarimetric imaging and a general description of polarization and coherence in (3D) random electromagnetic fields are likewise objects of active research.

Notions of expanding from single photon detectors into single photon counting detector arrays, both in electronic and quantum imaging, are on the horizon. Efforts are also directed towards the development of functional (or smart) pixels and detector arrays in CMOS compatible technology. These are mainly in the visible and near infrared (IR) parts of the spectrum, but extensions to other spectral ranges (using different technologies) are explored. Specific wavelength detectors for X-ray and far IR range, and up to the THz domain, are needed. Photonic detectors and arrays are employed in a variety of conditions, ranging from everyday applications such as digital imagery to innovative concepts in advanced optical instrumentation and astronomy. Closely related to detectors are the photovoltaic elements used in solar energy conversion.

An approach complementary to free electron lasers and synchrotron radiation to obtain (compact) short wavelength light sources is based on nonlinear frequency conversion starting from high-power infrared lasers. Laser induced plasma sources have shown the generation of both coherent and incoherent soft and hard X-rays. Optical parametric amplifiers and quantum cascade lasers (QCL) produce broadly tunable radiation in the mid IR region. The features such as high power, room temperature operation, broad spectral coverage, and small size make QCLs suitable sources for chemical sensing applications. Silicon photonics is an emerging field to combine standard CMOS manufacturing to produce photonic devices, such as the recently demonstrated silicon Raman laser. Organic light emitters (OLEDs) have great potential in many photonic devices. Terahertz sources allow new applications for 3D imaging in diffuse media and can also be used for security identification purposes. Super-continuum generation in photonic crystal fibers leads to high-intensity sources for white-light spectroscopy. Other directions of research are the generation of ultra-low noise (sub-Poissonian) quantum sources and the production of exotic quantum states (such as Fock states, and squeezed and entangled states of light) efficiently, on demand and at high rate.

Optical materials

Perhaps the most explosive area of research in optics in the recent years has been artificial (manmade, hybrid) materials, namely plasmonic structures, metamaterials, and photonic crystals. Plasmons allow ultra-short wavelengths (few nm) at optical frequencies, thus offering a method for delivering light to nanoscale structures. The significant losses are a major drawback. Photonic metamaterials consist of densely packed nanoscopic building blocks. Such artificial materials lead to unusual behavior, such as a negative refractive index, giant optical dichroism, enhanced nonlinearities, and magnetism at optical frequencies. Negative refraction in semiconductor metamaterials was recently observed. Applications of metamaterials include the superlensing effect and generation of invisibility cloaks. The tendency in research is towards experimental demonstrations at optical (visible) frequencies. Photonic crystals are complex dielectric structures with wavelength-scale building blocks. Photonic crystals admit tailoring the dispersion relation, polarization properties, spontaneous emission, etc. The main challenges include design and fabrication of high-quality 3D photonic crystals. Time-dependent materials allow exploiting novel functionalities, such as light storage and dynamic slow light structures. Other current research in optical materials deals, for instance, with ceramic gain materials, silicon photonics, and polymer and molecular materials.

Manipulation of light and matter

The coherent control of the interaction between light and matter has come a long way. These include a wide range of resonant atomic systems, chemical processes, and even atom optics in guiding structures. The studies of new methods for manipulating both light and matter, individually and together, are at the heart of modern optical science and technology. The connection between a photon, a polariton, and an electron offers new ways of information transfer between light and matter. Control of light by matter involves, e.g., the manipulation and detection of the information (whether quantum or classical) coded in the light. This, in turn, necessitates new materials, perhaps reconfigurable and capable of quantum-enhanced precision measurements. Inversely, imprinting information on light should take place with minimal energy and maximal information content per photon. In the control of matter by light, external or internal features of individual molecules (atoms, composite systems) are manipulated by tailored opto-mechanical forces, such as tweezers or optical lattices, and optical cooling techniques. Further, controlling individual bonds in matter would lead to entirely new ways of materials processing, with applications in designer assembly of optical nanostructures and bioengineered molecular complexes. Manipulation of light and matter constitutes a research theme of fundamental physics that will impact photonics many triennial periods to come.

Ari T. Friberg
President, ICO (AC.1 of IUPAP)
Celebrating 60 years of international optics
www.ico-optics.org

Professor Ari T. Friberg
ICO President (term 2005-2008)
KTH (Stockholm), TKK (Helsinki), Univ. Joensuu