Focus issue introduction: Renewable energy and the environment 2013

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Abstract: This focus issue highlights contributions from authors who presented their research at OSA's Renewable Energy and the Environment Optics and Photonics Congress held 3-6 November 2013 in Tucson, Arizona, USA.

OCIS codes: (350.6050) Solar energy; (040.5350) Photovoltaic; (310.6628) Subwavelength structures, nanostructures; (220.1770) Concentrators; (220.4298) Nonimaging optics; (230.7370) Waveguides.

References and Links

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A little less than one year ago a Focus Issue for the 2012 Renewable Energy and the Environment (REE) Optics and Photonics Congress was published in *Optics Express* [1]. We once again publish a Focus Issue to highlight the research advances in the broad fields of energy and the environment that were presented at OSA's Renewable Energy and the Environment Optics and Photonics Congress held 3-6 November 2013 in Tucson, Arizona, USA. This Congress was comprised of five topical meetings: Optical Instrumentation for Energy and Environmental Applications (E2), Optical Nanostructures and Advanced Materials for Photovoltaics (PV), Optics for Solar Energy (SOLAR), Solid State and Organic Lighting (SOLED), and Freeform Optics. This OSA Congress is maturing, but it is still

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growing due to the global importance and impact of renewable energy since it has the potential to have lower future costs compared to traditional energy technology (e.g., fossil fuels). Additionally, through the E2 meeting the interdependence between energy and environment is explored. In 2014 the Congress will be held 2-5 December at the Energy Change Institute, Australian National University, Canberra, Australia, while in 2015 the event is tentatively scheduled to be held in China. Henceforth, this conference is being renamed the Light, Energy, and Environment Congress in order to better represent the content of the meetings. This Congress is truly worldwide in scope since it has been held previously in Karlsruhe, Germany/Tucson, USA in 2011, Eindhoven, The Netherlands in 2012, and Tucson, USA in 2013.

Research groups, government bodies, and companies in all countries are studying optical methods and materials for renewable energy, metrology methods within the field of energy, and novel methods to efficiently illuminate our surroundings. In 2013, the primary publication areas were light trapping in solar cells, dye-sensitized solar cells, concentrated solar, and LED technology. This year the primary areas are:

1. Energy nanotechnology: structures at the nano level, including films, powders, and wires, play an integral role in the development of energy technology. Three papers explore concepts in this area. The conference papers in this area were predominately from the PV and SOLED meetings, while E2 and SOLAR also were represented in this area.
2. Waveguide concentrators: structure akin to that from the photonics field has been employed within the solar community to both guide and concentrate captured radiation. These structures allow significant reduction in size, especially with the implementation of arrayed geometries. Challenges are imposed by physical limits, such as étendue. Three papers introduce the reader to this subfield. The PV and SOLAR conferences dominate here.
3. Optical design for energy applications: optical configurations from the micro scale to large format systems are being explored globally. This technology is both used for the generation of energy (SOLAR) and for illuminating our locales (SOLED). While SOLAR and SOLED provide the specific applications, the Freeform conference is directed to the fundamental optical design techniques.

Specifically, in the nanotechnology arena, three papers provide distinct insight into how nano-scale structure can be used in the energy field. Leela et al explore the spatio-temporal characteristics of energy release from nanopowder materials such as aluminum, boron potassium nitrate, and potassium bromide when illuminated by an intense laser beam [2]. The goal is to better understand the dynamics of energy generation through the resulting shock fronts. Wang et al compare via three-dimensional simulation of the optical-to-electrical efficiency for both individual nanowire and standard planar photovoltaic solar cells [3]. The single nanowire solar cell is investigated in both radial and vertical junction alignments. Schuster et al present a metric entitled light trapping efficiency, which is normalized to Lambertian scatter, so that trapping configurations from the past, present, and future can be compared to one another [4]. Theoretical models of light trapping geometries are compared to experimental measurements to investigate the limitations of simplified modeling.

In the next section, comprised of three papers, we progressively increase the size of the individual optic components. All of these papers explore the integration of waveguide structures used as concentrators to channel incident solar radiation to the solar cells. These structures overlap the illumination and concentration paths with the goals of maximizing efficiency while reducing required volume. The first paper by Liu et al uses a lens array as the primary optic and a channel waveguide as the secondary [5]. A theoretical model is compared

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to a computer simulation. Next, Bouchard and Thibault present a gradient index planar waveguide that concentrates incoming solar radiation onto a solar cell while only requiring single-axis tracking of the Sun [6]. This system is made with a molding process such that fabrication is simple and the cost is low. Zagolla et al discuss the design and simulation of a planar concentrator system that couples into a waveguide via a phase change at the focal spot of the optics [7]. This setup allows self-tracking and simulation shows that this system can work at 150X with an angular acceptance angle of greater than 40°.

In the last section, a number of optical systems are investigated from the micro size to meter class. The first two papers perfectly segue from the previous section on waveguide structures since their sizes are comparable. The first by Arnaoutakis et al presents up-conversion photovoltaic components that have concentrators integrated into them to effectively capture the sub-band-gap photons while leaving the other incident radiation unaffected [8]. The goal is to provide a more efficient transference of the full incident spectrum to the solar cell. Jared et al take a in-depth look at the engineering and fabrication aspects of arrayed micro concentrators [9]. Moderate concentration is realized experimentally in a small package while the overall cost is low due to the reduced use of expensive solar cells (i.e., multijunction). Coughenour et al present a detailed system model of a XRX-Köhler configuration that uses a primary reflector (X), a secondary ball lens (R), and finally an array of reflectors (R) positioned near the solar cells [10]. The meter-class scale of this system provides significant power generation capability at a measured optical-to-electrical efficiency of 28%. The last paper by Wester el al studies the significant challenges of designing freeform optical surfaces, i.e., those that lack rotational symmetry, for extended sources such as LEDs used in solid-state lighting [11]. Traditional optical design is for rotationally symmetric surfaces either on a full or piecewise basis, but freeform design allows for specific tailoring of the resulting illumination patterns for sources with complex emission distributions.

The layout of the papers is such that generally the size of the individual optics developed or analyzed progressively increases in size from the nano-scale to meter class. Additionally, the first and last papers present material outside of photovoltaics or solar concentration. In conclusion, the contributions presented herein offer an illustrative understanding of the trends and topics in the fields renewable energy and the environment. We would like to thank the Chairs and Program Committees of the meetings that made up the Congress, the OSA staff, the attendees of the conference, and, of course, the presenters and authors. We look forward to the 2014 meeting in Australia.