LIGHT BASED TECHNOLOGIES FOR ENHANCED SUSTAINABILITY

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1. Preamble

Photonics is the science and engineering of generating, controlling, sensing and utilizing photons either in the form of waves or particles of light. Photonics encompasses gamma rays to radio waves of the electromagnetic spectrum. In photonic systems, information and process signals are conveyed as pulses of light generally through optical fibers. It is interesting to note: the light from the big bang phenomenon provided our astronomers with a vision to the origin of the universe; the spectrum of light based technologies from X-rays to IR lasers provides commercial and strategically important products and devices to our industry; the interaction of light with human body provide novel diagnostic and therapeutic tools to our doctors; and nano-photonics and quantum-optics have inspired our engineers to discover new devices and techniques that are so essential for developing new energy efficient systems. Insect wings which can absorb the entire visible light spectrum possess optical surfaces. The observations of nature have helped engineers to develop state of art camaflouging techniques for high security systems.

The scientific achievements in photonics have been well recognized and rewarded by a series of Nobel prizes awarded during 2005 to 2015. These include high speed optoelectronics, quantum theory of optical coherence, integrated circuits, optical frequency comb technique, light transmission through optical fiber communications, blue light emitting diodes and super resolved florescence microscopy. During 68th session of UN General Assembly on 20 December 2013, the year 2015 has been declared as the International Year of Light, which includes light-based technologies. The CAETS as the Premier Council of Engineering Academies of the world has decided to commemorate this event in a befitting manner during CAETS-2015 to be held at New Delhi in India from 12 to 17 October 2015.

2. Photonics Applications

From application point of view, light based technologies have contributed to sustainable development in energy, education, communication, agriculture, healthcare and a host of other domains. These technologies have been making a strong influence on commercial markets in several sectors of global economy; e.g., photonic products are currently worth USD 350 billion per annum with a projected market value of over USD 700 billion by 2020.

2.1 Energy, Mobility, Communications and Consumer Electronics

The recent developments in harnessing light based technologies for smart products are inspiring. A totally new approach to 3D printing has now emerged by employing a continuous liquid interphase production concept. It facilitates manipulation of light and oxygen to fuse objects in liquid media to produce 3D prints. Apart from the established uses of light pulses and advanced optical fiber cables in internet and satellite communications, solar cell technologies are making new waves in creating novel renewable energy systems for housing, transportation and a number of industrial sectors. A laser which can generate light as a focused beam at a miniscule target has

given birth to laser diodes which can light up millions of residential buildings, the entire ceiling of a large ball room or a public building. Photonics has been playing a major role in optical communications, optical pulses, commercial electronics, large screen televisions with 3D technologies, optical bandwidth to offer 4G and higher data rates in mobile communications, energy efficient optical interconnects, PCBs, metal marking systems and high power lasers for strategic applications. As stated earlier, the light emitting diodes (LEDs) have revolutionized the illumination of buildings and street lighting in terms of illumination power, energy utilization efficiency and longer life span. The smart buildings, highways and transportation concepts have enabled engineers to effect further energy reduction through photonics-based intelligent control systems. Even with the present state of advanced scientific and engineering knowledge, commercial solar panels are not able to convert on the average more than 17% of the sunlight incident on them. A larger efficiency of solar energy harvesting is being attempted by researchers using concentrated solar power onto the photovoltaics. Intense research is seen in this area. Two dimensional photonic materials including monolayers as insulators, photonic based road logistics in multimodal transport systems, control units in energy efficient road, rail, air and marine engines and as transport telematics are gaining industrial prominence. Another interesting application is in laser equipped wheel chairs used by the handicapped persons which employ video analytic system for navigation purposes.

2.2 Medical Diagnostics and Therapeutics

The developments in X-ray tomography (CT scan), magnetic resonance imaging (MRI) and ultrasonography have inspired photonics to peep inside the human body for diagnostic health monitoring and disease therapeutics. Photonic tools can image microstructure of living tissues with resolution down to . The laser light when coupled with thin optical fibres can be guided endoscopically to examine internal organs without any major incision. Employing low energy femto second pulse lasers, malignant melanomas are being identified for further treatment. Early cancer scanning, measuring bone strength, biomedical imaging and bio-sensing are other diagnostic applications of photonics. The cancer scanning systems employ spectrophotometry to detect the difference in pattern of light spectra scattered by charged nuclei of malignant cells as compared to normal cells. A laser based spectroscopy is employed to measure collagen density in bones. Techniques like optical coherent tomography (OCT) are being used for imaging the retinal nerve fiber layers and optic nerves. Photoacoustic tomography (PAT) employs ultrasound waves to generate 3D image of tissues. Efforts are being made in recent years to integrate spectroscopic and imaging techniques through optical micromanipulation for morphological measurement of cellular and sub-cellular objects. Development of microfluidic chips for performing diagnostic tests such as immune assays is another interesting development in which smart phones can be employed for remote operation.

Photo-activated drugs which are inert until photo excited by radiation of right wavelength are specifically used to target a tissue selectively. This field is emerging as photodynamic therapy. Delivery of light to deep-seated tumors is still a challenge owing to the photonic penetration limitations in human tissues. Photosensitizers conjugated with metal nano particles are being employed to inactivate antibiotic resistant bacteria to heal chronic wounds. Lasers in combination with non-coherent light are also employed for wound healing. The micro irradiation capabilities of lasers of appropriate wavelength, pulse duration and energy intensity are being employed in ultra-precise eye surgeries.

3. Critical Issues for CAETS Interactions on Light Based Technologies

A few advanced and emerging countries have established national Photonic Initiatives to raise knowledge based on photonics amongst the scientific community and mobilize investments for academic studies and applied research in areas of their national security, lower carbon energy, delivering healthcare and telecommunications. Most of these initiatives are driven by frontiers of science and innovations. There is scope for CAETS member academies to establish an inter-academy photonic engineering initiative. Photonics being an interdisciplinary area, it offers good prospects for inter academy initiative with science and medical academies. The fellows of the member academies are invited to make brief presentations at the CAETS Council meeting to be held on 15 October 2015 at New Delhi by covering one or more of the following issues:

- Status of photonics engineering in the member countries;
- Prospects for higher engineering education and advanced research in photonics;
- Areas of interest for inter-academy joint initiatives in photonics engineering and for strengthening engineering-science-medicine interphase;
- Incentives needed for Young Engineers to pursue research career in photonics engineering.
- Make photonic technologies to reach lower income citizens of the world - affordability with robustness;
- Nurturing young leaders of substance in photonics technology through initiative of CAETS.