R. JOHN KOSHEL

Wyant College of Optical Sciences
The University of Arizona
1630 East University Boulevard
Tucson, Arizona 85721-0094
jkoshel@optics.arizona.edu
www.optics.arizona.edu and wp.optics.arizona.edu/jkoshel/

Office: (520)-621-6357 Fax: (520)-626-1480 Cell: (520)-591-9526

RESEARCH AND EDUCATION INTERESTS

Optical System Engineering: Illumination, Solar Energy, System Design, Optimization, Tolerancing, Manufacturing, and Testing, Radiometry, Computer Visualization
Lasers: Coherence, Propagation, Spatial-Mode-Tunability, Optical Pumping.
Teaching and Mentoring Undergraduate and Graduate Students in Optical Sciences and Engineering.

EDUCATION

Ph.D. Optics, University of Rochester, Rochester, New York; September 1996.
Thesis: "Optimal Design of Optically Pumped Lasers," supervisor: Ian A. Walmsley.
B.S. Optics, University of Rochester, Rochester, New York; May, 1988.

EXPERIENCE

February 1999 to present: Associate Dean, Undergraduate Affairs and Professor (starting January 2014), Adjunct Professor (starting May 1999), College of Optical Sciences, The University of Arizona, Tucson, AZ.

Oversight of the academic program at the College of Optical Sciences, including courses, graduate student admissions, outreach, teaching laboratories, and ABET.
Instructor for project-based graduate/undergraduate course on illumination engineering (OPTI 485/585).
Instructor for Radiometry, Sources, and Detectors (OPTI406/506; 2006, 2014-present), instructor for project-based course Illumination Engineering (2006, 2009-present), guest instructor for Advanced Optical Design (OPTI696A, 2007).
Guest Lecturer for graduate Lens Design (2005-present; graduate course) and Current Subjects in Optics (2005-2006, graduate course).
Short course instructor – Illumination Design (4 DVDs): basics, sources, lightpipes and reflectors, and displays (2007).
Faculty advisor for senior design project: inline illuminator (2006-2007).
Project sponsor for senior design project: scatterometer (2005-2006).
Research projects in the field of illumination: novel display methods, sparse aperture telescope.
Organizer and presenter for the Illumination Optics Seminar Series. Lectures on concentrator and lightpipe design, source modeling, use of software for optical design, and coherent system modeling via software.

Interacting with students from the Optical Sciences Center, including research projects in optimal lightpipe design, comparison of lightpipe structures to experimental results, illuminator design for endoscope, freeform illumination optics, stray light within laser sensor, and novel contrast measurement for transflective displays.
Mentored a group of 6 college students on the optics aspects of the UA CubeSat project.

February 2008 to January 2014: Vice President of Consulting (starting 2009), Principal Illumination Engineer, Photon Engineering, LLC, Tucson, AZ.

Managed over $1M per year in optical design and analysis consulting, managed on average 18 projects concurrently, oversight of 4 optical engineers,
Illumination projects including two solar energy concentration projects, novel analyses illumination codes with GUIs, aviation warning lights, and solid-state applications in lighting, displays, dental systems, and consumer appliances.
Software algorithms and research within the field of illumination, including fractional optimization, lit appearance, automated object building, and LED modeling.
Programmer: added features and fixed bugs to FRED optical analysis program (C++).

December 2004 to January 2008: Senior Staff Engineer, Lambda Research Corp., Tucson, AZ.

Software algorithms and research within the field of illumination, including optimization, tolerancing, source modeling, solar concentrators, textured displays, CAD integration into ray-trace software, and ray-tracing techniques.
Quality control of TracePro and OSLO software and documentation.
Proposals and oversight of illumination projects including calibration source for space-bound telescope, machine vision and dental lightpipes, solar concentrator for energy generation, and SSL wall wash.
Oversight of transportation-based illumination optics.

June 2003 to December 2004: Senior Optical Systems Engineer, Spectrum Astro / General Dynamics Space Systems, Tucson, AZ.

Modeling LADAR systems, sensors, lasers, and lens designs for space-borne applications.
Developed a LADAR software tool to ease and automate the design process of laser radar systems
Development of a sub-photon LADAR algorithm.
Development and simulation of a control sensor algorithm for a space-borne boost-phase experiment.
Stray light analysis of space-borne optical systems to ensure maximum performance while improving signal-to-noise ratio.
Lead optical engineer on a hypertemporal, hyperspectral, polarization-imaging sensor.
Lead optics proposal writer and engineer for a $480M satellite mapping system awarded October 2004 (telescope was a $20M part of the proposal).
Design of control system algorithm between primary and secondary of a space-borne telescope.

January 1999 to June 2003: Manager Optical Engineering Services (starting March 2001), Breault Research Organization, Inc., Tucson, AZ.

Managing projects, contracts, proposals, and personnel at BRO; while establishing relationships with the optics community. Handled over $3M in new design business since starting as Manager.

Overseeing seven-plus optical engineers and many long-term optical design project, increasing the number of projects and billable rate during my tenure.
Technical Director for illumination projects at BRO.
Technical Advisor for *Optics Report*, a BRO newsletter to venture capitalists about new opportunities within optics. Topics include noninvasive glucometry, ARDs, and OLEDs.
Developing and teaching advanced tutorials in automotive and general illumination.
Designing and analyzing optical systems with ASAP and ReflectorCAD for customer projects, including lightpipes, luminaires, optical sensors, concentrators, stray light, and telecom.
Director of optical telecommunications task force, which includes managing, finding, and directing projects within the telecommunications field.

August 1997 to August 1998: Assistant Professor in the Department of Physics and Applied Optics. Rose-Hulman Institute of Technology, Terre Haute, Indiana.

Instructor for undergraduate classes: Introductory physics, introductory physics laboratories, modern physics, introductory optics, and project laboratories.
Instructor for graduate classes: Optical metrology, computer-aided optical system design, and nonimaging optics.
Supervisor for Master's thesis: Laser stability for surface quality metrology.
Supervisor for undergraduate research projects: automated focal length determination and Gaussian beam propagation through toric lenses.
Acquired funding: Acquisition of illumination design software for instruction and Gaussian beam propagation through laser printer lens assemblies.

March 1997 to August 1997: Postdoc supervised by Professor Kelvin Wagner, Optoelectronic Computing Systems Center, University of Colorado at Boulder, Boulder, Colorado.

Supervised the KAOS group during a sabbatical by Prof. Kelvin Wagner.
Assisted in the acquisition of an ultrashort pulse (20 fs) tunable laser system.
Optical computing research: single-pulse optical target recognition, nonlinear optical elements, spatio-temporal solitons for switching, holographic displays, and photon echoes.
Design of antireflection coatings for SBN and $BaTiO_3$ photorefractive crystals.

CONSULTING AND TEMPORARY POSITIONS

Technical advising and consulting:

Technical expert: number of intellectual property infringement cases (currently confidential) (2014-2018).
Dallas Police and Fire Pension System: light reflection study of Museum Tower onto Nasher Gallery (2012-2016).
GEOST: laser beam shaping methods and novel laser retroreflectors (2006-2008).
Ostendo Technologies: technical advisor for a tiled-display startup (2006-2008).
Illumintex: technical advisor for a SSL startup (2005-2007).

August 1998 to December 1998: Consultant for Coherent Technologies, Inc., Lafayette, CO.

Fabricating, testing, and improving the performance of a high-power, diode-pumped Nd:YAG slab laser at 1.32 μm to be used as the pump for an eye-safe Raman laser at 1.5 μm.
Developing Raman lasers with non-co-linear pumping.

Proposal funded for development of carbon-carbon composite submounts for heat removal from diode laser bars.
Designing, modeling, and mounting carbon-carbon composite submounts for diode laser bars.

May 1997 to October 1998: Consultant for UltraLaser, Boulder, Colorado.

Specified and modeled the pump configuration for a cavity-dumped Nd:YAlO laser.
Modeled the pulse dynamics for a cavity-dumped Nd:YAlO laser.
Fabricating and testing a cavity-dumped Nd:YAlO laser.

December 1996 to March 1997: Contractor supervised by Dr. Richard Jones, NIST 815.01, Boulder, Colorado.

Development of standard laser sources for measurement of laser beam quality.
Design and analysis of spatial-mode tunable lasers.

September 1996 to December 1996: Postdoctoral studies supervised by Prof. Ian A. Walmsley, The Institute of Optics, University of Rochester, Rochester, New York.

Experimental testing of LED-pumped Cr:LiSAF and Cr:LiSGAF solid-state lasers.
Development of novel pump cavity reflectors based on principles of nonimaging optics.

UNIVERSITY OF ARIZONA SERVICE

Faculty Advisor, Student Optics Chapter (SOCk), dual OSA and SPIE student chapter at the University of Arizona, 2014-present.
Undergraduate College Academic Administrators Council (U-CAAC), member, New Degree Program and Policy Review subcommittee chair (2021-present), Student Success and Retention subcommittee chair (2021-present), 2021-present.
College Academic Administrators Council (CAAC), member and chair (2019-2020), 2014-2020.
Internal ABET review committee chair for Wyant College of Optical Sciences, 2015 and 2022.
Research Initiatives Committee for the College of Engineering, 2019-present.
Curriculum Academic Committee for College of Engineering, 2018-present.
Undergraduate Curriculum Committee for Wyant College of Optical Sciences, 2014-present.
Assessment Committee for Wyant College of Optical Sciences, 2017-present.
Executive Committee for Wyant College of Optical Sciences, 2014-present.
Faculty Academic Steering Committee for Wyant College of Optical Sciences, 2014-present.
Graduate Curriculum Committee for Wyant College of Optical Sciences, 2014-2019.
Graduate Admissions Committee for Wyant College of Optical Sciences, 2014-2019.
Graduate Exams Committee for Wyant College of Optical Sciences, 2014-2019.

PROFESSIONAL SOCIETIES

Phi Beta Kappa: member since 1988
Optica (formerly OSA): lifetime member, senior member, student chapter president (1986-1988), member since 1985.
International Society for Optical Engineering (SPIE): lifetime member, senior member, member for 22+ years.
Illuminating Engineering Society (IES), member for 12+ years.

OPTICA PROFESSIONAL ACTIVITIES

Conferences:

Chair and presider, Program Committee, Freeform Optics, 2013-present.
Chair (2006), member, and presider, Executive Committee and Program Committee, International Optical Design Conference, Optica and SPIE sponsored conference, 2006-present.
Member, Solid-State and Organic Lighting, 2012-2016.
Member, Program Committee, Bio-Optics: Design and Application, 2011-2013.
Chair and presider, Optical Instrumentation for Energy and Environmental Applications, 2011.
Member and presider, Program Committee, Optics for Solar Energy, 2009-2012.
Member and presider, Program Committee, Frontiers in Optics, Optica Annual Meeting 2008-2016 (Chair for Fabrication, Design, and Instrumentation content 2008).
Member, Program Committee, Illumination Modeling: Simulation and Perception of Lit and Unlit Objects, 2007-2008.
Co-chair, Educator's Day, Frontiers in Optics, Tucson, AZ, 2005.
Co-chair, Software Algorithms for Illumination Design, Optica Annual Meeting/Frontiers in Optics, 2003.
Chair, Educator's Day, Optica Annual Meeting, Santa Clara, CA, 1999.
Presider, Forum on Education, Optica Annual Meeting, 1996-1997.
Member, Committee for Forum on Education, Optica Annual Meeting, Optica, 1995 & 1997.
Member, Committee for the Student Forum, Optica Annual Meeting, Optica, 1995 & 1997.

Editorial:

Deputy Editor, *Optics Express*, Optica, 2019-present.
Feature Editor, with B. Breault, Y.-C. Fang, C.-W. Liang, J. Sasian, and Y. Wang, Optical Design and Testing, *Appl. Opt.* **53** (2014).
Focus Issue Editor, with C. Seassal, O. Deparis, and R. S. Santosh Kumar, Renewable Energy and Environment 2014, *Opt. Exp.* **22** (2014).
Focus Issue Editor with C. Seassal, Renewable Energy and the Environment 2013, *Opt. Exp.* **21**, S3 (2013).
Associate Editor, *Energy and Environmental Express* periodic supplement in *Optics Express*, OSA, 2010-2016.
Editor, *SPIE Proc. of International Optical Design Conference 2006*, Vol. **6342** (2006).
Guest Editor, *Optics and Photonics News* special issue on illumination, published Aug. 2001, Optica.

Guest Editor, *Optics and Photonics News* special issue on education, published Sept. 1998, Optica.
Contributing Editor, *Optics and Photonics News*, Education (1994 – 2007), Professional Development (2001 – 2005), Optics in XXXX (2004 – 2007, 2009), and Light Touch columns (2002), Optica.

Leadership Activities:
Member, Women in Optics – University of Arizona Scholarship Committee, 2021.
Member, Fraunhofer Award Committee, 2014-2017.
Chair (2012-2013) and member, Board of Meetings, Optica, 2008 – 2014.
Member, Board of Directors, Optica, 2012-2013.
Member, Meetings Council, Optica, 2012-2013.
Chair, Leadership Award Committee, Optica, 2010 (membership stated 2009).
Chair, Fabrication, Design, and Instrumentation Division, Optica, 2008 – 2011.
Chair-Elect, Optical Design and Instrumentation Division, Optica, 2007 – 2008.
Traveling Speaker, Optica and SPIE, 2007-present.
Member, Information Technology committee, Optica, 2003 – 2005
Chair/Member, Esther Hoffman Beller Medal award, Optica, 2001 – 2003 (chair 2003).
OPN liaison, Publications Council, Optica, 1999.
Member & *OPN* liaison, Membership and Education Services Council, Optica, 1999 – 2006.
Panelist, Student Forum: Life after Graduation, Optica Annual Meeting, Santa Clara, CA, 1999.
Member, Student Subcommittee, Membership & Education Services Cncl., Optica, 1995-1997.
Member, Publicity Committee, Expanding your Horizons Conference, Cornell University, 1995.
Member, *Optics and Photonics News* Advisory Committee, Optica, 1994-2007.
Member, *ad hoc* Committee on Membership and Education Services Council, Optica, 1994.
Member, Toy Committee, Expanding your Horizons Conference, Cornell University, 1994.
Organizer and Presider, Student Forum, Optica Annual Meeting, Optica, 1993 – 1994, 1996.
Member, New Focus Travel Grant Awards Committee, Optica, 1992 – 1996, 1999.
Member, Education Council, Optica, 1992 – 1995.
President, OSA Rochester Student Chapter, University of Rochester, 1986 – 1988.

SPIE PROFESSIONAL ACTIVITIES

Conferences:
Chair (2006), member, and presider; Executive Committee, Program Committee, and Illumination Design Problem Committee, International Optical Design Conference, Optica and SPIE sponsored conference, 2006 – present.
Chair, Member, and Presider, Program Committee, Novel Optical Systems Design and Optimization, Optics and Photonics/SPIE Annual Meeting, 2000 – present (chair 2002 – 2005, 2007 – 2011).
Member and Presider, Program Committee, Illumination Optics, Optical System Design, SPIE, 2006 – present.
Chair, Member, and Presider, Nonimaging Optics and Efficient Illumination Systems, Optics and Photonics/SPIE Annual Meeting, 2004 meeting – 2022 (Chair 2003 – 2005, 2007 – 2010, 2022).
Chair, program committee, Freeform Optics, SPIE, 2014.

Track Chair, Optical Engineering and Applications, Optics and Photonics, 2010-2017.
Chair and Presider, SSL SPIE.TV Virtual conference, Solid-State Lighting – Systems, November, 2007.
Member and Presider, Program Committee, Laser Beam Shaping, Optics and Photonics/SPIE Annual Meeting, 2001 – 2007.
Member, Program Committee, Photovoltaics, SPIE Annual Meeting, 2004 – 2005.
Chair and Presider, Program Committee, Design of Efficient Illumination Systems, SPIE Annual Meeting, 2003.
Member and Presider, Program Committee, Source Modeling, SPIE Annual Meeting, 2002.

Editorial:
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization XIV*, Vol. 8129 (2011).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization XIII*, Vol. 7787 (2010).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization XII*, Vol. 7429 (2009).
Editorial Advisory Board, Illumination and Displays, *SPIE Newsroom*, 2005 – 2008.
Contributing Editor, Illumination and Displays, SPIE Newsroom, 2007-2008.
Editor, *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems V*, Vol. 7059 (2008).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization XI*, Vol. 7061 (2008).
Editor, *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems IV*, Vol. 6670 (2007).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization X*, Vol. 6668 (2007).
Editor, *SPIE Proc. of International Optical Design Conference 2006*, Vol. 6342 (2006).
Editor, *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems II*, Vol. 5942 (2005).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization VIII*, Vol. 5875 (2005).
Guest Editor, Special Section on Illumination Engineering, *Opt. Eng.*, published July 2004.
Editor, *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems I*, Vol. 5529 (2004).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization VII*, Vol. 5524 (2004).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization VI*, Vol. 5174 (2003).
Editor, *SPIE Proc. Of Design of Efficient Illumination Systems*, Vol. 5186 (2003).
Editor, *SPIE Proc. of Novel Optical Systems Design and Optimization V*, Vol. 4768 (2002).

Leadership:
Member, Kingslake Award, SPIE, 2006 – present.
Member, Audit Committee, SPIE, 2005 – present.
Member, Symposia Committee, SPIE, 2005-2006, member of North American subcommittee, SPIE, 2005 - 2006.
Member, Awards Committee, SPIE, 2004 – 2006,
Founder and Chair, SPIE Illumination Technical Group, 2004 – 2008, 2022.

IES PROFESSIONAL ACTIVITIES

Member, Computer Committee, oversight of software ANSI standards (2016 – present).
Member, ANSI/IESTM-25-20, *Ray File Format for Description of the Emission Properties of Light Sources* (2013 – 2016).

PUBLICATIONS (all)

Journal Papers:

L. Graves, H. Quach, R. Koshel, C. Oh, and D. Kim, "High contrast thermal deflectometry using long-wave infrared time modulated integrating cavity source," *Opt. Exp.* **27**, 28660-28678 (2019).

Ross D. Uthoff, Rachel N. Ulanch, Kaitlyn E. Williams, Liliana Ruiz Diaz, Page King, R. John Koshel, "Designing a freeform optic for oblique illumination", in International Optical Design Conference 2017, Richard N. Pfisterer; John R. Rogers; Julius A. Muschaweck; Peter P. Clark, Editors, Proceedings of SPIE Vol. **10590** (SPIE, Bellingham, WA 2017), 105900X.

Janos C. Keresztes, R. John Koshel, Karlien D'huys, Bart De Ketelaere, Jan Audenaert, Peter Goos, and Wouter Saeys, "Augmented design and analysis of computer experiments: a novel tolerance embedded global optimization approach applied to SWIR hyperspectral illumination design," *Opt. Exp.* **24**, 29380-29405 (2016).

Yi Chin Fang, Chao-Wen Liang, John Koshel, Jose Sasian, Toyohiko Yatagai, Yongtian Wang, and James M. Zavislan, "Optical design and testing: introduction," *Appl. Opt.* **54,** ODT1-ODT2 (2015).

Chao-Wen Liang, John Koshel, Jose Sasian, Robert Breault, Yongtian Wang, and Yi Chin Fang, "Optical design and testing: introduction," *Appl. Opt.* **53,** ODT1-ODT4 (2014).

R. J. Koshel, C. Seassal, O. Deparis, and R. S. Santosh Kumar, "Focus issue introduction: renewable energy and the environment," *Opt. Exp.* **22**, A561-A563 (2014).

C. Seassal and R. J. Koshel, "Focus issue introduction: renewable energy and the environment," *Opt. Exp.* **21**, S3, A430-A432 (2013).

J. J. Kim and R. J. Koshel, "Modeling transflective LCD illumination systems," Proceedings of SPIE Vol. **7652**, 76521G (2010).

B. Yang, Y Yang, Y. Liu, J. Sasian, and R. J. Koshel, "Efficient ray-tracing for free-form reflectors," *Optik* **120**, 40 (2007).

R. J. Koshel, "Optimization of parameterized lightpipes," published in *SPIE Proc. of the Intl. Opt. Des. Conf. 2006* **6342**, 63420P (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2006).

W. J. Smith, E. Betensky, D. Williamson, J. C. Miñano, and R. J. Koshel, "The past, present, and future of optical design," published in *SPIE Proc. of the Intl. Opt. Des. Conf. 2006* **6342**, 63422Y (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2006).

R. J. Koshel, "Simplex optimization method for illumination system design," *Opt. Lett*. **30**, 649 (2005).

R. J. Koshel and I. A. Walmsley, "Non-edge ray design: improved optical pumping of lasers," *Opt. Eng*. **43**, 1511 (2004).

R. J. Koshel, "Illumination engineering," *Opt. Eng*. **43**, 1478 (2004).

R. J. Koshel, "Enhancement of the downhill Simplex method of optimization," *SPIE Proc. of the Intl. Opt. Des. Conf. 2002* **4832**, 270 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2002).

A. Gupta, J. Lee, and R. J. Koshel, "Design of efficient lightpipes for illumination using an analytical approach," *Appl. Opt.* **40**, 3640 (2001).

R. J. Koshel and I. A. Walmsley, "Optimal Design of Optically Side-Pumped Lasers," *IEEE Jnl. of Quantum Electron.* **33**, 94 (1997).

R. J. Koshel, I. A. Walmsley, R. Utano, and D. Caffey, “Diode side pumping of a Nd:YAG laser rod with nonimaging optics,” *OSA Proceedings of the International Optical Design Conference* (Optical Society of America, Washington, D. C., 1994) p. 304.

R. J. Koshel and I. A. Walmsley, "Modeling of the gain distribution for diode pumping of a solid-state laser rod with nonimaging optics," *Appl. Opt.* **32**, 1517 (1993).

M. M. Hayhoe, M. E. Levin, and R. J. Koshel, "Subtractive processes in light adaptation," *Vis. Res.* **32**, 323 (1992).

C. G. Blough, *et. al.*, "Effects of axial and radial gradients on Cooke Triplets," *Appl. Opt.* **29**, 4008 (1990).

Books:

R. J. Koshel, editor, *Illumination Engineering: Design with Nonimaging Optics*, author of three chapters (IEEE-Wiley, New York, NY, 2013).

A. V. Arecchi, T. Messadi, and R. J. Koshel, *Field Guide to Illumination* (SPIE Press, Bellingham, WA, 2007).

Book Chapters:

A. Gupta and R. J. Koshel, “Lighting and Applications,” *Handbook of Optics* Volume II (McGraw-Hill, New York, NY, 2009).

Other Papers:

Justina Bonaventura, Thomas Knapp, R. J. Koshel, and Travis Sawyer "Smartphone spectroscopy for melanoma detection", published in *SPIE Proc. of the Optics and Biophotonics in Low-Resource Settings VIII* **11950**, 1195004 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2022).

Jacob Boyer, Janos C. Keresztes, Wouter Saeys, R. John Koshel, "An automated imaging BRDF polarimeter for fruit quality inspection", in Novel Optical Systems Design and Optimization XIX, Arthur J. Davis; Cornelius F. Hahlweg; Joseph R. Mulley, Editors, Proceedings of SPIE Vol. **9948** (SPIE, Bellingham, WA 2016), 99481G.

Janos C. Keresztes, R. John Koshel, Russell A. Chipman, John C. Stover, Wouter Saeys, "A cross-polarized freeform illumination design for glare reduction in fruit quality inspection", in Optical Systems Design 2015: Illumination Optics IV, Tina E. Kidger; Stuart David, Editors, Proceedings of SPIE Vol. **9629** (SPIE, Bellingham, WA 2015), 962904.

Janos C. Keresztes, Bart De Ketelaere, Jan Audenaert, R. John Koshel, Wouter Saeys, "Illumination system development using design and analysis of computer experiments", in Novel Optical Systems Design and Optimization XVIII, G. Groot Gregory; Arthur J. Davis; Cornelius F. Hahlweg, Editors, Proceedings of SPIE Vol. **9579** (SPIE, Bellingham, WA 2015), 95790I.

Janos C. Keresztes, Ben Aernouts, R. John Koshel, Wouter Saeys, "Dynamic noise corrected hyperspectral radiometric calibration in the SWIR range using a supercontinuum laser", in Novel Optical Systems Design and Optimization XVIII, G. Groot Gregory; Arthur J. Davis; Cornelius F. Hahlweg, Editors, Proceedings of SPIE Vol. **9579** (SPIE, Bellingham, WA 2015), 95790A.

R. J. Koshel and S. Mulder, "Toleranced freeform optical design with extended sources using ray targeting,” Proceedings of SPIE Vol. **8842**, 88420L (2013).

G. G. Gregory, I. E. Ashdown, W. Brandenburg, et al., "Data format standard for sharing light source measurements," Proceedings of SPIE Vol. **8835**, 88350D (2013).
R. J. Koshel, V. Abraham, J. Kim, et al., "Illumination system design in a project-based course," Proceedings of SPIE Vol. **7423**, 742305 (2009).
L. Wang, J. M. Sasián, P. Su, et al., "Generation of uniform illumination using faceted reflectors," Proceedings of SPIE Vol. **7423**, 74230Y (2009).
R. J. Koshel, "SSL design with LED binning tolerances," *SPIE Proc. of Illumination Optics* **7103**, 710303 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2008).
R. J. Koshel, "Fractional optimization of illumination optics," *SPIE Proc. of Novel Optical Systems Design and Optimization XI* **7061**, 70610F (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2008).
R. J. Koshel, "Software conquers design and analysis of backlit LCDs," *Las. Foc. World* (October 2007).
R. J. Koshel, "Illumination system tolerancing," *SPIE Proc. of Optical System Alignment and Tolerancing I* **6676**, 667604 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2007).
R. J. Koshel, "Why illumination engineering?" *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems IV* **6670**, 667002 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2007).
R. J. Koshel, "A course in illumination engineering," *SPIE Proc. of Novel Optical Systems Design and Optimization X* **6668**, 66680F (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2007).
A. Kano, R. J. Koshel, and A. F. Gmitro, "Broadband endoscopic imaging through a single fiberoptic channel," *SPIE Proc. of Novel Optical Systems Design and Optimization X* **6668**, 666806 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2007).
E. C. Kintner, W. K. Wong, E. S. Jacobs, P. J. Cucchiaro, and R. J. Koshel, "Efficient and versatile internal reference sources for remote sensing space telescopes," *SPIE Proc. of Infrared Spaceborne Remote Sensing XIV* **6297**, 62970FG (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2006).
Groot Gregory and R. J. Koshel, "Modeling the operating conditions of solar concentrator systems," *SPIE Proc. of Photonics Europe* **6197**, 61970J (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2006).
R. J. Koshel, C. Walker, and J, Briggs, "Education events at Frontiers in Optics 2005," *Opt. Phot. News* **17**, 16 (January 2006).
G. Groot Gregory and R. J. Koshel, "Using software interoperability to achieve a virtual design environment," *SPIE Proc. of Optical Design and Engineering II* **5962**, 59620A (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2005).
R. J. Koshel, "Lit-appearance modeling uses ray tracing and visualization," *Las. Foc. World*, 71 (May 2005).
R. J. Koshel and A. Gupta, "Characterization of lightpipes for efficient transfer of light," *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems II* **5942**, 594205 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2005).
R. J. Koshel, "Aspects of illumination system optimization," *SPIE Proc. of Nonimaging Optics and Efficient Illumination Systems I* **5529**, 206 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2004).

R. J. Koshel, “Optimal simplex optimization for optical design,” *SPIE Proc. of Novel Optical Systems Design and Optimization VII* **5524**, 205 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2004).
M. S. Kaminski and R. J. Koshel, "Methods of tolerancing injection-molded parts for illumination systems," *SPIE Proc. of Efficient Illumination System Design* **5186**, 61 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2003).
R. J. Koshel, "Lit appearance modeling of illumination systems," *SPIE Proc. of Novel Optical Systems Design and Optimization V* **4768**, 65 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2002).
M. S. Kaminski, K. J. Garcia, M. A. Stevenson, M. Frate, and R. J. Koshel, "Advanced topics in source modeling," *SPIE Proc. of Source Modeling I* **4775**, 46 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2002).
M. A. Stevenson, M. S. Kaminski, M. Frate, and R. J. Koshel, "Modeling filament-based sources for system tolerancing,” *SPIE Proc. of Source Modeling I* **4775**, 67 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2002).
A. Gupta, J. Lee, and R. J. Koshel, “Lightpipe Design,” Optics in 2001, *Opt. and Phot. News* **12**, No. 12, 53 (2001).
R. J. Koshel and E. R. Freniere, "Illumination: lighting our lives," Introduction to Illumination Special Issue, *Opt. and Phot. News* **12**, No. 8, (August 2001).
B. Cassarly, D. Jenkins, A. Gupta, and R. J. Koshel, "Hidden devices that light our world: lightpipes," *Opt. and Phot. News* **12**, No. 8, 34 (August 2001).
R. J. Koshel, "Intracavity beam shaping," *SPIE Proceedings of Laser Beam Shaping II* **4443**, 47 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, August 2001).
R. S. Upton and R. J. Koshel, "Modeling coherent propagation aids accurate coupling," *WDM Solutions*, 73 (June 2001).
R. J. Koshel, “Traffic lights must meet strict standards,” *Laser Focus World* (October 2000).
R. J. Koshel, “Non-edge ray reflector design (NERD) for illumination systems,” *SPIE Proceedings of Novel Optical Systems Designs and Optimization II* **4092**, 71 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 2000).
J. Shiefman and R. J. Koshel, “Modeling predicts WDM source performance,” *WDM Solutions*, 19 (February 2000).
R. J. Koshel, “Tailored pump reflectors for lasers: a new conformal optics application,” *Laser Focus World* (July, 1999).
R. J. Koshel, "Information Technology for Education," *Opt. and Phot. News* **10**, No. 4 (April 1999).
R. Trebino and R. J. Koshel, "Encyclopedia Optica," *Opt. and Phot. News* **10**, No. 3 (March 1999).
R. J. Koshel, “My First Year as a Professor,” *Opt. and Phot. News* **9**, No. **10**, 43 (Oct. 1998).
R. J. Koshel, Guest Editor, “Optics Education: The Past Leading to the Future”, *Opt. and Phot. News* **9**, No. 9, 17 (September 1998).
R. J. Koshel, "Optics for the Fish II," *Opt. and Phot. News* **9**, No. 5, 63 (May 1998).
R. J. Koshel, "Book Review: The *Art and Science of Optical Design*," *Opt. and Phot. News* **9**, No. 4, 54 (April 1998).
R. J. Koshel, "Optics for the Fish I," *Opt. and Phot. News* **9**, No. 4, 50 (April 1998).
R. J. Koshel, "Reach Out," *Opt. and Phot. News* **9**, No. 2, 73 (February 1998).

R. J. Koshel, "Optics for the Fish," *Proceedings of the Forum on Education*, OSA Annual Meeting 1997, Long Beach, CA (Optical Society of America, Washington, D. C., 1997).
R. J. Koshel, "Career planning and education events at the annual meeting," *Opt. and Phot. News* **8**, No. 9, 53 (September 1997).
R. J. Koshel, "Wiring the educational experience," *Opt. and Phot. News* **8**, No. 5, 64 (May 1997).
R. J. Koshel, "Book Review: *Geometrical Optics and Optical Design*," *Opt. and Phot. News* **8**, No. 5, 66 (May 1997).
R. J. Koshel, "Electronic Job Search," *Opt. and Phot. News* **8**, No. 4, 47 (April 1997).
R. J. Koshel, "Book Review: Solid-*State Laser Engineering*, 4th Ed.," *Opt. and Phot. News* **7**, No. 7, 53 (1996).
R. J. Koshel and I. A. Walmsley, "Modulating Light," *Opt. and Phot. News* **7**, No. 6, 54 (June 1996).
R. J. Koshel, "Book Review: Laser *Experiments for Beginners,*" *Opt. and Phot. News* **6**, No. 9 (September 1995).
J. Koshel, "Future Shock: Controlling Your Career," *Opt. and Phot. News* **6**, No. 7, 51 (July 1995).
R. J. Koshel, "Expansion of the Forum on Education," *Opt. and Phot. News* **6**, No. 4 (April 1995).
I. A. Walmsley and R. J. Koshel, *Manual For SeidelPlot* (Optical Society of America; Washington, D. C., 1995).
R. J. Koshel, "Optics Online in the Classroom," *Opt. and Phot. News* **5**, No. 4, 39 (April 1994).
V. Wong, R. J. Koshel, M. Beck, and I. A. Walmsley, "Measurement of the amplitude and phase of pulses from passively mode-locked lasers," *SPIE Proceedings of OE/Lase 93: Ultrafast Pulse Generation and Spectroscopy* **1861**, 137 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 1993).

PRESENTATIONS

Justina Bonaventura, Thomas Knapp, R. J. Koshel, and Travis Sawyer "Smartphone spectroscopy for melanoma detection", presented at Optics and Biophotonics in Low-Resource Settings VIII**,** Photonics West, January 2022.
Liliana Ruiz Diaz, Ross D. Uthoff, Rachel N. Ulanch, Kaitlyn E. Williams, Nathan Saxton, R. John Koshel, "Solid-State Lighting for High-Valued Artwork," presented at Solid-State Lighting, November 2017.
Ross D. Uthoff, Nathan W. Saxton, Rachel N. Ulanch, Kaitlyn E. Williams, Page King, Liliana Ruiz Diaz, R. John Koshel, "Object-Specific Lighting Design for Mark Rothko's Green on Blue, a Collaboration between The University of Arizona Museum of Art and College of Optical Sciences," presented at 1st International Museum Lighting Symposium and Workshops, London, UK, September 2017.
Rachel N. Ulanch, R. J. Koshel, "Replicating Blue Wool Testing for Art Conservation Using a Smartphone Spectrometer," presented at 1st International Museum Lighting Symposium and Workshops, London, UK, September 2017.
Ross D. Uthoff, Rachel N. Ulanch, Kaitlyn E. Williams, Liliana Ruiz Diaz, Page King, R. John Koshel, "Designing a freeform optic for oblique illumination," presented at International Optical Design Conference, July 2017.

Kaitlyn E. Williams, Rachel N. Ulanch, Page King, Ross D. Uthoff, Liliana Ruiz Diaz, Jessica Steidle, R. John Koshel, “Functional Fitting of Freeform Optics,” presented at International Optical Design Conference, July 2017.

Jacob Boyer, Janos C. Keresztes, Wouter Saeys, R. John Koshel, "An automated imaging BRDF polarimeter for fruit quality inspection,” presented at SPIE Optics and Photonics, August, 2015.

Janos C. Keresztes, R. John Koshel, Russell A. Chipman, John C. Stover, Wouter Saeys, "A cross-polarized freeform illumination design for glare reduction in fruit quality inspection,” presented at SPIE Optics and Photonics, August, 2015.

Janos C. Keresztes, Bart De Ketelaere, Jan Audenaert, R. John Koshel, Wouter Saeys, "Illumination system development using design and analysis of computer experiments,” presented at SPIE Optics and Photonics, August, 2015.

Janos C. Keresztes, Ben Aernouts, R. John Koshel, Wouter Saeys, "Dynamic noise corrected hyperspectral radiometric calibration in the SWIR range using a supercontinuum laser,” presented at SPIE Optics and Photonics, August, 2015.

R. J. Koshel and S. Mulder, "Toleranced freeform optical design with extended sources using ray targeting,” invited paper presented at SPIE Optics and Photonics, August 2013.

G. G. Gregory, I. E. Ashdown, W. Brandenburg, et al., "Data format standard for sharing light source measurements,” presented at SPIE Optics and Photonics, August 2013.

J. J. Kim and R. J. Koshel, "Modeling transflective LCD illumination systems,” presented at Int. Opt. Des. Conf., Jackson Hole, WY, June 2010.

R. J. Koshel, “Perturbation design of illumination optics,” invited paper presented at Int. Opt. Des. Conf., Jackson Hole, WY, June 2010.

R. J. Koshel, V. Abraham, J. Kim, et al., "Illumination system design in a project-based course,” presented at SPIE Optics and Photonics, August 2009.

L. Wang, J. M. Sasián, P. Su, et al., "Generation of uniform illumination using faceted reflectors,” presented at SPIE Optics and Photonics, August 2009.

R. J. Koshel, “What’s hot in the Fabrication, Design and Instrumentation: Design Events – Solar Technology: Design, Fabrication, and Testing,” invited paper, What’s Hot session at Frontier in Optics, San Jose, CA 2009.

R. J. Koshel, “Accurate Lit-Appearance Modeling of Illumination Systems,” invited paper presented at OSA Frontiers in Optics, Rochester, New York, October 2008.

R. J. Koshel, “SSL design with LED binning tolerances,” presented at SPIE European Optical System Design, Glasgow, United Kingdom, September 2008.

R. J. Koshel, “Fractional optimization of illumination optics,” presented at SPIE Optics and Photonics, August 2008.

R. J. Koshel, “Illumination system tolerancing,” presented at SPIE Optics and Photonics, San Diego, CA, August 2007.

R. J. Koshel, “Why illumination engineering?” presented at SPIE Optics and Photonics, San Diego, CA, August 2007.

R. J. Koshel, “A course in illumination engineering,” presented at SPIE Optics and Photonics, San Diego, CA, August 2007.

A. Kano, R. J. Koshel, and A. F. Gmitro, “Broadband endoscopic imaging through a single fiberoptic channel,” presented at SPIE Optics and Photonics, San Diego, CA, August 2007.

R. J. Koshel, "Optimization of parameterized lightpipes," presented at Intl. Opt. Des. Conf. 2006, Vancouver, BC Canada, June 2006.

G. Groot Gregory and R. J. Koshel, “Modeling the operating conditions of solar concentrator systems,” presented at Photonics Europe**,** Strasbourg, France, April 2006.

R. J. Koshel, “The Nuances and Complexity of Illumination System Optimization,” invited paper presented at Frontiers in Optics/OSA Annual Meeting 2005, Tucson, AZ, October 2005.

G. Groot Gregory and R. J. Koshel, “Using software interoperability to achieve a virtual design environment,” presented at Optical Systems Design, Jena, Germany, September 2005.

R. J. Koshel and A. Gupta, “Characterization of Lightpipes for Efficient Transfer of Light,” presented at SPIE Annual Meeting 2005, San Diego, CA, July 2005.

R. J. Koshel, “Aspects of illumination system optimization,” presented at SPIE Annual Meeting 2004, Denver, CO, August 2004.

R. J. Koshel, “Optimal simplex optimization for optical design,” presented at SPIE Annual Meeting 2004, Denver, CO, August 2004.

R. J. Koshel, “Optimization of Illumination Design,” invited talk presented at Frontiers in Optics/OSA Annual Meeting 2003, Tucson, AZ, October 2003.

R. J. Koshel, “Methods of tolerancing injection-molded parts for illumination systems,” presented at SPIE Annual Meeting 2003, San Diego, CA, August 2003.

R. J. Koshel, "Lit-appearance modeling of illumination systems," presented at SPIE Annual Meeting, Seattle, WA, July 2002.

R. J. Koshel, "Gain effects on laser beam shaping," presented at SPIE Annual Meeting, Seattle, WA, July 2002.

M. Stevenson, M. Kaminski, M. Frate, and R. J. Koshel, "Modeling filament-based sources for system tolerancing," Invited talk presented at SPIE Annual Meeting, Seattle, WA, July 2002.

M. Kaminski, K. Garcia, M. Stevenson, M. Frate, and R. J. Koshel, "Advanced topics in source modeling," presented at SPIE Annual Meeting, Seattle, WA, July 2002.

R. J. Koshel, "Enhancement of the downhill Simplex method of optimization," presented at Intl. Opt. Des. Conf. 2002, Tucson, AZ, June 2002.

R. J. Koshel, "Intracavity laser beam shaping," Invited talk presented at the LIA ICALEO 2001, Orlando, FL (October 2001).

R. J. Koshel, "Connection between technical and non-technical aspects of illumination," Invited talk presented at the OSA Annual Meeting, Long Beach, CA (October 2001).

R. J. Koshel, "Intracavity beam shaping," presented at the SPIE Annual Meeting, San Diego, CA (August 2001).

R. J. Koshel, “Non-edge ray reflector design (NERD) for illumination systems,” presented at the SPIE Annual Meeting, San Diego, CA, paper 4092-17 (2000).

A. Gupta and R. J. Koshel, “Optimal design of a light pipe,” presented at the OSA Annual Meeting, Santa Clara, CA, paper TuTT5 (1999).

R. J. Koshel, " Improved control of the gain profile in an optically pumped laser via conformal optics," presented at the Annual Meeting of the OSA, Baltimore, MD, paper MK3 (1998).

R. J. Koshel, "Tailored emission from a diode-pumped, solid-state laser for lithography," presented at the Annual Meeting of the OSA, Baltimore, MD, paper ThRR2 (1998).

R. J. Koshel, "So you want to become a professor," Invited talk at the Annual Meeting of the Optical Society of America, Long Beach, CA, paper ThRR2 (1997).

R. J. Koshel and R. D. Jones, "Performance of a spatial-mode tunable Nd:YVO_4 laser," Annual Meeting of the Optical Society of America, Long Beach, CA, paper WHH3 (1997).

R. J. Koshel, B. Adolf, and R. D. Jones, "Laser beam characterization round robin," Annual Meeting of the Optical Society of America, Long Beach, CA, paper WC4 (1997).

R. J. Koshel, "Optics for the Fish," Annual Meeting of the OSA, Long Beach, CA, paper ThO3 (1997).
R. J. Koshel and I. A. Walmsley, "Toward optimal pump cavity design," Annual Meeting of the Optical Society of America, Rochester, NY, paper MMM7 (1996).
R. J. Koshel and I. A. Walmsley, "Optimal design of optically pumped lasers," Annual Meeting of the Optical Society of America, Rochester, NY, paper WD9 (1996).
R. J. Koshel and I. A. Walmsley, “Gain distribution effects on laser output power,” Annual Meeting of the Optical Society of America, Dallas, TX, paper FV5 (1994).
R. J. Koshel. I. A. Walmsley, R. Utano, and D. Caffey, “Diode side pumping of a Nd:YAG laser rod with nonimaging optics,” International Optical Design Conference, Rochester, NY, paper IWC3 (1994).
R. J. Koshel, "Diode side pumping of a Nd:YAG laser rod with nonimaging optics," Spring Industrial Associates, The Institute of Optics, University of Rochester, Rochester, NY (1994).
V. Wong, R. J. Koshel, M. Beck, and I. A. Walmsley, “Measurement of the amplitude and phase of pulses from passively mode-locked lasers,” presented at OE/Lase 93: Ultrafast Pulse Generation and Spectroscopy (1993).
R. J. Koshel, M. Beck, and I. A. Walmsley, "Role of coherent interactions in pulse shaping in passively mode-locked lasers," Annual Meeting of the OSA, Albuquerque, NM, paper FM5 (1992).
R. J. Koshel and I. A. Walmsley, "Nonimaging optics for diode pumping of solid-state lasers," Workshop on Diode Pumping Techniques, sponsored by Night Vision Laboratories, Ft. Belvoir, VA (1990).
R. J. Koshel and I. A. Walmsley, "Diode pumping of solid-state lasers with nonimaging optics: a theoretical study," Annual Meeting of the OSA, Boston, MA, paper TuVV6 (1990).

PATENTS

Smartphone Application for Spectroscopic Calibration, Acquisition and Analysis for Skin Cancer Diagnosis, T. Sawyer, J. Bonaventrua, T. G. Knapp, and R. J. Koshel, preliminary patent (2021).
Apparatus for Adjustable Spectral Resolution, Self-Calibration, and Self-Stabilization of Smartphone Spectrometer, T. Sawyer, J. Bonaventrua, T. G. Knapp, and R. J. Koshel, preliminary patent (2021).
High Performance UV Disinfection in a HVAC System with Integrated Concentrator Optics, S. Pau, L. Jiang, and R. J. Koshel, preliminary patent (2020).
On-Chip CMOS Threshold Processing, E. Landsiedel and R. J. Koshel, preliminary patent (2019).
White Light Interferometry Imager, E. Landsiedel and R. J. Koshel, preliminary patent (2019).
Calibration technique for Smartphone Spectroradiometer, R. Ulanch and R. J. Koshel, U.S. patent #10,514,335 (2018).
Micro-Scale Concentrated Photovoltaic Module, S. Pau, L. Jiang, and R. J. Koshel, U.S. patents #10,505,059 and #11,056,599 (2015).

STUDENTS SUPERVISED

Page King (Optical Sciences, M.S. and Ph.D.) 2014 – present.
Michael Schur (Optical Sciences, M.S.) 201 – present.
Haley Knapp (Optical Sciences, M.S.) 2020 – present.
Katherine Sherer, Modeling of Ultraviolet Scatter Using Bidirectional Reflectance Distribution Functions (Optical Sciences, M.S. report, awarded) 2020 – 2021.
Jesse Odle (Optical Sciences, M.S. non-thesis, awarded) 2020 – 2021.
Scott Newman (Optical Sciences, M.S. non-thesis, awarded) 2019 – 2020.
Meg Tidd, *Far-Field Illumination Optic Style Recommender Algorithm* (Optical Sciences, M.S., awarded) 2019 – 2020.
Emma Landsiedel, *High-Speed White Light Interferometry for Imaging Applications* (Optical Sciences, M.S. thesis, awarded) 2018 – 2019.
Alex Erstad, *Applications of Eikonals in Optical Design* (Optical Sciences, Ph.D., awarded) 2018-2019.
Jared Talbot, *Testbed Design for Investigating the Irradiance and Intensity Uniformity Performance of Lightpipes* (Optical Sciences, M.S. thesis, awarded) 2018-2019.
Georgia Piatt, *From Cell to Barbule the Optics of Iridescent Bird Feathers* (Optical Sciences, M.S. thesis, awarded) 2017 – 2018.
Kaitlyn Williams, *Parametrizing Freeform Optical Systems for the Optimized Design of Imaging and Illumination Systems* (Optical Sciences, M.S. thesis, awarded) 2016 – 2017.
Rachel Ulanch, *Replicating the Blue Wool Response Using a Smartphone Spectroradiometer* (Optical Sciences, M.S. thesis, awarded) 2016 – 2017.
Roger Lucheta, *A Survey of Laser Diagnostic Techniques for Combustion Measurements* (Optical Sciences, M.S. report, awarded), 2014 – 2015.
Brian Cranton, *Product Development – Raman Photometer* (Optical Sciences, M.S. report, awarded), 2013 – 2014.
Chen Yen Lin, *Design of Efficient Lightpipe Couplers* (Optical Sciences, M.S. report, awarded), 2010-2011.

THE UNIVERSITY OF ARIZONA PROJECT FUNDING

Smartphone Spectrometer for Skin Cancer Detection (with Travis Sawyer), Tech Launch Arizona – University of Arizona, $37k, 2021-2022.
White Light Interferometer for EDOF, ASM, $127k, 2018-2020.
Research in Optics, NSF Research Experience for Undergraduates, Engineering Directorate, $350k, 2015-2018.