ICO Newsletter

April 1999, No. 39

International Commission for Optics.

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ICO XVIII - August 2-6, San Francisco, California : at first major ICO event in the United States in 27 years, ICO will elect new bureau, vote on new statutes.

Every three years, the International Commission for Optics holds a major conference on optical science and technology together with its triennial membership General Meeting. In the last 10 years, the locations were Garmisch-Partenkirschen, Germany (1990), Budapest (1993) and Taejon, Korea (1996). This year, for the first time since 1972, the ICO Congress will be held in the United States. The Fairmont Hotel in San Francisco, Ca, has been selected for the meeting place. The US Advisory Committee for ICO has delegated the organization to SPIE - the International Society for Optical Engineering and Alexander J. Glass of has been appointed General Chair. Milton Chang agreed to serve as Conference Development Chair and William Krupke as Local Arrangements Chair. The scientific meeting is entitled « Optics for the New Millennium ». Its Technical Program Committee, chaired by former ICO President J.W. Goodman, met late in January to select the submissions and arrange the sessions. 324 contributed papers from 45 different Territories were accepted for presentations and will complement the 44 invited talks to form a comprehensive program covering a large part of the broad field of Optics. Steven Chu and Shuji Nakamura, both from the USA, have agreed to be the plenary speakers. The invited speakers will include the winners of the last three years' ICO awards, the ICO Prize and the ICO Galileo Galilei medal. The ICO General Meeting will, among others, elect the ICO Bureau for the triennium 1999-2002 and examine new statutes under which ICO would offer membership to the major learned societies with individual membership that are active internationally in optics meetings, exhibits and schools. The ICO intention is to provide a better coverage and guarantee a better representativity of the whole field of Optics to take new initiatives in such domains as actions for developing countries, optics education, and standards. So far, the Optical Society of America, SPIE - The International Society for Optical Engineering, and the European Optical Society have expressed interest in joining ICO. Please have a look at the ICO XVIII program under http://www.ico-optics.org and join us at San Francisco !

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Optics 2000

This document was written by the International Commission for Optics Bureau at the invitation of IUPAP, the International Union on Pure and Applied Physics and its International Commission on Physics Education as a contribution to the celebration of year 2000. IUPAP invites conference organizers in the year 2000 to schedule a special invited talk devoted to a long term perspective of their field. This document is meant to be used as a background, explains the major advances in Optics in the last part of this century and makes predictions about how Optics may be expected to develop, and what it might achieve in the next 10-20 years.

Introduction

Lessons from the past may be helpful when thinking about the future. In 1948, the founders of ICO selected for their discussions such topics as the accommodation of the human eye and its resolving power, the combination of aberrations and diffraction, the design of microscope objectives, interferometers for testing camera lens aberrations, elements of thin film design, diffraction gratings, new mineral and polymer glasses.

When comparing this list with the scope and state of the art of optics nowadays, two major facts appear quite conspicuously.

Fact number one is that indeed, there has been progress on all of these fields. The human retina is being investigated by adaptive optical systems, where a deferrable mirror compensates the aberration of ophthalmic media to focus and scan a diffraction limited spot on the retinal cells. Will adaptive optics ever be fitted to our spectacles and provide diffracted limited imaging to everyone, no matter how poor his natural vision ? The most complex optical systems ever built provide f:0.5 diffraction limited imaging at near ultraviolet wavelength over several square centimeters for computer chip masks replication. Thin films can be designed and fabricated in stacks of nearly one hundred layers to match virtually every conceivable spectral reflectance profile in the visible. Progress into the near ultraviolet and the infrared and their extension into the vacuum ultraviolet domain has started. How far in the X ray range will they affect future lithography tools for micro- and nanotechnologies ? Interferometers are available in all sizes from submicron Fabry Perot cavities to sensors with kilometer long arms, including computerized commercial optical test tools. Diffractive optics has emerged from gratings into holography and lens achromatization. Will miniaturization techniques allow to fit an optical system in the volume of a microcomputer CPU chip ? Optical materials include nonlinear crystals, rewritable holographic materials such as photorefractive crystals, liquid crystals and polymer light emitting diodes. Will white LEDs invade our daily life for better energy yield and longer lifetime of our lamps ? Ten meter mirror telescopes, all fitted with adaptive optics facilities to compensate for atmospheric turbulence, combine their images coherently over distances larger than 100 m. What shall we learn about planets outside the solar system that we have just started to identify ?

Yet, the second obvious fact is that optics is still much more than those cases of great, unforeseeable progress on subjects that were already of interest fifty years ago. In 1948, nobody predicted the advent of the laser just twelve years later, or about the role of optics in information systems, that are both commonplace to us in 1999. By emphasizing these two domains in the following two sections, we shall undoubtedly fall short of many forthcoming revolutionary changes. But we may be able to point at some major aspects of 1999 optics and their development in the first years of the new millennium. In the United States, NRC, the National Research Council, has devoted a significant effort in identifying the growth points in optics. A detailed account of the findings of the NRC appointed Committee on Optical Science and Engineering can be found in their report and presents a much broader overview of optics than these few pages can do.

Lasers

The diversity of lasers that have developed is an indication of their wide variety of uses, ranging from basic science to many branches of engineering. We shall examine just a few.

Cold atoms experiments and the rise of atom optics, a new field of Physics which was recognized by the 1997 Nobel Prize in physics being awarded to S. Chu, C. Cohen-Tannoudji and W. Philips, rely in part on the mature state of laser instrumentation. Atomic beams, usually of noble gases or alkaline metals, are first slowed down by a large number of successive collisions with photons from a laser frequency stabilized on a resonance line of the atomic species. When the atoms have been put essentially at rest in the laboratory frame, they are trapped and cooled by additional interaction with laser beams and magnetic dipole interaction in suitable magnetic fields. The result is a so-called atomic molasses with typically billions of atoms grouped in a cubic millimeter or so and with a residual temperature below one microkelvin, i.e. root mean squares speeds in the range of millimeters per second. When the trap is opened, the falling molasses becomes the source for atom optics, the first kind optics so far that applies to massive neutral particles, as opposed to light optics, electron optics, and ion optics ; atomic lenses, mirrors, beam splitters, interferometers are being developed. For example, the molasses can be further monitored by laser beams, such as the evanescent wave formed in a vacuum by a light beam that undergoes total internal reflection on a plane dielectric surface. Surface dipole interaction with the evanescent field gradient can be used to reflect atomic wavefunctions like a mirror reflects light waves. The latter experiment has turned out to be an unexpectedly fine surface roughness sensor based on van der Waals interactions, and it may ultimately lead to ultrafine measuring instruments. Other possibilities with atomic molasses include diffraction by holes in a membrane. Extremely cold and compact molasses with controlled quantum state have been driven to the coherent state of Bose Einstein condensates, where all atomic wavefunctions widely overlap and all atoms are in the same quantum state. The possibility of individually driving the atoms may open the way to an ultimate tool for lithography.

Large lasers such those as the National Ignition Facility under development in the United States are the record holders in terms of energy per pulse - as well, indeed, as cost and space for laser systems. The challenge of inertial confinement fusion, for both military and energy applications, is being pursued by irradiating millimeter-sized deuterium-tritium targets with megajoules of 350 nm light produced by tens or hundreds of frequency-tripled, amplified doped glass laser beams. The technique here combines laser-diode optical pumping of glass laser resonators, gain switched to reach nanosecond pulse emission, glass laser amplifier rods to reach the final energy of several tens of kilojoules per beam, deformable mirrors to actively compensate for wavefront distortion arising from thermal effects in the higher energy amplifiers, and frequency tripling in a highly nonlinear crystal. The near term perspective here is more scientific in nature, with a better understanding of dense plasma. The very far term, infinite energy supply from fusion, is at this stage considered completely irrealistic by most specialists.

Other large lasers are being developed for the optical detection of gravitational waves using the largest interferometers ever designed : about 10 W continuous, frequency stabilized laser beams will feed Michelson interferometers with arm lengths in the range of several kilometers, with the arms themselves being Fabry Perot cavities to increase the effective length of interaction with gravitational waves. A relative path length sensitivity of better than one part in 10 (to the power of) 21 will be needed to observe the expected events. Several projects in Europe, the United States and Japan are in various stages of development and their combined operation will essentially form a world observatory for gravitational events, since departing gravitational events from artifacts with imply their simultaneous observation at several sites thousands kilometers apart. When shall we have evidence of the black hole density in the universe ?

These examples may give the impression that lasers are huge, complex and costly systems. While lasers always belong to high technology, the largest market for lasers lies in the million pieces sales of compact disk readers, based on 780 nm compound semi-conductor lasers manufactured by the methods of microelectronics with unit costs down to less than one US dollar. Yet, laser miniaturization is still going on with the so-called « vertical cavity » lasers. For about two decades, laser diodes used to be edge-emitting structures with the laser cavity formed in waveguides on the surface of a semi-conductor structure, and with typical cavity lengths in the range of tenths of millimeters. A radically new concept imagined in the nineteen-eighties, that took several years to turn into a real device, was to stack a bottom mirror, a submicrometer-thick gain medium and a top mirror all atop a semi-conductor substrate to emit light « vertically », i.e. perpendicular to the substrate. The total laser volume is reduced to a few cubic micrometers and arrays of thousand lasers have been built on one chip - with the only difficulty that it is impractical to connect them to thousands of independent electrodes. At present, 760 nm and 980 nm wavelength VCSELs (Vertical Cavity, Surface Emitting Lasers) are manufactured in arrays of a few tens for their first commercial applications to optical interconnect, and development is in progress for the extension of the principle to the optical telecommunication wavelength range near 1.5 μm (see below).

Yet another class of lasers are the so-called solid state microlasers. Indeed, semi-conductor are solids, but the name solid state laser is traditionally used to designate doped dielectric crystals showing high gain at specific wavelengths. It is difficult to obtain high powers from laser diodes in the form of high quality optical beams. The identification of materials for highly efficient conversion of pump diode laser light into high optical quality laser beams over a wide range of wavelengths is in progress. Some compact, centimeter size designs include the pump laser, the solid state laser and a frequency doubler. More complex, experimental systems even include all-solid-state wavelength tunable nonlinear crystals, the so-called optical parametric amplifiers and oscillators. The goal here, indeed, is to offer easy to use, compact laser sources for the broadest possible wavelength range, from the blue to the mid infrared. Applications will dictate which systems can be manufactured in large quantities and therefore at a low cost.

An overview of the field of lasers cannot be given in just one or two pages. We shall therefore skip such important aspects as laser cutting and welding, laser ablation, lasers in metrology standards and atomic clocks, lidars (laser radars) that monitor air quality by measuring the back scattered light from aerosols above polluted areas, ultrafast lasers and their developing application to non-invasive biomedical imaging through diffusing tissues, laser « tweezers » that manipulate micrometer sized samples, and fundamental physics aspects such as the use of lasers to experimentally explore the dynamics of nonlinear physical effects with chaos, multistability, spatial solitons, light bullets and other pattern forming effects in space and time. While lasers are almost ubiquitous in modern optics, progress in optics cannot be reduced to lasers and we should now turn to some other aspects of the field.

Information optics

For many years, the issue of optical computers competing with electronic computers was a favorite in science journals and indeed an optical computer - it was an acousto-optic counterfeit of a Sun station - was built successfully around 1990. This was, however, a naive point of view. It is now apparent that it is not appropriate to use light in computers that just mimic electronic computers, just as it is not appropriate to put the driver seat of a horseless carriage atop in front of the roof as was the case in some of the very first automobiles. Instead, light beams in information systems are extremely useful for very important tasks that were not immediately apparent (in fact, is the role of light in a compact disk so apparent ? Light is involved there, anyway). One common fallacious and extremely naive argument for optical computers is that computers always need to go faster, and that photons travel much faster in any medium than electrons in conducting wires and semi-conductor devices, therefore computers based on photons ought to be better than those based on electrons. In fact, there are two trivial mistakes here : how fast a computer computes is expressed by a number of operations per second, not a speed ; and, signals in wires travel with the electromagnetic field associated with the moving charges, not with the slow charges themselves, so that signal propagation in a computer occurs at essentially the speed of light already. The main correct arguments are the following.

1. Operations in computers get faster when capacitors to be loaded during circuit operation get smaller - RC time constants get smaller -, as is possible if some of the longer wires are replaced by the propagation of electromagnetic waves through free space or in dielectrics as can be conveniently performed using light.
2. Light is an electromagnetic wave in the hundreds of terahertz range. This leaves space to a very broad signal bandwidth to be carried by a single beam, which is still far from being completely exploited today.
3. « Photons cross each other », or in more elaborate terms nonlinear effects and scattering in light propagation can be made extremely low, allowing many beams to propagate without crosstalk in a small volume, while it may be impossible to fit as many non-intersecting conducting wires in the same volume without disastrous capacitive and inductive effects.

The development of optical telecommunication as the first, and in any case the most important, application for optics in information technologies dwells on the first two arguments above. Improvement in the absorption and dispersion of optical fibers led to the first optical communication links around 1980. The replacement of multimode fibers by monomode fibers allowed reduced dispersion and better signal quality. In the following years, attempts were made to increase optical link capacity by introducing phase modulation in so-called coherent transmission schemes instead of the usual intensity modulation : in coherent transmission, a phase reference is carried in the optical link together with the signal and the detector uses interferences to decode the signal. However, the advent of fiber amplifiers around 1990 proved a much more efficient way to increase the optical telecommunication bandwidth : amplifying and regenerating optical signals optically turned out to be better than detecting and re-emitting them using optoelectronic repeaters. Data rates in the range of 5 Gbit/s were reached. Further progress is now arising from the simultaneous transmission of several signals coded on different wavelength channels in one fiber, the so-called WDM (wavelength division multiplexing) scheme, which is becoming everyday practice in long distance communication. One noteworthy consequence of fiber amplifiers and WDM techniques is that while optics was hardly present in the early days with just one beam propagating from one emitter to one detector, optics is now becoming an important technique in optical telecommunications. Current commercial capacities are increasing from 10 to 40 Gbit/s even in the more demanding undersea networks and 1 Tbit/s has been demonstrated in the laboratory. The control of beam propagation now relies not only on low absorption, on the order of 0.15 dB/km, but also on controlled low dispersion and on a delicate balance between linear dispersion and nonlinear effects. While exponential growth of the performance measures of electronic computer elements - the so-called Moore's law - has been observed for astonishingly long periods of time and has not yet ceased, the exponent that has been applicable for about twenty years to optical telecommunication is even larger. One may wonder which new ideas will be needed to pursue on the same line : perhaps subpoisson statistics allowing lower energy per bit will be one of them, with quantum optics directly impacting large scale markets. Optical computing as such will quite probably emerge again in the form of all-optical operations in switching, allowing to avoid detection and repeaters not only for amplification, but also for signal routing. Everyday life will quite likely be dramatically affected by inexpensive fiber to the home hardware and the ensuing terabit/s internet links.

Other challenges that are quite likely to be met in the field of information optics are optical interconnects for short distances between the various levels of computer architectures (racks, boards, chips and gates) that are emerging as viable solutions for some interconnect functions requiring high bandwidth and multiple beams, thus building on the third argument in favor of optics mentioned above, and more compact, faster and most likely parallel access optical memories such as those based on quadratic nonlinear effects in crystals and on rewritable holographic memories in photorefractive materials. How much optics will there be in 2020 computers ? Or, will computer evolution end up following nature and combining photosensors and neurons into smart retinas ?

Conclusion

While various branches of physics, such as atomic and molecular physics, plasma physics, semiconductors and quantum electronics, are well entitled to claim their share in the subjects that we considered, there is a unity in the broad and disperse field of optics. There are many facets to optics. The development and the impact of lasers followed from the discovery of one fundamental physical phenomenon, stimulated emission, and ended up triggering progress in a wide variety of fields, within and outside science and technology. In optical telecommunication, the initial trigger was an unexpected success in engineering low loss materials for silica fibers, and the impact on high technology and on society is just as considerable. Other aspects of optics could have been highlighted, such as the impact of optical imaging and sensors in the life sciences and in the humanities, the importance of materials development for optics, the interrelations between optics and micro- and nanotechnologies that may some day combine with micro-electronics to produce smart optoelectronic detector arrays for full electronic imaging in video and still pictures. Pasteur once said, « there are applications of science, there is no applied science. » Optics is progressing as a branch of science, with its roots deeply in physics ; applications of optics are progressing and extend their impact well outside physics. Optics has served as the foundation for many of the advances in physics and engineering that have enriched the field of science at the end of the twentieth century. Optics has also been a direct contributor to the improvement of human life world-wide. The impact and recognition of Optics has been increasing steadily in the last decades and the trend will continue well into the next century.

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ICO Traveling Lecturer application form

ICO has established a Traveling Lecturer Program to promote lectures on modern aspects of optics in interested territories by scientists of international reputation with good lecturing skills. The program is aimed specially at developing nations, but is not necessarily restricted to them. As a rule, it is expected that the lecturer's local expenses will be met by the host institution and that ICO's contribution will be towards the travel costs. For the triennium 1996-1999, the ICO budget includes an amount of US$5000 for the Traveling Lecturer Program. While an ICO Traveling Lecture may be given during a trip where the Traveling Lecturer is also an invited speaker at a conference, or a visiting scientist at a research institution for some period, the funds will be granted only for the presentation of a series of lectures on some active subfield of optics in one or preferably several laboratories in one (or several) foreign countries. This form should normally be submitted by the host (or one of the hosts).

Applications should be filed at the earliest possible time when plans start to be clear and sent to the ICO treasurer, Prof. Robert R. Shannon, CIO, P.O. Box 32576, Tucson AZ 85751-2576, USA, fax +1 (520) 721-1035, e-mail shannon@ccit.arizona.edu.

Name of traveling lecturer :

Address, fax, e-mail (as applicable) :

Detailed route : institutions to be visited, person responsible for hosting lecturer at every institution, tentative dates, lectures titles

Name and capacity of person submitting application :

Address, fax, e-mail (as applicable) :

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Forthcoming Events with ICO Participation

June 21-23, 1999
Photonics '99, Prague, Czech Republic, Prof. P. Tomanek, Technical Univ., Technica 8, CZ 616 00 Brno, fax +4205 750604
tomanek@dphys.fee.vutbr.cz
http://www.fee.vutbr.cz/UFYZ/Photonics/

July 28-30, 1999
ETOP'99, Sixth Intl. Conference on Education and Training in Optics and Photonics
Cancun, Q.R., Mexico
(organized in association with SPIE and OSA), Dr. J.J. Sánchez-Mondragón, CIICAP, UAEM
Av. Universidad 1001, Col. Chamilpa, CP 62210, Cuernavaca, Morelos, Mexico
fax. +52 73 297084
etop@uaem.mx
http://www2.uaem.mx/cii/etop.html
(ICO-18 satellite meeting)

July 28-30, 1999
Light for Life
Cancun, Q.R., Mexico
(organized in association with OWLS), Prof. Jorge Ojeda-Castañeda, UDLA
Apdo Postal 100, Exhda, Sta. Catarina, Cholula 72820, Puebla, Mexico
fax. +52 22 292066
light@uaem.mx
http://www2.uaem.mx/cii/lightwel.html
(in parallel with ETOP'99, ICO-18 satellite meeting)

August 2-6, 1999
ICO-18, Triennial Congress of the International Commission for Optics
«Optics for the Next Millennium», San Francisco, California, USA
ico18@spie.org
http://www.spie.org/info/ico/
http://www.ico-optics.org/

23-25 August 1999
DO'99, EOS Topical Mtg on Diffractive Optics
Jena, Germany
Prof. Frank Wyrowski, Inst. of Applied Physics, Friedrich-Schiller-Universität Jena
Max-Wien-Platz 1, D-07743 Jena, Germany
fax +49 3641 657675, do99@iap.uni-jena.de

April 2000 (tentative)
ICO Topical Meeting, Optical Sciences and Applications for Sustainable Development
Dakar, Senegal, Prof. Ahmadou Wague, Université C.A.D.
Departement de Physique, Dakar, Senegal
fax +221 8 246318, wague@smtp.refer.sn

18-23 June 2000
OC'2000, Optics in Computing
Quebec City, Canada
Dr. Denis Gingras, INO, 369, rue Franquet, Sainte-Foy (Quebec), Canada G1P 4N8
fax +1 418 657 7009, gingras@ino.qc.ca
http://gabor.phy.ulaval.ca/oc/index.html

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