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# PROCEEDINGS OF SPIE

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**Peter P. Clark**  
**Julius A. Muschaweck**  
**Richard N. Pfisterer**  
**John R. Rogers**  
*Editors*

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*Lens Design Problem Committee*

**Richard C. Juergens**, Raytheon Missile Systems (United States)  
**David Shafer**, David Shafer Optical Design (United States)  
**Paul K. Manhart**, IMAGE-N (United States)  
**Thomas Nobis**, Carl Zeiss AG (Germany)

*Illumination Design Problem Committee*

**William J. Cassarly**, Synopsys, Inc. (United States)  
**Henning Rehn**, OSRAM GmbH (Germany)  
**Alois M. Herkommer**, Universität Stuttgart (Germany)

*Session Chairs*

Joint Plenary Session

**Jessica Degroote Nelson**, Optimax Systems, Inc. (United States)

Design Theory I

**Julie L. Bentley**, University of Rochester (United States)

Design Theory II

**Richard C. Juergens**, Raytheon Missile Systems (United States)

Standards

**Scott A. Lerner**, Carl Zeiss AG (United States)

Tolerancing

**Michael J. Hayford**, Synopsys, Inc. (United States)

Freeform Theory I

**Pablo Benítez**, Universidad Politécnica de Madrid (Spain)

Freeform Designs I

**Stephen D. Fantone**, Optikos Corporation (United States)

Freeform Designs II

**Bryan D. Stone**, Synopsys, Inc. (United States)

Design Methods

**Akira Yabe**, Akira Yabe Lens Design (Japan)

Freeform Theory II

**Fabian Duerr**, Vrije Universiteit Brussel (Belgium)

Design for Visual Systems

**David Shafer**, David Shafer Optical Design (United States)

Freeform Designs III

**James McGuire Jr.**, Jet Propulsion Laboratory (United States)

Design Examples I (Plastic/Diffractive)

**Michael Missig**, Bausch and Lomb, Inc. (United States)

Freeform Designs IV

**William J. Cassarly**, Synopsys, Inc. (United States)

Design Examples II (Microscopy)

**John E. Greivenkamp**, College of Optical Sciences, The University of Arizona (United States)

Illumination

**R. John Koshel**, College of Optical Sciences, The University of Arizona (United States)

Design for Space and Astronomy

**Joseph M. Howard**, NASA Goddard Space Flight Center (United States)

Design for Photography

**Michael P. Chrisp**, MIT Lincoln Laboratory (United States)

Design for Manufacturing and Tolerancing  
**Paul F. Michaloski**, Corning Tropel Corporation (United States)

Design for Computational Imaging  
**Andrew Rakich**, GMTO Corporation (United States)





## Introduction

In what is now a 40+ year tradition that includes conferences held in Rochester (1966), Haverford College (1975), Mills College (1980), Cherry Hill (1985), Monterey (1990), Rochester (1994), Kona (1998), Tucson (2002), Vancouver (2006), Jackson Hole (2010), Kona (2014), optical designers from around the world converged on Denver, Colorado for the International Optical Design Conference 2017 (IODC 2017). Held 9-13 July 2017 at the Denver Marriott City Center, 495 attendees gathered to share their mutual interests and passion for optical design, fabrication and testing.

As has become custom, the IODC was co-located with Optical Fabrication and Testing (OF&T). With the rapid development and interest in freeform optical elements, the OSA Freeform conference was also co-located with the IODC.

The conference was replete with special events, talks, and opportunities.

On Sunday night the OSA Foundation and Jannick Rolland sponsored a special celebration in honor of Kevin Thompson (co-chair IODC 1998) to kick off the Kevin P. Thompson Optical Design Innovator Award. Kevin was a driving force behind the IODC for many years and so it was entirely fitting that the first event of the IODC 2017 was held in his honor.

On Monday night, the Congress Barbeque was held in the courtyard outside the Marriott.

On Tuesday night, the poster session was held in the exhibit hall. Twenty-five posters were presented.

The joint plenary session for all three conferences featured three speakers: Dr. Joshua Smith from Cal State Fullerton spoke on the optical challenges of detecting gravity waves in his talk, "Using optics and precision metrology to measure black hole mergers from across the universe with LIGO"; Dr. Patrick McCarthy from Giant Magellan Telescope (GMT) spoke on the development of the largest optical telescope ever constructed in his talk, "Giant Magellan Telescope, optics and science"; Dr. Jannick Rolland from the University of Rochester discussed the exciting opportunities offered by freeform optical surfaces in her talk, "Freeform optics from design to manufacture and its envisioned impact on technology to enable the science of tomorrow."

Over four days, 19 sessions were held where over 100 papers were given. Given the large number of submissions on the topic of freeform optics and the desire to disseminate as much of this emerging technology as possible, parallel sessions were scheduled on Tuesday and Wednesday.

Lens designers and illumination system designers from around the world (with the exception of Antarctica) enthusiastically participated in the Lens Design Problem and Illumination Design Problem. Both problems embraced a theme that celebrated the 100th anniversary of OSA. The results were presented to a standing room only crowd on Wednesday evening. Hosted by Rick Juergens, the Centennial Lens Design winner was Takeshi Akiyama of Cybernet Systems Company whose solution employed 54 lenses, was over 19 km long, but whose focal length was only 0.02 mm! Hosted by Bill Cassarly, the Centennial Illuminator winner was Steve Mulder of Synopsys whose dual half ellipsoid system beat out four other contestants for delivering the highest flux in the target area.

At the beginning of the Design Problem event, we paid tribute to our colleagues and fellow lens designers/software developers who had passed away since IODC 2014: Darryl Gustafson, Leo Gardner (co-chair IODC 1998), and Doug Sinclair.

Synopsys created the Robert S. Hillbert Memorial Student Travel Grant in 2009; at this IODC grants were awarded to Rebecca Berman and Yang Zhao, both of the University of Rochester, and Niamh Fitzgerald of the University of Ireland Galway. The Michael Kidger Memorial Scholarship was awarded to Jonathan Papa, a Ph.D. student at the University of Rochester.

Exhibitors included Airy Optics (USA), American Elements (USA), Edmund Optics (USA), European Patent Office (Germany), Lambda Research Corporation (USA), MLD Technologies (USA), Nikon Precision (USA), Optikos Corporation (USA), Optimax Systems (USA), PHASICS Corporation (USA), Photon Engineering (USA), Spectrum Scientific (USA), Synopsys (USA) and Universal Photonics (USA).

It has been an honor and privilege to serve as chairs for the IODC 2017. However the success of IODC is the result of the combined efforts of so many people and organizations that it is impossible to give credit to everyone. Special thanks go to the members of the program committee and their respective companies and institutions for their support of the IODC. We thank the IODC's corporate sponsors Photon Engineering, Synopsys, Optimax Systems, American Elements, Lawrence Livermore National Laboratory, and Spectrum Scientific for their generous financial support. We'd like to acknowledge the efforts of Groot Gregory for again managing the IODC website [www.iodc.info](http://www.iodc.info) for us as a conduit of information specific to the conference. Finally, we are especially grateful to OSA and SPIE for supporting this (and previous) IODCs with their organizational and management skills, and help in preparing this proceedings volume.

Ultimately the success of any conference depends upon participation of the attendees, and so we thank everyone who took time out of busy lives to be part of the IODC 2017. Your experiences and insights, presentations, side discussions, and networking contributed to the richness of the IODC 2017. We look forward to sharing future International Optical Design Conferences with you. As of this writing, the date and location of the next IODC have not been established and so we

suggest that you visit the IODC website [www.iodc.info](http://www.iodc.info) for updated information about the next IODC.

**Peter P. Clark**  
**Julius A. Muschaweck**  
**Richard N. Pfisterer**  
**John R. Rogers**



In Memoriam, a tribute to

**Leo R. Gardner**  
1960–2016



Leo Gardner was an active member of the optical design community. He and Kevin Thompson co-chaired IODC 1998 in Kona, HI.

After earning his PhD in Optics at Rochester, Leo designed lenses at SSG, and then founded Optical Data Solutions. ODS's LensVIEW was a database product that facilitated patent searches for lens designers.

In 2000, Leo joined Lambda Research, traveling around the world educating engineers on optical design and analysis software. In 2008, he moved to BAE Systems, and four years later transferred to Honolulu as BAE's Principal Optical Engineer for their Hawaii operations.

Leo went through life with an upbeat attitude and a smile. His optimism served him well when he taught lens design to students and professionals, many of which did not know an aberration from an index of refraction. Leo also enjoyed sharing his love of optics and engineering with high school students in outreach events in New England.

Leo was creative as demonstrated in the creation of LensView with his business partner Brian Caldwell. LensView combined patent information with innovative search terms and corrected design examples helping designers find starting points for new lens solutions. Moving to Hawaii inspired a new side to his creative nature as a painter and sculptor.

Leo was active in OSA and the New England Optical Society.



In Memoriam, a tribute to

**Darryl E. Gustafson**  
1935–2017



Darryl Gustafson passed away on April 28, 2017. He was an engineer and entrepreneur who had a major influence in the success of Optical Research Associates (ORA) and the development of CODE V as a commercial product.

Darryl received his B.S. degree in mechanical engineering at Northwestern University and was initially exposed to optical design as a co-op student at Bell and Howell. Darryl started his professional career at Bell and Howell, where he designed lenses for 8- and 16-mm Cine cameras and projectors. He also assisted Tom Harris with the development of optical design software.

In 1965 Darryl joined Tom as a partner at ORA where he was involved in the design of countless lenses (e.g., Cinematography, Military, and Space) as well as in the development of the then-fledgling program CODE V. He was an advocate of making CODE V available as a commercial product, first as a turnkey hardware-software system in 1975, later through Cybernet in the early 1980s, and finally on Sun and Windows workstations. The latter part of his career at ORA was spent in software marketing and customer service activities, and ultimately business development until his retirement in 1998.

Darryl was well known within the optical design community and was a frequent contributor to the ILDC (now IO DC) Lens Design Problem.





In Memoriam, a tribute to

**Douglas C. Sinclair**  
1938–2015



Doug Sinclair passed away on Oct 10, 2015 at age 77. He had a long and influential career in the field of optics. In particular, he pioneered the development of optical design tools on early programmable calculators and PCs.

He received his PhD from The Institute of Optics in the early 1960s, studying HeNe gas lasers and working at Spectra-Physics. He was awarded the OSA Adolf Lomb medal in 1968 for this work and coauthored the book, *Gas Laser Technology*, with W. Earl Bell in 1969.

In 1970, he returned to the Institute as a professor and shifted research to geometrical optics and optical design. He was a pioneer in the use of programmable calculators for optical design calculations. In 1976 he founded Sinclair Optics and began development of his optical design software OSLO, first on increasingly powerful H-P desk calculators and then on IBM PCs. OSLO became one of the most widely used optical design software packages and is used to this day.

Doug contributed to the optical community not only as an educator, but also as the editor of both *Optical Engineering* in 1972 and *JOSA* in 1976–78. He was also chairman of the U.S. delegation to the ICO Congress in Spain in 1978.

*We have chosen Doug's image of his solution for 1985 IODC Lens Design Problem to be the cover graphic of this Proceedings volume.*

