Classical Optics 2014
Congress Program

22–26 June 2014
The Fairmont Orchid, Kohala Coast, Hawaii, USA

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Welcome to OSA’s inaugural congress on Classical Optics which convenes this year at the beautiful Fairmont Orchid in Kohala Coast, Hawaii. This year’s meeting consists of three collocated topical meetings (listed above) which bring together integral parts of the challenging design of optical systems. Though these three meetings relate to different aspects of the design, analysis and manufacture of optical systems, there is an expanding amount of interplay among them. Optical engineers and scientists have to increasingly understand parts of each aspect in order to develop state-of-the-art optical systems. We hope that bringing together leaders and experts among the different communities to share information and discuss topics across the disciplines of Classical Optics will provide you with a rich experience in Hawaii.

The Congress will begin on Monday 23 June at 07:45 (Grand Ballroom Salons II & III) with opening remarks and the presentation of the Joseph Fraunhofer Award/Robert M. Burley Prize. This will be followed immediately by a Joint Plenary Session (08:00–10:15) featuring three prominent speakers in their respective fields. Jeff Kuhn, Inst. for Astronomy, Univ. of Hawaii, will first discuss the motivation, enabling new technologies and status of the group now planning the Colossus telescope in his talk entitled, “Finding Life in the Universe: The Colossus Project.” David Brady, Duke Univ., will then present, “How to Measure Everything” in which multiscale optics and compressive coding in regards to ideal camera measurements will be considered. Finally, Kevin P. Thompson, Synopsys, Inc., will present the talk, “Will Computational Imaging Change Lens Design?” in which he will discuss the dramatically changing lens design environment.

The Classical Optics Joint Poster Session will be held on Tuesday, 24 June from 18:00–20:00 in the Grand Ballroom Salon I & Pre-function area. Posters are an integral part of the technical program and offer a unique networking opportunity. Presenters can discuss their results one-to-one with interested parties. Presentations from all three topical meetings will be featured.

The Congress Welcome Reception and Luau will be held on Monday, 23 June from 18:00–20:00 at the Coconut Grove at the Fairmont Orchid. The reception is open to committee members, presenting authors, students and full conference attendees. Conference attendees may purchase extra tickets for their guests. Please join us for this event and enjoy delectable fare while networking.

The Computational Optical Sensing and Imaging (COSI) meeting consists of topics that range from theoretical to experimental demonstration and verification of the latest advances in computational imaging research. This meeting covers subject matter in fundamental physics, numerical methods and physical hardware that has led to significant improvements in the fields of imaging and sensing for medical, defense, homeland security, inspection, testing applications. This year, we have prepared an extremely strong program of 21 invited speakers and 51 contributed oral presentations, as well as 5 poster presentations. We extend a warm welcome to both the longstanding members of the COSI community and those joining us for the first time.

Topics of special interest for IODC are classical lens design for photography, astronomy, microscopy and lithography, optical and numerical theory, illumination optics, and design with gradient index materials, complemented by nearly a full day of talks on freeform optics both for imaging and illumination. This year’s IODC meeting will include 15 sessions, featuring 15 invited speakers, 86 oral contributed presentations, and 27 poster presentations. The winners of the traditional Illumination and Lens Design Contests will be announced Wednesday, June 25, 18:30, together with the award ceremony for the Michael Kidger Memorial Scholarship. We look forward to meeting many old friends and new members of the field, and we hope you will enjoy the informal chats during breaks and evenings as much as the scientific presentations.
This year the meeting on Optical Fabrication and Testing (OF&T) consists of 14 sessions organized around new ideas and concepts for the shaping, smoothing, testing and manufacture of conventional and novel optics/optical systems finding applications in existing and emerging technologies. All topics of interest to the precision optics community are amply represented with 27 invited talks; 6 upgraded invited talks; and 50 contributed talks, including 12 poster presentations. We appreciate that many of you have come long distances in this challenging economic climate, to be together with longstanding friends and colleagues. We encourage you to renew acquaintances, to mingle and meet other members of the OF&T community with like interests, and to make new contacts and friendships.

Thank you for coming and contributing to Classical Optics 2014. Enjoy this opportunity to explore the Kohala Coast.

COSI Chairs
Amit Ashok, University of Arizona, USA, General Chair
Jason Fleischer, Princeton University, USA, General Chair
Predrag Milojkovic, US Army Research Laboratory, USA General Chair
Eddie Jacobs, University of Memphis, USA, Program Chair
Sapna Shroff, Ricoh Innovations, Corp., USA, Program Chair

IODC Chairs
Mariana Figueiro, Rensselaer Polytechnic Institute, USA, Co-Chair
Scott Lerner, Carl Zeiss AG, USA, Co-Chair
Julius Muschaweck, Arnold & Richter Cine Technik GmbH & Co., Germany, Co-Chair
John Rogers, Synopsys, Inc, USA, Co-Chair

OF&T Chairs
Stephen Jacobs, Univ. of Rochester, USA, Co-Chair
Dae Wook Kim, University of Arizona, USA, Co-Chair
James Mooney, Exelis, Inc., USA, Co-Chair
Jessica DeGroote Nelson, Optimax Systems Inc., USA, Co-Chair
Jannick Rolland, Inst. of Optics, Univ. of Rochester, USA, Co-Chair
Committees

Computational Optical Sensing and Imaging (COSI) Committee List

General Chairs
Amit Ashok, Univ. of Arizona, USA
Jason Fleischer, Princeton Univ., USA
Predrag Milojkovic, US Army Research Laboratory, USA

Program Chairs
Eddie Jacobs, Univ. of Memphis, USA
Sapna Shroff, Ricoh Innovations, Corp., USA

Program Committee Members
David Brady, Duke Univ., USA
Christy Fernandez-Cull, Massachusetts Inst of Tech Lincoln Lab, USA
Michael Fiddy, Univ. of North Carolina at Charlotte, USA
Michael Gehm, Duke Univ., USA
Andrew Harvey, Univ. of Glasgow, UK
Kedar Khare, Indian Inst. of Technology, Delhi, India
Kenneth Kubala, FiveFocal, LLC, USA
Joseph Mait, US Army Research Laboratory, USA
Ram Narayanswamy, Intel Corp., USA
Mark Allen Neifeld, Univ. of Arizona, USA
Chrysanthe Preza, Univ. of Memphis, USA
Jun Tanida, Osaka Univ., Japan
Laura Waller, Univ. of California Berkeley, USA
Zeev Zalevsky, Bar-Ilan Univ., Israel

International Optical Design Conference (IODC) Committee List

Chairs
Mariana Figueiro, Rensselaer Polytechnic Inst., USA
Scott Lerner, Carl Zeiss AG, USA
Julius Muschaweck, Arnold & Richter Cine Technik GmbH & Co., Germany
John Rogers, Synopsys, Inc, USA

Program Committee Members
Dave Aikens, Savvy Optics Corp., USA
Miguel Alonso, Univ. of Rochester, USA
Rob Bates, FiveFocal LLC, USA
Julie Bentley, Univ. of Rochester, USA
Florian Bociort, Technische Universiteit Delft, Netherlands
Peter Brick, OSRAM Opto Semiconductors, Germany
Thomas Brown, The Inst. of Optics, USA
Scott Cahall, Eastman Kodak Company, USA
William Cassarly, Synopsys, Inc, USA
Chier-Wei Li Chang, Industrial Technology Research Inst., Taiwan
Russell Chipman, Univ. of Arizona, USA
Peter Clark, LensVector Inc, USA
Josh Cobb, Corning Tropel Corporation, USA
Jim Contreras, Ball Aerospace & Technologies, USA
Jasmin Cote, Side by Side Optical Engineering, Canada
Marta De La Fuente, INDRA, Spain
J. Rufino Diaz-Uribe, Univ Nacional Autonoma de Mexico, Mexico
Alexander Epple, Carl Zeiss AG, Germany
Florian Fournier, Univ. of Central Florida, USA
Edward Freniere, Lambda Research Corporation, USA
G. Groot Gregory, Synopsys, Inc, USA
John Greivenkamp, Univ. of Arizona, USA
Anurag Gupta, Google, USA
Lakshminarayan Hazra, Univ. of Calcutta, India
Joseph Howard, NASA Goddard Space Flight Center, USA
Rainer Jetter, Optikentwicklung, Germany
Richard Juergens, Raytheon Missile Systems, USA
Norbert Kenwien, Carl Zeiss AG, Germany
David Kessler, Kessler Optics & Photonics Solutions Ltd, USA
John Koshel, College of Optical Sciences/Univ Arizona,
Kenneth Kubala, FiveFocal, LLC, USA
Jay Kumler, JENOPTIK Optical Systems, LLC, USA
Wai-sze Tiffany Lam, Univ. of Arizona, USA
Paul Leisher, Rose-Hulman Inst. of Technology, USA
Rongguang Liang, Univ. of Arizona, USA
Irina Livshits, Nat. Research Univ. of Information Technology, Mechanics & Optics, Russia
Virendra Mahajan, The Aerospace Corporation, USA
Daniel Malacara Hernandez, Centro de Investigaciones en Optica AC, Mexico
Stephan Malkmus, OSRAM, Germany
Paul Manhart, Sigma Space Corporation, USA
Romeo Mercado, RM Optical Design Consulting, USA
Paul Michaloski, Corning Advance Optics, USA
Michael Missig, Bausch & Lomb, Inc, USA
Kenneth Moore, Radiant Zemax, LLC, USA
Pantazis Mouroulis, Jet Propulsion Laboratory, USA
Iain Neil, Scotoptix, Switzerland
Thomas Nobis, Carl Zeiss AG, Germany
Vladimir Oliker, Emory Univ., USA
Craig Olson, L-3 Communications, USA
Donald O’Shea, Georgia Inst. of Technology, USA
Richard Pfisterer, Photon Engineering LLC, USA
Andrew Rakich, European Southern Observatory, Germany
Henning Rehn, Osram GmbH, Germany
Jannick Rolland, Univ. of Rochester, USA
Kevin Rolland-Thompson, Synopsys, Inc, USA
Martha Rosete-Aguilar, Universidad Nacional Autonoma de Mexico, Mexico
Jose Sasian, Univ. of Arizona, USA
David Shafer, David Shafer Optical Design, USA
Vesselin Shauloulov, Univ. of Central Florida, USA
Narkis Shatz, Science Applications International Corp, USA
Bryan Stone, Synopsys, Inc, USA
Wilhelm Ulrich, Carl Zeiss AG, Germany
Sergio Vazquez-Montiel, Inst Nat Astrofisica Optica Electronica, Mexico
Yongtian Wang, Beijing Inst. of Technology, China
Rolf Wartmann, Carl Zeiss Microimaging, Germany
David Williamson, Nikon Research Corporation of America, USA
Andrew Wood, Qioptiq Ltd, UK
Akira Yabe, Optical Design, Germany
Garam Young, Synopsys, Inc, USA
Richard Youngworth, Ryo LLC, USA
Maria Yzel, Universitat Autonoma de Barcelona, Spain

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Optical Fabrication and Testing (OF&T) Committee List

Chairs
Stephen Jacobs, Univ. of Rochester, USA
Dae Wook Kim, Univ. of Arizona, USA
James Mooney, Exelis, Inc, USA
Jessica Nelson, Optimax Systems Inc, USA
Jannick Rolland, Univ. of Rochester, USA

Program Committee Members
Dave Aikens, Savvy Optics Corp., USA
Anthony Beaucamp, Chubu Univ., Japan
James Burge, Univ. of Arizona, USA
Myung Cho, AURA NOAO, USA
Veera Dandu, Clarkson Univ. & Intel Corporation, USA
Chris Evans, Univ. of North Carolina at Charlotte, USA
Oliver Faehnle, FISBA OPTIK AG, Switzerland
William Goodman, Trex Enterprises Corp, USA
Ulf Griesmann, National Inst of Standards & Technology, USA
James Hadaway, Univ. of Alabama in Huntsville, USA
Matthew Jenkins, Raytheon Company, USA

John Lambropoulos, Univ. of Rochester, USA
Panomsak Meemon, Suranaree Univ. of Technology, Thailand
Brigid Mullany, Univ. of North Carolina at Charlotte, USA
Robert Parks, Optical Perspectives Group, USA
Francois Piche, QED Technologies, USA
Michael Ponting, PolymerPlus LLC, USA
Kathleen Richardson, Univ. of Central FL-CREOL, USA
Sven Schröder, Fraunhofer IOF, Germany
Katie Schwertz, Edmund Optics, USA
Jim Schwiegerling, Univ. of Arizona, USA
Shai Shafrir, Corning Incorporated, USA
Paul Shore, Cranfield Univ., UK
Erika Sohn, Instituto de Astronomia UNAM, Mexico
Tayyab Suratwala, Lawrence Livermore National Laboratory, USA
Flemming Tinker, Aperture Optical Sciences, USA
Ray Williamson, Ray Williamson Consulting, USA
Xue-Jun Zhang, Changchun Inst of Optic, Fine Mech & Phy, China
Weiyao Zou, ASML Optics LLC, USA
Short Courses

Short Courses cover a broad range of topic areas at a variety of educational levels (introductory to advanced). The courses are taught by highly regarded industry experts in a variety of specialties. Short Courses are an excellent opportunity to learn about new products, cutting-edge technology and vital information at the forefront of your field. They are designed to increase your knowledge of a specific subject while offering you the experience of knowledgeable teachers.

Certificate of Attendances are available for those who register and attend a course. To request a Certificate of Attendance after the conference, please email cstech@osa.org with your name, the course name, conference name, and year.

Each Short Course requires a separate fee. Paid registration includes admission to the course and one copy of the Short Course Notes. Advance registration is advisable. The number of seats in each course is limited, and on-site registration is not guaranteed.

Classical Optics 2014 Short Course Schedule

Sunday, 22 June, 09:00–12:00
SC415 Making Sense of Waviness and Roughness on Optics
SC418 Optical Materials, Fabrication and the Testing for the Optical Engineer

Sunday, 22 June, 13:00–16:00
SC416 Practical Aspects of Measurement Uncertainty, Calibration, Traceability and Accreditation

Sunday, 22 June, 17:00–20:00
SC417 Evaluating Aspheres for Manufacurability

2014 Short Course Descriptions

SC415 Making Sense of Waviness and Roughness on Optics
Dave Aikens, Savvy Optics Corp, USA
Sunday, 22 June, 09:00–12:00

Course Description

The surface texture of a polished optical surface is an important, if misunderstood, surface property. This course is designed to bring photonics personnel up to an immediate working knowledge on surface texture specifications and the impact surface roughness and waviness can have on an optical system. Surface roughness causes scatter and system transmission loss, while waviness and mid-spatial frequency ripple can cause loss of resolution, image quality, veiling glare, beam modulation and a host of other issues.

Until recently, surface texture could be safely described by a single number, RMS roughness, following MIL-STD-10A, since most polished optical surfaces were manufactured using the same slurry-pitch process that had existed for decades. In the past 30 years, however, new manufacturing technologies have evolved using molding, diamond turning, synthetic lap polishing and deterministic figuring which have dramatically altered the surface finish of optics. In order to control the resultant surface texture errors, new specifications like gradients, correlation values, PSDs and MSF waviness specifications have been introduced. Most users do not completely understand these new notations however, and the meaning of even a simple RMS roughness specification has become obscure, or even meaningless.

The course defines the terms and parameters used to control surface texture in the modern optical manufacturing world. The potential performance impact of surface texture errors will be covered, and some specific case studies will be used to show the impact of various amplitudes of these errors on precision optical instrument performance. The national and international standards are introduced, and the derivation of meaningful specification for texture and waviness for common applications is discussed. Finally, the identification, measurement and reduction of these manufacturing errors is treated.

Benefits and Learning Objectives

This course should enable participants to:

- Describe the surface texture of a polished optical surface based on its specifications
- Understand the meaning of a Power Spectral Density plot
- Quantify the requirements for surface texture using PSD and gradient notations
- Predict the impact of mid-spatial frequency ripple and roughness on system performance
- Compose a meaningful surface texture specification for both waviness and roughness
- Identify waviness surface errors in measurement data
Intended Audience
This course is intended for engineers, managers and experienced technicians working in optical design, manufacturing, metrology and quality control and assurance. Anyone who is responsible for specifying or interpreting surface roughness and waviness specifications will find it extremely useful. Some understanding of algebra is beneficial.

Instructor Biography
Dave Aikens has been writing on the subject of surface texture and ripple for more than 20 years and is one of the foremost experts on optics mid-spatial frequency waviness today. Dave is President and founder of Savvy Optics Corp., is the head of the American delegation to ISO TC 172 SC1, and is Executive Director of the Optics and Electro-Optics Standards Council. He also served as the project manager for the current ISO surface texture notation standards for optics.

SC418 Optical Materials, Fabrication and the Testing for the Optical Engineer
Jessica Nelson, Optimax SI, USA
Sunday, 22 June, 09:00–12:00

Course Level
Introductory

Course Description
This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of optical materials, fabrication and testing. This knowledge will help the optical engineer understand which optical specifications/tolerances lead to more cost effective optical components. Topics covered include optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

Benefits and Learning Objectives
This course will enable you to:

- Identify key mechanical, chemical and thermal properties of optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
- Understand the basics of optical fabrication
- Define meaningful surface tolerances
- Communicate with optical fabricators
- Design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies

Intended Audience
Optical engineers, lens designers, or managers who wish to learn more about how optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

Instructor Biography
Jessica DeGroote Nelson is the R&D manager and scientist at Optimax Systems, Inc. She specializes in optical materials and fabrication processes. She is an adjunct faculty member at The Inst. of Optics at the Univ. of Rochester teaching an undergraduate course on Optical Fabrication and Testing, and has given several guest lectures on optical metrology methods. She earned a Ph.D. in Optics at The Inst. of Optics at the Univ.and SPIE.

SC416 Practical Aspects of Measurement Uncertainty, Calibration, Traceability, and Accreditation
Ulf Griesmann and Dr. Johannes A. Soons, NIST, USA
Sunday, 22 June, 13:00–16:00

Course Level
Advanced beginner - basic understanding of topic is necessary to follow the course material.

Course Description
Successful national and international trade is based on mutual understanding, trust, and verification. Standards organizations, trade associations, and professional societies have created a framework of standards that enables reliable exchange of information between trading partners. International and national measurement Inst.s provide the foundation for a single system of measurements throughout the world traceable to the International System of Units (SI). We give an overview of this standards and metrology framework and describe its practical implications for the optics industry. We explain the central role of measurement uncertainty, calibrations, and check standards in a quality system for optical manufacturing and testing. Hands-on examples will be used to show how to evaluate and express the uncertainty of typical measurements encountered in optics manufacturing. We discuss common misunderstandings of measurement traceability and outline different routes that optics fabricators and metrologists may take to provide objective evidence that their measurement results are traceable. The course concludes with a discussion on the role of measurement uncertainty in conformity assessment of products and the associated balancing of risk between trading partners.

Benefits and Learning Objectives
This course will enable participants to

- Describe the concepts of the International System of Units (SI), measurement uncertainty, measurement assurance, and measurement traceability.
- Explain the essential elements of metrological traceability and identify different approaches to achieve traceable measurements in the optics industry.
- Apply the Guide to the expression of Uncertainty in Measurements (GUM) to evaluate and state the uncertainty of common measurements in optics manufacturing.
- Describe the role of measurement uncertainty in conformity assessment.
- Explain practical aspects of measurement assurance and its role in demonstrating measurement traceability.
- Identify requirements and options for demonstrating competence of testing and calibration laboratories (ISO/IEC 17025).
- Decide on a route to achieve traceable measurements, which suit the needs of their organization.
Intended Audience
This course is intended for practitioners: fabricators of optical components and metrologists who are increasingly urged by their customers to provide uncertainty statements and evidence of traceable measurements for their products. It is intended for quality managers planning to establish or improve a quality system for their company or who are considering laboratory accreditation. Finally, the course is also intended for anyone wishing to understand how the modern international metrology system applies to the optics industry.

Instructor Biographies
Ulf Griesmann is a physicist with the National Inst. of Standards and Technology (NIST). He received his Dr. rer. nat. from the Univ. in Bonn, Germany. At NIST Dr. Griesmann worked on precision spectrometry and properties of optical materials. His current research focus is form metrology of precision surfaces, methods for absolute metrology, and metrology of aspheric and free-form surfaces using nano-structured optics. Dr. Griesmann carries out calibration measurements of flatness and sphericity at NIST.

Johannes A. Soons is a mechanical engineer at the National Inst. of Standards and Technology (NIST). He received his Ph.D. from the Eindhoven Univ. of Technology in the Netherlands. Since 1994, Dr. Soons has conducted research at NIST on precision machining, documentary standards for machine tool metrology, form metrology of optical surfaces, surface texture metrology, and the role of measurement uncertainty in fabrication and testing.

SC417 Evaluating Aspheres for Manufacturability
Paul Dumas, QED Technologies, Inc., USA
Sunday, 22 June, 17:00–20:00

Course Level
Advanced Beginner

Course Description
This course provides an overview of how aspheric surfaces are designed, manufactured, and measured. The primary goal of this course is to teach how to determine whether a particular aspheric surface design will be difficult to make and/or test. This will facilitate cost/performance trade off discussions between designers, fabricators, and metrologists.

We will begin with a discussion of what an asphere is and how they benefit optical designs. Next we will explain various asphere geometry characteristics, especially how to evaluate local curvature plots. We will also review flaws of the standard polynomial representation, and how the Forbes polynomials can simplify asphere analysis. Then we will discuss how various specifications (such as figure error and local slope) can influence the difficulty of manufacturing an asphere. Optical assembly tolerances, however, are beyond the scope of this course - we will focus on individual elements (lenses / mirrors).

The latter half of the course will focus on the more common technologies used to generate, polish, and/or measure aspheric surfaces (e.g. diamond turning, glass molding, pad polishing, interferometry). We’ll give an overview of a few generic manufacturing processes (e.g. generate-polish-measure). Then we’ll review the main strengths and weaknesses of each technology in the context of cost-effective asphere manufacturing.

Benefits and Learning Objectives
This course will enable you to:

• Identify the most important metrics of aspheric shape that relate to manufacturability
• Evaluate key characteristics of an aspheric surface to determine whether an asphere will be difficult to manufacture and/or test
• Describe how Forbes polynomials can simplify asphere interpretation
• Interpret an aspheric prescription from an optical component print
• List common ways aspheres are manufactured and tested
• Answer the question “Which technologies are best suited to manufacture this asphere?”

Intended Audience
This material is intended for engineers, optical designers, and managers who want an overview of the benefits and challenges associated with manufacturing aspheric surfaces for use in optical systems. It will be of benefit for specialists in a particular area (e.g. design, manufacturing, or testing), as it will give a broad overview in all three of those areas with a focus on aspheric surfaces. It is intended to facilitate communication between designers, fabricators, and testers of aspheric surfaces.

Instructor Biography
Paul Dumas is one of the founding members of QED Technologies, where he has developed software and processes for aspheric optical manufacturing. He received his B.S. and M.S. in Optics from The Inst. of Optics at the Univ. of Rochester. In the early 1990s, and since has managed various engineering groups throughout the company’s history, including Software, Systems, and Applications.
Special Events

Joint Plenary Session and Presentation of the Joseph Fraunhofer Award / Robert M. Burley Prize
Monday, 23 June, 07:45–10:15
Grand Ballroom Salons II & III

The Joint Plenary Session will feature three Plenary speakers (one from each of the three topical meetings - COSI, IODC, and OF&T). For more information on the plenary presentations, see page 10 of the program. The Joseph Fraunhofer Award/Robert M. Burley Prize will also be presented to Juan Carlos Miñano, Universidad Politecnica de Madrid, Spain following the opening remarks.

Welcome Reception and Luau
Monday, 23 June, 18:00 – 20:00
The Coconut Grove at The Fairmont Orchid

Join us in the Coconut Grove for some of Hawaii's best entertainment and island food. The reception luau is open to committee/presenting author/student and full conference attendees. Conference attendees may purchase extra tickets for their guest.

Joint Poster Session
Tuesday, 24 June, 18:00–20:00
Grand Ballroom Salon I & Pre-Function

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.

Postdeadline Sessions

Each of the three topical meetings will accept a limited number of postdeadline papers for oral presentation. The postdeadline sessions will give participants the opportunity to hear new and significant material in rapidly advancing areas. Only those papers judged to be truly excellent and compelling in their timeliness were accepted. More information, including the schedule, will be posted in the weeks preceding the conference. Postdeadline Programs will not be printed for this year’s Classical Optics Congress. Selected Postdeadline Papers will be announced on the conference Update sheet which is distributed at registration. All Postdeadline papers can be accessed by visiting www.osa.org/ClassicalOPC and clicking the “Access Digest Papers” button. The times and locations for the three Postdeadline session are as follows:

COSI Postdeadline Session, Tuesday, 24 June, 16:30–18:00, Plaza Ballroom I & II

IODC Postdeadline Session, Tuesday, 24 June, 16:30 –18:00, Grand Ballroom Salon III

OF&T Postdeadline Session, Thursday, 26 June, 16:30–18:00, Plaza Ballroom III

Presentation of the Michael Kidger Memorial Scholarship Award
Wednesday, 25 June, 18:30
Grand Ballroom Salon III

The Michael Kidger Memorial Scholarship Award will be presented to Brian Wheelwright prior to the Lens Design and Illumination Problems Presentations in Salon III. For more information on the Kidger Award winner, view the Awards section on page 11 of this program.

Illumination and Lens Design Problems Presentations
Wednesday, 25 June, 18:35–20:30
Grand Ballroom Salon III

Join the IODC community for a guaranteed highlight of the conference: the illumination and lens design contest presentations. As usual, significant work has gone into developing and scoring the submissions, as well as all of the hard work put in by solution submitters. Additionally, the winners of the best student paper awards for the 2014 IODC will be announced at the conclusion of the design problem presentations.

Illumination Design Problem: The Cinderella Lamp

You have recently come across the guts of a 35-mm film projector and a roll of the 1950 Walt Disney “Cinderella” movie (an Academy format film), and have added it to your box of optical knick-knacks in your lab. There is no working lamp for this projector, but it has working mechanics and a Cooke Triplet projection lens. Your optical tool box includes lots of unique components, which are listed below. It also includes a bunch of light sources (Lambertian emitters and lasers) which are also specifically defined below.

Your task is to build an illuminator for the projector to create an image of the film. You can use anything in the tool box, but you cannot add to the toolbox, and you do not need to use everything in the toolbox. The goal is to produce the brightest screen image with some specific constraints listed below.

Lens Design Problem: The Cinderella Lens

In the Cinderella story, Cinderella’s two stepsisters cannot squeeze their big feet into the glass slipper, no matter how hard they try; however, Cinderella’s foot fits the glass slipper perfectly. The 2014 IODC Lens Design Problem is to design a Cinderella lens. You are provided with ten lens blanks, each 100 mm in diameter, 30 mm thick, and flat on both sides. All the lens elements in the Cinderella lens must be fabricated from these ten lens blanks. Just as Cinderella’s foot fit the glass slipper, each element of the Cinderella lens must fit inside one of the lens blanks provided.

Presentation of the OF&T Best Student Papers
Thursday, 26 June, 16:30–18:00
Plaza Ballroom III

The presentation of the three winners of the OF&T Best Student Papers will be presented during the OF&T Postdeadline Session. For more information about the OF&T Student Awards, see page 11 of this program.
Plenary Speakers

Finding Life in the Universe: The Colossus Project, Jeff R. Kuhn; Institute for Astronomy, University of Hawaii, USA
Monday, 23 June, 08:00–08:45
Grand Ballroom Salon II & III

Jeff Kuhn is an optical scientist and teacher. He earned his physics PhD from Princeton, and spent the last three decades as a professor of physics, or astrophysics at Princeton, Michigan State, and the University of Hawaii. He was science head for the National Solar Observatory at Sunspot NM. and the director of the Institute for Astronomy on Maui for a decade. He’s written over 200 papers on subjects ranging from gravitational radiation to novel instrumentation. He has been the recipient of a Sloan Foundation Grant and a Senior Humboldt Prize from Germany. Some of the optical concepts he’s written about are now core technologies for telescopes under construction, like the Advanced Technology Solar Telescope on Haleakala and the Giant Magellan Telescope. He is a founder of the Colossus Project -- a public and private consortium now designing an instrument to find Earth-like civilizations in the galactic solar neighborhood. Jeff lives on Maui where he researches and teaches at the Institute for Astronomy, University of Hawaii.

How to Measure Everything, David Brady, Duke University, USA
Monday, 23 June, 08:45–09:30
Grand Ballroom Salon II & III

David Brady is the Michael J. Fitzpatrick Endowed Professor of Photonics at Duke University, where he leads the Duke Imaging and Spectroscopy Program. Brady’s contributions to computational imaging systems include lensless white light tomography, optical projection tomography, compressive holography, reference structure tomography, coded aperture snapshot spectral imaging and coded aperture x-ray scatter imaging. He is the principal investigator for the DARPA AWARE Wide Field of View project, which aims to build compact streaming gigapixel scale imagers and the DARPA Knowledge Enhanced Exapixel Photography project, which focuses on code design for high pixel count spectral imagers. He is the author of Optical Imaging and Spectroscopy (Wiley-OSA, 2009) and is a Fellow of IEEE, SPIE and OSA and was the 2013 winner of the SPIE Dennis Gabor Award.

Will Computational Imaging Change Lens Design?, Kevin P. Thompson, Synopsys, Inc., USA
Monday, 23 June, 09:30–10:15
Grand Ballroom Salon II & III

Kevin P. Thompson, Ph.D. is the Group Director of R&D/Optics at Synopsys Inc. and a Visiting Scientist at the University of Rochester, Institute of Optics. Dr. Thompson’s primary technical expertise is as a lens designer and aberration theorist, particularly for optical systems without symmetry including head worn displays, EUV lithography projection and illumination optics, and advanced reconnaissance systems. Dr. Thompson joined Optical Research Associates (now part of Synopsys) as an optical designer in 1986 after 5 years with the optical design group at Perkin-Elmer’s government division. Kevin conducted his PhD research with Prof. Roland Shack at the College of Optical Sciences where he developed Nodal Aberration Theory (NAT), the optical aberration field descriptions for optical systems without positional symmetry, which was recently discovered to also be the aberration theory for the emerging field of freeform optics. Kevin is an OSA Fellow, a Fellow of the SPIE, and the 2013 recipient of the 2013 SPIE A.E. Conrady award.
Awards and Grants

Joseph Fraunhofer Award / Robert M. Burley Prize
The Joseph Fraunhofer Award/Robert M. Burley Prize recognizes significant research accomplishments in the field of optical engineering. The Fraunhofer Award was established in 1982. The accompanying prize was established in 1992, and honors the memory of Robert M. Burley, who exemplified many of the highest attributes of the optical engineer and was the first recipient of the Fraunhofer Award.

The recipient of the 2014 Joseph Fraunhofer Award/Robert M. Burley Prize is Juan Carlos Miñano, Universidad Politecnica de Madrid, Spain. The award is being presented to Dr. Miñano for the discovery of exceptional new design methods and devices in both nonimaging and imaging optics over more than three decades, with special emphasis in freeform surface design. This award will be presented during the Congress opening remarks on Monday, 23 June, 07:45–08:00.

The prize is endowed by the Baird Corporation and individuals including Prof. Shin-Tson Wu. Please consider making a donation to support this special honor by visiting www.osa.org/foundation. Your gift will be matched by OSA with a contribution to the OSAF General Fund.

OF&T Student Travel Grants
We are pleased to announce the recipients of the OF&T Travel Grant. Funds were obtained through the generous support of the National Science Foundation (NSF). The following students have been awarded grant funds:

Alejandro Maldonado, UA College of Optical Science, USA
Erick Koontz, Clemson Univ., USA
Margaret Dominguez, Univ. of Arizona, USA
Jianing Yao, Univ. of Rochester, USA
Laura Coyle, Univ. of Arizona, USA
Run Huang, Univ. of Arizona, USA

Grant recipients are all full time students at an US Institution and currently performing research in optical engineering and associated technologies. All recipients will give an oral or poster presentation as part of the OF&T Topical Meeting.

Michael Kidger Memorial Scholarship Award
The 2014 Kidger scholarship award will be presented to Brian prior to the Illumination and Lens Design Problem Presentations (Wednesday, 25 June, 18:30–20:30, Grand Ballroom Salon III) by Kevin P Thompson, Synopsys Inc. USA. The award consists of a $5,000 cash grant supported by the Michael Kidger Memorial Scholarship Fund.

OF&T Best Student Paper Awards
Three student award winners will be selected onsite as winners for the OF&T Best Student Paper Award. Judging will be conducted by members of the OF&T Program Committee attending the meeting. A brief awards ceremony will be held at the conclusion of the last session on 26 June where certificates and awards will be presented. First place winners will receive $300. Second place winners will receive $200. Third place winners will receive $100. Student nominees are indicated in the program.

COSI Best Paper Award
Three winners have been selected to receive the COSI Best Paper Award by the COSI Program Committee. Papers were judged on the novelty of the proposed research idea; the significance and breadth of its potential impact; and the feasibility to translate to real-world operating conditions. Award winners will receive $450 each. This year’s COSI Best Paper Award Winners will be identified on the Update Sheet.

The OSA Foundation
Inspire Students. Reward Success
Valuable programs & resources for the next generation.
Learn more and make a difference by visiting www.osa.org/foundation
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. Three grants of $1,100 USD are awarded annually. We thank the Optical Solutions Group at Synopsys for their sponsorship of this program.

The 2014 Hilbert Travel Grant recipients are:

Aaron Bauer, University of Rochester, USA
Stacey Sueoka, University of Arizona, USA
Tamer Elazhary, University of Arizona, USA

OSA Foundation Student Travel Grant

We are pleased to announce The OSA Foundation Travel Grant recipient for the Classical Optics Congress:

Rafael Izazaga-Pérez, Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), Mexico

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 grant is given to a student working or studying science in qualifying developing nations so they can attend OSA-managed technical meetings and conferences. The student receives $1,500 USD in travel support and is selected by the co-chairs of the meeting. Their application is 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 Foundation are made possible by the generous donations of its supporters as well as the dollar-for-dollar match by OSA.
General Information

Registration
Paniolo Lounge

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>Sunday, 22 June</td>
<td>08:00–18:00</td>
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<tr>
<td>Monday, 23 June</td>
<td>06:45–18:00</td>
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<tr>
<td>Tuesday, 24 June</td>
<td>07:30 – 18:00</td>
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<tr>
<td>Wednesday, 25 June</td>
<td>07:30–18:00</td>
</tr>
<tr>
<td>Thursday, 26 June</td>
<td>07:30–16:30</td>
</tr>
</tbody>
</table>

Exhibit
Monday, 23 June – Wednesday, 25 June
Grand Ballroom Salon I

The Classical Optics exhibit is open to all registered attendees. Visit a diverse group of companies representing every facet of optics. Coffee breaks will be held with the exhibit from Monday - Wednesday.

Exhibit Only Hours

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>Monday, 23 June</td>
<td>10:15–11:00</td>
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<tr>
<td></td>
<td>16:00–16:30</td>
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<tr>
<td>Tuesday, 24 June</td>
<td>10:00–10:30</td>
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<td></td>
<td>16:00–16:30</td>
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<tr>
<td>Wednesday, 25 June</td>
<td>10:00–10:30</td>
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<td></td>
<td>16:00–16:30</td>
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</tbody>
</table>

Recorded Presentations

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Early Online Access to the Technical Digest and Postdeadline Papers

Full Technical Attendees have both EARLY and FREE continuous access to the digest papers through Optics InfoBase. To access the papers go to www.osa.org/ClassicalOPC and select the “Access digest papers” essential link on the right hand navigation. As access is limited to Full Technical Conference Attendees only, you will be asked to validate your credentials by entering 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.

About OSA’s Optics InfoBase

Registrants and current subscribers can access all of the conference papers, posters and postdeadline papers on OSA’s digital library, Optics InfoBase. The Optics InfoBase is a cutting-edge repository that contains OSA Publishing’s content, including 16 flagship, partnered and co-published peer-reviewed journals and 1 magazine. With more than 240,000 articles including papers from over 450 conferences, Optics InfoBase is the largest peer-reviewed collection of optics and photonics.

Poster Presentation PDFs

The PDFs of select poster presentations will be available two weeks after the conference. While accessing the papers in Optics InfoBase look for the multimedia symbol.

Update Sheet and Postdeadline Papers

All technical program changes will be communicated in the onsite Conference Program Update Sheet. All attendees receive this information with registration materials, and we encourage you to review it carefully to stay informed to changes in the program. Postdeadline papers will also be announced on the update sheet.

IODC Proceedings

Accepted authors from the IODC topical meeting were encouraged to submit an expanded 4-10 page technical Proceedings paper that will be published and mailed to IODC registrants after the Classical Optics Congress. The cost of the IODC proceedings is included in the registration for this topical meeting.

The Proceedings of this conference are published in the SPIE Digital Library along with over 400,000 papers from other outstanding conferences and SPIE Journals and books from SPIE Press.
Explanation of Session Codes

IM1C.4

Meeting Name
C – COSI
I – IODC
O – OF&T
J – Joint Session

Day of the Week
M = Monday
Tu = Tuesday
W = Wednesday
Th = Thursday

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

Number
(Presentation order within the session)

The first letter of the code designates the meeting (C = COSI, I = IODC, O = OF&T, J = Joint Session). The second element denotes the day of the week (Monday = M, Tuesday = Tu, Wednesday = W, Thursday = Th). 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 IM1C.4 indicates that this paper is part of IODC and is being presented on Monday (M) 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 Invited
Plenary papers are noted with Plenary
Recorded Presentations are noted with

Early Online Access to the Technical Digest and Postdeadline Papers

Full Technical Attendees have both EARLY and FREE continuous access to the digest papers through Optics InfoBase. To access the papers go to www.osa.org/ClassicalOPC and select the “Access digest papers” essential link on the right hand navigation. As access is limited to Full Technical Conference Attendees only, you will be asked to validate your credentials by entering 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, 22 June

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</thead>
<tbody>
<tr>
<td>08:00–18:00</td>
<td>Registration, Paniolo Lounge</td>
</tr>
<tr>
<td>09:00–12:00</td>
<td>Short Course 415</td>
</tr>
<tr>
<td>13:00–16:00</td>
<td>Short Course 416</td>
</tr>
<tr>
<td>17:00–20:00</td>
<td>Short Course 417</td>
</tr>
</tbody>
</table>

## Agenda of Sessions — Monday, 23 June

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</thead>
<tbody>
<tr>
<td>06:45–18:00</td>
<td>Registration, Paniolo Lounge</td>
</tr>
<tr>
<td>07:45–10:15</td>
<td>JM1A • Opening Remarks and Joint Plenary Session, Grand Ballroom Salons II &amp; III</td>
</tr>
<tr>
<td>10:15–11:00</td>
<td>Coffee Break and Exhibits, Grand Ballroom Salon I</td>
</tr>
<tr>
<td>11:00–13:00</td>
<td>IM2A • Photography</td>
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<tr>
<td></td>
<td>IM2B • Exotic Optics I</td>
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<tr>
<td></td>
<td>OM2C • Materials</td>
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<tr>
<td></td>
<td>CM2D • Compressive Imaging and Optical Super-resolution (ends at 12:45)</td>
</tr>
<tr>
<td>13:00–14:00</td>
<td>Lunch Break, On Your Own</td>
</tr>
<tr>
<td>14:00–16:00</td>
<td>IM3A • Astronomy</td>
</tr>
<tr>
<td></td>
<td>IM3B • Microscopy/Lithography</td>
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<tr>
<td></td>
<td>OM3C • Testing I</td>
</tr>
<tr>
<td></td>
<td>CM3D • Holography and Ptychograph (ends at 15:45)</td>
</tr>
<tr>
<td>16:00–16:30</td>
<td>Beverage Break and Exhibits, Grand Ballroom Salon I</td>
</tr>
<tr>
<td>16:30–18:00</td>
<td>IM4A • Measurement Manufacturing</td>
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<td></td>
<td>OM4B • Figuring and Finishing Science</td>
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<tr>
<td></td>
<td>CM4C • Computational Displays and Illumination</td>
</tr>
<tr>
<td>18:00–20:00</td>
<td>Welcome Reception Luau, The Coconut Grove at The Fairmont Orchid</td>
</tr>
</tbody>
</table>

### Key to Conference Abbreviations
- COSI: Computational Optical Sensing and Imaging
- IODC: International Optical Design Conference
- OF&T: Optical Fabrication and Testing
### Agenda of Sessions — Tuesday, 24 June

<table>
<thead>
<tr>
<th>Time</th>
<th>Grand Ballroom Salon III</th>
<th>Plaza Ballroom III</th>
<th>Plaza Ballroom I &amp; II</th>
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</thead>
<tbody>
<tr>
<td>07:30–18:00</td>
<td>Registration, Paniolo Lounge</td>
<td></td>
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</tr>
<tr>
<td>08:00–10:00</td>
<td>ITu1A • Theory I</td>
<td>OTu1B • Fabrication Process Technologies I</td>
<td>CTu1C • Microscopy and Medical Imaging</td>
</tr>
<tr>
<td>10:00–10:30</td>
<td>Coffee Break and Exhibits, Grand Ballroom Salon I</td>
<td></td>
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<tr>
<td>10:30–12:30</td>
<td>ITu2A • Tolerancing</td>
<td>OTu2B • Figuring, Finishing and Cleaning</td>
<td>CTu2C • Spectroscopy and Spectral Imaging (ends at 12:15)</td>
</tr>
<tr>
<td>12:30–14:00</td>
<td>Lunch Break, On Your Own</td>
<td></td>
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<tr>
<td>14:00–16:00</td>
<td>ITu3A • Exotic Optics II</td>
<td>OTu3B • Fabrication Process Technologies II</td>
<td>CTu3C • Novel Imaging Architectures (ends at 15:45)</td>
</tr>
<tr>
<td>16:00–16:30</td>
<td>Beverage Break and Exhibits, Grand Ballroom Salon I</td>
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<tr>
<td>16:30–18:00</td>
<td>ITu4C • IODC Postdeadline Session</td>
<td>OTu4A • Testing II</td>
<td>CTu4B • COSI Postdeadline Session</td>
</tr>
<tr>
<td>18:00–20:00</td>
<td>JTu5A • Joint Poster Session, Grand Ballroom Salon I &amp; Pre-Function</td>
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### — Wednesday, 25 June

<table>
<thead>
<tr>
<th>Time</th>
<th>Grand Ballroom Salon III</th>
<th>Plaza Ballroom III</th>
<th>Plaza Ballroom I &amp; II</th>
</tr>
</thead>
<tbody>
<tr>
<td>07:30–18:00</td>
<td>Registration, Paniolo Lounge</td>
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<tr>
<td>08:00–10:00</td>
<td>IW1A • Optimization</td>
<td>OW1B • Mid-spatial Frequency (ends at 09:45)</td>
<td>CW1C • Imaging in Diffuse Media (ends at 09:45)</td>
</tr>
<tr>
<td>10:00–10:30</td>
<td>Coffee Break and Exhibit, Grand Ballroom Salon I</td>
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<tr>
<td>10:30–12:30</td>
<td>IW2A • GRIN</td>
<td>OW2B • Freeform Testing</td>
<td>CW2C • Non-Optical Imaging and Sensing</td>
</tr>
<tr>
<td>12:30–14:00</td>
<td>Lunch Break, On Your Own</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:00–16:00</td>
<td>IW3A • Theory II</td>
<td>OW3B • Freeform Manufacturing</td>
<td>CW3C • Spectral and Polarization Imaging</td>
</tr>
<tr>
<td>16:00–16:30</td>
<td>Beverage Break and Exhibit, Grand Ballroom Salon I</td>
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<td></td>
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<tr>
<td>16:30–18:00</td>
<td>IW4A • Medical / Biology (ends at 17:45)</td>
<td>OW4B • Testing -Calibration</td>
<td>CW4C • Algorithms and Methods (ends 17:45)</td>
</tr>
<tr>
<td>18:30–20:30</td>
<td>Lens Design and Illumination Problems Presentations, Grand Ballroom Salon III</td>
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</tbody>
</table>

### Key to Conference Abbreviations
- COSI: Computational Optical Sensing and Imaging
- IODC: International Optical Design Conference
- OF&T: Optical Fabrication and Testing
## Agenda of Sessions — Thursday, 26 June

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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</thead>
<tbody>
<tr>
<td>07:30–16:30</td>
<td>Registration, Paniolo Lounge</td>
</tr>
</tbody>
</table>
| 08:00–10:00  | ITh1A • LED Optics Solar  
OTh1B • System Engineering and Assembling  
CTh1C • Novel Imaging Optics and Systems.                                                                                           |
| 10:00–10:30  | Coffee Break, Grand Ballroom Pre-Function                                                                                                                                                     |
| 10:30–12:30  | ITh2A • Freeform Optics I  
OTh2B • Large Optics  
CTh2C • PSF Engineering and Extended Depth of Field Imaging (ends at 12:15)                                                          |
| 12:30–14:00  | Lunch Break, On Your Own                                                                                                                                                                      |
| 14:00–16:00  | ITh3A • Freeform Optics II  
OTh3B • Testing III  
CTh3C • Phase-based Imaging (ends at 15:30)                                                                                          |
| 16:00–16:30  | Coffee Break, Grand Ballroom Pre-Function                                                                                                                                                     |
| 16:30–18:00  | ITh4A • Freeform Optics III  
OTh4B • OF&T Postdeadline Session                                                                                                                                                              |

### Recorded Presentations

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Monday, 23 June

Opening Remarks and Presentation of Joseph Fraunhofer Award/Robert M. Burley Prize

08:00–10:15
JM1A • Joint Plenary Session

**JM1A.1 • 08:00 Plenary**
Finding Life in the Universe: The Colossus Project, Jeffrey R. Kuhn1; Inst. for Astronomy, Univ. of Hawaii, USA. Work progresses on the design of a sixty by 8-meter diameter telescope. This 77+ m diameter, optically phase controlled, almost-filled aperture interferometer can see atmospheric biomarkers and even the thermal footprints from Earth-like civilizations on exoplanets. This talk describes the motivation, enabling new technologies, and status of the group now planning the Colossus telescope.

**JM1A.2 • 08:45 Plenary**
How to Measure Everything, David J. Brady, Duke Univ., USA. The ideal camera measures wide-field diffraction-limited images of the full focal stack with photon-limited spectral and temporal resolution and infinite dynamic range. Multiscale optics and compressive coding may bring practical cameras close to this limit.

**JM1A.3 • 09:30 Plenary**
Will Computational Imaging Change Lens Design?, Kevin P. Rolland-Thompson1; Synopsys, Inc, USA; 2The Inst. of Optics, Univ. of Rochester, USA. Computational imaging is changing the landscape in many dimensions. This work will present some of the extremes in lens systems and examples of potential simplifications when combined with computational methods that extend depth of focus.

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10:15–11:00 Coffee Break and Exhibit, Grand Ballroom Salon I

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**Grand Ballroom Salons II & III**

06:45–18:00 Registration, Paniolo Lounge

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**Grand Ballroom Salon III**

International Optical Design

11:00–13:00
IM2A • Photography
Presider: Kenneth Kubala; FiveFocal, LLC, USA

IM2A.1 • 11:00 Invited
Digital Imaging System Design and Trade Space Analysis, Rob Bates1, Kenneth Kubala1, Adam Greengard2,3; FiveFocal LLC, USA. Designers of modern digital imaging systems may use image processing to explore vastly different architectures. We demonstrate the opportunity this degree of freedom enables through design of wide-angle systems evaluated with a system-level performance metric.

IM2A.2 • 11:30
Fast Calculation of Bokeh Image Structure in Camera Lenses with Multiple Aspheric Surfaces, Viktor P Sykot1, Michael D Thorpe2; Raytheon ELCAN Optical Technologies, Canada. Approaches to calculate bokeh image structure in camera lenses with two aspheric surfaces are analyzed and compared. Aspheric surfaces contribute to bokeh structure differently increasing complexity of bokeh image. Off-axis bokeh image is also analyzed.

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**Grand Ballroom Salon II**

International Optical Design

11:00–13:00
IM2B • Exotic Optics I
Presider: Michael Missig; Bausch & Lomb, Inc, USA

IM2B.1 • 11:00 Invited
Design and Analysis of an X-ray Differential Phase Contrast Imaging System with Grating-less X-ray Source and Detectors, Yuzuru Takashima1, Jihun Kim1,2, Yoo-To Cheng1, Max Xu1, Lambertus Hesselink3,4; 1College of Optical Sciences, Univ. of Arizona, USA; 2Material Science, Stanford Univ., USA; 3Applied Physics, Stanford Univ., USA; 4Electrical Engineering, Stanford Univ., USA; 5Korea Astronomy & Space Science Inst., Republic of Korea. X-ray differential phase contrast imaging system with a grating-less X-ray source and grating-less detectors are effective for applications with higher X-ray photon energy by decoupling a trade-off the parameters, signal contrast and field-of-view.

IM2B.2 • 11:15
Iterative Design Process for Highly Efficient Optical Trapping Systems, Ronald Kampmann1, Annemieke K. Choll1, Roman M. Kleindienst1, Stefan Szininger1; Technische Optik, Technische Universität Ilmenau, Germany. The development of an optical system for trapping particles in air is presented. Based on optics design as well as optical force simulations an efficient optical system is designed, manufactured and characterized.

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**Plaza Ballroom III**

Optical Fabrication and Testing

11:00–13:00
OM2C • Materials
Presider: Tayyab Suratwala; Lawrence Livermore National Lab, USA

OM2C.1 • 11:00 Invited
Recent Results of Infra-red Compressive Sensing, Abhijit Mahalanobis1; Lockheed Martin Corporation, USA. We discuss the impact of real-world devices on the process of compressive sensing, and issues that must be addressed in practice. We will discuss a CS architecture based on a reflective spatial light modulator and a focal plane array with variable pixel sizes, as well as the experimental results for infrared imaging. In particular, we will present a preliminary sensitivity analysis, measured noise characteristics, and results of image reconstruction.

OM2C.2 • 11:30
Post-Curing Dye Diffusion for Creating a Durable Photopolymer, Mitsunori Saito1, Junpei Nogami2, Ryukoku Univ., Japan. Dye-dispersed polymethylmethacrylate self-heals optical degradation, since dye molecules diffuse rapidly in the solid matrix and replace bleached molecules by fresh ones. Bleaching in the curing process is also avoidable by diffusing dye molecules after solidification.

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**Plaza Ballroom I & II**

Computational Optical Sensing and Imaging

11:00–12:45
CM2D • Compressive Imaging and Optical Super-resolution
Presider: Amit Ashok, Univ. of Arizona, USA

CM2D.1 • 11:00 Invited
Information-optimal Scalable Compressive Imaging System, Ronan Kerviche1, Nan Zhu2, Amit Ashok1,2; 1College Of Optical Sciences, Univ. of Arizona, USA; 2Department of Electrical and Computer Engineering, Univ. of Arizona, USA. We present a scalable compressive imager using information-optimal measurements design and single-pass piece-wise linear reconstruction algorithm. Superior performance of such design compared to random binary projections is demonstrated via a real-time, high-resolution implementation of said system.
International Optical Design

IM2A • Photography—Continued

IM2A.3 • 12:15
Design, Fabrication and Test of Miniature Plastic Panomorph Lenses with 180° Field of View, Simon Thibault1,2, Joseelyn Parent1, Hu Zhang3, Patrick Roulet1,2; 1Caltach Optical Observatories, California Inst. of Technology, USA. Zemax models were built for 68 folded zoom lenses. Glass types and paraxial properties are computed. The analysis is presented for two of the most-similar designs, in terms of both engineering and IP.

IM2A.4 • 12:20
Folded Zoom Lenses - a Review of Patent Literature, Daniel Reiley1; 1Caltach Optical Observatories, Canada. We present two miniature all plastic megapixel panomorph lenses for consumer electronics (TTL of 6.56 mm) and mobile phone (TTL of 3.80 mm) showing the unique challenges from specification, design, manufacturing and testing phases of these new generation of miniature 180° FoV wide-angle lenses.

IM2A.5 • 12:15
Enhanced Field of View Fiber Coupled Image Sensing, Ashkan Arianpour1, Ilya Agurk1, Nojan Motamed1, Joseph E. Ford2; 1ECE, Univ. of California San Diego, USA. Fiber-coupled sensors allow detection of spherical image surfaces. We investigate the field of view possible with a single straight fiber bundle, demonstrating how the field can be extended by annular micropipets near the image surface.

IM2A.6 • 12:30
Mobile Platform Optical Design, Peter P. Clark1,2; 1LensVector Inc, USA; 2ImmerVision, Canada. Mobile Platform Optical Design, Peter P. Clark1,2; 1LensVector Inc, USA; 2ImmerVision, Canada.

IM2B • Exotic Optics I—Continued

IM2B.4 • 11:43
Design of the Curvilinear Reflectors for Linear Rotary Optical Delay Lines, Makim Skorobogaty1,2,2; 1Ecole Polytechnique de Montreal, Canada. We present design principles for the linear optical delay lines based on using curvilinear reflectors. An optical rotary delay line with a composite rotating blade having two reflector surfaces is then fabricated using CNC machining.

IM2B.5 • 12:00
Broadband Infrared Optical Materials and Methods, Nathan Carlier1; 1SCHOTT North America, USA. The evolution of infrared optical systems toward multi-spectral applications requires a new tool set for the selection and design of new optical materials and systems based on first principles.

IM2B.6 • 12:30
Optimization of Manufacturability of Chalcogenide Glasses for Mid-Infrared Optical Components, Kathleen A. Richardson1,2,1; 1Department of Physics, Univ. of North Carolina at Charlotte, USA; 2Army Research Lab, USA. The paper outlines a super resolution imaging method for viewing microscopic features in the resolving power of a single-lens imager, by processing images acquired under a lattice of light spots.

IM2B.7 • 12:30
Compositional dependence of structural relaxation behavior in the Ge-As-Se glass system characterized by length dilatometry, Erick Koontz1,2; 1ECE, Univ. of North Carolina at Charlotte, USA; 2Army Research Lab, USA.

OM2C • Materials—Continued

OM2C.4 • 11:45
The Emergence of SiC Optics in the 21st Century, Fiammingo Tinker1; 1Aperture Optical Sciences, USA. Abstract not available.

OM2C.5 • 12:15
Compositional dependence of structural relaxation behavior in the Ge-As-Se glass system characterized by length dilatometry, Erick Koontz1,2; 1ECE, Univ. of North Carolina at Charlotte, USA; 2Army Research Lab, USA.

CM2D • Compressive Imaging and Optical Super-resolution—Continued

CM2D.3 • 11:45
Compressive extended depth of field using image space coding, Patrick Lull1, Xin Yuan1, Xuejun Liao1, Jaribo Yang1, Lawrence Carin2; 1Electrical and Computer Engineering, Duke Univ., USA. We present a prototype imaging system that utilizes focal and temporal image space modulation to compress volumetric three-dimensional information into planar images. Videos and extended depth of field reconstructions from single compressive measurements are reported.

CM2D.4 • 12:00
Object Tracking via Compressive Sensing, Yun Li1, Chinmay Hegde1, Kevin F. Kelly1; 1Department of Electrical and Computational Engineering,, Rice Univ., USA; 2Computer Science and Artificial Intelligence Lab, Massachusetts Inst. of Technology, USA. We propose a novel, low-cost and efficient tracking system for various spectrums based on the single pixel camera. By designing patterns that effectively preserve the object location, the guaranteed tracking speed is considerably improved.

CM2D.5 • 12:15
Optical super resolution using a lattice of light spots, Prasanna V. Rangarajan1, Indranil Sinha2,1; 1Optical Super-Resolution Group, Case-Western Reserve Univ., USA; 2Compressive Imaging and Machine Learning Lab, USA.

Plaza Ballroom I & II

Computational Optical Sensing and Imaging

CM2D.6 • 12:30
Exploiting reciprocity for super resolution using metamaterials, Robert Ingle1, Prashanna R. Rangarajan1, Robert Ingle1; 1Univ of North Carolina at Charlotte, USA. Near field capture of evanescent waves may be possible using negative index metamaterials but practicalities encourage their conversion to propagating waves. Using a metamaterial for this and fabricating it’s “reciprocal” might allow far field reconstruction.
International Optical Design

14:00–16:00
IM3A • Astronomy
President: Joseph Howard; NASA Goddard Space Flight Center, USA

IM3A.1 • 14:00
Invited
Ray-tracing for coordinate knowledge in the JWST Integrated Science Instrument Module, Derek S. Sabarte1; Ball Aerospace & Technologies Corp., USA. We describe the matrix/vector ray tracing methods used to maintain pupil and image position knowledge in the James Webb Space Telescope Optical Telescope Element Simulator. These prove broadly useful to in optical engineering problems.

IM3B.1 • 14:00
Hyper NA Catadioptric Imaging Lens, Tamer T. Elazhari1, Nakano Masatsugu2, Momoru Miyawaki1, Jose M. Savian1; *Univ of Arizona, USA; **Carnegie Inst., USA. We present designs of 1.65 NA visible imaging lens with 1.75 mm field size and 20X magnification. Small obscuration is enabled using semi-transparent annular surface or novel multi reflections optical element.

Grand Ballroom Salon II

International Optical Design

14:00–16:00
IM3B • Microscopy/ Lithography
President: Alexander Apple; Carl Zeiss AG, Germany

IM3B.2 • 14:00
Invited
Characterization of DKIST Retarder Components with Polarization Ray Tracing, Stacey R. Suesoka1, Russell A. Chipman1, David F. Elsemore1; *College of Optical Sciences, The Univ. of Arizona, USA; **National Solar Observatory, Association of Universities for Research in Astronomy, USA. Super achromatic retarders and polychromatic modulators are required to meet the polarization specifications of DKIST. These components have been analyzed and modeled using a birefringent polarization ray trace over wavelength and field of view.

IM3B.3 • 14:30
Invited
Illumination in Microscopy - A Brief History, Daniel Smith1; Nikon Research Corporation of America, USA. Historically, illumination design has been linked with the development of microscopy technologies and many tricks have been developed to achieve resolutions below the classical definition. This is a review of illumination engineering in microscopy development.

OM3 • Testing I

President: Ulf Griesmann; National Inst of Standards & Technology, USA

OM3C.1 • 14:00
A 2D high accuracy slope measuring system based on a Stitching Shack Hartmann Optical Head, Mourad Idr1, Guillaume Doulfi1, Brookhaven National Lab, USA; *Imagine optic, France. We present a 2D Slope measuring System based on a Stitching Shack Hartmann Optical Head aiming to perform high accuracy optical metrology for X-ray mirrors needed for synchrotrons or Free electrons Lasers.

OM3C.2 • 14:30
An Alternative Approach to Measure the Interferometer Transfer Function, Ping Zhou1, Jianxin Li2, James H. Burge1; *School of Electronic and Optical Engineering, Nanjing Univ. of Science and Technology, China; **Univ. of Arizona, USA. Current methods to quantify transfer function of an interferometric test are limited to off-line characterization of interferometer itself. We propose an in situ technique for measuring instrument transfer function of a complete interferometric test system.

OM3C.3 • 14:45
Light Scattering of Optical Components for Space Applications, Sven Schröder1, Dina Katse1, Uwe Zeimet1, Angela Dupunde1; Fraunhofer Inst. IOF, Germany; *Ac+Nov Ltd, Israel. Light scattering can critically affect the performance of high-end optical systems. Bidirectional Reflectance Distribution Functions (BRDF) are used to quantify scattering properties. Measurements on mirrors, black coatings, and diffraction gratings for space applications are discussed.

OM3C.4 • 15:00
Interferometric Length Measurement in Extreme Temperature Ranges, Tatjana Quast1, Rene Schröer1, Uwe Zeimet1, *Fraunhofer Inst. IOF, Germany; **Ac+Nov Ltd, Israel. Interferometry is an important technique for highly accurate length measurements of functional materials. To characterise their properties under harsh operating conditions, interferometric setups for extremely low and high temperatures have been developed.

OM3D • Holography and Ptychography

President: Laura Waller; Univ. of California Berkeley, USA

OM3D.1 • 14:00
Invited
Synthetic Optical Holography, Brad Deutsch1, Martin Schnell1, Rainer Hillenbrand1, P. Scott Carney1; *Beckman Inst. for Advanced Science and Technology, *Univ. of Illinois at Urbana-Champaign, USA; **IKERBASQUE, Basko Foundation for Science, Spain; **Dept. of Electrical and Computer Engineering, *Univ. of Illinois at Urbana-Champaign, USA. To illustrate the advantage of SOH, we use it in conjunction with a scattering-type near-field optical microscope to perform near-field holography, improving the speed of operation by more than an order of magnitude while significantly simplifying the experiment.

OM3D.2 • 14:30
Ptychography: lensless high-resolution phase-sensitive imaging, John M. Rodenburg1, Mandeep Singh1, Samsheer Ali1, Julie Bentley1; *Univ. of Sheffield, UK. Ptychography has made a big impact in high-energy X-ray microscopy, but it also has important potential applications in visible light optics and electron microscopy. This talk will review recent progress in the field.

OM3D.3 • 15:00
Single Shot High Resolution Digital Holographic Imaging, Kedar Khare1, Samsheer Ali1, Mandeep Singh1, Joby Joseph1; *Indian Inst. of Technology, Delhi, India. We describe a constrained optimization approach to image recovery in digital holography that is unlike the physical hologram replay process. The possibility of single shot high resolution quantitative phase imaging is illustrated with experimental results.
IM3A • Astronomy—Continued

IM3A.5 • 15:15
Design, Fabrication, and Test of WFIRST/AFTA GRISM Assembly, Qian Gong1, David A. Content1, Jeffrey Kruk2, Bert A. Pasquale3, Thomas E. Wallace2, Walter F. Smith4. This paper discusses how to use a diffractive lens surface to compensate the wavelength dependent aberration created by the grating in non-collimated space, and how to reduce the impact of unwanted diffraction orders. Element fabrication, test, and assembly alignment are also discussed.

IM3A.6 • 15:30
CFRP Variable Curvature Mirror Used for Realizing Non-moving-element Optical Zoom Imaging, Hu Zhaol, Xuewu Fan1, Zhihai Pang1, Guoru Ren1, Wei Wang1, Yongjie Xie1, Zhen Ma1, Yunfei Du1, Yu Su1, Jingxuan Wei1, 1Xizhou An1 of Optics and Precision Mechanics, Chinese Academy of Sciences, China; 2School of Computer Sciences, Beijing University of Chemical Technology, China. A CFRP [carbon-fiber-reinforced-polymer] variable curvature mirror, which is suitable for non-moving-element optical zooming, is designed, fabricated and tested. With 100mm diameter, 2mm thickness and initial curvature radius of 1740mm, this mirror can provide a center deflection of about 22.9um.

IM3A.7 • 15:45
Optical Design of WFIRST/AFTA Wide-field Instrument, Bert A. Pasquale1, David A. Content1, Jeffrey Kruk1, David A. Vaughn1, Qian Gong1, Joseph M. Howard1, Alden Jurling1, Eric A. Mentele1, Nesrey V. Armani1, Gary Kuan1, 1Goddard Space Flight Center, NASA, USA; 2Jet Propulsion Lab., USA. The WFIRST/AFTA Wide-field Infrared Survey Telescope TMA optical design provides 0.28sq° FOV at 0.11" pixel scale, operating between 0.6–2.4um, including a spectrograph mode (1.3-1.95um). An IFU provides a discrete 3’x3.15’ field at 0.15’ sampling.

IM3B • Microscopy/ Lithography—Continued

IM3B.5 • 15:15
Broad-spectrum fiber-coupled monomeric optical imaging, Iker Stamenov1, Stephen Olivas2, Ashkan Arabapour3, Ilya Agurak3, Adam R. Johnson1, Ronald A. Stack4, Joseph E. Ford1, 1CEC, Univ. of California San Diego, USA, 2Distant Focus Corporation, USA. Monomeric lenses provide high-resolution panoramic imaging onto a spherical image surface. We characterize the curved image transfer via fiber bundles onto CMOS focal planes and two lens prototypes—designed for visible and NIR spectrum.

IM3B.6 • 15:30
193 nm Scatterfield Microscope Illumination Optics, Martin Sohn1, Richard Silver1, 1National Inst. of Standards and Tech, USA. Illumination optics for a scatterfield microscope for 193 nm light was designed with a commercial cathodoluminescence objective lens. Numerical aperture and diameter of a telecentric conjugate back focal plane were optimized and evaluated for angular illumination.

IM3B.7 • 15:45
CODE V to Matlab Extensions, Garrett J. West1, Joseph M. Howard1, 1Goddard Space Flight Center, NASA, USA. A suite of CODE V macros has been developed to assist the optical designer in developing and manipulating optical data. Limits within the CODE V macro language and graphics functions are surpassed by accessing a MATLAB subroutine. A number of extension macros are discussed and examples are shown.

OM3C • Testing I—Continued

OM3C.5 • 15:15
Vertex radius calculation and sensitivity analysis for measuring paraboloidal surfaces with a three-ball spherometer, Margaret Z. Dominguez1, Jianxin Li1, Ping Zhou1, James H. Burge1, 1College of Optical Sciences, Univ. of Arizona, USA; 2School of Electronics and Optical Engineering, Nanjing Univ. of Science and Technology, China. This paper expands on work previously presented that describes how to calculate the vertex radius of an off-axis parabolic segment using the sag measured by a three-ball spherometer. An example of the vertex radius calculation is also presented.

OM3C.6 • 15:30
Optical Testing and Finite Element Analysis of a CFRP Variable Curvature Mirror Used for Non-moving-element Optical Zooming, Rualda Izaga-Pérez1, Daniel Aguirre-Aguirre1, Fermín Granados-Aguirre1, María Elizabeth Percinos-Zacarias1, 1Departamento de Óptica, Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), Mexico. In this work an off-axis conical mirror is fabricated by stressed mirror polishing; the fabrication process is monitoring by using the interferometrical developed theory and the deformation accuracy by means of finite element analysis software.

OM3C.7 • 15:45
Simultaneously testing surface figure and radius of curvature for spheres by a point diffraction interferometer, Qin Yuan1,2, Shizhan Gao1, Zhangmin Yang1, 1School of Optical and Electrical Engineering, Nanjing Univ. of Science and Technology, China; 2The Inst. of Optics, The Inst. of Optics, USA. We report on the development of a point diffraction interferometer in visible light with surface figure measurement accuracy of ±50 PV. The system enables simultaneous testing of the radius of curvature with the accuracy 8µR ±510-4.
Large data sets of highly accurate BSDF measurements require large data sets of highly accurate BSDF measurements that cover the range of illumination angles incident on the diffuser in the simulation.

Efficient Assessment of Lens Manufacturability in Optical Design, Eric Herman, Richard N. Youngworth, Jose M. Sasian; Synopsys, Inc, USA. Based on an example lens designed to be passively athermalized over a 200°C temperature range, we examine the accuracy to which the expansion coefficients and divergence coefficients of the system must be known.

Passive Athermalization: Required Accuracy of the Thermooptic Coefficients, John R. Rogers, Synopsys, Inc, USA. This paper presents a tolerance grade mapping system that is particularly useful in assessing cost-effective manufacturability. A lens design example is included that illustrates the method and its ease of use.

Dressed Photon-Phonon Polishing for Ultra-Smooth Surfaces, Takashi Yatsu; Univ. of Tokyo, Japan. This paper describes the mechanism of dressed photon-phonon (DPP) generation. Recent progress in ultraprecision fabrication technologies using DPPs is reviewed, including DPP-photochemical etching and deposition, which can be used to produce angstrom-scale flat surfaces.

Contamination of fused silica optics surface after magnetorheological polishing, Philipp Cormor, Radoslav Catin, Jerome Nauport, Danel Taroupi, Cedric Maunier, Sebastien Lamberti, Olivier Rondeau; CEA, France. Quantities of pollutants present in silica optics polished by MRF are measured with ICP-AES after wet chemical etching. Iron contamination is mostly confined in two µm thick layer at surface and decreases exponentially with depth.

OM4B.4 • 17:30
Ion Beam Technology: Figuring, Adding and Smoothing for Ultra-smooth Surfaces, Hao Hu, Xuhui Xie; Univ. of Arizona, USA. Besides conventional ion beam figuring process, ion beam adding has been proposed and applied in optical fabrication. Ion beam smoothing processes, especially on fuse silica and Zerodur are discussed, and ultra-smooth surfaces are achieved.

A Compressive Superresolution Display, Felix Heide, James Gregson, Gordon Wetzstein, Ramesh Raskar, Wolfgang Heidrich; Department of Computer Science, Univ. of British Columbia, Canada. We demonstrate a new compressive display architecture for superresolution image presentation that exploits co-design of the optical device configuration and compressive computation. Our display allows for superresolution, HDR, or glasses-free 3D presentation.

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Grey's Orthonormal Optimization: a 50-year Retrospective, ITu1A.2 • 08:30
Dewen Cheng, 2Optical Solutions Group, Synopsys, Inc, USA; 2College of Optical Sciences, Univ. of Arizona, USA.

The skew aberration is polarization aberration which is intrinsic to optical systems. A critical angle corner cube system is analyzed to review the skew aberration’s effects.

Fat Rays Revisited: A Synthesis of Physical and Geometrical Optics with Gaussian Beams, ITu1A.3 • 08:45
D. Hayford 1, Optical Solutions Group, Synopsys, Inc, USA, 2College of Optical Sciences, Univ. of Arizona, USA.

The method of Grey’s orthonormal optimization is reviewed. Aspects of the method that contributed to its success are reviewed, and factors limiting its application are discussed. Current status of the method is summarized.

Grey’s Orthonormal Optimization: a 50-year Retrospective, ITu1A.4 • 09:00
D. Hayford, Optical Solutions Group, Synopsys, Inc, USA, College of Optical Sciences, Univ. of Arizona, USA.

The skew aberration is polarization aberration which is intrinsic to optical systems. A critical angle corner cube system is analyzed to review the skew aberration’s effects.

The 2013 China Lens Design Problem: The conjugate Zoom Lens, ITu1A.5 • 09:15
Zhong Jingshan 1, Osaka Prefecture Univ., Japan; 2Chair for Laser Technology, Carl Zeiss AG, Germany.

The 2013 China lens design competition was to design a conjugate zoom lens with maximum magnification ratio, and factors limiting its application are discussed. Moreover, first combinations of both processes are presented.

Recent Advances in Precision Thermal Forming of Glass and Polymeric Optics, ITu1B.4 • 09:15
J. Mendes-Lopes 1, Universidad Politécnica de Madrid (UPM), Spain; 2High Concentration Photovoltaics (HCPV), Spain. High Concentration Photovoltaics require an optical system with high efficiency, low cost and large tolerance. We review physics-based models of photoacoustic computed tomography and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media. Transcranial brain imaging and breast cancer detection applications will be presented.

Polishing and Form Correction with Laser Radiation, ITu1B.5 • 09:30
Sebastian Heidrich 1, Edgar Willenberg 2, Christian Wengarten 1, Reinhart Poprawe 1, Fraunhofer ILT, Germany; 2Chair for Laser Technology ILT, RWTH Aachen Univ., Germany. Within this paper, a preview towards the 1st Conference on Laser Polishing LaP 2014, held in Aachen from May 6 to 7 2014, is given.

Recent Development in Precision Thermal Forming of Glass and Polymeric Optics, ITu1B.6 • 09:30
Lihong V Wang 1, Biomedical Engineering, Washington Univ. in St. Louis, USA. We review physics-based models of photoacoustic computed tomography and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media. Transcranial brain imaging and breast cancer detection applications will be presented.

Computational Optical Sensing and Imaging, Plaza Ballroom I & II

OTu1C.1 • 08:00
Volume by Optical Displacement, Ethan F. Schonbrun 1, Harvard Univ., USA. By measuring multispectral absorption of the light transmitted through a cell surrounded by dye, we demonstrate a method to quantify the volume of a cell invariant to its shape or optical properties.

OTu1C.2 • 08:30
Recent Advancements in Photoacoustic Tomography Image Reconstruction, Mark A. Anastasio 1, K. YuWang 1, Kenji Mitsuhashi 2, LiHong V Wang 1, Biomedical Engineering, Washington Univ. in St. Louis, USA. We review physics-based models of photoacoustic computed tomography and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media. Transcranial brain imaging and breast cancer detection applications will be presented.

OTu1C.3 • 09:00
Compressive Three-Dimensional Localization Microscopy, Anthony J. Barat 1, Ginni Grover 1, Rafael Pieutun 1, Electrical, Computer and Energy Engineering, Univ. of Colorado at Boulder, USA. Localization microscopy requires a large number of image frames, an issue aggravated in 3D imaging. Sparse reconstruction methods can resolve overlapping 3D point spread functions from dense emitter scenes, leading to shorter measurement times.

OTu1C.4 • 09:15
Point-Diffraction Interference Microscope with a Wire-Grid Polarization Pinhole, Aiko Matsu 1, Atsushi Nogami 1, Hsiao Kudzu 1, Osaka Prefecture Univ., Japan. A point-diffraction interference microscope with a wire-grid polarization pinhole was developed for quantitative phase-imaging. The phase image was obtained, and a focused image was calculated from the defocused phase image with the digital holography technique.

OTu1C.5 • 09:30
Partially coherent phase microscopy with arbitrary illumination source shape, Zheng Jiang 1, 2, Lei Tian 1, Justin Dauels 1, Electrical and Computer Sciences, Univ. of California Berkeley, USA; 2Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore. We propose a phase imaging method that uses through-focus images taken within a microscope having illumination of any arbitrary source shape (coherence). We use a Kalman filtering approach, which is fast, accurate and noise robust.

OTu1C.6 • 09:45
Quantitative Tablettop EUS Phase-Contrast, Coherent Diffraction Imaging Microscope, Daniel Adams 1, 2, Bosheng Zhang 1, Matthew Seaberg 1, Dennis Gardner 1, Elisabeth Shariatb 1, Dennis Gardner 1, Dennis Gardner 1.

We demonstrate the utility of our CDI-based EUS microscope by quantitatively imaging objects in transmission and reflection. Feature depth is obtained in transmission and height is extracted in the first general, tabletop reflection CDI microscope.

ITu1A.1 • 08:00
International Optical Design, Grand Ballroom Salon III

ITu1A.7 • 08:00
Optical Fabrication and Testing, Plaza Ballroom III

ITu1A.8 • 08:00
Optics with Gaussian Beams, Plaza Ballroom III
Optical Fabrication and Testing

10:30–12:30

OTu2A • Tolerancing
Presider: Dave Aikens; Savvy Optics Corp., USA

OTu2A.1 • 10:30
Invited Integration of Optical Fabrication and Metrology into the Optical Design Process, James E. Harvey1; Photon Engineering LLC, USA. New insight concerning the effect of scattered light upon the MTF, the development of generalized surface scatter theories, new computational techniques and increased computer speed leave us poised to integrate optical fabrication and metrology into the optical design process.

OTu2A.2 • 11:00
An Investigation of Aberration-Insensitive Lens Shuffles, Giles Sheppard1; Qiqing Ltd, UK. Decenteration of a lens causes a change in aberrations of an optical system. This paper will show that, despite first order limitations of a simple design form presented, lens shuffle insensitivity can still be achieved.

OTu2A.3 • 11:15
A Monte Carlo Analysis of Cross Tolerances in Lenses, Michael Kelhoe1; Resonon Inc., USA. Cross tolerances, or the interactions between tolerances, are examined for ten double Gauss lens specifications drawn from U.S. patents. In the context of these ten lenses, it is often efficient to specify tight tolerances jointly.

OTu2A.4 • 11:30
Linear Optical Models for NASA’s WFIRST Mission, Joseph M. Irwin2; Lawrence Livermore National Lab, USA. Progress on understanding phenomena influencing surface figure and roughness during pad polishing is reviewed, followed by a description of a new Convergent Polish process allowing single iteration, process variation-free finishing of optical flats & spheres.

OTu2A.5 • 11:45
Mechanisms & Control of Surface Figure & Roughness during Pad Polishing, Taoyi B. Suwarta1; William A. Steel2; Lawrence Livermore National Lab, USA. Progress on understanding phenomena influencing surface figure and roughness during pad polishing are reviewed, followed by a description of a new Convergent Polish process allowing single iteration, process variation-free finishing of optical flats & spheres.

OTu2A.6 • 12:00
An Efficient Method of Reducing Glass Dispersion Tolerance Sensitivity, Scott W. Sparrow1; R. H. Shepard2; Edmund Optics, USA. A novel method of reducing glass dispersion tolerance sensitivity is presented. Computational efficiency is achieved by utilizing a computational optimization tool based on Seidel aberrations. Comparisons to commercial software are made.

OTu2A.7 • 12:15
Scanning Pupil Tolerancing, Mark C. Sanson1; Edmund Optics, USA. The method proposed in this paper focuses on tolerancing to meet system performance, not the fight against the surface fingerprint of a particular fabrication process.

OTu2B • Figuring, Finishing and Cleaning
Presider: Flemming Tinker; Aperture Optical Sciences, USA

OTu2B.1 • 10:30
Invited Diamond Turned Kiniform in Calcium Fluoride Having a Depth Larger than the Standard Blaze Depth, James L. Ramsay1; Gerard Desroches2; ELCAN Optical Technologies, Canada. Single Crystal CaF2 was diamond turned to produce a high-quality kiniform where the depth is greater than 20 microns with a tool size smaller than the depth.

OTu2B.2 • 11:00
Multi Object Spectrograph of the Fireball-II Balloon Experiment, Gerard Lemaître1; Robert Grange2; Samuel Quiret3; Bruno Milliard1; Sandrine Pascal1; Vincent Lamande1; Laboratoire d’Astrophysique de Marseille, France. Fireball-II is a NASA/CNES balloon-borne telescope and MOS to study faint diffuse emissions of galaxies in the space ultraviolet. The MOS is based on two identical reflective Schmidt systems sharing an plane-asphereded grating obtained by active optics methods.

OTu2B.3 • 11:15
Invited Roughness reduction on aspheric surfaces, Sven Kornek1; Sebastian Kokot1; asphericon GmbH, Germany. In recent years, roughness has become increasingly important. This paper introduces the new capabilities in roughness on aspheric surfaces combined with an overview of achievable results and some insights on how to analyze them properly.

OTu2B.4 • 11:45
Roughness reduction on aspheric surfaces, Sven Kornek1; Sebastian Kokot1; asphericon GmbH, Germany. In recent years, roughness has become increasingly important. This paper introduces the new capabilities in roughness on aspheric surfaces combined with an overview of achievable results and some insights on how to analyze them properly.

OTu2B.5 • 12:00
Characterization of Surface and Coating Imperfections for Advanced Laser Optics, Xinbin Cheng1; Huasong Liu1; Weiliang Zhu2; Key Lab of Computational Optical Imaging Technology, Chinese Academy of Sciences, China. We propose a spectral imaging approach using a plenoptic camera with an imaging lens with longitudinal chromatic dispersion. Multispectral images are reconstructed from a single light field image through digital refocusing followed by 3D deconvolution.

CTu2C • Spectroscopy and Spectral Imaging
Presider: Michael E. Gehm, Duke Univ., USA

CTu2C.1 • 10:30
Using Speckle to Build Compact, High-Resolution Spectrometers, Hui Cao1; Yale Univ., USA. Speckle pattern produced by a random structure or a multimode fiber carries spectral information of the input signal. We build a disordered on-chip spectrometer with sub-nm resolution and an all-fiber spectrometer with 1 pm resolution.

CTu2C.2 • 11:00
Single-pixel spectroscopy via compressive sampling, Yotah August1; Adrian Stern1; Dan G. Blumberg1; Department of Electro-Optical Engineering, Ben Gurion Univ. of the Negev, Israel. Recently we presented a method for compressive spectrometry based on a liquid crystal cell. Here we describe the spectrum reconstruction dependence on the type of sparsifier used in the reconstruction process.

CTu2C.3 • 11:15
An all-fiber spectrometer using deconvolution of intensity images at the output of photonic bandgap fiber bundle, Maxim Skorobogaty1; Hang Gu1; Ecole Polytechnique de Montreal, Canada. An all-fiber spectrometer based on a photonic bandgap fiber bundle is demonstrated. The test spectrum is reconstructed by applying deconvolution algorithm to the images registered at the output of the photonic bandgap fiber bundle.

CTu2C.4 • 11:30
Snapshot Multispectral Imaging Using a Plenoptic Camera with an Axial Dispersion Lens, Zhiliang Zhou1; Bin Xiangli2; Key Lab of Computational Optical Imaging Technology, Chinese Academy of Sciences, China. We propose a spectral imaging approach using a plenoptic camera with an imaging lens with longitudinal chromatic dispersion. Multispectral images are reconstructed from a single light field image through digital refocusing followed by 3D deconvolution.

CTu2C.5 • 11:45
Coded Aperture Snapshot Imaging Based Spectral Classification, Sehoon Lim1; Chongseung Cho1; Awek Das1; Sek Chai1; Information & Computing Sciences, SR International, USA. Coded aperture snapshot imaging (CASSI) is used for spectral classification in a compact form. A CASSI data cube is classified by using an adaptive cosine estimator (ACE), to detect target pixels, and signal-to-noise ratio (SNR) of the data cube is improved by video stabilization (VS) technique.

CTu2C.6 • 12:00
Experimental Demonstration of a Coded Aperture-based Compressive Spectral Imaging System, Hoover Rueda1; Henry Augello2; Gonzalo R. Aracil1; Electrical and Computer Engineering, Univ. of Delaware, USA. A proof-of-concept implementation of a compressive spectral imaging system using a coded aperture in the coding element is presented. The colored coded aperture provides more flexible coding compared with the widely used chrome-on-quartz photomasks.
Towards an Optimized Superposition Lens, Harvey M. Spencer
Optical Design Considerations for Wide Spectral Band Applications, Andrew Harvey, Nick Bustin, James Downing, Guillame Carles, Gonzalo Muyo, Andrew P. Wood, Paul Zammit, Qiop et, UK; School of Physics and Astronomy, UK; RT Microsystems, UK. Synoptic combination of innovative optical design with computational image recovery promises high performance imaging from cheaper, lighter and more compact optics. We describe practical multi-aperture, multi-scale and hybrid imaging systems.

A multi-aperture imager for a wearable camera, Mamoru Miyawaki
A study on Elastic Grinding Tools, Christian Vogl, Stefan Sinzinger, Rolf Rascher, Lab of Optical Engineering, Univ of Applied Sciences Deggendorf, Germany; Mechanical Engineering, Univ of Darmstadt, Germany. This paper reports on results of test runs with experimental grinding tools. The ball shaped tools comprise of abrasive layers with diamond grits, on top of an elastic layer. The tool's design allows dwell time based corrections on simple and complex shapes, such as spheres and parabolic shapes.

Fabrication of Spherical Lens Array Mold by Electrical Discharge Machining with Single Rod Electrode, Hideo Takino, The Univ of Tokyo, Japan. We propose a method of fabricating lens array molds by electrical discharge machining. The effectiveness of our proposed method is demonstrated by shaping a lens array mold with 16 elements using a single rod electrode.

Grating for Hyperspectral Imaging, Cheng-Hao Ko, Chia-Hui Lin, Jih-Run Tsai, Bang-Ji Wang; Graduate Inst. of Automation Control, National Taiwan Univ. of Science and Technology, Taiwan. An optimization process to reduce the aberration of a concave grating is developed. The result shows that the new approach has a dramatic reduction in aberration and great improvement in spectral resolution.

Modeling and Measuring Liquid Crystal tunable Lenses, Peter P. Clark, Lenslet Inc., USA. Tunable GRIN lenses that operate in randomly polarized light may be produced using liquid crystal (LC) materials. We will describe one such device, and discuss practical methods of evaluating its performance, considering its dependence on polarization.

Fabrication and Replication of Telescope Arrays for Vision Alids, Adrian Grewe, Patrick R. Gill, Let Source, Rambus Labs, USA. We demonstrate in hardware that an ultra-miniature, lensless computational diffractive imager can yield images of QR code symbols sufficient for accurate code reading, even amidst modest variation in target orientation.

Reading QR Code Symbols with an Ultra-miniature Computational Diffractive Imager, Patrick R. Gill, David G. Stork, Rambus Labs, USA. We demonstrate in hardware that an ultra-miniature, lensless computational diffractive imager can yield images of QR code symbols sufficient for accurate code reading, even amidst modest variation in target orientation.
Tuesday, 24 June

International Optical Design

16:30–18:00 IT4C • IODC Postdeadline Session

Plaza Ballroom III

16:30–18:00 OTu4A • Testing II

President: Dave Aikens; Savvy Optics Corp., USA

OTu4A.1 • 16:30 Comparison of 2D and 3D measurements of aspheres with a tactile and optical sensor on one measuring instrument, Andreas Beutler; R&D, Mahr GmbH, Germany. New results and opportunities of 2D and 3D, contact and non-contact measurements of high precision aspheric lenses on a new high accuracy cylinder coordinate measuring machine equipped with a tactile and optical sensor are presented.

OTu4A.2 • 16:45 OTu4A.3 • 17:00 Stitching interferometry for the measurement of cylinder, Junzheng Peng, Haifeng Xu, Yingjie Yu, Department of Precision Mechanical Engineering, Shanghai Univ., China. A stitching interferometry based on the Legendre-Fourier polynomials offsetting the form error (cylindricity) is introduced to measure the shape error of cylinder. A cylinder with diameter of 75mm is prepared for the experiment.

OTu4A.4 • 17:15 Experimental demonstration of a diffractive zoom-lens for an interferometric setup, Alexander Bielke, Christof Pruss, Wolfgang Osten; Univ. of Stuttgart, Institut für Technische Optik, Germany. We present our first results of a stray light optimized and compact interferometer zoom lens with a large range of measurable sphere radii and the option to compensate astigmatism, based on an idea of Lohmann.

OTu4A.5 • 17:30 Figure Metrology for X-Ray Focusing Mirrors with Fresnel Holograms and Photon Sieves, Ull Griesmann, Quandou Wang, Johannes A. Soons, Lahsen Assoufid; National Inst of Standards & Technology, USA; X-ray Science Division, Argonne National Lab, 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 from an undulator x-ray source.

OTu4A.6 • 17:45 Comparison of Non-null Figure Error Reduction Methods in Testing Deep Aspherics with Large Errors, Tu Shi, Dong Lu, Lei Zhang, Yongying Yang, Yiping Shen; Zhejiang Univ., China. Four commonly used figure error reduction methods for aspheric surface error in a non-null test are discussed and compared. Simulations are presented to show the behaviors of the four methods in the case of testing a deep aspheric with large figure error in a non-null test. Exhibit
**JTu5A.1**
Rotational error correction in lateral shearing interferometry for freeform surface measurement, Hyo-Yoo Rhee, Young-Sik Ghim, Jooyong Lee, Ho-Soon Yang, Yun-Woo Lee, 
1Korea Research Inst. of Standards and Science, Republic of Korea;
2Department of Posts and Telecommunications, China.
Experiments for verification are undergoing.

**JTu5A.2**
Optical interferometry for 3D surface profiling of freeform optics, Young-Sik Ghim, Hyo-Yoo Rhee, Angela D. Davies, Ho-Soon Yang, Yun-Woo Lee, 
1Center for Space Optics, Korea Research Inst. of Standards and Science, Republic of Korea;
2Department of Physics and Optical Science, Univ. of North Carolina at Charlotte, USA.
As a summary version of the authors’ previous report of Ref 1, we describe a new variant of lateral shearing interferometer with a tunable laser source that enable us to measure 3D surface profile of freeform optics with high speed, high vertical resolution, large departure, and large field-of-view.

**JTu5A.3**
Pressurization system aided polishing for fabrication of a quilting-free lightweight mirror, JOOYOUNG LEE, Haygong Kim, Yuhyub Kim, Joo-Hoob Lee, Yun-Woo Lee, Ho-Soon Yang, 
1KRISS, Republic of Korea. We adopted simplified pneumatic pressurization system in polishing process to remove quilling effect. Optimized air pressure was investigated by FEM analysis and fabrication of 25 mm surface without quilling effect was experimentally verified.

**JTu5A.4**
Influence of the abrasive size distribution and process parameters on surface quality of polished fused silica, Sebastian Campagnolle, Cédric Mauvier, Jerome Neauport, 
1Centre Technique des Travaux Publics, France; 2Ingenierias, Universidad Politecnica de Tulancingo, Mexico.
We discuss the application of electrical discharge machining in the forming step in the fabrication of SiC optics. Chemical vapor deposition SCOTs and sintered SC plates were machined to investigate their removal characteristics.

**JTu5A.5**
Fabrication of Silicon Carbide Optics by Electrical Discharge Machining: Removal Characteristics of Silicon Carbide with Low Electrical Resistance, Hideo Takino, 
1Chiba Inst. of Technology, Japan. We discuss the application of electrical discharge machining in the forming step in the fabrication of SiC optics. Chemical vapor deposition SCOTs and sintered SC plates were machined to investigate their removal characteristics.

**JTu5A.6**
Dual Channels Hybrid Integrated Receiver With High-Speed InGaAs Photodetector Array Integrated On-Glass Ceramic, Yong Luo, Yongjing Huang, Ga Ze, Xiaoning Ren, Xiaofang Duan, 
1State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. The 1 x 2 photodetector array and transimpedance CMOS chip were mounted on a square glass-ceramic substrate platform using low-temperature polymer bonding technology. The detail to fabricate receiver and packaging technology were demonstrated.

**JTu5A.7**
Study of camera lens effects for a deflectometry surface measurement system: SCOTS, Run Huang, Peng Su, Tianquan Su, Yuejin Zhao, Wenqi Zhao, James H. Burge, 
1Univ. of Arizona, USA; 2Beijing Inst. of Technology, China. The camera lens effects for deflectometry surface measurements are analyzed. The evaluation of aberration induced errors are based on image simulation. Experiments for verification are undergoing.

**JTu5A.8**
Dynamic Point Shifting With Chromatic Null Screens in Three LCDs for Testing Fast Convex Surfaces, J. Rufino Diaz-Urbieta, Martin I. Rodriguez-Rodriguez, 
1Alberto Jaramillo-Núñez, 2Centro de Ciencias Aplicadas y Desarrollo Tecnológico, Universidad Nacional Autonoma de Mexico, Mexico; 3Coordinación de Optica, Instituto Nacional de Astrofisica, Óptica y Electricidad, Mexico. Using chromatic null screens together with dynamic point shifting technique within a triangular prism setup of three LCDs is proposed for testing small convex fast surfaces. This increases the lateral and depth resolution of the test.

**JTu5A.9**
Realization of Quantum Efficiency Enhanced PIN Photodetector by Assembling Broadband Resonant Waveguide Grating, Jinhua Hu, Yongqiang Huang, Xiaofeng Duan, Yehong Li, Yang Luo, 
1State Key Lab. of Information Photonics and Optical Communications, Inst. of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We demonstrated an InPInGaAs PIN photodetector assembling with broadband silicon resonant grating for polarization sensitive systems. The results show that the quantum efficiency of the photodetector has increased by 31.6% with a bandwidth of 100 nm for TE-polarization.

**JTu5A.10**
Testing an Aspheric Lenses Combining the Ronchi and Null Surface Test, Maria Elizabeth Percinco, Fermin Granados-Agustin, 
1Daniel Aguirre-Aguirre, 2Manuel Campos-Garcia, 3Lieny Tinndad-Perez, Esperanza Carrascas-Licea, 4INAOE, Mexico. To measure a fast concave spherical surface, we use Ronchi Test to measure central area and Null Screens Test for outside area of the surface. Then integrate both test data and compare with CDRH results.

**JTu5A.11**
Detection of Laser Damage Precursors in High Power Laser Materials by Photothermal Reflectance Microscopy, Ki Soo Chang, 
1Woo June Choi, 2Dong Uk Kim, 3Jun Ki Kim, 4Jee Sung Lee, 5Song Won Hyun, 6Geon Hee Kim, 7Center for Analytical Instrumentation Development, Korea Basic Science Inst., Republic of Korea. We present a wide-field photothermal reflectance microscopy for fast mapping of the laser damage precursors inside optical materials. This method offers a mapping speed of about 0.01 mm2 per minute and detectivity of a few tens of nanometers.

**JTu5A.12**
Relating Wavefront Error, Apodization and the Optical Transfer Function, Jim Schwiegerling, 
1Univ. of Arizona, USA. The Optical Transfer Function is represented as a linear combination of elementary functions where the weighting of each term is directly related to the wavefront error coefficients and apodization coefficients.

**JTu5A.13**
Withdrawn.

**JTu5A.14**
Wave optical optimization of a high NA fiber tip TIR lens, Simon Theule, Alois M. Horwitz, 
1TUM, Univ. of Munich, Germany. Using scalar diffraction theory and a genetic algorithm, a 0.99 NA fiber tip TIR lens is designed and optimized. Comparison with a geometrical design reveals an improvement in efficiency of more than 20 %.

**JTu5A.15**
Withdrawn.

**JTu5A.16**
Design of a high-efficiency LED-based headlamps with Oiler's ellipses technology, Shu-Chun Chu, Min-Shuan Yang, Yu-Sheng Tsai, 
1Physics, National Cheng Kung Univ., Taiwan. Using the Oiler’s ellipses technology, this study designs a low-beam reflector for LED-based headlamps LED-based headlamp that fulfills the ECE regulation R112. The proposed LED-based headlamps provides a high optical efficiency of 89.13%.

**JTu5A.17**
Optical Design of Beam Delivery System for Laser Micromachining, Min Wang, Jonny Guo, Marie Savard, Sonia Verreault, 
1Optical design, INO, Canada. We present the design of a UV Beam Delivery System working at 248 nm. The system has the capability of drilling uniform 2 um hole pattern in polymer over a field of 6.5 x 6.5 mm.

**JTu5A.18**
Withdrawn.

**JTu5A.19**
A Method of Choosing Glasses in the Aplanatic Cemented Doublet Design Using BK7 Glass, Omar Garcia Leonvias, Sergio Naquin Fernandez, 
1Pasgro, Instituto Politecnico Nacional, Mexico; 2Ingenierias, Universidad Politecnica de Tulancingo, Mexico. The BK7 glass can be combined with LASF35, LASF32, SF5, SF6, SF8, SF9, SF12, SF19, and TIFNS to obtain aplanatic doublets. With all doublets we have diffraction limited images on and off-axis.

**JTu5A.20**
Optical Design for Laser Radiation Instrumentation, Nimmi C. Sivarasan, 
1National Oceanic and Atmospheric Administration, USA. An optical laser radar instrument for atmospheric aerosol remote sensing has been developed. Wide angle optics coupled with CCD detection allow detection of particulate scattering from laser pulses. Design challenges and experimental results are discussed.

**JTu5A.21**
Freeform micro optics for compound collimated beam shaping, Enguo Chen, Zhixian Lin, Jintang Lin, Tablei Guo, 
1Fromou Univ., China. We propose a kind of freeform shaping optics for compound collimated beam shaping. This design can achieve prescribed uniform rectangular illuminations without concern for the initial pattern, position or intensity of collimated beam.

**JTu5A.22**
Side-emitting optical probe on beam expanding coreless silica fiber for biomedical applications, Jun Ki Kim, Dong Uk Kim, 
Hwan Hui, Ki Soo Chang, Ick-Hee Kim, 1Center for Analytical Instrumentation Development, Korea Basic Science Inst. (KBSI), Republic of Korea; 2General Surgery, Medical School, Kyungil Univ., Republic of Korea. We fabricate a compact all-optical side-emit-ing probe on beam expanding hybrid fiber using high precision femtosecond laser ablation process. The illuminating properties of the side-emit-ing fibers are experimentally investigated and compared with numerical simulations.

**JTu5A.23**
Design Method of the Stabilized Zoom Lens Using the Focal-length Variable Elements, Qun Hui, Xuemin Cheng, Ke Du, 
1Heng Li, 2School of Optoelectronics, Beijing Inst. of Technology, China; 3Graduate School at Shenzhen, Tsinghua Univ., China; 4Shanghai Inst. of Spaceflight Control Technology, China. We discuss the design method of the practical optical layout for the stabilized zoom system based on the first-order solution. The results show successful implementation of the four-group stabilized zoom system on the optical platform.

**JTu5A.24**
Design of Subwavelength Resolution 3D Diffractive Optics, Oleg V Minin, Igor V Minin, 
1Siberian State Academy of Geodesy, Russia; 2Institute of Applied Mathematics and Experimental Verification of innovative radiating structures as concave FZP lens are discussed. The curvilinear 3D diffractive concave optic allow to overcome 3D Abbe barrier with focal distance more than 2 of wavelength.

**JTu5A.25**
Multi-order Retarders and the Mystery of Retardance Discontinuities, Garam Young, 
1Russel A. Chipman, 2Optical Solutions Group, Synopsis, Inc., USA; 3College of Optical Sciences, Univ. of Arizona, USA. Multi-element high-order retarders’ retardance discontinuities must be introduced. A retardance unwrapping algorithm is developed.
Yanyan

Scan Patterns Measurement of a Risley-prism System, JTu5A.30

Photovoltaic generation when the liquid is pumped out. If index matching liquid is filled in and becomes a concentrator for structure has been proposed as a pure window for nature lighting.

Guo1; Enguo Chen1-

Beam refracted by Risley-prism is derived. A scan patterns measurement with uniformity greater than 0.8 and optical efficiency above 90%.

Lin Sheng-

Based on prescribed candela distribution is presented. By using this method, an LED lens of arbitrary beam angle can be obtained with uniformity greater than 0.8 and optical efficiency above 90%.

Te-Shu Liu1, Kuang-Lung Huang 2;

Freeform LED Lens Design for Uniform Illumination with Prescribed Candela Distribution, Jia-Ju Chen 1, Ze-Yu Huang, Te-Shu Liu, Kuang-Lung Huang 2, National Changhua Univ of Education, Taiwan; 3Mingdao Univ, Taiwan. A lens design method based on prescribed candela distribution is presented. By using this method, an LED lens of arbitrary beam angle can be obtained with uniformity greater than 0.8 and optical efficiency above 90%.

JTu5A.29

Switchable sky window with spiral Fresnel structure, Lin Sheng-Rong 1, Department of Power Mechanical Engineering, National Tsing Hua Univ., Taiwan. A Fresnel lens with equal height spiral structure has been proposed as a pure window for nature lighting if index matching liquid is filled in and becomes a concentrator for photosynthetic generation when the liquid is pumped out.

JTu5A.30

Scan Patterns Measurement of a Risley-prism System, Yanyan Zhao 1, Beihang Univ, China. An exact scan footprint formula of beam refracted by Risley-prism is derived. A scan patterns measurement method is proposed and apparatus is set up to measure the footprint. The simulation and measurement results is compared.

JTu5A.31

Design and demonstration of an integrated light-guide plate for LED backlights, Enqiu Chen 1, Zhixian Lin 1, Jinting Lin 1, Tailang Guo 2, Fuzhou Univ, China. This paper reports an integrated light-guide plate with periodically diamond-shaped and single-sized microstructures. Laser printing process is introduced for fabrication. Results show that thin structure and high performance are both available for LED backlights.

JTu5A.32

High Efficient Y-branch Coupler for Plastic Optical Fiber Lightguide, Kuang-Lung Huang 2, Te-Shu Liu 1, Jes Ding 1, Jia-Ju Chen 1, Department of Electro-Optical and Energy Engineering, Mingdao Univ, Taiwan; 2Department of Electrical Engineering, National Changhua Univ of Education, Taiwan. A duplex Y-branch coupler for plastic optical fibers is studied in this paper. Two high efficient structures with different spirals are constructed, and achieve coupling efficiency both in forward and reverse directions greater than 93%.

JTu5A.33

Stress-Induced Index Gradients in Optical Design, Anthony Viscimi 1, Thomas G. Brown 1, The Inst. of Optics, USA. Analytic theories of stress-engineered optical elements are applied to the more general problem of index gradients induced by n-fold symmetric peripheral forces. Their impact on optical systems can be modeled using commercial lens design software.

JTu5A.34

Lamp Spectrum Modification by the Use of Lens Aberration, Mitsuuori Saito 1, Hiroto Umemi 1, Byokulu Univ, Japan. A cylindrical lens system with chromatic aberration focused ultraviolet and infrared rays at a point where visible rays are defocused. A uniform spectral intensity was attained by collecting a xenon lamp emission at this point.

JTu5A.35

Compact tunable optics for dynamic lighting, Xueling Li 1, Jia Wei 1, Jing Ma 1, Cadmus Yuan 1, Lin Sarro 1, Koulu Zhang 1, DIMES, TU Delft, Netherlands; 2State Key Lab of Solid State Lighting, China. We demonstrated a tunable optics system for dynamic lighting applications. Driven by a flexible actuator, the tunable optics can achieve light distribution change by tuning the applied voltage, without losing the efficiency.

JTu5A.36

Study of Coupling Performance of Multimode Optical Fiber Coupler Using Integrated Elliptical Point Contacts and CMT, Latifah S. Supian 1, 2, Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Malaysia; 2, Malaysia. Coupling characteristics of a directional coupler using lapping technique is analyzed through Hertz elliptical point contacts and its relation with simplified coupled mode theory (CMT) of the multimode fiber coupler when core size is varied.

JTu5A.37

A Study of Performance Measurement of Digital Imaging System, Szu-Yuan Tseng 1, Yi-Chin Fang 1, National Kaohsiung First Univ of Science and Technology, Inst. of Electrical engineering, Taiwan; 2National Kaohsiung First Univ. of Science and Technology, Inst. of Electrical Engineering, Taiwan. This study propose a method for evaluation of digital imaging system, using the three sections of camera: DMTF of camera lens, transfer function of CCD/CMOS (MTF of CCD), and ratio of signal to noise.

JTu5A.38

A Study of Optical Design of Non-invasive Ophthalmoscopy for Rapid Diagnostic Purposes, Chin-Hsien Chu 1, Yi-Chin Fang 1, Nai-Wei Hsueh 1, National Kaohsiung First Univ. of Science and Technology, Inst. of Optics, China. This research is proposed to go proceeding rapid diagnostic of eyes via a 3D ophthalmoscopy with visible and near infrared spectrum. Optical design of this 3D ophthalmoscopy is demonstrated in this experiment.

JTu5A.39

A Study of Modulation Transfer Function of Digital Image System Via Microscanning Technique, Ho-Lin Tsai 1, Yi-Chin Fang 1, SZU-YUAN TSENG 1, National Kaohsiung First Univ of Science and Technology, Inst. of Electrical Engineering, Taiwan; 2National Applied Research Laboratories, Instrument Technology Research Center, Taiwan. A National Kaohsiung First Univ. of Science and Technology, Inst. of Electrical Engineering, Taiwan. This research investigates the MTF of Telecentric Non-Telecentric Lens via the Microscanning technique and proposes a method to measure the MTF (Modulation Transfer Function) of digital systems that might eliminate the aliasing due to insufficient sampling.
Algorithms and examples for chromatic aberrations correction and athermalization of complex imaging systems, Dmitry Rednikov1, Jose M. Sasan2; 1Optical Sciences, Univ. of Arizona, USA. Ray tracing methods for correcting chromatic aberration of imaging system are described. Monochromatic and chromatic aberration correction is separated into two independent problems. Similar algorithm is applied to athermalize an optical system.

Use of very low departure aspheric surfaces in high quality camera lenses, Kristy Dalziel1, Reginald P. Jonas1, Michael D. Thorpe1; 1Elican Optical Technologies, Canada. Aspheric surfaces offer great benefits in aberration correction but there are departure related issues in their use for high performance lenses. We present design considerations and examples for cine designs using very low departure aspheres.

Obtaining Different Lens System Shapes by using Saddle-Point Construction, Pascal van Grieken1, Martin van Turnhout2; 1Florian Bocort1, 2Optics Research Group, Delft Univ. of Technology, Netherlands; 3TNO, Netherlands. In this paper, we show the potential of Saddle-Point Construction in the global coverage of design shapes. This will be illustrated by describing how all triplet lens system shapes can be obtained from a singlet.

GPU-accelerated ray tracing for optical simulation and design, Florian Mauch1, Marc Grönte1, Wolfgang Östen1; 1Institut für Technische Optik, Univ. Stuttgart, Germany. Using an open source tool based on rVidas OptX engine, the applicability of GPU-accelerated ray tracing to optical simulation is investigated for a variety of applications including coherent ray tracing and nonsequential stray light analysis.

Noise as a Design Constraint in Broadband Wavefront Systems, Kathleen Adelsberger1,2, Robert Boye1, James Zavislak1; 1Univ. of Rochester, USA; 2Sandia National Laboratories, USA. Simulated results demonstrate the impact of detector noise on the design of a broadband wavefront coded optical system. We conclude that noise must be included as a first-order design constraint in cubic phase-encoded systems.

Automatic Design of Multi-Lens Optical Systems Based on Stock Lenses for High Power Lasers, Martin Traub1, Dieter Hoffmann1, Stefan Hengesbach1; 2, Peter Losen1,1, 2Laser and Laser Optics, Fraunhofer Inst. for Laser Technology, Germany; 1Chair of Laser Technology, RWTH Aachen Univ., Germany; 2Chair of Optical Systems Technologies, RWTH Aachen Univ., Germany. Time and cost for manufacturing prototypes can be significantly decreased by using stock lenses. An #4 lens design based on our approach and a comparison to the Zemax stock lens matching tool are presented.

Optical design with stock lenses, Dewen Cheng1, Yongtian Wang1; 1Beijing Inst. of Technology, China. A tool is developed with the macro capability of CODE V for optical design with off-the-shelf catalog lenses. This tool can greatly reduce the fabrication costs for an optical system and shorten its development cycle.

Confocal and Telecentric, Paul K. Manhart1; 1NASA Langley Research Center, USA. Optical Imaging and relay systems are often designed around the simplistic principals of telecentricity and/or confocal layouts. This paper will discuss these two design principals and show some examples of how they are used in basic optical systems.
**Optical Fabrication and Testing**

**Grand Ballroom Salon III**

**International Optical Design**

10:30–12:30

**IW2A • GRIN**

Presider: Julie Bentley; Univ. of Rochester, USA

**IW2A.1 • 10:30**

Homogeneous and Gradient Index (GRIN) Materials For Multi-Band IR Optics, Daniel Gibson1, Shaym Bayya1, Jas Sanghera1; ‘Code 5623’ Optical Materials, US Naval Research Lab, USA. We report new materials for multi-spectral infrared (IR) optics including IR gradient index (IR-GRIN) materials with a delta-n of 0.1 and new homogeneous glasses. These new materials transmit SWIR-LWIR (0.9 µm – >12 µm) and fill gaps in the IR materials dispersion map.

**IW2A.2 • 10:45**

Axial and Lateral Color Correction in Zoom Lenses Utilizing Gradient-Index (GRIN) zoom lenses are shown to offer superior axial and lateral color correction in zoom lenses utilizing Williams Spherical Gradient-Index Lens, James A. Carusotti1, Greg R. Schmidt1, Duncan T. Moore1; ‘Univ. of Rochester, USA. Gradient-index (GRIN) zoom lenses are shown to offer superior imaging performance to homogeneous designs over the visible spectrum. For a given element count, capopolymer GRIN designs are better corrected for axial and lateral color than homogeneous aspheric designs.

**IW2A.3 • 11:00**

Optical Design Study in the 1-5μm Spectral Band with Gradient-Index (GRIN) Zoom Lenses, James A. Carusotti1, Greg R. Schmidt1, Duncan T. Moore1; ‘Univ. of Rochester, USA. A design study is conducted for an f/3.5, 15 degree full field of view, 38mm focal length broadband 1-5μm imager. Homogeneous triplet designs are compared with a gradient-index doublet design that yields comparable performance.

**IW2A.4 • 11:15**

Modeling Mid-Spatial Frequency Wavefront Error in Gradient-Index Materials, Peter McCarthy1, Rebecca Berman1, Daniel J. Williams1, Anthony Jesse1, Duncan T. Moore1; ‘Univ. of Rochester, USA. A design study is conducted for an f/3.5, 15 degree full field of view, 38mm focal length broadband 1-5μm imager. Homogeneous triplet designs are compared with a gradient-index doublet design that yields comparable performance.

**IW2A.5 • 11:30**

Near-diffraction-limited F/3.1 apochromat singlet lens design enabled by spherical gradient index, Richard A. Flynn1, Guy Beadie1; ‘US Naval Research Lab, USA. A refractive singlet lens design that is near-diffraction-limited across the F, d, C wavelengths, hence across most of the visible spectrum, is presented. The lens is a reasonably fast F/3.1. An offset spherical gradient index (GRIN) and careful choice of GRIN materials enables this performance.

**IW2A.6 • 11:45**

All-Plastic High-Performance Eyepiece Design Utilizing a Spherical Gradient-Index Lens, Anthony Visconti1, Kejia Fang2, Greg Schmidt1, Duncan T. Moore1; ‘Univ. of Rochester, USA. An all-plastic high-performance eyepiece design utilizing a polymer spherical-gradient-index optical element is presented. The gradient-index eyepiece offers better lateral color correction and overall performance improvement compared to a similar homogeneous eyepiece.

**IW2A.7 • 12:00**

Design of a First-order Radial GRIN Achromat, Joseph N. Mait1, Predrag Milanovic1; ‘Univ. of Rochester, USA. A design study is conducted for an f/3.5, 15 degree full field of view, 38mm focal length broadband 1-5μm imager. Homogeneous triplet designs are compared with a gradient-index doublet design that yields comparable performance.

**Plaza Ballroom III**

**Optical Fabrication and Testing**

10:30–12:30

**OW2B • Freeform Testing**

Presider: Sven Schröder; Fraunhofer IOF, Germany

**OW2B.1 • 10:30**

Slumping Process of the Horizontally Progressive Type of Automobile Side Mirror, Hochoel Lee1, GungLeel SungkooLee1, Jingu Kim1; ‘Mechanical Eng., Hankuk National Univ., Republic of Korea; ‘R&D Inst., Bulltone Co. Ltd, Republic of Korea. The horizontally progressive mirror has been suggested to reduce the blind spot in the automobiles by wide rear-view angle. And glass molding by slumping process and measurement technique are introduced to meet the curvature distribution.

**OW2B.2 • 11:00**

Adapting Interferometric Metrology to Freeform Surfaces, Kyle Funsbach1; ‘The Inst. of Optics, Univ. of Rochester, USA. Abstract not available.

**CW2C • Non-Optical Imaging and Sensing**

Presider: Eddie Jacobs; Univ. of Memphis, USA

**CW2C.1 • 10:30**

System Design for Joint Attenuation and Scatter Imaging for Baggage Inspection, Joseph A. O’Sullivan1, David G. Pollett1, David J. Brady1, Kenneth P. MacCabe1, Ikena Odinaka1, ‘Washington Univ. in St Louis, USA; ‘Electrical and Computer Engineering, Duke Univ., USA. Baggage inspection in security applications requires fast and accurate scanning systems. High performance of x-ray scatter imaging requires accurate knowledge of x-ray attenuation. We describe the design considerations for such systems that combine three-dimensional attenuation estimation with x-ray scatter imaging.
IW2A.8 • 12:15
Bi-AGRIN Sphero-Apochromats, Paul K. Manhart1; NASA Langley Research Center, USA. This paper discusses how the correct choice of glass families and the correct merit function can be used to correct axial color and sphero-chromatism and spherical aberration.

IW2A.8 • 12:15
Bi-AGRIN Sphero-Apochromats, Paul K. Manhart1; NASA Langley Research Center, USA. This paper discusses how the correct choice of glass families and the correct merit function can be used to correct axial color and sphero-chromatism and spherical aberration.

CW2C.5 • 12:15
Improved phase retrieval for X-ray differential phase-contrast radiography, Masih Nilchian1, Zhentian Wang1, Thomas Thuring2, Michael Unser1, Marco Stampanoni3,4; Ecole Polytechnique Federale de Lausanne, Switzerland; 2wiss light source, Paul Scherrer Inst., Switzerland; 3Inst. for biomedical engineering, ETH Univ., Switzerland. Phase retrieval for X-ray differential phase-contrast radiography is an essential problem for quantitative analysis in medical imaging. We propose a novel retrieval technique and show that it can provide valuable information to mammography screening.
Representing the power and astigmatism distribution of a PAL. Design of progressive addition lens is to obtain the desired focus and minimize aberrations, and to calculate the propagating astigmatic optical system to obtain the desired Gaussian beam.

A method is presented of using skew rays to optimize a generally astigmatic Gaussian beam. The encoding is achieved by decentering spherical lens elements, rather than introducing a phase mask.

Field Curvature Aberration: What is New? Jose M. Sassin; Univ. of Arizona, USA. This presentation provides an overview of field curvature aberration. Historical aspects and current correction techniques are discussed.

Extended depth of field in an intrinsically wavefront-encoded biometric iris camera, Matthew Bergkötter, Julie Bentley; The Inst. of Optics, Univ. of Rochester, USA. We describe a method for increasing the depth of field of a biometric iris recognition camera with a variation on wavefront encoding. The encoding is achieved by decentering spherical lens elements, rather than introducing a phase mask.

Development of the image restoration technique using the OTF of imaging systems, Takeshi Watanabe; Canon, Japan. Abstract: We present the image restoration technique combining both the optical technology and digital image processing. We show the image restoration technique for captured images influenced by lens aberration, diffraction, sampling process and many filters.

Generally Astigmatic Gaussian Beam Representation and Optimization Using Skew Rays, Paul D. Colbourne; UDSU, Canada. A method is presented of using skew rays to optimize a generally astigmatic optical system to obtain the desired Gaussian beam focus and minimize aberrations, and to calculate the propagating generally astigmatic Gaussian beam parameters at any point.

Observations on the formulation of paraxial and Gaussian optics, John E. Greenkamp; Univ. of Arizona, USA. A reformulation of the paraxial raytrace equation provides a better understanding of the key concepts of basic image formation. The paraxial refraction equation is shown to be a bridge between paraxial optics and Gaussian optics that defines the power of an optical system.

Design of progressive addition lens with newly developed curvature polynomials, Chunyu Zhao; Univ. of Arizona, USA. Design of progressive addition lens is to obtain the desired power distribution, and control the unwanted astigmatism. And newly developed curvature polynomials are ideal candidates for representing the power and astigmatism distribution of a PAL.

Producing Smooth Surfaces on Polycrystalline ZNS Aspherales and Freeforms, Matthew Brophy; Jessica D. Nelson, Thomas Hordin; Optimax Systems Inc., USA. Commercially available deterministic polishing methods commonly induce excessive surface roughness and optical scatter on polycrystalline aspheres and freeforms. A process developed at Optimax called VIBE smoothing reduces surface roughness, while maintaining the figure corrected form.

Freeform Optics Metrology Using Optical Coherence Tomography, Jianing Yao, Jannick P. Roland; Univ. of Rochester, USA. We investigate the capability of a custom Fourier-domain swept-source optical coherence tomography method for non-contact freeform optics metrology. First results demonstrate the feasibility of measurement of an Alvarez surface with 400 µm sag.

Fabricating and Testing Freeform Optics: Current Capabilities, Lessons Learned and Future Opportunities, Jessica D. Nelson, Kate Medicus, Matthew Brophy; Optimax Systems Inc., USA. Freeform optics designed with non-symmetric features are gaining popularity with lens designers and system integrators. This paper overviews a freeform optical fabrication process that includes VIBE polishing, figure correction and testing of freeform surfaces.

Dual-Coded Compressive Hyper-Spectral Imaging, Xing Lin, Gordon Wetzstein, Yebin Liu, Qiang Zhang; Department of Automation, Tsinghua Univ., China; 2Beijing Key Lab of Multi-dimension & Multi-scale Computational Photography (MMCP), Tsinghua Univ., China; Media Lab, Massachusetts Inst. of Technology, USA. We present a new snapshot approach to hyper-spectral (HS) imaging via dual optical coding and compressive reconstruction. We demonstrate various applications including programmable spatially-varying color filtering, multiplexed HS imaging, and high-resolution compressive HS imaging.

Advancements in Sub-aperture Stitching and Magnetorheological Finishing for Freeform Surfaces, Paul Dumas; QED Technologies Inc, USA. Magnetorheological finishing (MRF) and Subaperture stitching interferometry (SSI) are well suited to extend their benefits to high-precision freeform surfaces. Freeform capabilities and example results of both technologies will be discussed.

A new medical-diagnostic tool based on computational spectral imaging of the diffusion-reflection measurement, Doro Fixler; Faculty of Engineering, Bar-Ilan Univ., Israel. We present a novel, non-invasive and highly sensitive molecular detection method based on computational spectral imaging of the near infrared diffusion-reflection measurements while adding gold nanoparticles as contrast agents.

A Light Field Imaging Polarimeter Using a Division of Focal-Plane Device, Liping Su, Fan Yuan; Beihang Univ., China. The division of focal-plane DoFP polarimeter suffers registration error, while the multimodal light field polarimeter has alignment difficulties. We presented a light field imaging polarimeter with a DoFP array device to overcome the problems.

Spatial Light Modulator Based Spectral Polarization Imaging, Teung-Han Tsai, Xin Yuan, Lawrence Carin, David J. Brady; Duke Univ., USA. We describe a compressive snapshot spectral polarization imager that encodes spatial, spectral and polarization information by a liquid crystal on silicon modulator. The camera multiplexes the spatial distribution of four polarizations and three color channels.

Spatial Light Modulator Based Hyperspectral Imaging of Space Object, Qiang Zhang, Robert J. Plemmons; Biostatistics, Wake Forest School of Medicine, USA; Mathematics and Computer Science, Wake Forest Univ., USA. For space objects, because of wavelength-dependent atmospheric turbulence blurring, the coded-aperture snapshot spectral imager (CASSI) multiplexes blurred hyperspectral images in a single snapshot. An algorithm is proposed to solve for true hyperspectral images.

The Fourier Crosstalk Matrix in Tomographic Hyperspectral Imaging Systems, James F. Scholl, Daniel O’Connell, Keith Hagle; Hilka Photonics, USA; MKS Imaging Technology USA. The Fourier crosstalk matrix is used to study imaging spectrometers that operate on tomographic principles. An application is presented here for which the ‘missing cone’ of low spatial frequency information is revealed and quantitatively mapped.
Providing two TIR reflections. The reflector’s surface is designed as a grooved surface consisting of a central high-power LED module and a metal-free TIR reflector. We will present a design approach for a surgical light optical system for studying the retinal movement of jumping sp-

Telescopic Contact Lenses and the Fiber-Coupled Scale Model Eye, Joseph E. Ford1, Ashkan Anarpour1, Glenn Schuster1, Igor Stamenov1, Alex Grassman1, Jerry Legerton1, Arthur Zhang1, Scott Cookson1, William Meyer1, Gorety Alonso1, Joshua Cummings4, Isaac Skaw1, Gregoire Smail1, Eric Tremblay1; Electrical and Computer Engineering, Univ. of California San Diego; USA; 3Physics, Univ. of California San Diego; USA; 4Innoviga, USA; 5Paragon Vision Sciences, USA; 6Inst. of Microengineering, École polytechnique fédérale de Lausanne, Switzerland. Catadioptric telescopes that can switch between 1x and 3x magnification have been built into scleral contact lenses. We will describe lens design and fabrication, the first clinical test, and a scale-model eye used for Lab characterization.

An Achromatized Miniature Objective for Microendoscopy, Tzu-Chen Wu1,2, Arthur F. Gmitro1,2, Andrew R. Rouse2; 1College of Optical Sciences, Univ. of Arizona, USA; 2, Elizabeth Jakob3, Jannick P. Rolland1; École polytechnique fédérale de Lausanne, Switzerland. The lens is nearly diffraction-limited over a 486 - 1000 nm spectral range for in-vivo imaging.

Using the random ball test to calibrate slope dependent errors in optical profilometry, Yue Zhou1, John Trautman1, Chris J. Evans1, Angela D. Davies1; Physics and optical science, Univ. of North Carolina at Charlotte, USA. The high overlapping density stitching interferometry not only can measure the tested surface but also precisely calibrate the reference errors of the interferometer in a single phase stitching process. The simulation results prove the feasibility.

The Self-Calibration of High Overlapping Density Subaperture Stitching Interferometry, Po-Chih Lin1, Hung-Sheng Chang1, Chao-Wen Liang1, Yi-Chun Chen1; Department of Optics and Photonics, National Central Univ., Taiwan. The high overlapping density stitching interferometry not only can measure the tested surface but also precisely calibrate the reference errors of the interferometer in a single phase stitching process. The simulation results prove the feasibility.

A Design Approach for an Innovative LED Surgical Light, Stefan Hadath1, Nico Morgenbrod1; Specialty Lighting, OSRAM GmbH, Germany. We will present a design approach for a surgical light consisting of a central high-power LED module and a metal-free TIR reflector. The reflector’s surface is designed as a grooved surface providing two TIR reflections.

The high overlapping density stitching interferometry not only can measure the tested surface but also precisely calibrate the reference errors of the interferometer in a single phase stitching process. The simulation results prove the feasibility.

Absolute Testing of Flats Based on Translational Shears, Rotational Shears and Tilt Measurements, Axel Wiegmann1, Susanne Quabis2, Michael Schulz1, Clemens Elstner1, Manuel Stavridis1; Physikalisch-Technische Bundesanstalt, Germany. Two methods for absolute flatness metrology are presented. Both methods need specimen translations. One method requires at least three autocollimators for tilt measurements, one method requires only one autocollimator but an additional specimen rotation.

Measurement of high accurate mirror using nanoprofiler with self-calibratable rotary encoder, Kenya Okita1, Takuya Kojima1, Koji Usuki1, Kohei Okuda1, Yasuake Tokuda1, Motohiro Nakano2, Ryota Kudo3, Kazuya Yamamura1, Tsukasa Watanabe1, Katuyoshi Endo1; 1Department of Precision Science and Technology, OSAKA UNIV, Japan; 2Research Center for Ultra-precision Science and Technology, OSAKA UNIV, Japan; 3National Metrology Inst. of Japan, National Inst. of Advanced Industrial Science and Technology, Japan. Surface profiler using some stages requires high accurate encoder, and self-calibratable rotary encoder can detect angle error. Therefore the nanoprofiler has been developed with the encoder. The profile results have high repeatability of 0.17 nm.
### Optical Fabrication and Testing

#### ITh1A • 08:00

**XRF-Köhler Optical Design and System Optimization**
- Blake M. Coughenour
- Roger Angel
- Univ. of Arizona, USA
- We present multiple optical design embodiments of a data-based concentration photovoltaic system utilizing Köhler illumination. Spectral optimization, opto-mechanical tolerancing, prototype development, and on-sun field validation are presented showing good agreement with the illumination model.

#### ITh1A • 08:15

**Freeform Lens Design to Achieve 1000X Solar Concentration with a Parabolic Trough Reflector**
- Brian Wheelwright
- Univ. of Arizona, USA
- We study the performance of HBU vs. various parameters of conventional dual-axis tracking. Single-axis solar module tracking is supplemented by small-distance motion of optical elements, giving effective 2D tracking.

#### ITh1A • 08:30

**Tracking-Integrated Optics: Applications in Solar Concentration**
- Brian Wheelwright
- Univ. of Arizona, USA
- Tracking-integrated optical designs for solar concentration offer an alternative to conventional dual-axis tracking. Single-axis solar module tracking is supplemented by small-distance motion of optical elements, giving effective 2D tracking.

#### ITh1A • 08:45

**Hollow Backlight Parametric Study**
- Blake M. Coughenour
- College of Optical Sciences, Univ. of Arizona, USA
- We present multiple optical design embodiments of a data-based concentration photovoltaic system utilizing Köhler illumination. Spectral optimization, opto-mechanical tolerancing, prototype development, and on-sun field validation are presented showing good agreement with the illumination model.

#### ITh1A • 09:00

**Challenges for Reducing the Size of Laser Activated Remote Phosphor Light Engines for DLP Projection**
- Matthias Brümmern
- SP D DO, Oram GmbH, Germany
- Laser activated remote phosphor (LAP) is an upcoming technology for high luminance SSL light engines. This presentation outlines some of the challenges met reducing the engine’s size, so it can be retrofitted into DLP-projectors.

#### ITh1A • 09:15

**Optical Design for a LED Search Light**
- Henning Rehn
- ‘Specialty Lighting’, Oram GmbH, Germany
- We demonstrate a searchlight based on a high brightness LED source. On the basis of conservation laws, an optical design is developed that concentrates the light of the source into a small cone.

#### ITh1B • 08:00

**Advantages to Using Commercial Off-the-shelf Optics for Design and Manufacture of Military Products**
- Jeremy Govier
- ‘Edmund Optics’, USA
- A discussion of the advantages of off-the-shelf and modified off-the-shelf optics from proof of concept to production for military products, which will include some helpful tools and suggestions for successful applications.

#### ITh1B • 08:30

**Locating computer generated holograms in 3D using precision aligned SMIs**
- Laura E. Coyle
- ‘Sloan Laboratory’, USA
- We demonstrate micron-level alignment of SMR references to patterns written on computer generated holograms, allowing the use of a laser tracker for precision alignment of CGH metrology systems.

#### ITh1B • 08:45

**Plug & Play Aspherical Surfaces**
- Remi Bourgeois
- REOSC, France
- REOSC developed means allowing the measurement & manufacturing of high accuracy aspherical surfaces. Optical axis position uncertainty down to 5µm is demonstrated, allowing much easier optical systems alignment.

#### ITh1B • 09:00

**Abrasive Technologies: Current Research Activities and Directions - Highlights of the ASME 2014 Manufacturing Science and Engineering Conference (MSEC2014)**
- Brigid A. Mullany
- Univ. of Arizona, USA
- This year’s symposium had papers addressing fundamentals and process related aspects of fixed and loose abrasive processes. Review papers covered the topical areas of grinding tool sustainability and grinding of aerospace alloys.

#### ITh1B • 09:30

**Fiber Bundle Information Relay for Monocentric Lenses**
- Stefan Nolte
- ‘Pelican Imaging’, USA
- We demonstrate a searchlight based on a high brightness LED source. On the basis of conservation laws, an optical design is developed that concentrates the light of the source into a small cone.
Engineered Optical Films with Microstructures for Solid State Lighting Applications, Zhuo Wang1, Bruce Radl1; Osram Sylvania, USA. Optical films with microstructures can achieve the uniform illuminance on the target and the glare control with no registration to LEDs. A spacing ratio of 1.64 is obtained comparing to 1.28 with just LEDs.

2 Megapixel Computational Imaging System with 5 Hz Frame Rate, Brant M. Kaylor1, Eric M. Seger1, Stephen Crouch1, Randy R. Reibel1, Amit Ashok2; 1Bridger Photonics, Inc, USA; 2College of Optics, Univ. of Arizona, USA. The design of a computational imaging system with 2 megapixel resolution and 5 Hz frame rates is described. Optical, opto-mechanical and opto-electronic design considerations are presented and discussed.
Freeform Surfaces, Xin Zhang, Jianping Zhang, Lingjie Wang, Guangwei Shi, Key Lab of Optical System Adv. Manufacturing Technology, Changchun Inst. of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun, Jilin, China. Optical design of a sky-survey telescope is presented, which is 2m aperture, 28m focal length, 1.72 deg FOV. In order to achieve wide field-of-view and high performance, off-axis Cook-TMA with freeform surfaces is adopted.

Analytic Optical Design of Generally Non Axi-Symmetric Optical Systems, Tamer T. Elzahary, Ping Zhou, Chunyu Zhao, James H. Burge, Univ. of Arizona, Coll. of Opt. Sciences, USA. We show a design method for non-axi-symmetric optical imaging systems that uses analytic conditions to constrain aberrations that have low order field dependence, but are corrected to all orders in the pupil.

Uniform and Efficient Illumination with Saddle Lenses, Tasso R. Sales, RPC Photonics Inc, USA. We introduce the concept of saddle lenses for the generation of uniform illumination with high efficiency. The design principles and experimental verification of beam shapers incorporating saddle lenses are discussed and demonstrated.

Nodal Aberration Theory Applied to Freeform Surfaces, Kyle Fuerschbach, Janick P. Rolland, Kevin P. Rolland-Thompson, The Inst. of Optics, Univ. of Rochester, USA; Synopsys Inc., USA. Using Nodal Aberration Theory the aberration fields induced by a freeform surface in an optical system are explored and experimentally validated with the design and implementation of an aberration generating telescope.

Freeform Arrays, William J. Cassarly, Synopsys Inc, USA. This paper will investigate both the case of arrays of freeform elements and also faceted structures that are applied to a freeform surface. Results will be shown using Monte Carlo simulations.

10:30–12:30  
ITh2A • Freeform Optics I
Presider: Richard Pfisterer; Photon Engineering LLC, USA

9:30–10:00  
Free Form Surfaces in Imaging Optics, Alexander Epple, LT-TSD, Carl Zeiss SMT GmbH, Germany. Known for a long time in non-imaging optics, free form surfaces are progressively used in imaging optics. We will give an overview about several aspects from design, surface description and testing and state-of-the-art systems.

ITh2A.1 • 10:30  
Optical design of off-axis astronomical telescope based on freeform surfaces, Xin Zhang, Jianping Zhang, Lingjie Wang, Guangwei Shi, Key Lab of Optical System Adv. Manufacturing Technology, Changchun Inst. of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun, Jilin, China. Optical design of a sky-survey telescope is presented, which is 2m aperture, 28m focal length, 1.72 deg FOV. In order to achieve wide field-of-view and high performance, off-axis Cook-TMA with freeform surfaces is adopted.

ITh2A.2 • 11:00  
Analytic Optical Design of Generally Non Axi-Symmetric Optical Systems, Tamer T. Elzahary, Ping Zhou, Chunyu Zhao, James H. Burge, Univ. of Arizona, Coll. of Opt. Sciences, USA. We show a design method for non-axi-symmetric optical imaging systems that uses analytic conditions to constrain aberrations that have low order field dependence, but are corrected to all orders in the pupil.

ITh2A.4 • 11:30  
Uniform and Efficient Illumination with Saddle Lenses, Tasso R. Sales, RPC Photonics Inc, USA. We introduce the concept of saddle lenses for the generation of uniform illumination with high efficiency. The design principles and experimental verification of beam shapers incorporating saddle lenses are discussed and demonstrated.

ITh2A.5 • 11:45  
Nodal Aberration Theory Applied to Freeform Surfaces, Kyle Fuerschbach, Janick P. Rolland, Kevin P. Rolland-Thompson; The Inst. of Optics, Univ. of Rochester, USA; Synopsys Inc., USA. Using Nodal Aberration Theory the aberration fields induced by a freeform surface in an optical system are explored and experimentally validated with the design and implementation of an aberration generating telescope.

ITh2A.6 • 12:00  
Freeform Arrays, William J. Cassarly; Synopsys Inc, USA. This paper will investigate both the case of arrays of freeform elements and also faceted structures that are applied to a freeform surface. Results will be shown using Monte Carlo simulations.

10:30–12:30  
OTh2B • Large Optics
Presider: Brigid Mullany; Univ. of North Carolina at Charlotte, USA

OTh2B.1 • 10:30  
Current and Future Fabrication and Testing Challenges for European Space Optics, Dominic B. Doyle; European Space Agency, Netherlands. The European Space Agency (ESA) has a wide range of space optical systems planned for and under development over the forthcoming decade and beyond. The applications are wide and varied covering space science, astronomy, robotic exploration, Earth observation, optical telecommunication, navigation and human spaceflight. The ever increasing demand for higher performance at lower cost, drives very strongly the innovation of novel and more efficient optical designs and in turn puts increasing demands on fabrication and performance verification capabilities. This talk surveys the most demanding applications, provides some details on the technological challenges faced, solutions found and discusses the fabrication and verification metrology aspects needed to assure space flight performance is guaranteed before launch.

OTh2B.2 • 11:00  
Testing and alignment strategy for large field-of-view multi-mirror telescope, Donglin Xue, Lu Ming; Changchun Inst. of Optic, Fine Mech & Phy, China. Three Mirror Anastigmat (TMA) systems including both on-axis and off-axis configurations have been widely used in space applications. In some designs, to correct for high order aberrations and realize large FOV, freeform surfaces are used to provide more design freedoms. This trend brings challenges to optical manufacturing and testing community. Since testing is critical to make high accurate aspheres and freeform surfaces, the paper addressed Computer Generated Hologram (CGH) design and implement to measure large freeform mirrors. In particular, CGH assisted alignment procedure for TMA telescopes were discussed in detail.

OTh2B.3 • 11:30  
Advanced Technology Solar Telescope 4.2 m Off-axis Primary Mirror Fabrication, Dae Wook Kim, Chang Jin Oh, Peng Su; James H. Burge; College of Optical Sciences, Univ. of Arizona, USA. Advanced optical surfacing technologies are applied for the Advanced Technology Solar Telescope 4.2 m off-axis primary mirror fabrication. A newly developed Stressed Lap and IR deflectometry system are demonstrated for a highly deterministic manufacturing process.

OTh2B.4 • 12:00  
Development and Results for Stressed-lap Polishing of Large Telescope Mirrors, Steve West; Univ. of Arizona, USA. The Univ. of Arizona Mirror Lab polishing program relies on the stressed-lap tool. Its implementation is discussed for recent mirrors including the off-axis Giant Magellan Telescope and Large Synoptic Survey Telescope mirrors.

10:30–12:15  
OTh2C • PSF Engineering and Extended Depth of Field Imaging
Presider: Chrysanthi Preza; Univ. of Memphis, USA

OTh2C.1 • 10:30  
Angular Momentum, PSF Rotation, and 3D Source Localization: A Statistical Performance Analysis, Sudhakar Prasad, Rakesh Kumar, Jankanthi Narravula; Univ. of New Mexico, USA. We present a computational imaging approach for encoding the 3D location of a point source via a rotating PSF. We also discuss statistical upper bounds on the precision of 3D sub-diffactive source localization, based on Bayesian error analysis.

OTh2C.2 • 11:00  
Effect of third order aberrations on the performance of cubic and quartic phase masks for waveform coding, Martin Lavière-Bastien, Simon Thibault; Université Laval, Canada. We compare the performance of phase masks in the presence of third order aberrations. The cubic phase mask shows better performance for astigmatism while the quartic phase mask is more robust to coma.

OTh2C.3 • 11:15  
Bandwidth Tunable Wave-front Coded Imaging System, Hui Zhao, Jingquan Wei; Univ. of Optics and Precision Mechanics, Chinese Academy of Sciences, China; School of Computer Science and Technology, Xidian Univ., China. An improved version of Jorge Cidra-Castaneda’s tunable phase mask [1] is proposed. By moving the two cosinusoidal phase components in an asymmetric way, both the sensitiveness to defocus and the effective bandwidth become tunable.

OTh2C.4 • 11:30  
Extended depth-of-field in superresolved image reconstruction on a compound-eye camera, Tomoya Nakamura, Ryoichi Horisaki, Jun Tanida; Osaka Univ., Japan. We present a technique to acquire an all-in-focus superresolved image using a compound-eye camera without depth estimation. The depth-of-field in image reconstruction is extended by computational emulation of phase modulation imaging.

OTh2C.5 • 11:45  
Passive 3D Imaging in a Single Snapshot with an Extended Depth of Field, Paul Zammitt, Andrew R. Hanvey, Guillem Carles; School of Physics and Astronomy, Univ. Of Glasgow, UK. We propose a new, simple and low-cost technique capable of acquiring extended depth-of-field 3D images in a snapshot based on hybrid imaging. The artifact problem which used to plague such hybrid systems has now been solved.

OTh2C.6 • 12:00  
Multi-Focus Imaging using Optical Phase Mask, Harel Haim, Alex Bronstein; Hebrew University, Israel. We present a technique to acquire an all-in-focus superresolved image using a compound-eye camera without depth estimation. The depth-of-field in image reconstruction is extended by computational emulation of phase modulation imaging.

12:30–14:00  
Lunch Break (On Your Own)
16:30–18:00
ITH4A • Freeform Optics III
*Presider: William Cassarly,* Synopsys, Inc, USA

**ITH4A.1 • 16:30**
The Pamplemousses: The Optical Design, Fabrication, and Assembly of a 3-mirror Freeform Imaging Telescope, Jannick P. Rolland1, Univ. of Rochester, USA. Since the last IODC meeting, the field of optical design with freeform surfaces has burst onto the scene. This talk will present one of the first operational freeform imaging telescopes.

**ITH4A.2 • 17:00**
Solving the wall wash problem with a single lens, Dave Aikens1, Mark Lahner2; 1Savvy Optics Corp., USA; 2Electrix, USA. This paper presents a novel approach to finding a solution to the wall wash problem based on HBLEDs and a single, transmissive optical element to optimize illumination using a segmented conventional optics approach.

**ITH4A.3 • 17:15**
Design of light field head-mounted display, Weitao Song1,2, Yongtian Wang1,2, Dewen Cheng1,2, Yue Liu1,2; 1Beijing Engineering Research Center of Mixed Reality and Advanced Display, China; 2School of Optoelectronics, Beijing Institute of Technology, China. A light field head-mounted display using a micro structure array is proposed to realize true three dimensional display. The method is capable of generating a dense light field to obtain a corrected perception of depth.

**ITH4A.4 • 17:30**
Intensity and phase profiles control of laser beam with the Monge-Ampère equation method, Yaqin Zhang1; 1Zhejiang Univ., China. Intensity and phase profiles control of laser beam is a classical and challenging problem of laser beam shaping. In this paper, two freeform surfaces are employed to solve this problem with the Monge-Ampère equation method.

**ITH4A.5 • 17:45**
The Monge-Ampère equation method in freeform optics design, Rengmao Wu1, Pablo Benítez1, Juan C. Miñano1; 1Universidad Politécnica de Madrid, Spain. The Monge-Ampère equation method could be the most advanced point source algorithm of freeform optics design. This paper introduces this method, and outlines two key issues that should be tackled to improve this method.

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NOTES
### Key to Authors and Presiders

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