Welcome to the 2013 Renewable Energy and the Environment Congress.

This congress brings together five topical meetings that have been co-located specifically to promote networking and the generation of new ideas by bringing together top-notch science and top-notch scientists. And in addition to technical content, this year’s congress features three plenary speakers and includes several special events -- such as a Welcome Reception and a Poster Session -- to ensure all congress participants have ample time to engage in important discussions and critical knowledge-sharing.

The Optical Instrumentation for Energy and Environmental Applications (E2) meeting provides a forum to discuss science and engineering applications and the optical technologies that directly support these applications. The E2 sessions highlight a diverse collection of in-situ environmental and industrial safety measurements that represent concerns from industry, academic and government interests. The scope of E2 techniques spans a wide range of optical media, time domains and wavelength ranges, spanning the UV to the infrared. Attendees can also expect 14 oral and 17 invited talks covering land management, CO2 sequestration, and combustion diagnostics using techniques such as lidar, open-path TDLAS, and optical fiber sensor networks.

Freeform optics is a growing area in the field of optical design. It typically denotes optical surfaces that are not rotationally symmetric, and such surfaces are increasingly being used in both imaging and non-imaging systems. Prof. Jannick Rolland of the University of Rochester plenary will commence the meeting; her discussion is followed by informative talks to introduce the audience to the field. Meeting sessions will include imaging optical design, illumination design, fabrication and testing methods, and special and emerging topics in the field. Featuring 18 invited and 19 oral talks, presentations will discuss aberrations of freeform surfaces, imaging and nonimaging design methods, beam shaping, manufacturing techniques, direct measurement of surfaces, and dynamic freeform surfaces. This meeting will bring together these three communities to discuss this exciting field of optical engineering.

The Optical Nanostructures and Advanced Materials for Photovoltaics (PV) meeting focuses on novel optical approaches and concepts for solar energy systems, particularly developments in photonic nanostructures and material systems, such as photonic crystals, plasmonics, quantum dots, rare-earth systems, and conjugated polymers; all these areas are important drivers of research on solar energy conversion. The goal of PV is to bring together experts from the fields of nanophotonics and photovoltaics to present their latest research and address the issues and opportunities for merging these two technologies. The scope of this meeting covers all relevant issues, such as basic physics, new phenomena, material properties, modeling, device design, fabrication technologies, and characterization. We have assembled an exciting program of 18 invited, 22 contributed oral and 11 contributed poster presentations this year.

The Solid State and Organic Lighting (SOLED) meeting covers topics relating to the performance, manufacture and application of traditional and organic light-emitting devices (OLEDs) for solid-state lighting. Presentations in the area of conventional LEDs are focused on progress in new materials and performance, and the emergence of increasingly mature applications for these devices. Sessions in the area of OLEDs focus on the realization of new emissive materials for high efficiency, optical
engineering for enhanced outcoupling, and emerging applications exploiting flexible substrates. The organizers look forward to bringing together the inorganic and organic light-emitting device communities under the common goal of advancing solid-state lighting.

The **Optics for Solar Energy (SOLAR)** meeting includes a strong collection of papers on optical concentrators and the manipulation of light in solar cells. We are looking forward to a lively, interactive panel discussion that will hopefully foster collaboration and teaming arrangements for the participants. The SOLAR meeting features 10 invited talks, 24 oral presentation and 2 posters. And on Tuesday evening, the SOLAR program committee, in conjunction the OSA Optics for Energy Technical Group, is pleased to present a special panel entitled *A Discussion on the Future Areas for Funding and Research for Solar.* By bringing together leaders and experts among the different communities to share information, we hope to provide you with a rich experience!

In 2014 this Congress will move to Australia with a new name - **Light, Energy and the Environment Congress.** We hope you will join us as we span an ocean and expand discussions from Tucson to Canberra!

Regards,

Sai Santosh Kumar Raavi, *Nanyang Technological University, Singapore*, **E2 Chair**  
Michael Wojcik, *Space Dynamics Laboratory, USA*, **E2 Chair**  
John Koshel, *Photon Engineering LLC, USA*, **Freeform Chair**  
Kevin Rolland-Thompson, *Synopsys, Inc, USA*, **Freeform Chair**  
Alan Kost, *University of Arizona, USA*, **SOLAR Chair**  
Raymond Kostuk, *University of Arizona, USA*, **SOLAR Chair**  
Russell Holmes, *University of Minnesota Twin Cities, USA*, **SOLED General Chair**  
Dongxue (Michael) Wang, *Intel Corporation, USA*, **SOLED General Chair**

**MARK BRONGERSMA, Stanford University, USA, PV General Chair**  
Lan Fu, *Australian National University, Australia*, **PV General Chair**  
Erin Ratcliff, *University of Arizona, USA*, **PV General Chair**  
Ralf Wehrspohn, *Fraunhofer IWM Halle, Germany*, **PV General Chair**  
Alexander Sprafke, *Martin-Luther University Halle, Germany*, **PV Program Chair**

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**LIGHT, ENERGY AND THE ENVIRONMENT CONGRESS**  
**2-5 December 2014**

This comprehensive Congress examines the frontiers in the development of optical technologies for energy production, transport, and use. It also examines the use of optical and photonic approaches to monitor energy usage and the effects energy production has on the environment. It is designed to bring together researchers, engineers, and managers and foster timely information exchange between several of the disciplines involved in energy production usage, cost and environmental and efficiency management. Additional topics to those outlined below may also be included.

- Optics and Photonics for Energy and the Environment (E2)
- Optical Nanostructures and Advanced Materials for Photovoltaics (PV)
- Optics for Solar Energy (SOLAR)
- Solid State and Organic Lighting (SOLED)

**Canberra, Australia – Manning Clarke Complex, Australian National University**

Visit [ww.osa.org/energyOPC](http://www.osa.org/energyOPC) for complete information.
Program Committee

Optical Instrumentation for Energy and Environmental Applications (E2)
Sai Santosh Kumar Raavi, Nanyang Technological University, Singapore, Chair
Michael Wojcik, Space Dynamics Laboratory, USA, Chair
Maruthi Brundavanam, University of Electro-Communications, Japan
Jong Chow, Australian National University, Australia
Zuguan Guan, Sailhero Environmental Technology, Norway
Jose Javier Laserna, Universidad de Malaga, Spain
Paulo Miranda, USP Inst de Fisica de Sao Carlos, Brazil
Michal Nikodem, Wroclaw Research Centre EIT+, Poland
Luca Palchetti, Istituto di Fisica Applicata - IFAC, Italy
Mark Phillips, Pacific Northwest National Laboratory, USA
Liyang Shao, Hong Kong Polytechnic University, Hong Kong
Hoe Tan, Australian National University, Australia
Brentha Thurairajah, Virginia Tech, USA
Gerard Wysocki, Princeton University, USA

Freeform
John Koshel, Photon Engineering LLC, USA, Chair
Kevin Rolland-Thompson, Synopsys, Inc, USA, Chair
James Burge, University of Arizona, USA
Angela Davies, Univ of North Carolina at Charlotte, USA
Chris Evans, Univ of North Carolina at Charlotte, USA
Gregory Forbes, QED Technologies Inc, Australia
Joseph Howard, NASA Goddard Space Flight Center, USA
David Jenkins, Synopsys, Inc, USA
Jannick Rolland, University of Rochester, USA
Mitchell Ruda, Ruda-Cardinal, Inc, USA
Jose Sasin, University of Arizona, USA
H. Philip Stahl, NASA Marshall Space Flight Center, USA
Wilhelm Ulrich, Carl Zeiss AG, Germany
Andrew Wood, Qioptiq Ltd, United Kingdom

Optical Nanostructures and Advanced Materials for Photovoltaics (PV)
Mark Brongersma, Stanford University, USA, General Chair
Lan Fu, Australian National University, Australia, General Chair
Erin Ratcliff, University of Arizona, USA, General Chair
Ralf Wehrspohn, Fraunhofer IWM Halle, Germany, General Chair
Alexander Sprafke, Martin-Luther University Halle, Germany, Program Chair
Lucio Andreani, Universita degli Studi di Pavia, Italy
Kylie Catchpole, Australian National University, Australia
Jan Goldschmidt, Fraunhofer Inst Solare Energiesysteme, Germany
Ewa Goldys, Macquarie University, Australia
Jung-Ho Lee, Hanyang University, South Korea
Paul Mulvaney, University of Melbourne, Australia
Carsten Rockstuhl, University of Jena, Germany
Hoe Tan, Australian National University, Australia
Carolin Ulbrich, Forschungszentrum Julian, Germany
Thomas White, Australian National University, Australia

Optics for Solar Energy (SOLAR)
Alan Kost, University of Arizona, USA, Chair
Raymond Kostuk, University of Arizona, USA, Chair
Chih-Hao Chang, North Carolina State University, USA
César Domínguez, Commissariat a l’Energie Atomique, France
Vernie Everett, Australian National University, Australia
Jesse Frantz, US Naval Research Laboratory, USA
Nasser Karam, Boeing Company, USA
Jun Ke, Beijing Institute of Technology, China
John Koshel, Photon Engineering LLC, USA
Ioannis Papakonstantinou, University College London, United Kingdom
Elizabeth Thomsen, Australian National University, Australia
Yong-Hang Zhang, Arizona State University, USA

Solid State and Organic Lighting (SOLED)
Russell Holmes, University of Minnesota Twin Cities, USA, General Chair
Dongxue (Michael) Wang, Intel Corporation, USA, General Chair
Vida Ilderem, Intel Corporation, USA, Program Chair
Bart Salters, Philips Research Laboratory, Netherlands, Program Chair
Paul Burn, University of Queensland, Australia
Geoff Burns, Intel Corporation, USA
Jiang Dong Deng, Harvard University, USA
Daniel Gamota, Jabil, Inc., USA
Min Gu, Swinburne University of Technology, Australia
Peng Jin, Peking University, China
John Koshel, Photon Engineering LLC, USA
Rongguang Liang, University of Arizona, USA
Jim Zhuang, Intel Corporation, USA
Special Events

Freeform Plenary
Monday, 4 November, 09:00–10:00
Tucson Ballroom G&H

Jannick P. Rolland, University of Rochester, USA

Jannick Rolland is the Brian J. Thompson Professor of Optical Engineering at the Institute of Optics at the University of Rochester (UoR), where she also serves as Associate Director of the R.E. Hopkins Center for Optical Design and Engineering and directs the Optical Diagnostics and Applications Laboratory (ODALab). She also holds an appointment in the Department of Biomedical Engineering and in the Center for Visual Science at UoR. Professor Rolland earned an Optical Engineering Diploma from the Institut d’Optique, France, and an MS and PhD in Optical Science from the College of Optical Sciences at the University of Arizona. Upon completing her degree, Dr. Rolland joined the Department of Computer Science at the University of North Carolina at Chapel Hill (UNC-CH) as a postdoctoral fellow, where she focused on learning vision and computer graphics while designing the first off-axis stereoscopic head-worn displays for medical visualization. She was appointed to lead the Vision Research Group for Medical Displays at UNC-CH (1992-96), where the team investigated the impact of the shape of objects on medical tasks. In 1996, she joined CREOL, the College of Optics and Photonics at the University of Central Florida, where she founded the ODALab.

General Session with Plenary Speakers
Tuesday, 5 November, 08:30–10:30
Tucson Ballroom F

Neal R. Armstrong, University of Arizona, USA

Neal R. Armstrong is Professor of Chemistry/Biochemistry and Optical Sciences at the University of Arizona, and has been on the faculty here since 1978. His research interests have focused on the interface science underpinning the development of new molecular electronic technologies, and new energy conversion platforms, and chemical sensors. He has authored/co-authored over 300 scientific publications, and produced ca. 50 Ph.D. and M.S./M.A. students in his career, along with a host of undergraduate researchers, postdocs and visiting scientists from around the world. He is currently a member of the Galileo Circle in the College of Science at UA, and has been recently selected as Regents Professor.

Heinz Frei, Lawrence Berkeley National Laboratory, USA

Heinz Frei is a Senior Scientist at Lawrence Berkeley National Laboratory in Berkeley, California. His main research is in the development of photocatalytic assemblies in nanostructured materials for the synthesis of everyday chemicals and fuels by visible and near infrared light, with emphasis on understanding elementary chemical processes by transient optical and infrared spectroscopy. He leads the Interface Project of the Joint Center for Artificial Photosynthesis (JCAP).

Doug Hall, U.S Department of Energy, USA

Doug Hall received a doctorate in 1982 in applied physics while a student employee at LLNL. He joined Corning for a 27 year career in a number of roles including research scientist, R&D manager, Technology Vice-President and business unit leader serving optical and glass product businesses. He joined the U.S. Department of Energy in 2011 as a Technology Manager in the SunShot Initiative. Doug is the author of over 20 articles in refereed technical journals and three book chapters. He holds 17 U.S. patents. He is a Fellow of the Optical Society of America and on the OSA Board of Directors.

Congress Reception
Monday, 4 November, 17:00–18:30
Ania Terrace

Join your fellow attendees for the Congress Reception. Enjoy delectable fare while networking. The reception is open to full conference attendees. Conference attendees may purchase extra tickets for their guest.

Joint Poster Sessions
Monday, 4 November, 14:30–15:15
Tucson Ballroom E

Posters are an integral part of the technical program and offer a unique networking opportunity, where presenters can discuss their results one-to-one with interested parties. Each author is provided with a 4 ft. × 8 ft. (1.22 m × 2.44 m) board on which to display the summary and results of his or her paper.
A Discussion on the Future Areas for Funding and Research for Solar
Tuesday, 5 November, 17:00–18:30
Tucson Ballroom F

The panel will discuss new directions in research for solar energy and possible funding sources. It will include a panelist from DOE and NREL, and industrial representative from Amonix and SOLON. The panel discussion will be guided to make it of general interest to all Congress attendees.

Panelist
• Harry Atwater, Caltech, USA
• Ken Baldwin, Australian National Univ. Energy Change Institute, Australia
• Matthew Fraser, Arizona State Univ./QESST, USA
• Adam Plesniak, Amonix, USA
• Andru Prescod, DOE CSP Program, USA
• Bill Richardson, SOLON, USA

Sponsored by the OSA Optics for Energy Technical Group

Registration Hours

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
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<tbody>
<tr>
<td>Sunday, 3 November</td>
<td>15:00–18:00</td>
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<tr>
<td>Monday, 4 November</td>
<td>7:30–17:00</td>
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<td>Tuesday, 5 November</td>
<td>7:30–17:30</td>
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<tr>
<td>Wednesday, 6 November</td>
<td>7:30–16:30</td>
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Exhibit Guide
The exhibitors will be located near registration on 4 November–6 November during coffee breaks and sessions.

American Elements- Sponsor
1093 Broxton Ave, Suite 2000
Los Angeles, CA 90024 USA
PH: +1 310.208.0551
F: +1 310.208.0351
www.americanelements.com
customerservice@americanelements.com

American Elements is the world’s manufacturer of engineered & advanced materials with a catalogue of over 12,000 products including high purity chemicals, semiconductors, metals and compounds for petrochemicals, photovoltaics, lasers, optics, solar energy, and fuel cells. American Elements maintains manufacturing and research in the U.S., Mexico, Europe and China.

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Ontario, NY 14519-8939 USA
PH: +1 585.221.0766
F: +1 585.265.1033
www.optimaxsi.com
sales@optimaxsi.com

Optimax is set up to manufacture, test and deliver with the speed and performance your program requires. Optimax reliability has allowed us to become America’s largest optics prototype manufacturer. We’ve invested in the technology and research that will enable your next program, but remain the people who are committed to small volume, high quality and quick delivery of your prototype optic needs.

Classical Optics 2014
22 – 26 June 2014
Kona, Hawaii, USA

OSA’s inaugural congress on Classical Optics brings together three disciplines that are integral parts of the challenging design of optical systems.
• Optical Fabrication and Testing (OF&T)
• Computational Optical Sensing and Imaging (COSI)
• International Optical Design Conference (IODC)

Featuring Freeform Day
This day features sessions from IODC, OF&T and American Society for Precision Engineering (ASPE) on the optical design of imaging systems with freeform surfaces, evolving methods for surface representation for illumination system optimization, and a perspective on the new challenges these surfaces present to optical testing.

Collocated with ASPE/ASPEN Summer Topical Meeting, Manufacture and Metrology of Freeform and Off-Axis Axisymmetric Surfaces.

Visit www.osa.org/classicalOPC for complete information
Awards

OSA Foundation Travel Grants
We are pleased to announce The OSA Foundation Travel Grant recipients for Imaging and Applied Optics Congress. The OSA Foundation Student Travel Grant Program is designed to provide career development opportunities by assisting students who wish to attend conferences and meetings. The grants are given to students working or studying science in qualifying developing nations so they can attend OSA-managed technical meetings and conferences.

This year’s recipient is: Leela Chelikani, University of Hyderabad, India

The students receive $1,500 USD in travel support and are selected by the co-chairs of the meeting. Their applications are judged on the following criteria:

- Work or study in a qualifying developing nation
- Enrollment in an accredited undergraduate or graduate program
- Demonstrated need for travel support
- Statement on the value of attending the conference

The OSA Foundation was established in 2002 to support philanthropic activities that help further the Optical Society’s (OSA) mission. The Foundation is concentrating its efforts on programs that provide career and professional development resources and support awards and honors that recognize technical and business excellence. The grants funded by the OSA Foundation are made possible by the generous donations of its supporters as well as the dollar-for-dollar match by OSA. The Foundation is exempt from U.S. federal income taxes under section 501(c)(3) of the Internal Revenue Code and is a public charity.

For more information, visit www.osa-foundation.org.

Robert S. Hilbert Memorial Student Travel Grants
Established in 2009 by Optical Research Associates (ORA), now the Optical Solutions Group at Synopsys, as a memorial to ORA’s former President and Chief Executive Officer Robert S. Hilbert, this program recognizes the research excellence of students in the areas of optical engineering, lens design and illumination design. We thank the Optical Solutions Group at Synopsys for their sponsorship of this program.

The recipient will receive $1,100 USD and are selected by the co-chairs of the meeting. Their applications are judged on the following criteria:

- Be the presenter of an accepted paper
- An undergraduate or graduate student
- Accepted paper must include research in the areas of optical engineering, lens design and/or illumination design.
- Encouraged to include graphics created using either CODE V® or LightTools® in their submission.

This year’s recipient may be found at www.osa.org/Foundation.

Call for Papers
Submit Your Research to the
2013 Renewable Energy Feature Issue
in Optics Express
(Energy Express Supplement)

Submission Deadline: 1 December 2013
Publish Date: March 2014

For more information, visit the Focus Issues section on the Optics Express website (http://oe.osa.org)
Explanation of Session Codes

ET1C.4

Meeting Name
E = E2
F = Freeform
P = PV
R = SOLAR
D = SOLED
J = Joint Session

Day of the Week
M = Monday
T = Tuesday
W = Wednesday

Series Number
1 = First Series of Sessions
2 = Second Series of Sessions

Number
(Presentation order within the session)

Session Designation
(alphabetically)

The first letter of the code designates the meeting (E=E2, F=Freeform, P=PV, R=SOLAR, D=SOLED, J=Joint Session). The second element denotes the day of the week (Monday=M, Tuesday=Tu, Wednesday=W). The third element indicates the session series in that day (for instance, 1 would denote the first parallel sessions in that day). Each day begins with the letter A in the fourth element and continues alphabetically through a series of parallel sessions. The lettering then restarts with each new series. The number on the end of the code (separated from the session code with a period) signals the position of the talk within the session (first, second, third, etc.). For example, a presentation coded ET1C.4 indicates that this paper is part of E2 (E) and is being presented on Tuesday (Tu) in the first series of sessions (1), and is the third parallel session (C) in that series and the fourth paper (4) presented in that session.

Invited papers are noted with 📘
Tutorials are noted with 📘
Plenary papers are noted with 📘
Recorded Presentations are noted with 📺

New Features for OSA Topical Meetings

Online Access to Technical Digest Now Available!

Full Conference Attendees now have both EARLY and FREE perpetual access to the Congress digest papers through Optics InfoBase. To access the papers go to www.osa.org/renewable_energy and select the “Access digest papers” essential link on the right hand navigation. As access is limited to Full Conference Attendees only, you will be asked to validate your credentials by using the same login email address and password provided during the conference registration process. If you need assistance with your login information, please use the “forgot password” utility or “Contact Help” link.

Recorded Technical Sessions on Demand

We are delighted to announce that your 2013 Renewable Energy and the Environment Congress full conference registration includes a valuable new enhancement! A portion of the presentations at this year’s congress have been digitally captured for on-demand viewing. All captured content from listed sessions will be live for viewing within twenty-four hours of being recorded, and will be available for 60 days. Just look for the record symbol 📺 in the Agenda of Sessions and abstracts to easily identify the presentations being captured. To access the presentations go to www.osa.org/renewable_energy and select the “Access meeting presentations” essential link on the right hand navigation. As access is limited to Full Conference Attendees only, you will be asked to validate your credentials by using the same login email address and password provided during the conference registration process. If you need assistance with your login information, please use the “forgot password” utility or “Contact Help” link.
### Agenda of Sessions — Sunday, 3 November

<table>
<thead>
<tr>
<th>Time</th>
<th>Tucson Ballroom B</th>
<th>Tucson Ballroom G&amp;H</th>
<th>Tucson Ballroom I&amp;J</th>
<th>Tucson Ballroom C&amp;D</th>
<th>Tucson Ballroom A</th>
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<tbody>
<tr>
<td>15:00–18:00</td>
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<td>Registration, Tucson Ballroom Foyer</td>
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### — Monday, 4 November

<table>
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<th>Time</th>
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<tr>
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<tbody>
<tr>
<td>08:30–10:30</td>
<td>EM1A • Sensors</td>
<td>FM1B • Freeform</td>
<td>PM1C • Nanostructured</td>
<td>RM1D • Economics</td>
<td>DM1E • Materials</td>
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<td>and Sensor</td>
<td>Optics Introduction</td>
<td>Crystalline Silicon</td>
<td>and Enhanced Solar</td>
<td>for High Efficiency</td>
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<th>Time</th>
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<th>Session 8</th>
<th>Session 9</th>
<th>Session 10</th>
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<tbody>
<tr>
<td>11:00–13:00</td>
<td>EM2A • Remote</td>
<td>FM2B • Imaging:</td>
<td>PM2C • Nanowire</td>
<td>RM2D • Light</td>
<td>DM2E • Progress</td>
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<tr>
<td></td>
<td>Sensing and Lidar</td>
<td>Descriptions of</td>
<td>Solar Cells</td>
<td>Trapping and AR</td>
<td>in LED Performance</td>
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<td></td>
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<td>Freeform Surfaces</td>
<td>ends at 12:45</td>
<td>Coatings I</td>
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<td>Aberrations</td>
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<tr>
<td>13:00–14:30</td>
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<tr>
<td>15:00–18:30</td>
<td>JM3A • Joint Poster Session, Tucson Ballroom E</td>
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</tbody>
</table>

**Key to Conference Abbreviations**

- **E2** Optical Instrumentation for Energy & Environmental Applications
- **F** Freeform Optics
- **PV** Optical Nanostructures and Advanced Materials for Photovoltaics
- **SOLAR** Optics for Solar Energy
- **SOLED** Solid State and Organic Lighting

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**All technical papers are currently available for online download.**

Access papers at [www.osa.org/renewable_energy](http://www.osa.org/renewable_energy) and click on Access digest papers under Essential Links

**Presentations selected for recording are designated with a ⚫.**

To view recorded presentations, go to [www.osa.org/renewable_energy](http://www.osa.org/renewable_energy) and click on Access meeting presentations slidecasts under Essential Links
## Agenda of Sessions — Tuesday, 5 November

<table>
<thead>
<tr>
<th>Time</th>
<th>Tucson Ballroom B</th>
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<tr>
<td>08:30–10:30</td>
<td>JT1A • Congress Plenary Session, Tucson Ballroom F</td>
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<tr>
<td>10:30–11:00</td>
<td>Coffee Break, Tucson Ballroom E</td>
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</tr>
<tr>
<td>11:00–13:00</td>
<td>ET2A • Optical Fiber Technologies for Sensors ends at 12:45</td>
<td>FT2B • Illumination: Design Methods I ends at 12:45</td>
<td>PT2C • Concepts for Photon Management in Solar Cells I</td>
<td>RT2D • Concentrators - Design and Manufacturing ends at 12:45</td>
<td>DT2E • Flexible Displays and Optical Outcoupling ends at 12:45</td>
</tr>
<tr>
<td>13:00–14:30</td>
<td>Lunch on your Own</td>
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<tr>
<td>14:30–16:30</td>
<td>ET3A • Optical Materials and Characterization I</td>
<td>FT3B • Imaging: Fabrication of Freeform Surfaces</td>
<td>PT3C • Spectral conversion and Quantum Dots ends at 16:00</td>
<td>RT3D • Concentrators - Tracking, Planar and Array Configurations ends at 16:00</td>
<td>DT3E • LED Applications</td>
</tr>
<tr>
<td>16:30–17:00</td>
<td>Coffee Break, Tucson Ballroom E</td>
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<td>17:00–18:30</td>
<td>A Discussion on the Future Areas for Funding and Research for Solar, Tucson Ballroom F</td>
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## — Wednesday, 6 November

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<tr>
<th>Time</th>
<th>Tucson Ballroom B</th>
<th>Tucson Ballroom G&amp;H</th>
<th>Tucson Ballroom I&amp;J</th>
<th>Tucson Ballroom C&amp;D</th>
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<tr>
<td>07:30–16:30</td>
<td>Registration, Tucson Ballroom Foyer</td>
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<td>08:30–10:30</td>
<td>EW1A • Sensors and Sensor Applications III ends at 10:15</td>
<td>FW1B • Testing of Freeform Surfaces</td>
<td>PW1C • Concepts for Photon Management in Solar Cells II ends at 10:15</td>
<td>RW1D • Luminescent Concentrators and Spectrum Splitting ends at 10:00</td>
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<td>10:30–11:00</td>
<td>Coffee Break, Tucson Ballroom E</td>
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<td>11:00–13:00</td>
<td>EW2A • Optical Materials and Characterization II ends at 12:45</td>
<td>FW2B • Topics in Freeform Surfaces ends at 13:15</td>
<td>PW2C • Organic Solar Cells, Hydrogen Production and Thermophotovoltaics ends at 13:15</td>
<td>RW2D • System and Device Modeling and Characterization ends at 12:30</td>
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<td>13:00–14:30</td>
<td>Lunch on your Own</td>
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<td>14:30–16:30</td>
<td>FW3A • Illumination: Design Methods II ends at 16:15</td>
<td>PW3B • Photon Management in thin-film amorphous Silicon Solar Cells &amp; Plasmonic Photon Management</td>
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EM1A • Sensors and Sensor Applications I

08:30–10:00

EM1A.1 • 08:30
Optical Tools and Techniques for Large Area Surface Monitoring of Carbon Sequestration Sites, Kevin S. Repasky1, William Johnson2, Benjamin Soukup3, John L. Carlsten4, Rick Lawrence3, Scott Powell5; 1Electrical and Computer Engineering, Montana State Univ., USA; 2Physics, Montana State Univ., USA; 3Land Resources and Environmental Sciences, Montana State Univ., USA. Carbon sequestration has the potential to reduce environmental impacts of power generation using fossil fuels. Many technological challenges exist for implementing carbon sequestration. In this presentation, detection techniques for carbon sequestration site monitoring are presented.

EM1A.2 • 09:00
Thermographic Particle Image Velocimetry, Frank Beyrau1; 1Imperial College London, UK. The particle image velocimetry technique can be extended to simultaneously measure fluid temperatures by seeding thermographic phosphor particles. Following UV excitation, these particles exhibit a temperature-dependent phosphorescence spectrum that can be utilized for thermometry.

EM1A.3 • 09:30
Environmental Discourses in Borana Oromo: A Focus on Narratives, Teshome Tafesse1; 1Humanities, Addis Ababa Univ., Ethiopia. This study explored discourses of environmental narratives in Borana Oromo of the southern Ethiopia. Accordingly, it identified discourses of environmental necessity and survival, scarcity and security, hopelessness, inclusion and exclusion, seniority, responsibility, and obedience and disobedience.

EM1A.4 • 09:45
Long-term Operation of an External Cavity Quantum Cascade Laser-based Trace-gas Sensor for Building Air Monitoring, Mark C. Phillips1, Ian M. Craig2; 1Pacific Northwest National Lab, USA. We analyze the long-term performance and stability of a trace-gas sensor based on an external cavity quantum cascade laser using data collected over a one-year period in a building air monitoring application.

FM1B • Freeform Optics Introduction

08:30–10:30

FM1B.1 • 08:45
The Past, Present and Future of Freeform Optics, Jannick P. Rolland1; 1Univ. of Rochester, USA. Freeform optical surfaces are emerging as a path to truly three-dimensional optical designs. In this talk I will provide a short historical context to this emergence and discuss the challenges as well as the rapidly emerging knowledge that spans from the mathematics of freeform surfaces to the implementation of freeform optical systems.

FM1B.2 • 09:45
Graphical Methods for Designing Optics in CAD, Steve Mulder1; 1Photon Engineering LLC, USA. A number of simple graphical methods for designing optics in CAD are presented. These methods are based on the law of reflection, Snell’s Law, Fermat’s principle and a property of focal conics. These graphical methods will be illustrated using the practical example of designing a catadioptric LED collimator.

FM1B.3 • 10:15
Data Format for Ray File Standard, John Koshel1,2; 1Ashdown1, Willi Brandenburg2, Dominique Chabaud3, Oliver Doss4, Sanjay Gangadhara5, Kevin Garcia6, Michael Gauvin7, Groot Gregory8, Dirk Hansen1, Kei Haraguchi2, Günther Hansa3, Jianzhong Jiao4,5,6, Thomas Käsebier2,3, Thomas Kroll4,5,6,7,8, Dominique Chabaud3,8, Ian Coshall3, Eric Croma4,5,6, Mark C. Phillips1, Ian M. Craig2; 1Pacific Northwest National Lab, USA. We demonstrate that carrier collection efficiency even using less and lower quality Si.

FM1B.4 • 10:45
11.5% efficient ultrathin black silicon solar microcell, Zhiduo Xu1, Yuan Yao2, Ralph Nuzzo3, Gana L. Liu4,1; 1Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA; 2Dept. of Chemistry, Univ. of Illinois at Urbana-Champaign, USA. After made black by a reactive ion etching process and SiNx passivated by thermal ALD deposited Al2O3, black silicon fabricated by reactive ion etching results in solar cells with excellent anti-reflection and light trapping properties. Good electronic properties of the silicon interface are preserved by a passivation scheme.

PM1C • Nanocrystalline Silicon Solar Cells

08:30–10:30

PM1C.1 • 08:30
18.2% Efficient Nanocrystalline Si Solar Cells, Jihun Oh1; 1Korea Advanced Inst. of Science & Tech, Republic of Korea. In this work, we systematically investigate the photocarrier recombination mechanisms in a nanocrystalline Si solar cell. By controlling these mechanisms, we demonstrate an 18.2% efficient nanocrystalline Si solar cell whose efficiency is compatible to the conventional solar cells.

PM1C.2 • 09:00
RIE Black Silicon for Photovoltaic Applications, Matthias Zilk1, Thomas Käsebier2, Martin Ott3, Matthias Kroll4; 1Physics, Montana State Univ., USA; 2College of Optical Sciences, Univ. of Arizona, USA; 3byHeart Consultants Limited, Canada; 4Brandenburg GmbH, Germany. Black silicon (b-Si) structures offer improved light absorption and high charge collection efficiency even using less and lower quality Si.

PM1C.3 • 09:30
Opto-electronic properties of different black silicon structures passivated by thermal ALD deposited Al2O3, Martin Ott1, Matthias Kroll4, Thomas Käsebier1, Xiaopeng Li1, Benjamin Gesemann1, Kevin Füchsel2, Johannes Ziegler1, Alexander N. Sprakel1, Ralf Wehrspohn2,1; 1Inst. of Physics, Martin-Luther Univ. Halle, Germany; 2Inst. of Applied Physics, Friedrich-Schiller Univ., Germany; 3Fraunhofer Inst. for Applied Optics and Precision Engineering, Germany; 4Fraunhofer Inst. for Mechanics of Materials (IWMH), Germany. Black silicon (b-Si) structures offer improved light absorption but require appropriate surface passivation for photovoltaic applications. Here, we compare the opto-electronic performance of different wet and dry etched b-Si structures passivated by thermal ALD deposited Al2O3.

PM1C.4 • 09:45
11.5% efficient ultrathin black silicon solar microcell, Zhiduo Xu1, Yuan Yao2, Ralph Nuzzo3, Gana L. Liu4,1; 1Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA; 2Dept. of Chemistry, Univ. of Illinois at Urbana-Champaign, USA. After made black by a reactive ion etching process and SiNx deposition, unprecedentedly, the efficiency of ultrathin solar microcell was improved from 8% to 11.5% and short circuit current increased by 65.7%.
High-efficient solar cells with III-V nanostructures, Jiang Wu1, Yunyan Zhang1, Frank Tutu1, Phu Lam1, Sabina Hatch1, Huiyun Liu1; Univ. College London, UK. We have developed a variety of semiconductor nanostructures grown by molecular beam epitaxy. We show that the photovoltaic cells based on these semiconductor nanostructures are promising to achieve unprecedented power conversion efficiency.

Recent Progress in Highly Efficient Phosphorescent White OLEDs, Jason Brooks1; Universal Display Corp., USA. We report our recent progress in high efficiency organic light emitting diodes based on phosphorescent emissive materials. Topics, such as, device performance and architecture as well as fabrication techniques will be covered.

Multiple solar cells for spectrum-splitting PV systems are fabricated using spatially composition-graded absorber materials, such as CdSe, grown in a single inexpensive CVD growth, integrating the fabrication processes of the subcells and potentially reducing costs.

This talk will introduce the approach of using nanoscale site isolation between different emitting species to realizing white emission. One system was based on block copolymers and the other involved polymer nanoparticles.

Ultrafast Carrier Relaxation Processes in Advanced Concept Solar Cells, Stephen M. Goodnick1, Christiana Honsberg1, Yongjie Zu1; Arizona State Univ., USA. We discuss short time carrier relaxation in advanced concept solar cells conditions using ensemble Monte Carlo (EMC) simulation coupled with rate equation and thermodynamic models, to understand the limiting factors affecting solar cell performance.

Highly Efficient Organic Light-Emitting Diode Based on a Hidden Thermally Activated Delayed Fluorescence Channel in a Heptazine Derivative, Jie Li1, Tetsuya Nakagawa1, James MacDonald1, Qisheng Zhang1, Hiroko Nomura1, Hiroshi Miyazaki1, Chihaya Adachi1; OPERA, Kyushu Univ., Japan; Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia; Functional Materials Lab, Nippon Steel and Sumikin Chemical Co., Ltd., Japan; International Inst. for Carbon Neutral Energy Research, Kyushu Univ., Japan. An orange-red OLED containing a heptazine derivative exhibits high performance with a maximum external quantum efficiency of 17.5% without any light out-coupling enhancement based on a hidden thermally activated delayed fluorescence channel.

Platinum Azaporphyrins for Near Infrared Organic Light Emitting Diodes, Liang Huang1, Tyler Fleet-ham1, Jian Li1; Materials Science and Engineering, Arizona State Univ., USA. We developed three platinum azaporphyrin emitters for near infrared OLED applications. The devices based on PtNTBP, cis-PtN2TBP, and PINTNP exhibit emission peak at 848nm, 846nm and 918nm with EQE of 2.76%, 1.47%, and 0.87% respectively.

Ligand Control of Radiative and Nonradiative Processes in Phosphorescent Cyclometalated Platinum Complexes, P. Djurovich1, M. Thompson1; Department of Chemistry, Univ. of California at Los Angeles, USA. Cyclometalated platinum complexes have been proposed for use in applications such as sensors, solar cells and organic LEDs. The role the cyclometalating ligand plays in modifying the phosphorescent properties of these compounds will be presented.
describe current efforts to develop and validate ground-based knowledge of two horizontal components. This seminar will focus on the velocity vector and the determination of wind speed requires consideration of the direction and magnitude of wind. It will be demonstrated that a vector approach is necessary for accurate wind measurement.

**CELiS (Compact Eyesafe Lidar System):** A narrow line width tunable DIAL LIDAR detector, Michael Wojcik1, Blake G. Crowther1, Robert Lemon1, Robert Lemon,1 Alan Bird1, Prasad Vakapis1, Long Fu1, Bonnie Leung1, Allan Chambers2, Space Dynamics Lab, Utah State Univ., USA; 2Aerospace, Canada. CELiS is conceived for the purpose of air quality compliance. The CELiS system for plume measurements in sugarcane burning operations.

**Freeform Spectacle Lenses:** Garhard Bermel1, Michael Wojcik1, Robert Lemon1, Alan Bird1, Prasad Vakapis1, Long Fu1, Bonnie Leung1, Allan Chambers2, Space Dynamics Lab, Utah State Univ., USA; 2Aerospace, Canada. Freeform spectacles are being developed to improve vision and comfort in high-stress environments. The use of freeform optics will be discussed.

**Performance limits for GaAs-based nanowire photovoltaics:** Peter Bermel1, Purdue Univ., USA. The performance limits of GaAs-based nanowire photovoltaics are explored under various configurations. Their connection to the traditional Shockley-Queisser limit and recent experimental results reported in the literature are discussed.

**Design of a Surface Passivation Scheme for Gallium Arsenide Nanowire Solar Cells:** Ningfeng Huang1,2, Michelle L. Povinelli1,2, Ming Hsieh Dept. of Electrical Engineering, Univ. of Southern California, USA; 2Center for Energy Nanoscience, Univ. of Southern California, USA. We design a surface passivation scheme for axial junction GaAs nanowire solar cells prepared by both top-down and bottom-up methods. Si doped radial shell was epitaxially grown. Optical properties, quantum efficiency, and conversion efficiency of Si radial junction nanowires are discussed.

**13:00–14:30 Lunch (on your own)**
Enhancing Solar Energy Light Capture with Multi-Directional Waveguide Lattices, RM2D.2 • 11:30
Switzerland; Optics & Photonics Tech Lab, Institut de Microtechnique-EPFL, Switzerland.
Söderström rigorous calculation, we discuss the impact of the cell geometry on the nature of its optical resonances. By
Julie Kho UV-Vis/Near-IR Transient Absorption Spectroscopy, Improving Solar Energy Harvesting by Self-Assembled Porphyrin-fullerene Complexes Through Light-trapping in the near field: the case for plasmonic thin-film solar cells, Ali Naqavi1, Karin Söderström3, Celine Pahud4, Gaël D. Osowiecki5, Franz-Josef Haug1, Toralf Scharl, Hans Peter Herziger2, Christophe Ballif1; Photovoltaics and Thin Film Electronics Lab, Institut de Microtechnique-EPFL, Switzerland. We study the plasmonic and non-plasmonic regimes of operation of a thin-film amorphous-silicon solar cell. By rigorous calculation, we discuss the impact of the cell geometry on the nature of its optical resonances.

Enhancing Solar Energy Light Capture with Multi-Directional Waveguide Lattices, Ian D. Hosein1, Hao Lin1, Matthew R. Ponte2, Dinesh K. Basker3, Kailaschvi Saravananamuttu3; McMaster Unv., Canada. Multiple, intersecting lattices of multimode and polychromatic waveguides were fabricated in photosensitive materials. The cumulative collection angle ranges of the lattices permits wide-angle illumination, which may enhance power output in solar cells.

Light-trapping in the near field: the case for plasmonic thin-film solar cells, Ali Naqavi1,2, Karin Söderström3, Celine Pahud4, Gaël D. Osowiecki5, Franz-Josef Haug1, Toralf Scharl, Hans Peter Herziger2, Christophe Ballif1; Photovoltaics and Thin Film Electronics Lab, Institut de Microtechnique-EPFL, Switzerland. We study the plasmonic and non-plasmonic regimes of operation of a thin-film amorphous-silicon solar cell. By rigorous calculation, we discuss the impact of the cell geometry on the nature of its optical resonances.

Improving Solar Energy Harvesting by Self-Assembled Porphyrin-fullerene Complexes Through UV-Vis/Near-IR Transient Absorption Spectroscopy, Julie Kho1, Cather Simpson1, Ali Hosseini1; School of Chemical Sciences, Unv. of Auckland, New Zealand. This report presents photophysical properties of self-assembled porphyrin-fullerene complexes as solar harvesting dyes. We study the lifetimes of photoinduced charge-separated states with time-resolved spectroscopy in various structural modifications.

The effect of transparent conductive oxides background spacer layer on light trapping in thin film solar cells, Guangyao Su1, Fangwang Gou1, Chuanhong Liu1, Xiao Deng1, Zhaoyu Zhang1; Peking Univ. Shenzhen Grad School, China. The influence of optical absorption in thin film solar cells induced by the transparent conductive oxide (TCO) spacer layer was numerically investigated. The paper results provide a guideline for designing TCO spacer layer.

Exploiting Internal Optics to Enhance the Performance of III-V Multijunction Solar Cells, Myles Steiner1; National Renewable Energy Lab, USA. We describe our model of photon recycling effects in single and multijunction solar cells, and show how exploiting the internal optics in high radiative-efficiency cells leads to demonstrated record efficiencies and increased energy yield.

Development of InGaN/GaN Light Emitting Diodes (LEDs) and Laser Diodes for Energy Efficient Lighting and Displays, Ali Naqavi1,2, Philips Color Kinetics Lighting, USA. High power pseudomorphic mid ultraviolet light emitting diodes (LED) and laser diodes (LD) for energy efficient lighting applications are discussed. Recent achievements in III-V based mid-ultraviolet LEDs and lasers for lighting and display applications are presented.

Increasing wavefunction overlap of carriers in an asymmetrically graded quantum well with polarization-effect-band-engineering, Bilal Janjua1, Tien K. Ng1, Boon S. Ooi1; National Renewable Energy Lab, USA. Semipolar GaN materials have enabled the development of LEDs in green, and recent achievements of green laser diodes at 520nm.

High Power Pseudomorphic Mid Ultraviolet Light Emitting Diodes with Improved Efficiency and Lifetime, Jianfeng (Jeff) Chen1, Crystal IS, Inc., USA. Mid ultraviolet light emitting diodes were pseudomorphically grown on bulk AlN substrates. Devices stressed at 100mA show minimal power decay for over 1000 hours. 66mW output power is achieved at continuous wave current of 300mA.

Intelligent High-quality White Light in Functional Application with Color Accent, Nadya Piskun1; Philips Color Kinetics Lighting, USA. Energy efficient, high quality, intelligent comfortable light is now required for professional illumination applications. Definitions of “high quality”, “comfortable” and “intelligent” light will be discussed and SkyRibbon Intellihue concept will be presented in this talk.
Joint Poster Session

14:30–15:15

JM3A • Joint Poster

JM3A.1 Effect of nonradiative recombinations in thin film solar cells with light trapping: a model study, Angelo Bozzola1, Piotr Kowalczykowski2, Lucio C. Andreani3; 1Universita degli Studi di Pavia, Italy. We develop an analytic electro-optical model to show that thin film silicon solar cells with Lambertian light trapping outperform thicker ones with the same bulk quality, provided surface recombination is kept below a critical value.

JM3A.2 Simulation of Lidar returns to consider the polarization light, through Monte Carlo method, Edmundo Reynoso Lara2, Manuel Rendon Marin1, Jose Antonio Davila Pintle1, Yolanda Elorri Bravo Garcia1, Maximino Luis Arroyo Carrasco1, Marcelo David Iturbe Castillo2; 1Facultad de Ciencias de la Electronica, Benemerita Universidad Autonoma de Puebla, Mexico; 2Optica, Instuto Nacional de Astrofisica Optica y Electronica, Mexico. Monte Carlo code simulates and generates the Lidar return signals. Results as histograms shows the photons that reached the photodetector with those that only came out of the medium.

JM3A.3 Plasmonic Metal Nitrides for Thin-Film Silicon Solar Cells, Clayton DeVault1,2,4, Uner Gulen1,4, Vladimir M. Shalaev2,4, Alexander Boltas-sesva1,4, Alexander V. Kildishev1,4; 1Birck NanoTech Center, Purdue Univ., USA; 2Physics, Purdue Univ., USA; 3Electrical and Computer Engineering, Purdue Univ., USA. We numerically investigate electromagnetic interactions with metal nitride nanoparticles and discuss potential applications for thin-film silicon solar cells. The results indicate strong local-field enhancement, particularly in the near infrared.

JM3A.4 Withdrawn

JM3A.5 Laser Induced Breakdown Spectroscopy as a tool for support to agriculture, Debora Milori1, Jader Cabral1, Gustavo Nicolodi1, Bruno Marangoni1, Aida Belechichuli1, Michelle Horti1, Paulino Villas-Boas1, Aline Segnini1, Aniele Ranalli1; Embrapa, Brazil. In this work, we will present the main results in agriculture research searches involving the use of LIBS technique for analysis in soils, plants and fertilizers. All results were achieved using a LIBS single pulse technique.

JM3A.6 Bi-Znernike polynomials for wavefront aberration function in rotationally symmetric optical systems, Jingfei Ye1, Zhishan Ga01, Shuai Wang1, Xiaoli Liu1, Zhongming Yang1, Congyang Zhang2; 1School of Electronic and Optical Engineering, Nanjing Univ. of Science and Tech, China. Wavefront aberration function is modified and expressed by combination of Bi-Zernike polynomials in rotationally symmetric optical systems. The field and pupil parameters of wavefront aberration function are separated and described respectively by orthonormal Zernike polynomials.

JM3A.7 Head-mounted display with low chromatic aberration, Nan Zhu1,2, Guangang Liang1; 1Univ. of Arizona, USA. Head-mounted display using freeform prism suffers low resolution by chromatic dispersion. This paper presents a novel freeform prism structure for head-mounted display using two different materials to balance the chromatic aberration and achieves high resolution.

JM3A.8 Purifying metallurgical silicon to solar grade silicon by metal-assisted chemical etching, Xiaoping Li1,2, Alexander N. Sprakel1; 1University of Ljubljana, Slovenia; 2Nanomechatronics, National Central Univ., Taiwan. By means of three-dimensional optical simulator CROWM that combines ray-optics/wave-optics we studied (i) micro-structures and (ii) micro-structures in combination with AR-coatings on both sides of glass substrate to improve out-coupling efficiency of white OLEDs.

JM3A.9 Dual-function ultra-thin a-Si solar cells for color generation and power harvesting, Jae Yong Lee1, Kye-Tae Lee1, Sungyoung Seo1, Hui Joon Park1,2, L. Jay Guo1,2; 1Electrical Engineering and Computer Science, Univ. of Michigan, USA; 2Macromolecular Science and Engineering, Univ. of Michigan, USA. Converting the absorbed light in color filters to electric power is challenging since conventional solar cells are too thick for efficient photon management. We investigate ultra-thin a-Si PISs, producing transmission colors with high angular tolerance.

JM3A.10 Scanning Photocurrent Microscopy for Investigation of Photovoltaic Properties of Nanomaterial Film, Won Seok Chang1,2; 1Nano Mechanics, KIMM, Republic of Korea; 2Nanomechatronics, Univ. of Science and Tech, Republic of Korea. We established the scanning photocurrent microscopy (SPCM) based on confocal and near-field scanning systems. The characteristics of photocurrent wavelet graphs of nonstructured film devices were analyzed directly and visually.

JM3A.11 Near infrared-to-visible up-conversion luminescence in hydrothermally derived LaF3:Yb3+,RE3+ (RE = Er, Ho) nanoparticles, Farzane Tabatabaei1,2, Ali A. Sabbagh Alivani1, Hassan Samie1,2, Shima Moosakhani1,2, Reza Salimi3, Mojde Taherani1,2; 1Polymer Engineering & Color Tech, Amirkabir Univ. of Tech, Iran; 2Color and Polymer Research Center (CPRC), Amirkabir Univ. of Tech, Iran. Hexagonal pure LaF3 and Yb3+/Er,Yb3+/Ho co-doped LaF3 nanostructures have been successfully synthesized via an efficient, environmentally friendly hydrothermal route and the up-conversion luminescence properties were comprehensively investigated for photovoltaic devices such as solar cells.

JM3A.12 A Novel Silver Base Sensitiveer for Quantum Dots Sensitized Solar Cells, Shima Moosakhani1, Ali A. Sabbagh Alivani1, Ali A. Sarabi1, Hassan Samie1,2, Reza Salimi1,2; 1Faculty of Polymer Engineering & Color Tech, Amirkabir Univ. of Tech, Islamic Republic of Iran; 2Color and Polymer Research Center (CPRC), Amirkabir Univ. of Tech, Islamic Republic of Iran. We report on the photovoltaic performance of Ag quantum dots sensitized solar cells. The assembled solar cells yielded a power conversion efficiency of 0.64% and a short-circuit current of 2.13 mA/cm2 under one sun illumination.

JM3A.13 Edge-absorbed concentrator photovoltaics with linear gratings, An-Chi Wei1,2, Jhy-Rou Sze3; 1Graduate Inst. of Energy Engineer - Combined Energy Science and Technology, National Cheng Kung Univ., 2Korea University, 3Institute of Optoelectronics, National Chiao Tung University, Taiwan. An edge-absorbed concentrator photovoltaics is proposed with a slab concentrator constructed by linear gratings to achieve a thin system. A design example with 25%-efficient solar cells demonstrated an output power of 0.38W under 1 sun.

JM3A.14 Determination of The Energy Efficiency of Polymer Electrolyte Membrane-Fuel Cell by Digital Shearography and Electrochemical Impedance Spectroscopy, Khalel I. Habib1,2; 1Materials Science and Photo-Electronics Lab, IRE Program, EBR Center, KISR,P.O.Box24885, Kuwait. Shearography and EIS were used to determine the energy efficiency of PEM-FC. The ratio of the conductivity of the PEMs after a certain hours of operation to the initial conductivity would lead to the determination of the energy efficiency of PEM-FC.

JM3A.15 Hybrid thin-films of Graphene materials and metallic nanowires for next generation transparent electrodes, Zhanghao Zhu1, Trent Mankowski1, Kaushik Balakrishnan1, Farid Toosi1, Mohieddine Benammar1, Masud Mansuripur1; 1Nano Mechanics, KIMM, Republic of Korea; 2Color and Polymer Research Center (CPRC), Amirkabir Univ. of Tech, Iran; 3Electric Engineering, Qatar Univ., Qatar. We report advances in the fabrication and characterization of transparent conductive electrodes based on thin-films of metallic nanowires (copper and silver) encapsulated with graphene, graphene oxide, and reduced graphene oxide, using solution-based processing techniques.

JM3A.16 Design for high out-coupling efficiency of white OLED using CROWM - a combined geometric/wave optics model, Jie Yong Lee1, Marko Topic1; 1Univ. of Ljubljana, Slovenia. By means of three-dimensional optical simulator CROWM that combines ray-optics/wave-optics we studied (i) micro-structures and (ii) micro-structures in combination with AR-coatings on both sides of glass substrate to improve out-coupling efficiency of white OLEDs.

JM3A.17 Optical Performance of Dichroic Filters in Solar Spectrum-Splitting application, Yuechen Wu1, Deming Zhang1, Juan M. Russol1, Shelby Vondran1, Raymond K. Kostuk1; 1Univ. of Arizona, USA. This paper describes the effects of non-ideal dichroic filter characteristics on the performance of concentrating spectrum splitting photovoltaic systems.

JM3A.18 Hybrid Gratings for Complementary Absorption Enhancement in Ultra-thin Film Solar Cells, Fangyong Guo1, Guangyao Su1, Chuanhong Liu1, Ji Chen1, Zhaoyu Zhang1; 1Peking Univ. Shenzhen Grad School, China. Amorphous silicon ultra-thin film solar cells with hybrid plasmonic and dielectric gratings on the surface of the active layer are studied numerically. Their respective advantages are combined to achieve the complementary absorption enhancement.

JM3A.19 Enhanced Up-conversion for Photovoltaics using 2D Photonic Crystals, Jonathan Morton1, Jose Marques-Hues1, Bryce S. Richard1,2; 1Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK. 2Up-conversion modification of the solar spectrum can increase the efficiency of a single junction solar cell. This paper investigates a 2D Photonic Crystal to improve the efficiency of the up-conversion process.

JM3A.20 A Solar Thermophotovoltaic Generation with a Monolithic Planar Absorber/Emitter Material, Hisraki Kobayashi1,2,3, L. Jay Guo1,2; 1Graduate Inst. of Energy Engineering - Combined Energy Science and Technology, National Cheng Kung Univ., 2Korea University, 3Institute of Optoelectronics, National Chiao Tung University, Taiwan. We report on the photovoltaic performance of Ag quantum dots sensitized solar cells. The assembled solar cells yielded a power conversion efficiency of 0.64% and a short-circuit current of 2.13 mA/cm2 under one sun illumination.

JM3A.21 Absorption enhancement for solar cells structured with quasi-periodic problems: low illumination uniformity and stray light. To address those issues, we have applied different freeform lens structures combined with optimization method to achieve high uniformity and reduce the stray light.

JM3A.22 Withdrawn

JM3A.23 Freeform Lens for LED Dental Headlight, Donglin Ma1,2; 1, USA. Currently commercially available dental headlights have two major problems: low illumination uniformity and stray light. To address those issues, we have applied different freeform lens structures combined with optimization method to achieve high uniformity and reduce the stray light.

JM3A.24 LED Lighting Freeform Lens for achieving Octagon Spot, Yin Shao1, Xiuhui Sun1, Liangqing Xia1, Chunlei Du1; 1Chinese Academy of Sciences, Chongqing Inst., of Green and Intelligent Tech, China. To decreasing the design error caused by the point source model, a method combining freeform and aspherical surface is presented. A LED spotlight lens for realizing octagon spot is designed, manufactured and tested.
15:15–17:00  
EM4A • Sensors and Sensor Applications II  
Presider: Gerard Wysocki; Princeton Univ., USA

EM4A.1 • 15:15  
Advanced Imaging and Spectroscopy for the Conservation and Monitoring of Cultural Heritage, Gianluca Valentini1,2, Daniela Comelli1, Lucia Tonolo1, Austin Nevin1; 1Physics, Politecnico di Milano, Italy; 2Chemistry, Politecnico di Milano, Italy; 3Inst. of Photonics and NanoTech, Consiglio Nazionale delle Ricerche, Italy. Imaging and spectroscopy techniques that have been developed in our Lab to support the conservation and monitoring of artworks will be presented along with some applications to mural paintings and sculptures.

EM4A.2 • 15:45  
Optical Laser Heterodyne Systems for Remote Sensing - From Terrestrial to Space Applications, Damien Weidmann1, Neil MacLeod2, Rebecca Rose1, Richard Brownward1, Mike Jenkins3; Space Science and Tech Dept., STFC Rutherford Appleton Lab, UK; 2HollowGuide Ltd, UK. Selected developments of high resolution remote sensing instruments operating in the thermal infrared and based on laser heterodyne spectroscopy are presented. Current performances and prospects of both passive and active quantum cascade laser heterodyne sounders are discussed.

EM4A.3 • 16:15  
Field Deployment of a Remote Multi-Path Methane Sensor, Genevieve Plant1, Michel Nikodem1,2, Phil Mullhall1, Ruth Varnes1, David Sonnenfroh1, Gerard Wysocki1; Princeton Univ., USA; 2Wroclaw Research Centre EIT, Poland; 3Physical Sciences Inc., USA; 4Univ. of New Hampshire, USA. The design and field deployment of a near-infrared chirped laser dispersion spectroscopy system for atmospheric methane detection at 1.651μm are discussed. A multi-path OH detection at Sallie’s Fen over a three-month campaign will be presented.

EM4A.4 • 16:30  
Dual Modulation Faraday Rotation Spectroscopy of HO for Combustion Diagnostics, Brian Brumfield1, Wenting Sun1, Yiqiang Ju1, Gerard Wysocki2; 1Electrical Engineering, Princeton Univ., USA; 2Mechanical and Aerospace Engineering, Princeton Univ., USA. Dual modulation Faraday rotation spectroscopy (DM-FRS) is used for sensitive measurements of HO, from an atmospheric flow reactor with a 3σ detection limit of 0.4 ppmv Hz-1/2.

EM4A.5 • 16:45  
Compact Nanoplasmonic Filter Based on FP Cavity, Xiukong Sun1,2, Afshari Bavil1; 1Harbin Inst. of Tech, China; 2Key Lab of Micro-Optics and Photon Tech of Heilongjiang Province, China. By utilizing a Fabry-Perot (FP) cavity and slot cavities, a compact filter with functionalized characteristics is designed. Its filtering wavelength can be manipulated by changing resonance conditions of the FP cavity and nanocavities’ parameters.

15:15–17:00  
FM4B • Imaging: Freeform Surfaces in Optical Design  
Presider: Kevin Rolland-Thompson; Synopsis, Inc, USA

FM4B.1 • 15:15  
What’s in the Designer’s Toolbox for Freeform Systems?, Christoph Menke1; 1Carl Zeiss AG, Germany. Freeform surfaces offer new degrees of freedom for the design of optical systems. Developments in aberration theory, surface characterization and optimization methodology are discussed that are key steps to gain the full benefit of freeform Tech.

FM4B.2 • 15:45  
Optical Design Experiences with Free Form Surfaces, Jose M. Sa-sian1; 1Univ. of Arizona, USA. This talk provides a variety of examples in optical design with free form surfaces. A number of problems result and useful considerations, tools, and tricks are highlighted.

FM4B.3 • 16:15  
Three Mirror Anastigmat Designed with NURBS Freeform Surfaces, Michael Chirps1; 1MIT Lincoln Lab, USA. Performance of the first three mirror anastigmat designed with NURBS freeform surfaces is presented, and a direct comparison is made with using surface shapes of conventional aspheres or Zernike polynomials.

FM4B.4 • 16:40  
Optical Design Method for Free Form Optics, Taner T. Elazhary1, Ping Zhou1, Chunyu Zhao1; 1Univ of Arizona, Coll of Opt Sciences, USA. In this paper we propose a method based on the generalized Sine condition for the design of aplanatic optical systems that are generally made of free form optics. As a proof of concept we present the design of a two mirrors fast aplanatic telescope.

FM4B.5 • 17:15  
A New Look Inside: Wavefront Analysis Tool for Freeform Designers, Xinda Hu1, Hong Hua1; 1Univ of Arizona, Coll of Opt Sciences, USA. We propose a new wavefront analysis tool for optical designers to evaluate the aberration contribution of each freeform surface inside a complex system, which has great advantages in determining the design form and optimization strategy.

15:15–16:45  
PM4C • Photon Management in Ultrathin Crystalline Solar Cells  
Presider: Alexander Sprafke; Martin-Luther Univ. Halle, Germany

PM4C.1 • 15:15  
Dielectric Light-Trapping Structures for Ultrathin Silicon and Gallium Arsenide Solar Cells, Harry Atwater1; California Inst. of Tech, USA. We show that superlattice photonic crystals introduce new optical modes that contribute to enhanced absorption, with greatest improvements obtained by combining a superlattice with a randomly textured dielectric incooper layer. Layers 1-4 microns in thickness, have absorbed currents competitive with conventional thick solar cells.

PM4C.2 • 15:45  
Front/Rear Decoupled Texturing in Refractive and Diffractive Regimes for Ultra-Thin Silicon-Based Solar Cells, Dino Isabella1, Andrea Ingenito1, Dane Linssen1; 1Photovoltaic Materials and Devices group, Deft Univ. of Tech, Netherlands. Front/ rear decoupled texturing was studied experimentally in passivated c-Si wafer and theoretically in complete thin-film nc-Si:H solar cells. Measured and simulated absorptances in Si absorbers are close to or exceed the Yablonovitch limit.

PM4C.3 • 16:15  
Experimental broadband absorption enhancement in silicon nanohole structures with optimized complex unit cells, Chenxi Lin1, Luis J. Martinez1, Michelle L. Povinelli1; 1Univ. of Southern California, USA. We design silicon membranes with nanohole structures with optimized complex unit cells that maximize broadband absorption. We fabricate the optimized design and measure an experimental broadband absorption 3.5 times higher than an equally-thick thin film.

17:15–18:45  
Conference Reception, Ania Terrace
15:15–16:15
DM4E • Quantum Dot Electroluminescence
Presider: Barry O’Brien, Arizona State Univ., USA

17:15–18:45
Conference Reception, Ania Terrace

All technical papers are currently available for online download.
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Presentations selected for recording are designated with a .
To view recorded presentations, go to www.osa.org/renewable_energy and click on Access meeting presentations slidecasts under Essential Links.
Dual-Comb Spectroscopy of Greenhouse Gases Over a 2-km Outdoor Path, Gregory B. Rieker1,2, Fabrizio R. Giorgetta1, Ian Coddington1, William C. Swann1, Laura Sinclair1, Christopher L. Cromer1, Esther Baumann1, Alex M. Zolot1, Nathan R. Newbury2; 1National Inst. of Standards and Tech, USA; 2Univ. of Colorado, USA. Frequency-comb lasers in the near-infrared are highly fidelity molecular spectroscopy. Dual-frequency combs harness this accuracy and allow for fast and highly fidelity molecular spectroscopy.

Freeform Lens Design for Uniform Rectangular Illumination, Donglin Ma1; 1Univ. of Arizona, USA. A new method to design a freeform lens for uniform rectangular illumination is proposed in this paper. This new method is based on freeform and TIR-Freeform structure. It can increase the light efficiency to as high as 90%.

Optical Instrumentation for Energy & Environmental Applications

Freeform Optics

Optical Nanostructures and Advanced Materials for Photovoltaics

Critical Interfaces in Emerging Thin Film Photovoltaic Technologies: From Basic Science to Policy and Economic Issues, Neal Armstrong, University of Arizona, USA. This talk will focus on some of the scientific/technical challenges we face in creating ‘scalable’ (solar cells that can be printed at 100’s of meters per day), where materials costs are extremely low, accompanied by low (but increasing) efficiencies. We will review studies underway that allow us to understand and control the critical interfaces in these PV platforms, that currently limit both efficiency an lifetime. We view all of this basic science in the context of a constantly changing political and economic environment for PV-based electricity, and an exciting future for these new PV technologies.

Optical Frequency Comb: A Tool for Photovoltaic Research, Thomas F. Krauss1; 1,2, Emiliano R. Martins2; 2Dept. of Physics, Univ. of York, UK; 2School of Physics & Astronomy, Univ. of St Andrews, UK. We introduce a novel approach for designing the rich Fourier spectra required for high efficiency broadband light trapping and show how these structures can be employed to achieve performance close to the Lambertian limit.

Dynamic Spectroscopy – a Critical Tool for Developing Artificial Photosynthesis, Heinz Frei, Lawrence Berkeley National Laboratory, USA. For the development of an efficient artificial photosystem that converts carbon dioxide and water to a fuel in a nanostructured inorganic unit, transient optical and infrared spectroscopy of charge transport and catalytic processes provide key insights that guide materials designs.

Invention and Innovation – Key to keeping Photovoltaic R&D in the United States, Doug Hall, US Department of Energy, USA. The photovoltaic industry, like other technology-based industries, has undergone a massive migration out of the US. To ensure participation of US-based manufacturing companies in this important technology (and US-based R&D), we need innovation, not just invention.
RT2D.1 • 11:00
Invited
A History of, update on and a Wish List for Optics in CPV, Adam Plesniak; Advanced Tech Group, Amonix, USA. A call-to-action for optical experts, with a review of topics in applied optics where Amonix and other CPV companies are currently looking for interesting new ideas and significant progress.

RT2D.2 • 11:30
Invited
Concentrating Optics with Big Glass Mirrors for Inexpensive CPV Generation, Roger P. Angel, Blake M. Coughenour, Thomas Stalcup, Brian Wheelwright; Univ. of Arizona, USA. Abstract: Large, inexpensive, back-silvered glass mirrors are widely used at solar thermal generation plants. The electrical output per mirror may be doubled by optical coupling to highly efficient, triple junction photovoltaic cells.

DT2E.1 • 11:00
Invited
Full Color Organic Light Emitting Diode Displays on Flexible Substrates, Barry O’Brien, Yong Kyun Lee, Michael A. Marrs, Mark Strnad, Eric Forsythe, David Morton; Flexible Display Center, Arizona State Univ., USA; Dept. of Materials Science and Engineering, Arizona State Univ., USA; Army Research Lab, USA. We demonstrate full color organic light emitting diode based flexible displays built on polyethylene naphthalate substrates. The backplane uses mixed metal oxide transistors with mobilities of 13.5 cm²/V-s fabricated by a low temperature process.

DT2E.2 • 11:30
Invited
High-Efficiency Flexible Polymer OLEDs, Qibing Pei; Dept. of Materials Science and Engineering, Univ. of California, Los Angeles, USA. Flexible polymer OLEDs employing a transparent polymer composite electrode have been fabricated by solution-based processing. The flexible OLEDs exhibit both higher efficiency and high mechanical flexibility including being stretchable by 50% strain.
This paper presents the pressure sensing using algorithms for the efficient detection of pressure. Saidi Reddy Parne 1, Anudeep kumar Reddy Ina 1, R C Reddy 1, Ginjala 1, Sanjeev Afzulpurkar 2, 1Dept. of Electrical Engineering and Information Systems, Univ. of Tokyo, Japan. Distributed optical fiber sensors have been developed as effective tools for smart structures and environmental monitoring. Superior functions have already been demonstrated, including mm-order spatial-resolution, kHz-order sampling-rate, random-accessibility, and discriminative measurement of strain and temperature.

FT2B.4 • 12:15  
An effective freeform surface design for collimated beam shaping, Rengma Wu 1, Pablo Benitez 1, Juan C. Milian 1, 1Universidad Politécnica de Madrid, Spain. A mathematical model is established to achieve one freeform surface design for incoherent collimated beam shaping. A novel technique is disclosed and boundary conditions are presented. The results show elegance of the model in tackling complex tasks.

FT2B.5 • 12:30  
Phase space transformations - a different way to understand freeform optical systems, Alois M. Herkommer 1, Denise Rausch 1, 1Universität Stuttgart, Germany. Phase space optics offers an alternate understanding of freeform surfaces and their impact and potential. We show that nonlinear transformations of phase space, are key to understand freeform illumination designs and aberrations within freeform systems.

ET2A • Optical Fiber Technologies for Sensors—Continued
ET2A.3 • 12:00  
High Performance Distributed Optical Fiber Sensors for Smart Structures and Environmental Monitoring, Kazuo Hotate 1; 1Dept. of Electrical Engineering and Information Systems, Univ. of Tokyo, Japan. Distributed optical fiber sensors have been developed as effective tools for smart structures and environmental monitoring. Superior functions have already been demonstrated, including mm-order spatial-resolution, kHz-order sampling-rate, random-accessibility, and discriminative measurement of strain and temperature.

ET2A.4 • 12:30  
Measurement of pressure in oceanography using fiber Bragg gratings, Saidi Reddy Parne 1, Radeep Kumar Reddy Ina 1, R C Reddy 1, Ginjala 1, Sanjeev Afzulpurkar 2; 1Physics, National Inst. of Tech Goa, India; 2Inst. of Science & Tech, Republic of Korea. This paper presents the pressure sensing using Fiber Bragg Grating (FBG) sensors for oceanography based on the proposed two novel sensor heads.

13:00–14:30  Lunch (on your own)
Proof-of-concept for a self-tracking solar concentrator, Volker Zagolla1, Eric Tremblay1, Christophe Moser1; 1LAPD, École Polytechnique Fédérale de Lausanne, Switzerland. A phase change material actuator is used for a passive, self-tracking solar concentrator system capable of achieving effective concentration factors of 100x with reasonable dimensions (40 x 10 cm2). We show simulations and an experimental proof-of-concept demonstrator of the proposed system.

Improving the optical efficiency of a waveguide concentrator used with a single-axis tracking system, Sebastien Bouchard1, Simon Thibault1; 1COPL, Université Laval, Canada; 2Physique, génie physique et optique, Université Laval, Canada. We propose a method to improve the optical efficiency of a planar concentrator used with a single-axis tracker. The low cost for mass producing the system is kept while the performance is improved.

13:00–14:30 Lunch (on your own)

14:30–16:00

RT3D • Concentrators - Tracking, Planar and Array Configurations

Presider: Chih-Hao Chang; North Carolina State Univ., USA

RT3D.1 • 14:30

A Lens-to-Channel Waveguide Solar Concentrator, Yu-xiao Liu1, Ran Huang1, Christi K. Madsen1; 1Electrical & Computer Engineering, Texas A&M Univ., USA. We present a lens-to-waveguide structure, employing a lens array and tapered channel waveguides. It eliminates decoupling losses for 100% concentration factors of 100X with reasonable dimensions (40 x 10 cm2). We show simulations and an experimental proof-of-concept demonstrator of the proposed system.

RT3D.2 • 14:45

Improving the optical efficiency of a waveguide concentrator used with a single-axis tracking system, Sebastien Bouchard1, Simon Thibault1; 1COPL, Université Laval, Canada; 2Physique, génie physique et optique, Université Laval, Canada. We propose a method to improve the optical efficiency of a planar concentrator used with a single-axis tracker. The low cost for mass producing the system is kept while the performance is improved.

14:30–16:30

DT3E • LED Applications

Presider: Nadya Piskun; Philips Color Kinetics Lighting, USA

DT3E.1 • 14:30 Invited

Smart Lighting - Illumination Systems that Think, Robert F. Karlicek1; 1Electrical, Computer and Systems Engineering, Rensselaer Polytechnic Inst., USA. Lighting systems with sensors and digital control are often called “Smart Lighting” systems. Emerging trends in illumination and controls will create future lighting systems that “think”, offering illumination systems with radically new capabilities.

DT3E.2 • 15:00 Invited

High CRI Spotlight for Art Galleries, Tobias Schmidt1; 1CT RI LUM OPT, OSRAM, Germany. For lighting art galleries, OSRAM has developed a high-end spotlight, featuring a high color rendering index, tunable color, dimmability, and extraordinary color mixing. The flat collimator enables a compact modern design.
Making the Invisible, Visible: Upconversion via Capped Er-doped NaGdF₄ Nanoparticles for Harvesting Sub Bandgap Photons, 
Sean K. MacDougall 1,2, Daqin Chen 2, Jose Marques-Hues 1, Feng Huang 2, Yuansheng Wang 2, Bryce S. Richards 1; 
1Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK; 2State Key Lab of Structural Chemistry, Fujian Inst. of Research on the Structure of Matter, Chinese Academy of Sciences, China. 
Upconversion core/shell nanoparticles are prepared for harvesting near infra-red radiation. Power dependent enhancement, due to shell passivation, of photoluminescence is between a factor of 13-38 (green emission) and 160-176 (red emission).

The Freedom of Freeforms: Current Optics Manufacturing Methods Allow for Freeform Optical Designs, 
Jessica D. Nelson 1, Nathan Smith 1, Mark Walters 1, Kate Medicus 1, Matthew Brophy 1, Mike Mandina 1; 
1Optimax Systems, USA. 
A common question about freeform optics is, “if I design it, can you really make it?” This presentation outlines current optical fabrication capabilities and associated optical tolerance guidelines for freeforms.

The internal photoluminescence quantum yield of β-NaYF₄:Er³⁺ is determined under broadband excitation and a photovoltaic-upconverter system with concentrating integrated optics is proposed to enhance the near-infrared response of silicon solar cells.

Evolution of laser induced Shock Waves (SW’s) generated from compacted nanopowders such as Aluminum (Al), Nickel coated Aluminum (Ni-Al), Boron Potassium Nitrate (BKN), Ammonium perchlorate (AP) and potassium Bromide (KBr) using shadowgraphy technique are presented.

An optical model is presented determining the constraints imparted by self-absorption on the luminescence emitted from down-conversion materials. The model clarifies the origin of the disparity between theoretical and experimental efficiencies reported for some materials.

Optimization of thickness in luminescent down-conversion layers for photovoltaic applications, 
Alessandro Boccolini 1, Jose Marques-Hues 1, Daqin Chen 2, Yuansheng Wang 2, Bryce S. Richards 1; 
1Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK; 2State Key Lab of Structural Chemistry, Fujian Inst. of Research on the Structure of Matter, Chinese Academy of Sciences, China. 
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Nanostructured In-Plane Solar Concentrator, Travis Rivord, Chih-Hao Chang, Abhijeet Bagal; Mechanical and Aerospace Engineering, North Carolina State Univ., USA. We present a solar concentrator utilizing two-dimensional (2D) periodic nanostructure on a glass window to redirect a portion of the incoming light to the edge pane to be harnessed by a small efficient photovoltaic cell.

Micro-Concentrators for a Microsystems-Enabled Photovoltaic System, Bradley H. Jared, Michael Saavedra, Ben Anderson, Ron Goethe, William Sweatt, Murat Okandan, Greg Nielson, Brenton Ellisberg, Dave Snively, John Duncan; Sandia National Laboratories, USA; Greenlight Optics, USA. A 100X magnification, ±3° field of view micro-concentrating optical array has been developed with better than 90% transmission for a microsystems-enabled photovoltaic (MEPV) prototype module using 250 µm diameter multi-junction “stacked” PV cells.

Wide-Angle Planar Microtracking for High Efficiency Microcell Concentrating Photovoltaics, Jared Price, Xing Sheng, John Rogers, Noel C. Giebink; Electrical Engineering, Pennsylvania State Univ., USA; Materials Science, Univ. of Illinois, USA. We explore a lenslet-based concentrating photovoltaic system integrated together with high efficiency microcell photovoltaics that enables planar micro-tracking at concentration ratios >200x over a 120° field of view.

Planar Waveguide Illuminator with Variable Directionality and Divergence, William Mellette, Glenn M. Schuster, Ilya P. Agurok, Joseph E. Ford; Univ. of California San Diego, USA. We present the design, model, and experimental characterization of a white light LED illuminator using mechanical actuation of a lenslet array relative to a micro-structured planar waveguide to control the divergence and direction of emitted light.

Light diffusing optical fiber for Illumination, Stephan L. Logunov, Edward Fewkes, Paul J. Shustack, Frederic C. Wagner; Science and Tech, Corning Incorporated, USA. We describe the design of thin, ~100-180 micron diameter, optical silica fibers for illumination. The fiber has a silica core with specially engineered scattering centers to scatter light through walls of the fiber across a wide wavelength range.

A Green Display for the Internet, Ken Foo, William Hamburgen, Jim Zhuang; Google, USA; Intel Corporation, USA. In typical use, a liquid crystal display (LCD) with high resolution, brightness and color saturation can consume over half the total system power in a modern mobile device. This paper examines LCD optical transmittance and system electrical design to extend battery run time. By applying a solid understanding of critical optical parameters and complementary system design, a low power “Green” display can be achieved. The LCD in the Pixel Chromebook [1], will be used as a baseline for discussion.
Gas Leaking From Underground, Joseph A. Shaw1, Jennifer E. Johnson1, Rick L. Lawrence2, Paul W. Nugent1; ‘Electrical & Computer Engineering Department, Montana State Univ., USA; 2Land Resources & Environmental Sciences Department, Montana State University, USA. Thermal imaging of vegetation has been used to detect CO2 gas leaking from an underground gas reservoir. Plant stress caused by increased soil gas concentration results in warmer daytime temperatures and larger diurnal temperature variations than surrounding vegetation.

Regional Air Pollution Monitoring by Spectroscopic Techniques, Janguo Liu1, Wenjing Liu1, Pihuaxi Xie1, Wei Huang1; ‘Key Lab of Environmental optics and Tech, CAS, Anhui Inst., of Optics and Fine Mechanics, Chinese Academy of Sciences, China. An integrated spatiotemporal monitoring system for regional air pollution was constructed which comprises a variety of spectroscopic techniques. The measured results during 2008 Beijing Olympic Games demonstrate the gaseous variations than surrounding vegetation.

Highly sensitive tunable diode laser absorption spectroscopy for process and emission monitoring, Barbara Panella1, Deran Maas1, Hubert Brändle1, Bernardo Galletti1; ‘ABB Switzerland Ltd, Switzerland. Laser absorption spectroscopy was combined with a high-temperature Herriott-type multipass cell for highly sensitive detection of gas components in process and emission control. The performance was verified on the example of ammonia detection for the denNox process.

Meeting the Conflicting Requirements for Direct Measurement of Freeform Optics - High Accuracy, Long Range, and High Slope Tolerance, Paul Glenn1, 2Bauer Associates, USA. Classic null corrector-based metrology is troublesome for freeform optics, making a direct measurement of the freeform asphericity attractive. We discuss one such approach, and its achievement of high accuracy, long range, and high slope tolerance.

Solar cell optimization should take into account sunlight incoherence, Aline Herman1, Michaël Sarraizin1, Olivier Deparis1; ‘Univ. of Namur, Belgium. Taking into account the degree of coherence of sunlight implies revisiting the way solar cells should be optimized. Optimal structures illuminated with coherent light are not necessarily optimal under incoherent light and vice versa.

Optical Instrumentation for Energy & Environmental Applications

Timing for Energy & Environmental Applications

Optical Nanostructures and Advanced Materials for Photovoltaics

Optics for Solar Energy

08:30–10:15
FW1A • Testing of Freeform Surfaces
President: Jessica Nelson; Optimax Systems, USA

08:30–10:15
FW1B • Direct Measurement of Freeform Optical Components, James H. Burge1; ‘Univ. of Arizona, USA. Advanced fabrication and testing techniques produce freeform optical surfaces that lack symmetry. We summarize new methods for modeling and designing with these surfaces, as well as some practical issues with their manufacture and measurement.

08:30–10:30
FW1C • Concepts for Photon Management in Solar Cells
President: Carolin Ulbrich; Forschungszentrum Jülich, Germany

08:30–10:10
FW1D • Luminescent Concentrators and Spectrum Splitting
President: TBD

08:30–10:00
PW1A • Sensors and Sensor Applications III
President: Mark Phillips; Pacific Northwest National Lab, USA

08:30–10:15
PW1B • Multidisciplinary Approach to Understanding Impact of Interfaces on Device Physics in Photovoltaics, Joseph Berry1; ‘National Renewable Energy Lab, USA. We review our integrated studies of material structure, synthesis and surface science to understand the role of interfacial energetics on photovoltaic performance. We show this multidisciplinary approach permits improved insight into carrier collection in photovoltaics.

08:30–10:00
PW1C • Concepts for Photon Management in Solar Cells II
President: Carolin Ulbrich; Forschungszentrum Jülich, Germany

08:30–10:15
RWC • Concepts for Photon Management in Solar Cells II
President: Carolin Ulbrich; Forschungszentrum Jülich, Germany

08:30–10:15
PW1D • Concepts for Photon Management in Solar Cells III
President: Carolin Ulbrich; Forschungszentrum Jülich, Germany

08:30–10:00
RW1E • Concepts for Photon Management in Solar Cells I
President: Carolin Ulbrich; Forschungszentrum Jülich, Germany

08:30–10:15
RWC • Sensor and Sensor Applications II
President: TBD

08:30–10:00
RWC • Sensor and Sensor Applications I
President: TBD
Optical Instrumentation for Energy & Environmental Applications

EW1A • Sensors and Sensor Applications III—Continued

EW1A.4 • 09:45
Observation of NO and C(I) Using Time-Resolved Fluorescence Spectroscopy - A New Approach for the Detection of Explosives, Hergen Eilers1, Helena Diez-y-Riega2; 1Inst. for Shock Physics, Washington State Univ., USA; 2Standoff detection of explosive molecules in the vapor phase requires detection of ppt-level concentrations. We use time-resolved fluorescence spectroscopy to detect the simultaneous emission from NO and C(I) at concentrations as low as 10 ppt.

EW1A.5 • 10:00
Application of a Backwards Lagrangian Stochastic Model to Lidar Data to Estimate Particulate Matter Emissions, Kori Moore1,2, Michael Wojcik1, Randal Martin1, Richard Pfeiffer3, John Prueger1, Jerry Hatfield4; 1Inst.. for Shock Physics, Utah State Univ. Research Foundation, USA; 2Space Dynamics Lab, Utah State Univ., USA; 3Agricultural Research Service, U.S. Dept. of Agriculture, USA. A backwards Lagrangian stochastic model will be applied to particulate matter mass calibrated Lidar data in order to estimate particulate matter emissions from a nearby source. This paper describes the methodology to be used.

FW1B • Testing of Freeform Surfaces—Continued

FW1B.4 • 10:00
Fabrication and Measurement of Freeform Surfaces Using an Integrated Machining Platform, Frank Niehaus1, Stephan Hüttenhuis2, Alex Feskas3; 1Schneider Optical Machines, USA; 2Schneider Optical Machines, USA; 3OptiPro Systems, USA. Currently the design and utilization of freeform shapes are costly due to the difficulties introduced with fabrication and metrology of these parts. OptiPro is developing freeform manufacturing solutions through computer controlled multi-axis optical generating, polishing, and metrology machines.

FW1B.5 • 10:15
Grinding, Polishing, and Metrology of Freeform Optics, Edward M. Fess1; 1OptiPro Systems, USA. The introduced machine and method for data handling enables efficient manufacturing of precision freeform surfaces.

PW1C • Concepts for Photon Management in Solar Cells II—Continued

PW1C.4 • 09:45
Invited Session
Novel Idealistic and Realistic Approaches for a Better Photon Management, Carsten Rockstuhl1, Stephan Fahle2, Samuel Wiesenganger1, Falk Lederer1; 1Inst. of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-Universitat Jena, Germany. We present our recent studies where we incorporate novel approaches to control light at the nanoscale into solar cells for the purpose of photon management. This covers ideas based on metamaterials and amorphous colloidal materials.

RW1D • Luminescent Concentrators and Spectrum Splitting—Continued

RW1D.5 • 09:45
Wideband Coherent Optical Concentrator for Photovoltaic and Rectenna Solar Cells, Patricia Bodan1; 1Univ. of Illinois Urbana-Champaign, USA; 2AMI Research & Development, USA; 3Univ. of Illinois Urbana-Champaign, USA. A wideband coherent optical 10 concentrator, intended for rectennas, has been designed with an integrated photovoltaic array solar cell. Modeled and measured results are presented for a wedge prism coupled SION waveguide array.
The importance of interfaces in excitonic solar cells: Towards control from first-principles. Oliver L. Montoli; Chemistry and Biochemistry, Univ. of Arizona, USA. The fundamental processes that determine efficiency in organic and dye-sensitized solar cells will be discussed. These excitonic photovoltaic cells offer the potential for cheap and large-scale solar energy conversion but require a fundamental understanding of the processes occurring at interfaces of complex materials.

Self-action effects on Laser-induced Dynamics States of Matter. Prem Kiran Patari; Leela Cheillani; Rakesh Kumar Vaddepally; Vinod Kumar Lakshmi; Venkateshwarlu Pinni; Manjula Gote; Sai Shiva Sakaraboina; ACRHEM, Univ. of Hyderabad, India. Evolution of laser-induced dynamic states of matter aimed at controlled release of energy from materials with inherent high energy is discussed. Optical and microwave spectroscopy has been performed to understand the challenge of controlled energy release is presented.

Femtosecond Laser Micro-machining for Energy Applications. Krishna C. Vishnubhatla; Istituto Italiano di Tecnologia, Italy. Femtosecond laser micro-texturing of silicon substrate at high repetition rates is performed. High absorption in the visible region was achieved as compared to the unstructured ones. A figure of merit is introduced for a quantitative guidance in the choice of fabrication parameters.

Mid-spatial Frequency Specification and Characterization for Freeform Surfaces. Thomas J. Suleski; Jason A. Shultz; Paul J. Smiley; Univ. of North Carolina at Charlotte, USA. Freeform fabrication is sub-aperture by nature and gives rise to mid-spatial frequency structure. This paper compares methods for quantifying mid-spatial frequencies: power spectral density, autocorrelation function and structure function, and discusses aspects unique to freeforms.

Design of Dynamic Freeform Optics. Thomas J. Suleski; Jason A. Shultz; Paul J. Smiley; Univ. of North Carolina at Charlotte, USA. Multi-element freeform systems with controlled relative motions enable dynamic optical functionality. In this paper, we discuss design approaches for such systems and explore examples ranging from the vari focal lenses to novel beamshaping elements.

Hybrid Radial Basis Function and Local $\phi$-Polynomial Surfaces. Ilhan Kayal; Jannick P. Rolland; Dept. of Electrical Engineering and Computer Science, Univ. of Central Florida, USA; The Inst. of Optics, Univ. of Rochester, USA. We present an efficient, localized, and hybrid surface description method combining assets of radial basis functions and local $\phi$-polynomials. The method reduces the order of $\phi$-polynomials terms required for optics and applicable to general apertures.

Figure Metrology for X-Ray Focusing Mirrors with Fresnel Holograms and Photon Sieves. Ulf Greßmann; Johannes A. Soons; Quandou Wang; Lahren Assoufid; National Inst. of Standards & Tech, USA. We report on interferometric measurements of the figure error of an ultra-precise mirror with the shape of an elliptical toroid for the diffraction limited focusing of hard-x rays form an undulator x-ray source. We describe measurement configurations using Fresnel type holograms and photon sieves.

Mid-spatial Frequency Specification and Characterization for Freeform Surfaces. Angela D. Davies; Liangiu He; Chris J. Evans; Univ. of North Carolina at Charlotte, USA. Freeform fabrication is sub-aperture by nature and gives rise to mid-spatial frequency structure. This paper compares methods for quantifying mid-spatial frequencies: power spectral density, autocorrelation function and structure function, and discusses aspects unique to freeforms.

Toward high performance Cu2ZnSn(S,Se)4 solar cells through nanocrystal precursors. Huanping Zhou; Univ. of California Los Angeles, USA. We present the progress of controlling elemental distributions in fully solution-processed 8.6% Cu2ZnSn(S,Se)4 device through nanocrystal precursors, and attempts in addressing open circuit voltage deficit and short minority carrier lifetimes.

Hydrogen Evolution at Si-based Metal-In insulator-Semiconductor Photoelectrodes Enhanced by Inversion Channel Charge Collection and Hydrogen Spillover. Alec A. Talin; Daniel Esposito; Igor Levin; Thomas Moffatt; Sandia National Laboratories, USA; NIST, USA. Photoelectrochemical (PEC) water splitting represents a promising route for renewable production of hydrogen, but trade-offs between stability and efficiency have limited the performance of PEC devices. I will describe a new approach using a Si MIS diode with catalyst metal contacts that combines stability with high performance.

A Line-Scanning Laser Hartmann Test for Para bolic Trough Mirrors. Brian Coughenour; Roger P. Angel; Jon Weiser; Thomas Stalcup; Blake M. Coughenour; College of Optical Sciences, Univ. of Arizona, USA; Steward Observatory, Univ. of Arizona, USA; Dept. of Physics, Univ. of Arizona, USA. We present a simple method to determine slope errors in large parabolic trough mirrors. While most slope-measurement schemes determine slope errors via indirect computation, the method presented here is direct, and has inherently high absolute accuracy.

Characterization and Use of a Sinton FMT-350 Flash Tester at the Tucson Electric Power Solar Test Yard. Daniella Delia-Giustina; Adria Brooks; Michael St. Germaine; Scott Patterson; Alexander Cronin; Univ. of Arizona, USA. We characterize a Sinton Inst.ruments FMT-350 module I-V flash tester using NREL primary calibration reference modules. We use the FMT-350 to measure the effect of soiling and light induced degradation on PV modules.
Development of a supercontinuum-based photoacoustic spectrometer for characterization of atmospheric aerosol optics, Ian Arnold1, Hans Moosmüller1, Noopur Sharma1,2, Claudio Mazzoleni1; 1Lab for Aerosol Science, Spectroscopy, and Optics, Desert Research Inst., USA; 2Physics, Michigan Technological Univ., USA; 3Atmospheric Sciences Program, Michigan Technological Univ., USA. The development of a novel Photoacoustic Aerosol Light Absorption and Albedo Spectrometer (PALAAS) for real time measurement of aerosol light absorption, scattering, and single scattering albedo using a supercontinuum light source is discussed.

Measurement of a freeform object with the TII-3D measurement system, Florian Schneider1,2, Rolf Rascher1, Christine Wänisch1; 1Univ. of Applied Sciences Deggendorf, Germany; 2University of the West of England, UK. Since interferometer based measurement systems mostly don’t have the capability to operate on free formed objects to be measured, coordinate measurement machines, like the TII-3D, can proof their right to exist and close this gap.

Comparison of CGH Testing To CMM Point Cloud Measurements for Freeform Surfaces, John M. Tamkin1, Roger Johnston1; 1LightWorks Optical systems, USA; 2Imaging Insights LLC, USA. CGH testing of off-axis aspheric segments is augmented using CMM point cloud measurement for highly off-axis aspheric mirrors.

Development of a Prototype Off-axis Secondary Mirror for the GMT, Young-Soo Kim1,2; 1KASI, Republic of Korea. The Fast Steering Mirror (FSM) of the GMT is going to be the first-light secondary mirror system. An FSM prototype has been developed which consists of 1m off-axis aspheric mirror and tip-tilt test-beds. The successful development results are presented.

Near Perfect Sunlight Absorption in 20nm-Thick Iron Oxide Photoanode Based on Core-Shell Nanocostructure, Ken Xingze Wang1,2,3, Victor Liu1,2, Mark Brongersma3, Thomas Jaramillo2, Shin Hyeok Jang1,3, Jin-Young Jung2,3, Sun-Mi Shin1,2, Jung-Ho Lee1,2, Min-Joon Park2,3, Dong-Hyung Kim1, Jung-Ho Lee1,2, 1Dept. of Chemical Engineering, Hanyang Univ., Republic of Korea. A photoelectrochemical cell and a thermoelectric device have been coupled to boost water splitting at bias-free condition. A photon-to-current efficiency of 13.6% was achieved at a 14.3 °C temperature gradient across a thermoelectric device.

Practicable fabrication Tech of high-temperature photonic materials for thermophotovoltaic systems, Makoto Shimizu1, Hiroaki Kobayashi1, Kunihiko Tanigawa2, Fumitada Iguchi1, Hiroo Yugami3; 1Graduate School of Engineering, Tohoku Univ., Japan. The high-temperature photonic materials fabricated by practicable Tech is described. The high-temperature photonic material using self-organization of a super-alloys and a monolithic planar absorber/emitter with multi-layer coating is obtained.
FW3A.2 • 14:45
Answers will be given!
- de Madrid, Spain.

28. John Koshel
Targeting, Designing Optical Freeform Surfaces for Extended Sources, Rolf Wester
1, Gideon Muller2

Zhenrong Zheng

Freeform illumination design: a nonlinear boundary problem for the elliptic Monge-Ampère equation, Yu-Lin Tsai1; Chinh-Tien Wu2, Chung-Hao Tien1; Dept. of Photonics, Nation ChiaoTung Univ., Taiwan; Dept. of Applied
Mathematics, Nation ChiaoTung Univ., Taiwan. We proposed an algorithm for single reflectors that locally solve a set of Monge-Ampère equation which characterize the flux transformation. Based on computational technique, proposed scheme imposes no restriction on desired distribution, or source distribution.

FW3A.2 • 14:45
Sharp imaging of Multiple object Points: How and Why, Pablo Benitez1; Universidad Politécnica de Madrid, Spain. Is it possible to sharply image M object points with N surfaces when N>M? Under what conditions? Why is it interesting for optimization? What is the role of the SMS method? Answers will be given!

FW3A.3 • 15:15
Freeform illumination design: a nonlinear boundary problem for the elliptic Monge-Ampère equation, Zhenrong Zheng1, Yu Qin Zhang1, Rengmao Wu1, Haifeng Li1, Xu Liu2; Zhejiang Univ., China; Universidad Politécnica de Madrid, Spain. The freeform surface illumination is converted into a nonlinear boundary problem for the elliptic Monge-Ampère equation based on the optimal mass transport. Results show the feasibility of this approach in tackling the illumination problem.

FW3A.3 • 14:30
An approach to construct freeform surface by solving Monge-Ampere equation, Yu-Lin Tsai1; Chinh-Tien Wu2, Chung-Hao Tien1; Dept. of Photonics, Nation ChiaoTung Univ., Taiwan; Dept. of Applied Mathematics, Nation ChiaoTung Univ., Taiwan. We proposed an algorithm for single reflectors that locally solve a set of Monge-Ampère equation which characterize the flux transformation. Based on computational technique, proposed scheme imposes no restriction on desired distribution, or source distribution.

FW3A.4 • 15:30
Design of hetero-structured lumpy nanoparticles conformal structures for improved absorbance of amorphous silicon thin film solar cells, Boyuan Cai1,2, Min Gu 1,2, Zhengrong Shi2, Yaqin Zhang1,2, Haifeng Li1, Xu Liu1; Univ. of Ljubljana, Slovenia; ONITEC B.V., Netherland; EPFL/IMT, Switzerland. Design and development of a periodic U-like single-texture and a periodic-random double-texture are carried out for micromorph silicon solar cell. Based on modeling supported by experiments more than 10% improvement in conversion efficiency is indicated.

FW3A.4 • 15:30
Optimization of advanced surface-textures for thin-film silicon solar cells, Janez Krn1,2, Andrej Campa1, Martin Sever1, Mark Steltenpoool1, Ettene Moulin1, Rob van Erven1, Franz-Josef Haug2, Christoph Ballif1, Marko Topic1; Univ. of Ljubljana, Slovenia; ONITEC B.V., Netherland; EPFL/IMT, Switzerland. Optimization and development of (i) periodic U-like single-texture and (ii) periodic-random double-texture are carried out for micromorph silicon solar cell. Based on modeling supported by experiments more than 10% improvement in conversion efficiency is indicated.

FW3A.4 • 15:30
Combined Optical and Electrical Modeling of Plasmon-Enhanced Organic Photovoltaic Devices, Phillip Manley1,2, Suprem R. Das1,3, Mark Steltenpool1,3, Rob van Erven1,2, Nathaniel Bocson1,2, Michael Schmidt1,3; Fraunhofer-Institut für Festkörperphysik, Germany; Char for Tech of Optical Systems, RTHW Aachen Univ., Germany. The increasing power and the often accompanying increase in size of LED-modules require design methods that allow for a reduction in lens size. This requires the enhancement of existing point source algorithms for extended sources or development of new design methods.

FW3A.4 • 15:30
Optimization of advanced surface-textures for thin-film silicon solar cells, Janez Krn1,2, Andrej Campa1, Martin Sever1, Mark Steltenpoool1, Ettene Moulin1, Rob van Erven1, Franz-Josef Haug2, Christoph Ballif1, Marko Topic1; Univ. of Ljubljana, Slovenia; ONITEC B.V., Netherland; EPFL/IMT, Switzerland. Optimization and development of (i) periodic U-like single-texture and (ii) periodic-random double-texture are carried out for micromorph silicon solar cell. Based on modeling supported by experiments more than 10% improvement in conversion efficiency is indicated.

FW3A.5 • 16:00
Merit Function Development for Toleranced Freeform Optics with Extended Sources Using Ray Targeting, John Koshe1, Steve Mulder1; Photon Engineering LLC, USA; College of Optical Sciences, Univ. of Arizona, USA. The designation of the merit function for the design of freeform optics using extended sources while including tolerancing with the technique of ray targeting is discussed. Examples are shown.

FW3A.5 • 16:00
Time-domain Modeling of Silver Nano-net for Transparent Conducting Electrodes, Jieran Fang1, Suprem R. Das1, Leonardo Edser1, Vladimir M. Shalaev1, David B. Janes1, Alexander V. Kildishev1, Etienne Moulin1, Mark Steltenpool1,3, Rob van Erven1,2; ECE, Purdue Univ., USA; Physics, Purdue Univ., USA. The transmittance of silver nano-net is simulated using the spectral averaging of a number of indiscriminately selected frames generated from the footprint of real sample. The simulated result shows a good match with experimental measurement.

FW3A.5 • 16:00
Design of hetero-structured lumpy nanoparticles conformal structures for improved absorbance of amorphous silicon thin film solar cells, Boyuan Cai1, Min Gu 1,2, Zhengrong Shi2, Yaqin Zhang1,2, Haifeng Li1, Xu Liu1; Univ. of Ljubljana, Slovenia; ONITEC B.V., Netherland; EPFL/IMT, Switzerland. Design and development of a periodic U-like single-texture and a periodic-random double-texture are carried out for micromorph silicon solar cell. Based on modeling supported by experiments more than 10% improvement in conversion efficiency is indicated.

FW3A.5 • 16:00
Light Extraction from Plasmonic Particles with Dielectric Shells and Overcoatings, Phillip Manley1,2, Frank Schmidt1, Martina Schmid2; Nanoptix, Heilmohrz Zentrum Berlin für Materialien und Energie, Germany; Zuse Inst. Berlin, Germany. We rigorously simulate light scattering via the FEM from core-shell plasmonic particles and plasmonic particles with an isolating overcoat, in order to recommend design principles for maximising plasmonic scattering gains.

FW3A.5 • 16:15
Plasmonic Titanium Nitride Nanostructures for Perfect Absorbers, Urcan Guler1, Wei Li1,2, Nathaniel Kinsey1, Gururaj V. Naik1,3, Alexandre Bolsi2,3, Janggu Guan1, Alexander V. Kildishev1, Vladimir M. Shalaev1; Birck NanoTech Center, Purdue Univ., USA; State Key Lab of Advanced Tech for Materials Synthesis and Processing, Wuhan Univ. of Tech, China; DFF Tofokon, Technical Univ. of Denmark, Denmark. We propose a metamaterial-based perfect absorber in the visible region, and investigate the performance of titanium nitride as an alternative plasmonic material. Numerical and experimental results reveal that titanium nitride performs better than gold as a plasmonic absorbing material.

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