LASERS AND ELECTRO-OPTICS
RESEARCH AND TECHNOLOGY

Tanya Scott
Editor

Advances in Photonics Engineering, Nanophotonics and Biophotonics

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ADVANCES IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS

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PREFACE

Light-based technologies have revolutionized medicine and opened up international communication via the Internet, and will continue to underpin the future development of human society. The science of light is applied in a technological field known as photonics, and this theme addresses the important ways that photonic devices impact areas such as medicine, communications and energy. The everyday gadgets in our lives such as DVDs, barcode scanners, smart phones, flat screen televisions are all based on photonics. Chapter One of this book discusses 2015 as the "International Year of Light" as declared by the United Nations, and provides a history of optics. Chapter Two describe the current state-of-the-art in reliability studies of both GaN electronic and photonic devices. Chapter Three studies the radiation effects in GaN-based materials and optoelectronic devices.

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Chapter 1

INTERNATIONAL YEAR OF LIGHT AND HISTORY OF OPTICS

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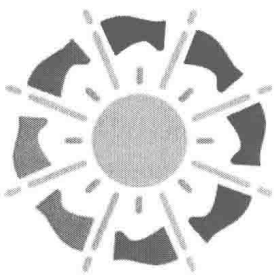

Abstract

The United Nations declared 2015 as the International Year of Light and Light-based Technologies. The yearlong celebrations are stimulating worldwide interest in light and related sciences and technologies. The role of light and associated technologies in our lives is described in detail. The year 2015 marks the 1000th anniversary since the appearance

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of the remarkable seven volume treatise on optics written by the great Arabic scientist Ibn al-Haytham. This Chapter traces the history of optics from the ancient civilizations. A detailed account of the medieval Arab contributions to optics and related sciences is presented. The impact of the Medieval Arab sciences on the European renaissance is also covered briefly. An outline of the history of modern optics is also presented.

Keywords and phrases: International Year of Light, Greek Optics, Arab Optics, Modern Optics

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1. Introduction

The international years are year-long observances (also known as dedication) to observe certain issues of international interest or concern. These are used to commemorate, promote and mobilize for action. Many of these years have been established by the United Nations General Assembly (UN); Economic and Social Council; United Nations Educational, Scientific and Cultural Organization (UNESCO); World Health Organization (WHO); and other United Nations bodies including the International Telecommunication Union (ITU); Food and Agriculture Organization of the United Nations (FAO); World Intellectual Property Organization (WIPO); United Nations Environment Programme (UNEP); International Maritime Organization (IMO); and the International Civil Aviation Organization (ICAO). Here, we shall cite some of the years observed under the auspices of the United Nations. The first year was the World Refugee Year (1959) in the contexts of the refugees and migration after the Second World War. The science related years include: the International Health and Medical Research Year (1960); the International Year of Physics (2005); the International Year of Astronomy (2009); the International Year of Chemistry (2011); 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 the International Year of Crystallography [1]-[3]. 2015 has been proclaimed as

the International Year of Light and Light-based Technologies (**IYL2015**). Year 2016 is the International Year of Pulses.

The mechanism of vision and the nature of the accompanying light have fascinated the human race since ancient times, and continue to this day. The greatest minds in each civilization worked on it. At a very basic level, light provides us vision. At the molecular level, light is used by plants for photosynthesis. The animal kingdom needs some amount of sunlight to synthesize the essential vitamin D in the skin. Light-based technologies have revolutionized medicine and opened up international communication via the Internet, and will continue to underpin the future development of human society. The science of light is applied in the technological field known as photonics, and this theme addresses the important ways that photonic devices impact on areas such as medicine, communications and energy [4]. The everyday gadgets in our lives such as the DVDs, barcode scanners, smart phones, flat screen televisions are all based on photonics the science of light-based technologies. When harnessed, the light-based technologies can promote sustainable development and provide solutions to global challenges in energy, education, agriculture, health and well-being. Hence, the United Nations proclaimed 2015 as the *International Year of Light and Light-based Technologies* (see [5]-[12] for details). We note the quotations from 1999 Chemistry Nobel Laureate Ahmed Zewail [13] of the California Institute of Technology:

> Civilization would not exist without light; light from our Sun and light from the focused and coherent lasers which now have become an important part of our daily lives-from scanning packages at supermarkets, to eye surgery, and to IT communications across oceans.
>
> The International Year of Light will surely raise awareness of these powerful discoveries and their present wide-ranging, light-based technologies which are significant contributors to the world market. As importantly, the International Year of Light will inspire future discoveries and applications for one of the most important element of our existence: light.

Light is electromagnetic radiation within a certain portion of the very wide electromagnetic spectrum, which is visible to human eyes. The interdisciplinary fields of light sciences and radiation sciences are intimately interlinked through the common thread of the electromagnetism. The mechanisms of detection and handling of course differ, when one is using visible sources, lasers, X-Rays or synchrotron radiation. The underlying mechanisms of production of the aforementioned sources of radiation differ dramatically. Oil lamps of antiquity have been replaced by the electrically heated filaments in evacuated bulbs. Lasers provide us highly coherent light. The X-Rays are produced by the collision of energetic electrons with tungsten or other surfaces. Different source serve different purposes. X-Rays are one of the most widely used tools to understand the structure of matter. It is a century since, it was discovered that crystals could diffract X-Rays, a finding that helped revolutionize our ability to visualize matter at the atomic scale. It was found that X-Rays can be used to determine accurately the positions of atoms within a crystal and thus unravel its three-dimensional structure. This discovery has contributed hugely to the modern development of all the natural sciences, because atomic structure governs chemical and biological properties of matter, and the crystal structure determines most of its physical properties. The insights gained from the structure of matter have impacted chemistry, solid state physics, biology and medicine. This has resulted in synthesis of novel materials, new drugs and our understanding of the structure of proteins and DNA. The United Nations adopted that 2014 be the *International Year of Crystallography* (**IYCr2014**). This was to commemorate the centennial of X-Ray diffraction and related discoveries [1]-[3].

Many path breaking discoveries in physics, chemistry and medicine have been made using light and X-Rays as a basic tool [14, 15]. At least twenty-three have been awarded with Nobel Prizes for work involving the X-Rays, with the distribution, Physics: 8; Medicine: 5; and Chemistry: 10. The count can be up to twenty-nine depending upon the algorithm used [16, 17]. The scope of the crystallographic studies has been extended by using electron, neutron and other particle beams in place of X-Rays. The underlying mechanisms differ but the resulting diffraction patterns are analyzed by similar procedures based on coherent diffraction imaging techniques. The different works arising from microscopy; laser applications; and photonics also have substantial figures for the Nobel Prizes respectively.

The Section-2 of this Chapter has a detailed account leading to the International Year of Light and Light-based Technologies. Section-3 covers the his-

tory of optics from the ancient civilizations. Section-4 is on the Medieval Arab Contributions to Optics. Section-5 has an outline of the modern era in optics. Section-6, the last section has our concluding remarks. Across the sections we shall highlight the research of recent and contemporary science historians who have shed new light on certain historical aspects, particularly the Arab contributions to optics. We shall also highlight the role of translations, which enabled the spread of knowledge from one civilization to the other. Finally we have the Appendix-A, which is on the International Working Group "Ibn al Haytham" (IWG).

2. International Year of Light and Light-Based Technologies

The origins o the International Year of Light (IYL2015) 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 [18]; ICTP: the Abdus Salam International Centre for Theoretical Physics [19, 20]; and ESA: the European Space Agency [21, 22]. The IYL Project was officially launched during the aptly named workshop, *Passion for Light*, held on 16 September 2011 in Varenna, Lake Como, Italy [23, 24]. This historic workshop was jointly sponsored by the European Physical Society and the Società Italiana di Fisica (SIF, the Italian Physical Society). It is to be noted that this historic meeting provided the Prospectus for the International Year of Light and the accompanying press releases in English and Italian. Luisa Cifarelli of the University of Bologna and the Istituto Nazionale di Fisica Nucleare (INFN, the National Institute of Nuclear Physics) served as the Chair of the Steering Committee. She was then the president of both EPS and SIF. In her leadership, the EPS led a delegation to the International Union of Pure and Applied Physics (IUPAP) during its General Assembly in London in November 2011. The endorsement from IUPAP paved the way for the organizers to prepare a formal request to the UN through UNESCO [24]. Thereafter, the IYL was on track. A brief history of the International Year of Light is available by John M. Dudley, Chairman of the IYL2015 Steering Committee [25].

A resolution welcoming and endorsing an International Year of Light in 2015 was adopted by the UNESCO Executive Board at its 190th session, which

took place at the UNESCO Headquarters in Paris from the 3-18 October, 2012 (see Table 1 for details). UNESCO formally submitted the resolution to the UN on 6 November 2013. On Friday the 20th of December 2013, during the 71st Plenary Meeting of the UN General Assembly 68th Session, 2015 was proclaimed as the *International Year of Light and Light-based Technologies*. The move has been lauded by a number of scientific societies and institutes. The IYL2015 partnership is a cross-disciplinary educational and outreach project with more than 100 partners from more than 85 countries, accompanied by the UNESCO International Basic Sciences Program. It is an effort of several years and the persuasion of the numerous optics-related organizations, which eventually lead to the proclamation. The text of the resolution, which was adopted as a part of a more general agenda item on science and technology for development, stated [5]-[10]:

> Applications of light science and technology are vital for existing and future advances in medicine, energy, information and communications, fiber-optics, astronomy, architecture, archaeology, entertainment and culture.

Reflecting back, it is interesting to note that the first draft (dated 26 September 2012) prepared by the UNESCO Executive Board (for submission to the United Nations for proclaiming 2015 as the International Year of Light) did not have Ibn al-Haytham in it [26]. 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. Aldrees mentioned his efforts in this direction during the inaugural session of the

Table 1. Rationale and Goals of an International Year of Light

Rationale and Goals of an International Year of Light

UNESCO Executive Board 26 September 2012

An International Year of Light will

1. improve public understanding of how light and light-based technologies touch the daily lives of everybody, and are central to future global development;
2. build worldwide educational capacity through activities targeted on science for young people, help address issues of gender balance and focus in particular on developing countries and emerging economies;
3. promote the importance of light-based technology in sustainable development particularly in healthcare, agriculture and communications so as to enable access to educational opportunities and for improving the quality of life worldwide;
4. promote awareness of the interdisciplinary nature of twenty-first century science, and emphasize how interactions between different thematic areas of science will be increasingly needed in future research and education;
5. highlight and explain the intimate link between light and art, enhancing the increasing role of optical technology in the preservation of cultural heritage;
6. enhance international cooperation by coordinating activities between learned societies, educational establishments and industry, focusing specifically on new partnerships and initiatives in the developing world;
7. establish durable partnerships to ensure that these activities, goals and achievements continue in the future beyond the International Year of Light.

UNESCO September-2015 event on Ibn al-Haytham. (this event shall be described in detail in Appendix-A). 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 Kitab al-Manazir (the *Book of Optics*, running into seven volumes written by Ibn al-Haytham, which shall be covered in detail in Section-4 on Arab optics).

The International Year of Light has created an ideal forum for scientists and engineers and all others inspired by light, to interact both with each other and with the public so as to learn more about the nature of light and its many applications. IYL2015 is a tremendous opportunity to ensure that policymakers are made aware of the problem-solving potential of light technology. As light becomes the key cross-cutting discipline of science and engineering in the 21st century, it is essential that the brightest young minds continue to be attracted into careers in this field. The *Opening Ceremony* of the International Year of Light and Light-based Technologies 2015 was held during 19-20 January 2015 at UNESCO Headquarters in Paris, France. The two-day event gathered over a thousand participants comprising international diplomats and decision-makers, Nobel laureates and science and industry leaders from across the globe [27]. The *Closing Ceremony* is scheduled to be held during 4-6 February 2016 in Mérida, Mexico [27].

Light is one of the main messengers in our understanding of the world around us, from the subatomic to the universe at large. The history of the study of light spans millenniums, and has involved virtually all the major figures of science. The year 2015 commemorates a remarkable series of important milestones in the history of optics. A number of major scientific anniversaries will be celebrated in 2015, starting with the early work on optics by the Islamic scholar Ibn al-Haytham in 1015 [28]. The French engineer Salomon de Caux invented a prototype solar-driven engine using lenses and reflectors in 1615. The notion of light as a wave was proposed by Fresnel in 1815; the electromagnetic theory of light propagation proposed by Maxwell in 1865; Einstein's theory of the photoelectric effect in 1905; Einstein's embedding of light in cosmology through general relativity in 1915; the discovery of the cosmic microwave background by Penzias and Wilson in 1965; and Charles Kao's achievements in 1965 concerning the transmission of light in fibers for optical communication. Electron spinor optics was initiated by Jagannathan, Mukunda, Simon and Sudarshan in 1989/1990 (Electron optics or charged-particle beam optics has