



# NEWSLETTER

COMMISSION INTERNATIONALE D'OPTIQUE • INTERNATIONAL COMMISSION FOR OPTICS

## Message from the new ICO President

**Yasuhiko Arakawa, the new ICO President strives for ICO to become an ICSU Union.**



For the term of 2014–2017, I am honoured to serve ICO as the President.

ICO was founded 68 years ago and has become the leading international academic organization in the field of optics and photonics. Immediately after I started the job last October, there was big news – the announcement of the 2014 Nobel Prize award was made. I would like to express my congratulations to Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura for the 2014 Nobel Prize in Physics for the invention of efficient blue light-emitting diodes that has enabled bright and energy-saving white light sources. I am also pleased to congratulate Eric Betzig, Stefan W Hell, and William E Moerner, recipients of the 2014 Nobel Prize in Chemistry, for the development of super-resolved fluorescence microscopy. I do hope that this event encourages more young people to be engaged in science and technology in the optics and photonics fields.

One of our focuses in 2015 is the celebration of the International Year of Light and Light Technology (IYL2015). IYL2015 is a global initiative to show the citizens of the world the importance of optical and photonic science and technology in their lives. Indeed, the applications of light technology have revolutionized society through medicine, communications, entertainment and culture. Initiation of new and durable partnerships between the scientific, public and private sectors is a priority for the IYL2015. ICO will contribute to the IYL2015 as one of the endorsing partners together with the International Council of Scientific Unions (ICSU), the International Union of Pure and Applied Physics (IUPAP), and other academic unions. I, as the ICO President, would like to solicit all ICO territorial committees and international member societies to enhance their activities in their own unique way for promoting the celebration of the IYL2015.

The opening ceremony of the IYL2015 will be held on 19–20 January at the UNESCO Headquarters in Paris, gathering together 1500 people, including eminent scientists, industrialists, high officials, decision-makers, and promising young researchers. The event will certainly provide a suitable forum for scientific and policy sharing in science and technology. All Executive Committee members of ICO will



**INTERNATIONAL  
YEAR OF LIGHT  
2015**

participate in the ceremony as delegates of ICO. I also believe that each ICO territorial committee plans to send several delegates to the ceremony.

I have started the discussion on re-organization of ICO during my term as President. ICO was founded as an affiliated commission of IUPAP, which is one of the regular members of ICSU. Taking into account the rich history of ICO and the huge increase in the science and technology of the optics and photonics fields, ICO has already started discussions aimed at the elevation of ICO as a union that can become a direct member of ICSU. If ICO is a member of ICSU, ICO activities will become more visible, further emphasizing its role and responsibility as the international organization for optics and photonics.

Promotion of optics and photonics for young researchers and students is important, particularly in developing countries. Those activities should be continuously supported by ICO. Moreover, we will host or support more conferences in developing countries in many formats, such as ICO topical meetings, which provides unique opportunities for young people in those countries to talk directly with distinguished researchers in the world. The exchange of knowledge and visions will pay great dividends for the future of our global society.

I am very happy to follow the wonderful job that Duncan Moore, immediate past-president of ICO, accomplished in the last three years. I have just started to work with excellent bureau members on many exciting events. For the success of ICO activities, contribution of all ICO members is indispensable. Finally, I want to thank Maria Calvo who served as past-president in the last term, for giving us her deep insight and significant suggestions.

**Yashuhiko Arakawa, ICO President**

# What is light?

Barry R Masters

**So simple: Let there be light! And yet so complicated. Indeed, just what is light?**

*"And God said, 'Let there be light,' and there was light."*

**Genesis 1:3**

*"For the rest of my life, I will reflect on what light is."*

**Albert Einstein, c. 1917**

*"All the fifty years of conscious brooding have brought me no closer to the answer to the question: What are light quanta? Of course today every rascal thinks he knows the answer, but he is deluding himself."*

**Albert Einstein, 1951**



Northern Lights, By Kshitijr96 (own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0>)], via Wikimedia Commons.



The eye is a photon detector.

By Woodwalker (own work) [CC BY 3.0 (<http://creativecommons.org/licenses/by/3.0>)], via Wikimedia Commons.

Light is a prerequisite for life, as it is the ultimate source of energy in our foods. Light is integral to religion, to creation stories, to poetry, to literature, to language, and to culture. Light is atmospheric beauty as in the sunrise and sunset, the rainbow, the aurora borealis, and the aurora australis. Light is a prerequisite for vision; in fact theories of light and vision have a convoluted history dating from the Greek and Arab philosophers. Vision requires light and optical devices such as glasses, contact lens, and laser refractive surgery can improve visual acuity. Light can diagnose and treat eye disease. The interaction of light and electrons in atoms or molecules is how light is detected. This is true for the photo-receptors in our retina and for the semiconductor detector elements in our cameras.

Colors enrich our environment, stimulate and delight people in all lands, and adds beauty to our homes, our cities, and our lives. Sunlight, moonlight, and starlight benefit and add beauty and wonder to all of Earth's people. Light is the foundation of our modern world; its generation, manipulation, transmission, and detection are integral to our communication, manufacturing, medical devices, public art, light shows, biotechnological instrumentation, educational programs, and laboratory instrumentation for the advancement of science and technology. Light is the source of information on the creation of the universe, on photophysical processes in the stars, and on the universal nature of physical laws throughout the universe. Light, through the tool of spectroscopy, led to our theoretical and experimental knowledge of the structure of

atoms and molecules. Light and its interaction with matter led to the invention and the development of quantum mechanics. Light has occupied the minds of poets, philosophers (from the fifth century BCE), artists, scientists, and engineers. Today, light connects disparate people, cultures, and nations into the human family. Light fascinates, stimulates, and connects us. Children are amazed how sunlight is concentrated by a magnifying glass to kindle a fire. People are astonished when they look into a telescope or a microscope and see the microcosm and the macrocosm.

Historically, light can be understood as a wave, as a quantum particle, and as a quantum field. Complicated? Yes! Indeed, the question "What is Light?" is often deferred to the question "How does light behave?". More specifically, the question "What is light?" is often replaced by the question "How does light propagate and interact with matter?". In this essay I point out some of the key conceptual origins of wave-particle dualism and theories of light-matter interactions in the early 20th century.

I discuss the seminal contributions of Albert Einstein to our understanding of the nature of light and its interactions with matter. Einstein's theories of relativity and their experimental confirmation made him popular worldwide; however, his contributions to the field of optics have transformed our understanding of light, as well as our ability to manipulate it for applications in a broad range of areas, including medicine, telecommunications, photonics, and experimental research on fundamental physics via Bose-Einstein condensates. His work on stimulated

The list of references mentioned in this article by Barry R Masters can be found at <http://e-ico.org/node/284>

Left: Sketch of the Whirlpool Galaxy as viewed from the Birr Castle Telescope (a 1.8 m reflecting telescope) by Lord Rosse in 1865. 2005 NASA/ESA digital image combination of a ground-based image from the 0.9-m telescope at Kitt Peak National Observatory and a space-based image from the Hubble Space Telescope (middle), and the Galaxy in infrared dust (right).



emission contributed to the development of the laser, a device that is transforming our world. Einstein's publications on light influenced both Louis de Broglie and Erwin Schrödinger and led to the invention of "wave mechanics". Einstein bridged the gap between the propagation of radiation in space and radiation-matter interactions. Between the years of 1905 and 1916, Einstein explained the interaction between light and matter by the absorption and emission of light quanta, thereby explaining several physical phenomena: Stokes' rule of fluorescence, ionization of gases by ultraviolet light, and the photoelectric effect. In the photoelectric effect radiation of a threshold frequency is incident on a metallic surface and electrons are ejected; this principle is embodied in light detectors such as the photomultiplier tube. Einstein's hypothesis of induced or stimulated emission is the basis of laser operation.

### Early experiments on light-matter interactions

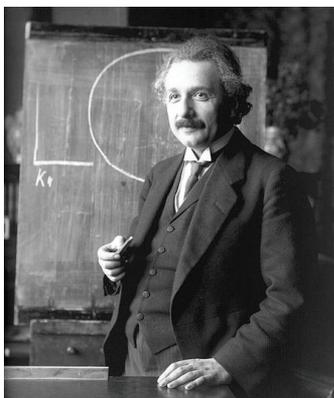
It is both interesting and instructive to study the antecedents to Einstein's work on light-matter interactions. In 1887, Heinrich Hertz, who generated, detected, and characterized propagating electromagnetic waves, observed that ultraviolet light incident on his spark gap resonators enhanced their capacity to spark. His assistant, Wilhelm Hallwachs, confirmed and expanded on this observation in 1888, when he demonstrated that ultraviolet radiation caused neutral metals to acquire a positive charge. In 1899, Joseph J Thomson studied the effect of ultraviolet radiation on the production of "corpuscles" [electrons] from a metal plate inside a Crookes tube. Thomson measured a current from the plate that increased with the frequency and intensity of the radiation. He was the first to state in a publication that the ultraviolet induced photoeffect results in the emission of electrons. In 1902, Philipp Lenard, who was working at the University of Kiel, demonstrated that the short wavelength radiation from a carbon arc lamp incident on a metal's surface caused the emission of electrons. The number of electrons ejected, but not their kinetic energy, increases with the light intensity, and below a specific frequency of radiation no electrons are emitted. Lenard also observed that the maximum kinetic energy of the emitted electrons is independent of the intensity of the incident radiation, but it increases with increasing frequency of the incident radiation; he measured the effects of three different frequencies of ultraviolet light on the emission of electrons from an aluminium plate.

### Einstein's light quantum

In 1905, Einstein published a ground-breaking paper, "On a Heuristic Viewpoint Concerning the Production and Transformation of Light", in which he deduced from Boltzmann's statistical thermodynamics that the entropy of radiation described by Wien's distribution law has the same form as entropy of a gas of elementary particles or quanta of energy, with each quantum proportional to the frequency of the corresponding wave. Einstein wrote: "Monochromatic radiation of low density (within the range of validity of Wien's blackbody radiation formula [valid for  $h\nu / kT \ll 1$ ]) behaves, in a thermodynamic sense, as if it consisted of mutually independent radiation quanta of magnitude  $[h\nu]$ ," the symbol  $h$  being Planck's constant,  $k$  the Boltzmann's constant and  $T$  the Kelvin temperature, and  $\nu$  the frequency of the light. Furthermore: "When a light ray spreads out from a point source, the energy is not distributed continuously over an increasing volume, but consists of a finite number of energy quanta that are localized at points in space, move without dividing, and can only be absorbed or generated as complete units." Einstein alternatively uses the words energy quantum (Energiequant) and light quantum (Lichtquant). This concept of discontinuous energy in propagating radiation contradicted Maxwell's continuous wave theory of electromagnetic radiation. A decade later, in 1916, Einstein discussed the momentum  $p=h\nu/c$  and the zero rest mass of his light quantum in his publication: "Emission and Absorption of Radiation in Quantum Theory", *Deutsche Physikalische Gesellschaft. Verhandlungen* 18, 318.

### The photon

The American physical chemist Gilbert N Lewis constructed the name *photon* in a paper published in the journal *Nature* in 1926. "It would seem inappropriate to speak of one of these hypothetical entities as a particle of light, a corpuscle of light, a light quantum, or light quant, if we are to assume that it spends only a minute fraction of its existence as a carrier of radiant energy, while the rest of the time it remains as an important structural element within the atom... I therefore take the liberty of proposing for this hypothetical new atom, which is not light, but plays an essential part in every process of radiation, the name photon." After Lewis proposed the term "photon" in 1926, many physicists adopted it as a name for Einstein's light quantum. However, Lewis' conception of the photon was completely different from Einstein's. As H Kragh discovered, the name photon was proposed by at least four scientists before 1926. The only vestige of Lewis' photon that remained valid was its name. Further historical insights are found in Lamb's 1995 publication, "Anti-photon".



Albert Einstein in 1921 by F Schmutzer [public domain], via Wikimedia Commons.



The first ruby laser is disassembled.

### Einstein's light quantum hypothesis explains the photoelectric effect

Einstein applied his concept of the light quantum to explain the photoelectric effect, which Maxwell's wave theory could not explain. Einstein wrote: "If monochromatic radiation behaves ... as though the radiation were a discontinuous medium consisting of energy quanta of magnitude  $h\nu$ , then it seems reasonable to investigate whether the laws governing the emission and transformation of light are also constructed as if light consisted of such energy quanta." Einstein assumed that light interacts with matter by the emission or absorption of his posited light quantum, and he posited a new mechanism for the perplexing phenomenon. Einstein described his theory of the photoelectric effect as follows. Light quanta penetrate the surface layer of matter, and their energy is converted into the kinetic energy of the electrons; a light quantum transfers its entire energy to a single electron. He wrote: "An electron in the interior of the body will have lost part of its kinetic energy by the time it reaches the surface." In addition, he assumed that the electron at the metal's surface must perform work  $\phi$ , (a function of each material, called the work function), to overcome the attractive forces holding it in the material in order to leave the surface; the maximum kinetic energy of such electrons is  $h\nu - \phi$ . In modern notation:  $eV = h\nu - \phi$ , where  $e$  is the charge of the electron and  $V$  is the retarding potential necessary to stop the fastest photoelectrons. This is the first equation in the quantum theory of radiation-matter interactions. Confirmation of Einstein's posited photoelectric effect came in 1912, when Arthur L Hughes measured the maximum velocity of photoelectrons from various metals and verified Einstein's photoelectric equation.

The first confirmation of the quantum hypothesis, in an area of physics other than radiation, occurred in 1907 when Einstein explained and demonstrated that energy quantization can be applied to condensed matter. Einstein explained the anomalous temperature dependence of the specific heats of solids (i.e. that they decreased with reduced temperature) by modelling a solid as a lattice of quantized oscillators. Einstein's formula was in good agreement with the experimental results provided in 1910 by Walther Nernst and his assistant Frederick A Lindemann.

Einstein's 1922 Nobel Prize in Physics cited his 1905 paper on the photoelectric effect: "For his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect." At the time that Einstein developed his theory of the photoelectric effect, many of the world's eminent physicists such as Max Planck, Hendrik A Lorentz, Max von Laue, Wilhelm Wien, and Arnold Sommerfeld could not accept his quantum theory of light because they cited the interference of light, which is consistent with wave phenomena. Both Planck and Lorentz

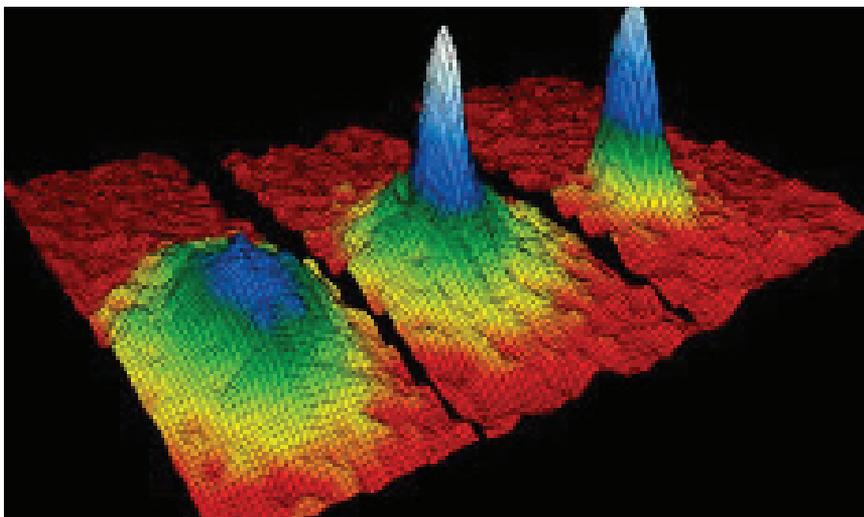
accepted that radiation interacts with matter in a quantized process, but rejected the concept that individual light quanta are propagated as a wave. One notable exception was Johannes Stark, who in 1909 proposed localized energy quanta in X-rays, and he also supported Einstein's light quantum hypothesis. Einstein himself realized that his hypothesis required experimental validation or rejection, and at the 1911 Solvay congress he stated: "I insist on the provisional character of this concept [light-quanta]." In 1921 Maurice de Broglie reported at the third Solvay Conference in Brussels that his analysis of the impact of X-rays on matter and the subsequent ejections of electrons could be explained by assuming the X-rays have an energy  $h\nu$ . His brother, Louis de Broglie, read Einstein's papers on light and following Einstein's concept of light quanta derived his theory of "matter waves." Erwin Schrödinger built on the prior derivations of Louis de Broglie in his invention of "wave mechanics".

### Skepticism and then experimental validation for Einstein's light quanta

In 1916, Robert A Millikan experimentally verified Einstein's photoelectric theory with high precision, extending the previous experiments of Lenard. Millikan showed that the maximum kinetic energy of the emitted electrons is proportional to frequency. His plots of the stopping voltage for photoemission versus the frequency of the incident radiation followed Einstein's predicted linear dependence, and for different metals the values of  $h$  were equal to the value that Planck calculated in his 1901 paper. Millikan also showed that the number of photoelectrons is proportional to the intensity of the radiation. Nevertheless, he rejected Einstein's posited light quanta.

Only after 1923 when Arthur Holly Compton and independently Peter Debye published their papers on the X-ray scattering by electrons, that was based on Einstein's light quantum hypothesis, did the physics community accept Einstein's light quantum. Compton studied X-ray and  $\gamma$ -ray scattering by light elements. His theory of 1923 showed that the energy of the scattered quantum is less than that of the incident quantum, and the difference is the increased kinetic energy of the recoiled scattering electron. Compton derived an equation that related the increased wavelength of the scattered beam to the angle  $\theta$  between the incident and scattered beam. An X-ray quantum of frequency  $\nu$  is scattered by an electron of mass  $m$ . The scattering electron is assumed to be initially at rest; after the collision with the quantum of radiation, the electron recoils. He then assumed the conservation of energy and momentum for the scattering process, and derived his scattering equation for the change of X-ray wavelength:

$$\lambda - \lambda_0 = \frac{h}{mc} (1 - \cos \theta)$$



Bose-Einstein condensate. Velocity-distribution data (three views) for a gas of rubidium atoms, confirming the discovery of a new phase of matter, the Bose-Einstein condensate. Left: just before the appearance of a Bose-Einstein condensate. Center: just after the appearance of the condensate. Right: after further evaporation, leaving a sample of nearly pure condensate. By NIST/JILA/ CU-Boulder (NIST Image) [Public domain], via Wikimedia Commons.

Compton validated his theory with a series of precise measurements and wrote: “The beautiful agreement between the theoretical and experimental values of the scattering is more striking ... There is not a single adjustable constant connecting the two sets of values.” He found that the increase of wavelength is independent of the wavelength. Compton then concluded: “The scattering of X-rays is a quantum phenomenon.” Furthermore: “... the theory indicates very convincingly that a radiation quantum carries with it directed momentum as well as energy.”

### Einstein’s theory of wave-particle duality of light

The origins of the wave-particle duality of light are found in Einstein’s 1909 milestone paper on energy fluctuations: “On the Present Status of the Radiation Problem.” Einstein calculated the fluctuations of energy and momentum in his analysis of Brownian motion (1905), and he applied these analytical methods to blackbody radiation. He generalized his 1905 fluctuation theory of mechanical systems (Brownian particles) to non-mechanical blackbody radiation. Einstein investigated the energy fluctuations of blackbody radiation that was contained in a partial volume  $V$  of an isothermal cavity at temperature  $T$ . Starting with Planck’s blackbody distribution law, he wrote the variance of the energy fluctuations as

$$\langle (E - \langle E \rangle)^2 \rangle = \langle E \rangle h\nu + \frac{c^3 \langle E \rangle^2}{8\pi\nu^2 dv V}$$

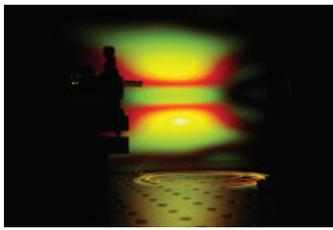
where  $\langle \rangle$  represents the statistical average,  $E$  is the radiation energy of frequency between  $\nu$  and  $\nu+dv$ , and  $c$  is the vacuum velocity of light. This equation is known as Einstein’s fluctuation formula for blackbody radiation. He reasoned from statistical mechanical analysis that the first term to the right side of the equals sign referred to the quantum properties of the radiation. This term, linear in average energy, is found in the high frequency limit in which Wien’s law is valid. Einstein concluded that radiation, in particular its energy fluctuations, is consistent with

a gas of independent particles, i.e. light quanta, each with energy  $h\nu$ . He reasoned from dimensional analysis that the second term, quadratic in average energy, is from the interference of waves. This term is obtained in the limit of low-frequency radiation. Einstein conceived the radiation inside the cavity was composed of many normal modes with various amplitudes, phases, and states of polarization and that they are propagated in many directions. He posited that the fluctuations in any partial volume of the cavity could arise from interference between different plane waves. In 1909, Einstein wrote: “...the next phase in theoretical physics will bring us to a theory that light can be interpreted as a kind of fusion of the wave and emission theory...”

### Einstein’s Theory of Stimulated Emission

Nine years after Einstein conceived of the light quantum, he returned to the problem of light-matter interaction, specifically, the transitions between energy states of atoms and the role of light quanta in these processes. In 1916, he postulated stimulated or induced emission in his seminal paper “Emission and Absorption of Radiation in Quantum Theory”. This paper is notable for its introduction of a probabilistic approach to quantum physics. It contained his so-called “A and B coefficients”, and his prediction of the process of induced emission or spontaneous emission. At that time, the concept of energy transitions in atoms mediated by the absorption and the emission of light quanta was not commonly accepted by the physics community. Bohr’s theory of the hydrogen atom did not utilize the idea of the photon; in fact, Bohr rejected that concept until the early 1920s. Note that even Max Planck, who is considered to have founded quantum theory in 1900, did not accept the reality of quantization until 1913 when Bohr quantized the energy levels of the hydrogen atom.

Einstein reasoned that the radiation field can cause a loss or gain of energy in the atoms. He assumed a process with two energy states for the atom, upper and lower, and transitions between the two with an absorption or an emission of a photon of energy equal to their energy difference. If an atom absorbs a photon then its electronic energy will be increased by the energy of the photon and the atom will be in an excited energy state. An atom in the excited energy state can spontaneously emit a photon and will now exist in a lower electronic energy state or the ground state of energy. The energy of the emitted photon is equal to the energy difference between the excited and the ground electronic states. Spontaneous emission from the excited state of an atom can occur in the absence of incident radiation. In induced, or stimulated, emission, an atom in an excited state interacts with an electromagnetic field, causing an electronic transition from the excited energy state to the lower energy state; the energy difference between the two states is trans-



Supercontinuum generation in a photonic crystal fibre. Courtesy of J Dudley, Chair of the Steering Committee of the International Year of Light 2015.

ferred to the electromagnetic field. The photon created in the process is identical in frequency, phase, polarization, and propagation direction to the photons in the incident field.

Einstein assumed a collection of atoms in thermal equilibrium. He assumed a process with upper and lower energy states and transitions between the two with an absorption or an emission of a photon of energy equal to the energy difference between the two energy states. The number of atoms in the upper and the lower states are constant. At thermal equilibrium, the same number of atoms per unit time will absorb radiation as the number that will emit radiation.

Einstein then distinguished between two types of transitions. The first is when the emission of radiation occurs in the absence of external influences. He made the analogy to Rutherford's law of radioactive decay. In modern terms, this is the process of spontaneous emission, which occurs when no external radiation is present, and is characterized by "Einstein's A coefficient". The resulting photon can be emitted in any propagation direction. The second type of transition is due to the interaction between the atoms and incident radiation. Einstein assumed that the effect of the incident radiation is proportional to the radiation density and causes the transition between states. Einstein assumed the principle of microscopic reversibility, which states that the rate of energy transfer from lower to upper states must equal that from upper to lower states for every transfer, can be applied to radiation in equilibrium. Einstein required that the process of stimulated emission occur in order for the energy levels of an atom in equilibrium with the radiation field to be given by the Boltzmann distribution and to be consistent with the Planck radiation law. If the Einstein coefficient for stimulated emission (Einstein's coefficient) was zero, there would not be a Boltzmann distribution of states at thermal equilibrium. At thermal equilibrium, the number of atoms gaining energy must equal the number losing energy. He deduced that the probabilities of induced absorption and emission are equal. The Einstein coefficients are

independent of radiation density.

Einstein presciently suggested that the coefficients A and B could be calculated if a new version of electrodynamics and mechanics was available that is in agreement with the quantum hypothesis (a new quantum mechanics). This prediction was fulfilled in 1927 when Dirac used his version of quantum mechanics to derive in one paper Einstein's B coefficients and in a second paper Einstein's A coefficient (spontaneous emission).

Experimental verification of Einstein's concept of stimulated emission came decades after Einstein theoretically predicted it. Bertolotti posits an explanation for this long delay in his article: *Why was the laser invented so late?* See the *ICO Newsletter*, January 2010, Number 82, <http://e-ico.org/node/94>. In 1954, Gordon, Zeiger, and Townes invented the maser (microwave amplification by stimulated emission of radiation), which operated in the microwave region. And, in 1960, Theodore H Maiman produced stimulated emission in a ruby crystal as a component of the first laser. The 1964 Nobel Prize in Physics was shared by Charles H Townes, Nicolay G Basov, and Aleksandr M Prokhorov for their independent work on the laser.

So the question remains: What is Light? Einstein conceived of the photon as a state of the electromagnetic field with a frequency  $\nu$ , a wave vector  $k$ , an energy  $h\nu$ , and a momentum  $\hbar k$ . It is a particle of zero rest mass, it has spin one, and it has two states of polarization. In 1924 Einstein wrote: "The positive results of the Compton experiment proves that radiation behaves as if it consists of discrete energy projectiles, not only in regard to energy transfer but also in regard to momentum transfer." So after all these years we come back to the statements: "Radiation... behaves...as if it consists of..." Statements addressing not What is light? but, rather, How does light behave?. Although we have not answered the original question, our increased understanding of light has brought beauty to our lives and has transformed our world. Thank you for light.

**Barry R Masters, Independent Scholar,  
Cambridge, MA, USA**



**Professor Barry R Masters** received a PhD from The Weizmann Institute of Science, Israel, a MS from The Florida State University, and a BS from The Polytechnic Institute of Brooklyn. Professor Masters was a Visiting Scientist, in the Department of Biological Engineering, at the Massachusetts Institute of Technology, a Visiting Scholar in the History of Science Department at Harvard University, a Visiting Professor, Department of Ophthalmology at the University of Bern, and a Professor in Anatomy and Cell Biology at the Uniformed Services University of the Health Sciences. He is a Fellow of the American Association for the Advancement of Science (AAAS), the Optical Society of America (OSA), and SPIE. From 1999 to 2000, Professor Masters was a AAAS Congressional Science & Engineering Fellow and served as a Legislative Assistant in the United States Congress. He is a Recipient of The Vogt Prize for Ophthalmic Research (Highest Swiss Award for Research in Ophthalmology) with Dr Böhne in 1999 for their work on: "Confocal Microscopy of the Cornea". Professor Masters has published 86 refereed research papers and 143 book chapters and proceedings articles. He is the editor or author of 10 books: *Noninvasive Diagnostic Techniques in Ophthalmology*; *Confocal Microscopy and Multiphoton Excitation Microscopy: the Genesis of Live Cell Imaging*; *Handbook of Biomedical Nonlinear Optical Microscopy* (with Peter So). He is writing a new book to be published by Cambridge University Press: *Superresolution Optical Microscopy: The Quest for Enhanced Resolution and Contrast*. He lectures worldwide on the responsible conduct of research, biomedical ethics, critical thinking, and biomedical photonics.

# 2014 IUPAP Young Scientist Prize in Optics

**Albert Schliesser, Niels Bohr Institute, Copenhagen University, Denmark.**



Albert Schliesser is a Research Assistant Professor at the QUANTOP Center of the Niels Bohr Institute, Copenhagen University, Denmark. He obtained his MSc (Physik-Diplom) from the Technische Universität München, and his PhD (Dr. rer. nat.) in physics from the Ludwig-Maximilians-Universität München. His PhD advisor was T W Hänsch. After a Postdoctoral position as Research Assistant for the Laboratory of Photonics and Quantum Measurement of the Swiss Federal Institute of Technology Lausanne (EPFL), he joined the Niels Bohr Institute. He has been awarded the 2014 IUPAP Young Scientist Prize in Optics “for his outstanding contributions to photonics and optomechanics, in particular by developing a micro-frequency comb and a radio-to-optical mechanical transducer”.

Since his graduate studies, Dr Schliesser has pursued research in optics at its intersections with other physics disciplines such as nanomechanics. In the Laser Spectroscopy division of the Max-Planck-Institute of Quantum Optics he worked on novel spectroscopic techniques based on laser frequency combs and on their applications in sensing and microscopy. One remarkable outcome of this research has been the discovery that frequency combs can be generated in optical microresonators via nonlinear optical processes (P Del’Haye *et al*, *Nature* **450**, 1214, 2007). Only one cw laser source is necessary to generate a large number of optical sidebands with exactly defined frequency spacing. Such “micro-comb” generators could find applications in trace gas sensing, astronomical spectrograph calibration, arbitrary waveform generation and telecommunications. The technique has been patent-protected

and is being explored for commercial use. It is also widely studied in research laboratories, in particular its extension to new spectral domains such as the mid-infrared (A Schliesser, N Plaque, T W Hänsch, *Nature Phot.* **6**, 440, 2012).

Dr Schliesser has also investigated the coupling of optical fields to micro- and nanomechanical oscillators. His work led to the observation of radiation-pressure induced laser cooling of mechanical modes (A Schliesser, P Del’Haye, N Nooshi, K J Vahala, T Kippenberg, *Phys. Rev. Lett.* **97**, 243905, 2006) and to the first demonstration of cooling in the resolved-sideband regime (A Schliesser, R Rivière, G Anetsberger, O Arcizet, T J Kippenberg, *Nat. Phys.* **4**, 415, 2008). Later he guided the team that first observed the effect of optomechanically induced transparency (S Weis *et al*, *Science* **330**, 1520, 2010). With his colleagues, he also showed that optomechanical coupling can be made stronger than the decoherence rates of the mechanical and optical degrees of freedom (E Verhagen, S Deleglise, S Weis, A Schliesser, T J Kippenberg, *Nature* **482**, 63, 2012).

In his present position he leads a small team geared toward experiments in optomechanics. This team, in collaboration within QUANTOP, the Danish Technical University, and Maryland’s Joint Quantum Institute, has demonstrated a proof-of-principle transducer of radio-frequency signals to the optical domain via a nanomechanical device (T Bagci *et al*, *Nature* **507**, 81, 2014). Such transducers enable optical measurements of RF and microwave signals and could deliver a significant boost of the sensitivity with which such measurements can be made, potentially down to the quantum level.

## ICO congratulates the ICTP on its 50th Anniversary



Roy J Glauber, Nobel Laureate, at ICTP’s 50th anniversary event. Courtesy of the ICTP.

The Abdus Salam International Centre for Theoretical Physics celebrated its 50th anniversary with a four-day academic event from 6–9 October.

The extraordinary success of the ICTP on forging international scientific cooperation and promoting scientific excellence in the developing world was recognized by more than 250 distinguished scientists, along with the representatives of the ICTP Governing bodies, namely, Mario Giro from the Italian Ministry of Foreign Affairs, Irian Bokova, the Director General of UNESCO, and Yukiya Amano, Director General of the International Atomic Energy Agency (IAEA), and local and regional Italian authorities. The highlight was the participation of H E Paul Kagame, President of Rwanda, HRE Prince El Hassan bin Talal of Jordan, and three Nobel Laureates: David Gross, Carlo Rubbia, and Roy J Glauber, the

“father of quantum optics”.

The ICO has been supporting the ICTP activities on optics and photonics for more than 15 years. In 2000 the ICTP Sarwar Razmi Prize in Optics, created by Gallieno Denardo in 1993, was replaced by the joint ICO/ICTP award, which was renamed in September 2007 as the ICO/ICTP Gallieno Denardo Award to honor the memory and legacy of the late Prof. Gallieno Denardo, who strengthened the optics and photonics activities initiated at the ICTP by its first director, Abdus Salam, in lasers and optical fibre communications.

ICO’s then Secretary General, Pierre Chavel, was an enthusiastic supporter of Gallieno Denardo’s initiative to create the Trieste System in Optical Sciences and Applications Advisory Group (TSOSA), which meets annually during the ICTP Winter College on Optics and Applications and advises ICTP on capac-

Fernando Quevedo (left), Director of the ICTP receives a commemorative Plaque from ICO's Vice-president Joseph Niemela (right).



ity building and research activities in optics and photonics. Chavel served as the first Chair of the TSOSA. Since 2009, Angela Guzmán (current ICO Secretary General) has chaired the group.

In April 2013, the TSOSA group celebrated its 10th anniversary and participated at the First International Planning Meeting of the International Year of Light 2015, a special meeting held at the ICTP and reported in the *ICO Newsletter 95*, April 2013.

ICO launches <http://luz2015.org>, the Iberian American webpage for the International Year of Light (IYL), which is available for posting information on local and regional events in celebration of the IYL, short articles, videos and other material in Spanish and Portuguese. Please send information that you want to be posted to the ICO Secretariat, including URL addresses of local web pages to be linked.



INTERNATIONAL  
YEAR OF LIGHT  
2015

## Contacts

International Commission for Optics (e-ico.org).

### Bureau members (2014–2017)

**President** Y Arakawa

**Past-president** D T Moore

**Treasurer** J A Harrington

**Secretary** A M Guzmán, CREOL, The College of Optics and Photonics, University of Central Florida, e-mail angela.guzman@creol.ucf.edu

**Associate secretary**

G von Bally

**Vice-presidents, elected**

J Harvey, F Höller, H Michinel, J Niemela, R Ramponi, S-H Park, J Zakrzewski, M Zghal

**Vice-presidents, appointed**

Y J Ding, J C Howell, S Morgan, E Rosas, P Urbach, A Wagué, M J Yzuel

**IUPAP Council representative**

C Cisneros

**Editor in chief** A M Guzmán

**Editorial committee**

W T Rhodes, Florida Atlantic University, K Baldwin, Australian National University, Australia; J Dudley, Université de Franche-Comté, France



## Forthcoming events with ICO participation

Below is a list of 2015 events with ICO participation. For further information, visit the new ICO webpage at <http://e-ico.org/node/103>.

### 9–20 February 2015 Winter College on Optics

Trieste, Italy

Contact: Joe Niemela

tel: +39-040-2240555

smr2691@ictp.it

### 20–22 February 2015 International Conference on Optics and Photonics (ICOP 2015)

Calcutta, India

Contact: Kallol Bhattacharya

tel: +91-9830443256

khattacharya@gmail.com

[www.icop2015.com](http://www.icop2015.com)

### 15–21 March 2015 Lighting UP Africa with lasers, optics, and fibres (LUPA'2015)

Carthage, Tunisia

Contact: Mourad Zghal

tel: +216- 71857000 (#1025)

[mourad.zghal@supcom.tn](mailto:mourad.zghal@supcom.tn)

<http://tunisia-optics.org/events/lighting-up-africa-2015>

### 8–12 April 2015 Discussions on Nano & Mesoscopic Optics (DINAMO-2015)

El Chalten, Argentina

Contact: Andrea Bragas

tel: +541145763426,

[bragas@df.uba.ar](mailto:bragas@df.uba.ar)

<http://dinamo2015.df.uba.ar/>

### 14–16 April 2015 International Conference on Optical and Photonic Engineering (icOPEN 2015)

Singapore

Contact: Anand Asundi

tel: +65-67905936

[d-cole@ntu.edu.sg](mailto:d-cole@ntu.edu.sg), [www.icopen.com.sg](http://www.icopen.com.sg)

### 29 June – 2 July 2015 Education and Training in Optics and Photonics (ETOP 2015)

Bordeaux, France

Contact: Elisabeth Boéri

tel: +33 5 57 01 74 00

[contact@etop2015.org](mailto:contact@etop2015.org)

<http://etop2015.u-bordeaux.fr>

### 14–18 September 2015 Twelfth International Conference on Correlation Optics “Correlation Optics ’15”

Chernivtsi, Ukraine

Contact: Oleg V Angelsky

tel: +380372244730; fax: +380372244730

[angelsky@itf.cv.ua](mailto:angelsky@itf.cv.ua)

[www.itf.cv.ua/corrupt15/](http://www.itf.cv.ua/corrupt15/)

Responsibility for the correctness of the information on this page rests with ICO, the International Commission for Optics; <http://www.e-ico.org/>. *President*: Prof. Yasuhiko Arakawa, Director, Collaborative Institute for Nano & Quantum Information Electronics, University of Tokyo, Japan, [arakawa@iis.u-tokyo.ac.jp](mailto:arakawa@iis.u-tokyo.ac.jp). *Associate Secretary*: Prof. Gert von Bally, Centrum für Biomedizinische Optik und Photonik, Universitätsklinikum Münster, Robert-Koch-Straße 45, 48149 Münster, Germany; [bally@uni-muenster.de](mailto:bally@uni-muenster.de)