Reflecting on the International Year of Light and light-based technologies

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The United Nations designated International Year of Light (2015) has just concluded with a formal closing ceremony in Mérida, Mexico. We shall reflect on the origins of this International Year and its activities.

Keywords: International Years, light-based technologies, optics and photomics, outreach programmes.

THE International Years are year-long observances on certain issues of international interest or concern. Such years are generally established by international bodies such as the United Nations (UN), United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Health Organization (WHO); among others. The first International Year was the World Refugee Year (1959) in the context of refugees and migration after the Second World War. The science-related years include: the International Health and Medical Research Year (1960), the World Year of Physics (2005), the International Year of Astronomy (2009), the International Year of Chemistry (2011) and the International Year of Sustainable Energy for All (2012). It is interesting to note that there is yet be an International Year of Mathematics! Year 2014 was designated the International Year of Crystallography[1] and 2015 as the International Year of Light and Light-based Technologies (IYL2015). Year 2015 was also the International Year of Soils. Year 2016 is the International Year of Pulses. The mechanism of vision and the very nature of light have fascinated human beings since antiquity, and continue to this day. Light-based technologies have impacted all facets of life: revolutionized medicine through novel diagnostic equipment, enabled the extraordinary communication networks via the internet, and will continue to play a decisive role in the development of global society. Technologies based on optics are expected to address the hurdles to sustainable development by providing solutions to the problems related to energy, illiteracy and areas related to agriculture and health. Hence, the year 2015 was proclaimed as the United Nations International Year of Light and Light-based Technologies[2–4] (Figure 1).

The origins of the International Year of Light can be traced to Italy. This is not surprising, as we shall recall that many international endeavours had their genesis in Italy. The relevant examples include CERN, the European Organization for Nuclear Research[5]; ICTP, the Abdus Salam International Centre for Theoretical Physics[6], and ESA, the European Space Agency[7]. On 16 September 2011, the Società Italiana di Fisica (SIF, the Italian Physical Society) and the European Physical Society (EPS) jointly hosted a workshop ‘Passion for Light’, in Varenna, Lake Como, Italy[8]. It was during this meeting that the IYL project was officially launched. This historic meeting had press releases in English and Italian along with the Prospectus for the proposed International Year of Light. Luisa Cifarelli of the Istituto Nazionale di Fisica Nucleare (INFN, the National Institute of Nuclear Physics) and the University of Bologna served as the Chair of the Steering Committee. Cifarelli was then serving as the president of SIF and EPS. So, it was under her leadership that the EPS presented the case of the IYL, in November 2011, to the International Union of Pure and Applied Physics (IUPAP) during its General Assembly in London, UK. IUPAP readily endorsed and made a case for a formal request to the United Nations (UN) through UNESCO[9]. This put IYL on a steady track. Finally, the year 2015 was proclaimed as the International Year of

Figure 1. Logo of the International Year of Light (courtesy: IYL2015 Steering Committee).

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Light and Light-based Technologies on Friday, 20 December 2013, during the 71st Plenary Meeting of the UN General Assembly's 68th Session. This proclamation was a result of the efforts of numerous optics and photonics-related organizations across the globe. At the time of the proclamation, the IYL had about 100 partners from about 85 countries, accompanied by the much needed support of the UNESCO's International Basic Sciences Program. A historical account of the events leading to IYL2015 can be found in Dudley[10].

Reflecting back, it is interesting to note that the first draft[11] (dated 26 September 2012) prepared by the UNESCO Executive Board (for submission to the UN towards proclaiming 2015 as the International Year of Light) did not include Ibn al-Haytham. This first draft stated: 'The year 2015 commemorates a remarkable series of important milestones in the history of the science of light dating back 200, 150, 100 and 50 years. In 1815, Fresnel in France introduced the theory of light as a wave; in 1865, Maxwell in England described the electromagnetic theory of light; in 1915, Einstein in Germany developed General Relativity which confirmed the centrality of light in both space and time; and in 1965, Penzias and Wilson in the United States discovered the Cosmic Microwave Background, an echo of the creation of the universe. Celebrating the scope of these milestones in 2015 will provide a tremendous opportunity for educational activities worldwide.'

Ziad Aldrees (Ambassador and Permanent Delegate of the Kingdom of Saudi Arabia to UNESCO) was instrumental in getting Ibn al-Haytham on-board. Aldress mentioned his efforts in this direction during the inaugural session of the UNESCO September 2015 event on Ibn al-Haytham[12]. It is also to be noted that the aforementioned draft did not have 'Light-based Technologies' in the title of the year. The later drafts had the familiar and longer title along with reference to the year 1015 marking the millennial anniversary of *Book of Optics* (*Kitāb al-Manāzir*, the seven volume encyclopedia written by Ibn al-Haytham). IYL2015 provided ample coverage to Ibn al-Haytham and Medieval Arab contributions to optics in general[13]. An event highlighting these ancient works was held at the UNESCO Headquarters in Paris, France[12]. IYL2015 would have been an ideal occasion to recognize Abu Said al-Ala Ibn Sahl (940–1000) for his contribution to optics. Ibn Sahl was the mentor of Ibn al-Haytham and worked in the Abassid court in Baghdad. He is the originator of the laws of refraction of light; this is evident by the detailed description in his voluminous book, *On the Burning Instruments* (*Kitāb al-Parraqāt*) written in 984 (refs 14–21).

The year 2015 has other anniversaries as well. In the year 1615, the French engineer Salomon de Caux demonstrated a solar-powered engine using light reflectors and lenses. Charles Kao demonstrated optical communication by transmitting light through optical fibres in 1965. This earned Kao the 2009 Nobel Prize in Physics. In 1989–90, Jagannathan *et al.*[22] derived the focusing action of a magnetic lens *ab initio* using the Dirac equation. This gave birth to the quantum theory of charged-particle beam optics[22]. Using Jagannathan's 1990 blueprint[23], the quantum theory of aberrations was developed using the Klein–Gordon and the Dirac equations respectively[24,25], with applications in electron microscopy and accelerator optics. It was shown that the quantum framework provides a unified treatment of the beam optics and the spin dynamics of a Dirac particle[26]. These works eventually led to the first doctoral thesis under the supervision of Jagannathan[27]. The experience of the quantum theory of charged-particle beam optics initiated by Jagannathan and co-workers led to the prescriptions of light beam optics using 'quantum methodologies'. The reasons are as follows. The scalar optics is governed by the Helmholtz equation, which is algebraically similar to the Klein–Gordon equation[28,29]. In the case of vector optics, the beam-optical Hamiltonian is derived from an exact matrix representation of the Maxwell's equations, which has an algebraic structure similar to the Dirac equation[30]. Exploiting these similarities, it has been possible to apply quantum methodologies in light beam optics. The Foldy–Wouthuysen transformation is a crucial technique in both the cases respectively[31,32]. The resulting beam-optical Hamiltonians have wavelength-dependent contributions in both the scalar[28,29] and vector[33,34] cases respectively. These non-traditional prescriptions of Helmholtz optics and Maxwell optics have wavelength-dependent contributions, which in the limit of low wavelength reproduce the traditional prescriptions of light beam optics. This is analogous to the classical limit of quantum prescriptions. Moreover, in the vector case, we obtain a unified description of beam optics and light polarization[35]. The quantum theories of charged-particle beam optics and the non-traditional prescriptions of light beam optics strengthen the Hamilton's opto-mechanical analogy, by showing that it persists in the wavelength-dependent regime[32,36]. Let us recall that the medieval Arab scholars had actively worked in optics. The opto-mechanical analogy can now be traced to Ibn al-Haytham (965–1037)[37,38]. But it was Hamilton, who in 1833 examined the trajectories of material particles in various potential fields and compared them with the paths of light rays in a media with varying refractive index. Thus, it was Hamilton who laid a rigorous mathematical foundation to the opto-mechanical analogy. This played an important role in the early years of the classical theories of charged-particle beam optics. In 1926, Hans Busch used the analogy to develop an electromagnetic lens, leading to the invention of the electron microscope by Ernst Ruska in 1931. In the 1920s, the opto-mechanical analogy influenced the development of quantum mechanics. These historical aspects of the analogy were widely covered in the just concluded International Year of Light. IYL2015 would have been an excellent opportunity to

Table 1. National nodes of the International Year of Light and Light-based Technologies

Participating countries (94)	
A	Algeria; Andorra; Argentina; Armenia; Australia; Austria
B	Bangladesh; Belgium; Bolivia; Bosnia and Herzegovina; Brazil; Bulgaria
C	Cameroon; Canada; Chile; China, Hong-Kong; China, Taipei; Colombia; Costa Rica; Croatia; Cuba; Cyprus; Czech Republic
D	Denmark; Dominican Republic
E	Ecuador; Egypt; El Salvador; Estonia
F	Fiji; Finland; France
G	Germany; Ghana; Greece
H	Honduras; Hungary
I	Iceland; India; Indonesia; Iran; Iraq; Ireland; Israel; Italy
J	Japan
K	
L	Latvia; Liberia; Lithuania
M	Malaysia; Mauritius; Mexico; Mongolia; Morocco
N	Nepal; Netherlands; New Zealand; Nigeria; Norway
O	Oman
P	Pakistan; Panama; Peru; Philippines; Poland; Portugal; Puerto Rico
Q	Qatar
R	Republic of Korea; Republic of Moldova; Romania; Russia
S	Saudi Arabia; Senegal; Serbia; Singapore; Slovakia; Slovenia; South Africa; Spain; Sudan; Sweden; Switzerland
T	Thailand; Tonga; Tunisia; Turkey
U	United Arab Emirates; United Kingdom; United States of America; Uruguay
V	Venezuela; Vietnam
Y	
Z	

cover the accelerator-based light sources such as synchrotron-radiation sources and free-electron lasers. This is particularly relevant as accelerator-based light facilities require huge funding, possible by government patronage and optimum technical expertise[39–41].

IYL2015 received a lot of recognition from numerous quarters, including prize-awarding committees. The 2014 the Nobel Prize in Physics was awarded to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for the creation of efficient blue light-emitting diodes, which has enabled a new generation of bright and much sought after energy-efficient white lamps[42]. Super-resolved fluorescence microscopy pioneers, Eric Betzig, Stefan Walter Hell and William Esco Moerner received the 2014 Nobel Prize in Chemistry[43]. Thus optics was the central theme of the 2014 Nobel Prizes in Physics and Chemistry, which is a rare occurrence. In 1964, the Physics Prize was awarded to Charles Hard Townes, Nicolay Gennadiyevich Basov and Aleksandr Mikhailovich Prokhorov for masers and lasers. In the same year, the Chemistry Prize was awarded to Dorothy Crowfoot Hodgkin 'for her determinations by X-ray techniques of the structures of important biochemical substances'. Two Nobel Prizes in optical sciences (announced in October 2014) in as many days was a fitting kickoff to the International Year of Light. Even the 2015 King Faisal International Prize for Chemistry was related to optics, as it was awarded to Michael Grätzel for his pioneering work on the development of photoelectrochemical systems for solar energy conversion[44]. These coincidences received a hearty welcome by the optics community. The inaugural Mustafa Prize (launched by Iran in December 2015) was awarded to Jackie Yi-Ru Ying and Omar Mwannes Yaghi for nanostructured materials. Their works have implications on the photonics technologies[45]. This was another fitting tribute to the year-long celebrations of light.

By proclaiming an International Year of Light, the UN has recognized the important role played by light and light-based technologies. IYL2015 has raised global awareness about light-based technologies and how they can assist in combating poverty, illiteracy and achieving sustainable development. Light is interdisciplinary and plays a crucial role in frontiers of science and technologies impacting our lives. The International Year of Light and Light-based Technologies had a formal opening ceremony at the UNESCO Headquarters in Paris, France, during 19–20 January 2015. IYL2015 was officially closed with a three-day closing ceremony in Mérida, Mexico[2]. Both the ceremonial events had speakers and attendees comprising Nobel laureates, CEOs, science and industry leaders, international diplomats and decision-makers, and media personnel from across the globe[2].

The International Year of Light and Light-based Technologies was an enormously successful large-scale initiative leading to over 5000 activities such as arts and science conferences, arts and science projects, exhibitions, laser shows, active learning workshops and festivals. Some of the aforementioned activities were also conducted in schools and rural areas across the world. These activities were attended by millions in about a 100 countries. United by the interdisciplinary theme of light, IYL2015 brought together a diverse range of participants in concert with UNESCO, all committed to raising awareness of how light science and technologies can provide solutions to the many challenges facing the world today. The potential legacies of IYL2015 include the proposal to have UN-designated International Day on Light and Light-based Technologies[46]. At the same time, it is to be noted that IYL2015 had only 94 national nodes (Table 1), which organized local campaigns, activities and events. It is to be recalled that UNESCO has 195 Member States and 10 Associate Members.

From the table it is evident that more than half the countries did not participate in IYL2015. These countries account for about three-quarters of the world population of over 7 billion. It is to be noted that 1.1 billion people do not have access to electricity, and are consequently using traditional means for light. The absence of several populous countries, points to the limitations of the optics community and the scientific community at large. IYL2015 had the distinct advantage, as it was endorsed by numerous international scientific unions, including the International Council of Science. Moreover, it was administered in collaboration with UNESCO's 'International Basic Sciences Programme', with the Global Secretariat at ICTP in Trieste, Italy. Light science is undoubtedly one of the most accessible themes to promote interdisciplinary education, and industrial collaboration. It is to be noted that ICTP is a UNESCO Category 1 Institute, well-known for its flourishing outreach programmes. But even that did not induce the much anticipated wider participation from the developing countries from Africa, Asia, Middle East and South America. Many of the 94 enlisted countries did not actively participate. This is evident by the small number of programmes registered by the national nodes in the calendar at the IYL2015 website. It also points to the weakness of the learned societies and government organizations, which have failed to work together. Even the central theme of light, without which civilizations could not exist, has failed to operate on a larger scale. It is time for the founding fathers of IYL2015 and the numerous organizers to reflect on this state of affairs. This aspect of inadequate participation needs to be examined by the organizers of the upcoming international years and other vehicles of outreach programmes.

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