

Editorial

Photonics—Advances in Fundamental Sciences and Engineering Technologies of Light

Nelson Tansu

Founding Editor-in-Chief of Photonics, Center for Photonics and Nanoelectronics, Department of Electrical and Computer Engineering, Lehigh University, Bethlehem, PA 18015, USA;
E-Mail: Tansu@Lehigh.Edu; Tel.: +1-610-758-2678

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Photonics is a field of sciences that focuses on the pursuit of the understanding basic properties of light, the interaction of light with materials, the fundamental concepts and technologies for generating and controlling the properties of light, the concept and technologies for transmitting and signal processing of light, the engineering of these technologies for manipulating light applicable for systems implementation. The optical light covers the electromagnetic radiation from X-ray, deep ultraviolet, ultraviolet, visible, infrared, and terahertz spectral regimes. Optical sciences is one of the earliest and most important areas of study in physical sciences. The successful understanding of wave optics within the Maxwell's electromagnetism theory has resulted in the development of physical optics [1,2], and its impact has penetrated areas in other disciplines including chemical and biological sciences, engineering and technology, and medical sciences. The birth of quantum theory emanated from the understanding of the discrete energy of light by Planck and Einstein, and understanding of discrete energy levels in atoms was also attributed to understanding the interaction of light and matter. Quantum electrodynamics and quantum optics formed the basis of the advanced theory of light-matter interaction. Today, fundamental concepts from photonics and optics have been widely implemented in technologies addressing substantial challenges in such fields as communications, medical and health sciences, energy efficiency and renewable energy, homeland security and defense, environmental and sustainable living, among others.

Advances in photonics and optics encompass both experimental and theoretical findings in basic sciences, technology, and engineering of light. The advances in both disruptive and progressive technologies in photonics and optics have enabled the development of new technologies which have transformed our life and addressed significant challenges in society. The journal *Photonics* (ISSN 2304-6732) provides a platform to share knowledge, being an online open access journal covering both the fundamental theory and applications of optical sciences and photonics. *Photonics* strives to provide a means for authors to disseminate their scientific findings—both theoretical/simulations and

experimental works—in highly accessible peer-reviewed publications, in order to achieve a fast dissemination of high impact works within the scientific community. Several key advances in the photonics and optical sciences and engineering are listed below.

New optical imaging and optical coherence tomography methods in biomedical optics [3–6] have resulted in low cost and practical methods to detect cancer cells at an early stage. The development of new optical imaging and holography methods has also improved medical imaging technology [7]. Recent developments in optogenetics [8] have also provided a new technique using both optics and genetics to control and modify the responses of neurons in cells.

Developments in semiconductor epitaxy, materials, and new device concepts based on compound semiconductors, specifically III-V and III-Nitride, have revolutionized the progress in telecommunication lasers and solid state lighting technologies [9–22]. Further, the improved understanding in the fundamental properties of quantum-based active regions, with regard to nanostructures formed by III-V and III-Nitride semiconductors, has enabled the disruptive advance resulting in low-threshold laser diodes for telecommunication and display, and high efficiency light-emitting diodes for solid state lighting, respectively. Recent developments of X-ray free electron lasers, deep UV emitters, visible LEDs and lasers, infrared lasers, mid and far IR lasers, and terahertz lasers have received tremendous attention in recent years. Significant progress has also been achieved in the development of new device architectures for improved efficiency in solar cells, faster and more responsive photodetector technologies, and higher speed and lower cost optical modulators.

Research in the physics of semiconductors and nanostructures has enabled further progressive improvements of these devices which have resulted in practical technologies currently being implemented in our daily life. As an example, advances in material synthesis and epitaxy have resulted in the ability to analyze materials composition to atomic precision levels, resulting in the ability to modify and control the optical and optoelectronic properties in a transformational manner. Nanostructure engineering of the active regions has been implemented to achieve high efficiency LEDs and low threshold lasers. New quantum confined structures based on quantum cascade lasers have also been realized, and these works have resulted in progress towards achieving lasers emitting in the mid-IR up to terahertz spectral ranges. Tremendous potential exists in new materials, device concepts, and applications in semiconductor photonics and optoelectronics which are currently being created in new directions impacting energy, healthcare, communications, water purifications, and environments.

Advances in nanofabrication technology have resulted in the ability to form sub-wavelength structures for controlling the propagation of light waves in media. One of the most successful examples in the field of nanophotonics is related to the development of photonic crystal technologies [23–28], which have been widely implemented for controlling the photonic bandgap, enabling compact photonic integrated circuits, new optical device functionalities, and many other new applications. Recent progress has also focused on the development of nanophotonic structures based on sub-wavelength gratings [29,30] and self-assembled colloidal based arrays [31,32]. The pursuit—both in fundamental theory and application—of cavity optomechanics in nano electromechanical structures (NEMS) is also an exciting research area [33,34].

Advancements in the ability to form high quality quantum dot active media [35–38] have also provided new device functionalities for solar cells, lasers, and light emitting diodes. The integration of

quantum dot and nanophotonic technologies have recently shown promise in its future potential for enabling a practical solid-state based quantum computing device platform [39,40].

Plasmonics technologies and metamaterials have been among the most active research topics in the fields of optical sciences and engineering [41–47]. The new functionalities enabled by plasmonics based technologies are at the early stage with innovations only limited by the need for new ideas and creativities. The exciting field of plasmonics has provided many new directions in the field of optics.

One of the mainstays of photonics and optical sciences and engineering has been the devices and systems developed for fulfilling the requirements of optical communications [48,49]. The increasing demand in this regard has not been met by similar investments in development of new technologies. The innovations in low cost device technologies based on photonic integrated circuits [50–54] to fulfill the system-driven requirements in optical communication will remain an important area of research topics in optics. Nonlinear optics and ultrafast optics [55–59] remain exciting areas of research that could result in new fundamental concepts, new phenomena, and new device functionalities. Portable and compact terahertz sources had also been reported by using difference frequency generation [60].

The progress in computing power has escalated the importance of computational photonics, computational nanostructures, and physics and simulation of materials and optoelectronic devices [61–67]. The expensive experiments can be reduced or planned with lower iteration rate by having the improved computational models of materials, nanostructures, and device concepts. Advances in computational models of physical systems have already enabled very accurate prediction of electronics and optical properties of materials, nanostructures, devices, and integrated photonics devices.

Low cost silicon based photonics, graphene photonics, and flexible electronics/optoelectronics materials and devices [68–75] have tremendous potential for enabling low-cost sensors and medical therapeutic devices. Recent research in these fields have been very active, and progress has demonstrated the potential of these platforms for enabling their practical implementation.

The idea of splitting water via of the use of catalyst by using solar radiation to produce hydrogen fuel has been suggested and pursued for sometimes [76–78]. The key challenges in practical implementation of this concept require solutions that provide absorber materials appropriate for tandem cell designs, and structures with stable chemical properties under illuminated aqueous environment. The pursuit of appropriate materials and nanostructures will enable efficient conversion efficient for solar hydrogen, which has tremendous impacts for renewable energy and energy storage technologies.

Understanding of photon-electron-phonon interaction in nanostructures and materials still needs to be developed [79]. The rich new areas of fundamental research in this discipline will have tremendous impact in the thermal management, heat transfer, laser cooling, and thermoelectric areas.

In summary, the fields of photonics and optics have contributed tremendously in the development of new technologies resulting in transformational impact on society. Technologies anchored in the fundamental and innovative applications in photonics and optics have been integrated in daily life with transformational impacts in wide range of fields such as health care, communications, energy, environments, and homeland security. The progress in new material syntheses, engineered material designs, device structures, and systems implementations in photonics and optical sciences and engineering will continue to provide disruptive advances and progressive solutions for addressing key challenges in society.

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Conflicts of Interest

The author declares no conflict of interest.

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