Feature issue introduction: light, energy and the environment, 2015

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Abstract: The feature issue highlights contributions from authors who presented their research at the OSA Light, Energy and the Environment Congress, held in Suzhou, China from 2 to 5 November, 2015.

OCIS codes: (350.6050) Solar energy; (040.5350) Photovoltaic; (220.1770) Concentrators; (230.3670) Light-emitting diodes; (060.2370) Fiber optics sensors; (080.4295), Nonimaging optical systems; (140.0140) Lasers and laser optics.

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Sustainable future of the earth depends heavily on reliable supply of energy and preservation of its healthy environment. World-wide industrial development and continual urge for growth, however, make it very challenging to achieve these goals from both near- and long-term perspectives. What light can do to cope with these challenges is the key question that *OSA's Light, Energy and the Environment (LEE) Congress* aims to answer. Being its seventh year, LEE Congress is establishing its role as a forum where scientists and engineers from both industry and academia can share their achievements, networks with potential collaborators, and discuss on new directions in this area. Given the wide range of applicability of the optical technologies, the LEE Congress 2015 consisted of four topical meetings: *Optical Nanostructures and Advanced Materials for Photovoltaics (PV)*, *Optics for Solar Energy (SOLAR)*, *Solid-State and Organic Lighting (SOLED)*, and *Optical Instrumentation for Energy & Environmental Applications (E2)*. Being held in the beautiful Suzhou, China, where tradition and nature are mixed in harmony with the hint of rapid industrial growth, the 2015 LEE Congress provided a perfect setting to think about the importance of finding a sustainable solution that strikes a good balance between energy/environmental issues and economical advances.

This feature issue is a collection of some of the works presented in the LEE Congress 2015 and consists of 23 papers in total that provide a glimpse on the quality and breadth of the works discussed therein. One program chair per each topical meeting served as a guest editor, and submissions went through the standard Optics Express peer-review process for the highest quality of the published work. Subjects covered in this issue include not only the topics such as spectroscopy and laser interferometry that directly deals with light but also those on nano-technologies and material synthesis that can eventually lead to improvement in the performance of optoelectronic devices. In particular, there are many contributions from environmental monitoring this year, which is in fact consistent with China's big efforts on protecting their air quality from their industrial growth. Detailed contents from each topical meeting are summarized below.

The Topical Meeting *Optical Nanostructures and Advanced Materials for Photovoltaics (PV)* discusses approaches for efficient solar energy systems by exploiting nanotechnology. The main objective in this field is to utilize as many of the incoming solar photons as possible, e.g. to build a truly black solar cell. This objective is impeded by the overall trend to use even less absorber material to decrease costs and increase sustainability, i.e. to increase material efficiency. In this context, light management becomes indispensable. In their work, Jäger *et al.* [1] investigate how different configurations of sinusoidal front-side nanotextures affect important properties such as antireflection and light trapping in crystalline silicon. Onwudinanti *et al*. [2] present their investigations on light management in Cu(In,Ga)Se_2 thin film solar cells by the use of 1D as well as 2D diffractive structures. Their numerical modelling delivers optimal grating dimensions and demonstrates the benefits of different front and back side materials. Isabella *et al*. [3] present an analysis of the optical performance of decoupled front/back dielectric textures for flat ultrathin c-Si solar cells. In their approach

#264176 Received 27 Apr 2016; published 13 May 2016

they not only take into account the fact that a solar cell needs to be optically textured on one hand, but on the other hand in an ideal case is electrically flat on the other hand. They achieve this by leaving the interfaces of an ultra-thin crystalline silicon stack flat and transferring the light management to transparent textured layers adjacent to the silicon.

The Topical Meeting *Optics for Solar Energy (SOLAR)* focuses on optical science, and its applications to solar energy conversion, mainly in the areas of solar thermal, concentrating photovoltaics, and new-type solar cells such as perovskite solar cells, two dimensional semiconductor devices, organic solar cells, nano-structured semiconductor solar cells, and others. In particular, it addresses the fundamental role of optics—collecting, guiding, concentrating, coupling, trapping, transforming and absorbing the light—in increasing the power output from the solar energy systems. Three contributions from SOLAR include a review on optics for solar central receiver system by Li *et al*. [4], a comparison-based optical study of a point-linecoupling-focus system with linear Fresnel heliostats [5], and an investigation of light harvesting based on silicon nanostructures for solar cell applications [6].

The Topical Meeting *Solid-State and Organic Lighting (SOLED)* covers various aspects important for advances of solid-state lighting technologies—from material sciences, device physics or engineering, to a system-level manufacturing, applications, and policy. This feature issue contains key contributions from light-emitting diodes (LEDs) based on III-V compound semiconductors, organic light-emitting diodes (OLEDs), and lighting applications. With energy efficiency being crucial for any solid-state light sources, many of the studies focus on the engineering leading to the efficiency enhancement of these devices. Lee *et al.* present a light extraction technology based on a nano-pillar array embedded below a transparent electrode, demonstrating 30% enhancement in light-extraction efficiency of OLEDs without causing optical blurring [7]. Chen *et al.* also reports on their study of a light extraction technology based on a composite transparent electrode of low-index conducting polymers covering indium-tin-oxide micromesh structure [8]. Analysis based on finite-difference time-domain (FDTD) method is provided for more rigorous understanding of the efficiency-enhancing mechanism. Applying light-extraction technologies to flexible OLEDs can often be tricky albeit not impossible. Ou *et al.* try to solve this issue by combining Ca:Ag-based ultrathin metal films and nano-imprinted quasi-random photonic structures [9]. With the proposed method, the authors demonstrate flexible OLEDs with external quantum efficiency as large as 43.7%. Efforts to improve the efficiency are found in inorganic LEDs as well. Chen *et al.* takes a closer look at the angular distribution of polarized light and studies its effect on light extraction efficiency of deep UV LEDs [10].

Energy conservation may be achievable not only by device engineering but also by a smart system-level management. As such an example, Hu and Davis propose to use a stepwise dimming control optimized based on the human detectability and acceptability of illuminance differences for energy saving in a lighting system [11]. Coming back to LEDs, the work by Kong *et al.* investigates the color tunability in InGaN/GaN LED with a multijunction structure [12]. The work by Choi and Suk takes a full advantage of such benefits of LEDs to see whether a lighting system with active control over correlated color temperature (CCT) can have a positive impact on the performance of students, demonstrating the feasibility of a dynamic lighting system in education environment [13].

The Topical Meeting *Optics and Photonics for Energy and the Environment (E2)* focuses on monitoring and controlling the generation of energy and its impact on the environment. There are 11 papers from the 2015 E2 Topical Meeting that can be roughly divided into four intersecting themes: i) quartz-enhanced photoacoustic spectroscopy (QEPAS), ii) cavity enhanced absorption spectroscopy (CEAS), iii) near-IR Chirped Laser Dispersion Spectroscopy (CLaDS), mid-IR quantum cascade laser (QCL) and interband cascade laser (ICL) spectroscopy, and iv) laser remote detection and other spectroscopy. The majority of the contributions highlight the theme of laser spectroscopy and their applications to environmental monitoring.

The work by Svanberg *et al.* presents the multidisciplinary applications of laser spectroscopy to environmental, ecological, food safety, and biomedical research [14]. Two of

#264176 Received 27 Apr 2016; published 13 May 2016

the contributions report a detailed investigation of technologies that can improve QEPAS for environmental monitoring [15,16]. For example, a remote-operable, sub-ppb-level nitrogen dioxide (NO_2) QEPAS sensor is demonstrated by Zheng *et al.* by use of a cost-effective wide stripe LED emitting at 450 nm and a novel background noise suppression method called scattered light modulation cancellation method (SL-MOCAM) [16]. LED-based innovation is also featured in the work by Yi *et al.* that reports a new application of LED-based incoherent broadband cavity enhanced absorption spectroscopy (LED-IBBCEAS) to NO_3 concentration-time profile for study of the NO_3-initiated oxidation process of isoprene in a smog chamber [17]. Improving the sensitivity of the toxic gas detection is studied in the work by Nikodem who reports on a near-IR Chirped Laser Dispersion Spectroscopy (CLaDS)-based setup for hydrogen sulfide (H_2S) detection [18], by Lang *et al.* who report a quantum cascade laser based optical feedback cavity enhanced absorption spectroscopy (OF-CEAS) system for CH_4 detection [19], and by Dong *et al.* who investigates two compact TDLAS based sensor with mid-IR interband cascade lasers for detection of CH_4 and CH_2O concentrations [20]. Their works demonstrate detection limit down to 39 ppt [19] and 3–5 ppbv [20], respectively.

Also covered in this issue is the standoff trace detection of atmospheric composition [21] and LIDAR-based visualization of wind turbine wakes [22]. Dogariu and Miles report on a new approach for standoff trace detection in the atmosphere based on backwards lasing in atomic argon directly excited via a three-photon pumping in air mixtures [21]. Wu *et al.* presents their study on a pulsed coherent Doppler LIDAR (PCDL) deployed to visualize wind turbine wakes and to characterize the geometry and dynamics of wakes, with a high updating rate and variable physical spatial resolution [22]. The proposed system demonstrates its capability suitable for wind-farm site selection, design, and optimization. Finally, Yang *et al.* reports a new algorithm for quantitative monitoring of polycyclic aromatic hydrocarbons (PAHs) in water by three-way fluorescence spectroscopy and demonstrates a detection capability down to μg/L level [23].

In summary, this feature issue represents a part of the works presented at the *2015 OSA Light, Energy and the Environment (LEE) Congress* held in Suzhou, China. Ranging from nano-enabled enhancement of solar cell efficiency and development of energy-efficient solid-state light sources to optical concentrator studies for a solar thermal systems and various spectroscopy techniques for environmental monitoring, the topics featured in this issue do demonstrate the breadth and depth of this LEE Congress and highlight opportunities in optics research to solve the energy and environmental challenges. Finally, we would like to express our sincere thanks to local chairs and everyone at Institute of Functional Nano and Soft Materials (FUNSOM), Soochow University, who made every effort to make the 2015 LEE Congress a successful and flawless event. Our special thanks also go to the Program Committee members, the staff at OSA, all authors and presenters, and all the Congress attendees. The 2016 LEE Congress will be held in Leipzig, Germany, November 14–17, 2016. The 2016 Congress will include two more topical meetings—Fourier Transform Spectroscopy (FTS) and Hyperspectral Imaging and Sounding of the Environment (HISE), further extending its scope. Please join us in making the LEE Congress in Leipzig another successful event.