



# SMART LIGHTING ENGINEERING RESEARCH CENTER

Lighting Innovation for a Smarter Tomorrow



## Smart Lighting ERC Academia - Industry Day

February 5, 2010

Boston University, Photonics Building, 9<sup>th</sup> floor, 8 St. Mary's St., Boston, MA

7:30 – 8:30	Registration, Continental Breakfast and Networking	
8:30 – 8:35	<b>Welcome</b> - <a href="#">Dr. Kenneth Lutchen</a> , Dean of Engineering, BU	
8:35 – 9:15	<b>Smart Lighting, The Next Wave in Solid-State Lighting</b> <a href="#">Dr. Robert Karlicek</a> , ERC Center Director, and Professor, ECSE Department, RPI	
9:15 – 9:25	<b>Industry and the ERC</b> - <a href="#">Dr. Silvia Mioc</a> , ERC Industrial Collaboration Director, RPI	
9:25 – 9:45	<b>Lensless Microscopes Enabled by Nanowire LEDs</b> <a href="#">Dr. Steve Hersee</a> , ERC Associate Director and Professor, ECE Dept., UNM	
9:45 – 10:05	<b>How Smart Lighting Fills a Gap for Wireless Communications</b> <a href="#">Dr. Thomas Little</a> , ERC Associate Director and Professor, ECE Dept., BU	
10:05 – 10:25	<b>Systems Integration and Smart Buildings</b> <a href="#">Dr. Art Sanderson</a> , ERC System Integration Committee Co-Chair and Professor, ECSE Dept., RPI	
10:25 – 10:50	Break and Networking	
10:50 – 11:10	<b>Photonics Crystals: Innovative Photon Management</b> <a href="#">Dr. Shawn Lin</a> , ERC Device Thrust Leader and Constellation Professor, Physics Dept., RPI	
11:10 – 11:30	<b>Point of Care Biosensors</b> <a href="#">Dr. Michael Ruane</a> , ERC Biosensors Application Area Leader, and Professor, ECE Dept., BU	
11:30 – 11:50	<b>A Second Kind of Light</b> <a href="#">Dr. Mark Rea</a> , ERC Lighting and Health Application Area Leader, and Director, Lighting Research Center, RPI	
11:50 – 12:10	<b>Educating the Next Generation in Smart Lighting</b> <a href="#">Dr. Kenneth Connor</a> , ERC Education & Outreach Director and Professor, ECSE Dept., RPI	
12:10 – 1:45	Lunch and <b>Keynote Address: The Smart Future of the Future of Light</b> <a href="#">Dr. Kevin Dowling</a> , Vice President of Innovation, Philips Color Kinetics, and ERC Scientific Advisory Board member, introduced by <a href="#">Dr. Majeed Foad</a> , ERC Industrial Advisory Board chair, <b>Applied Materials</b>	
1:45 – 3:00	<b>Industry Viewpoint on Smart Lighting - Panel Discussion</b> Moderator: <a href="#">Dr. Thomas Bifano</a> , Photonics Center Director, BU Participants: ERC Industrial Advisory Board members: <a href="#">Dr. Majeed Foad</a> , <b>Applied Materials</b> , <a href="#">Douglas Castor</a> , <b>Interdigital Inc.</b> , <a href="#">Dr. Matthew Stough</a> , <b>Osram Sylvania</b> , <a href="#">Dr. Leo Schowalter</a> , <b>Crystal IS</b> , <a href="#">John Taranto</a> , <b>Thorlabs</b>	
3:00 – 3:20	Student Poster Competition: Introduced by <a href="#">Dr. Silvia Mioc</a> , ERC Industrial Collaboration Director Selected students to present their work in 90 seconds	
3:20 – 5:30	Refreshments and <b>Poster Session</b>	Optional BU Lab tour – sign up at registration
5:30 – 7:30	<b>Reception</b> – announcement of winners of the <b>Student Posters Competition</b> Space will be available for informal discussions with researchers and students – signup sheet will be available at registration desk	



Rensselaer





**Robert Karlicek**  
**Director, Smart Lighting ERC**  
**Professor, Electrical, Computer & Systems Engineering**  
**Rensselaer Polytechnic Institute**

Dr. Karlicek is a well-known innovator and manager with extensive industry experience in technology management, new product development, and strategic business planning. He is the president and founder of Acton, Massachusetts-based SolidUV Inc., which develops high-power ultraviolet LED systems for industrial curing applications in printing, coating, electronics, packaging, and assembly operations. From 2005 through 2008, he served as chief scientist and VP for research at Luminus Devices in Woburn, Mass., where he led an interdisciplinary team of scientists and engineers in the development of advanced photonic crystal LED devices and other LED-based system designs.

Prior to this, Dr. Karlicek worked for more than 25 years in R&D and manufacturing of opto-electronic devices with industry leaders including AT&T Bell Labs, EMCORE, GE, Gore Photonics, and Microsemi. His primary research focus has been developing holistic approaches to solid state lighting and related LED applications, including advanced thermal management technologies, new approaches to chip and packaging integration, as well as color control and LED systems in large-scale lighting and industrial applications. Dr. Karlicek's technical contributions include more than 40 authored or co-authored papers in peer-reviewed technical journals, 24 issued U.S. patents, and numerous invited talks and workshop presentations. He is a member of the IEEE, OSA, American Chemical Society, and Radtech.

He received his PhD in Physical Chemistry at the University of Pittsburgh and his B.S. in Chemistry at Elmhurst College in Illinois.



**Silvia Mioc**  
**ERC Industrial Collaborations Director**  
**Rensselaer Polytechnic Institute**

Dr. Silvia Mioc received her PhD in Physics from the University of Illinois at Chicago, and her MBA from the Keller Graduate School of Management. Her professional experience spans displays, medical devices and optical technologies, in settings ranging from academia and national labs to startups, large companies and non-profits. In addition, she has been involved in working with state, local and regulatory agencies, and has lobbied federal legislators for sustained increased funding for R&D and Math and Science Education. She speaks 5 languages, and has done business in Europe and Asia.

Dr. Mioc comes to RPI after having been with Corning, Inc. since 2006 as a Business Development Manager in the Display Future's Emerging Markets and Technologies group. In that role, she was a key player in bringing to the corporation the understanding of the latest developments in the display industry in order to feed and support early R&D projects in the pipeline. Among other responsibilities, she led the strategic external engagement with academia and industry. She also organized complex series of events targeted at increasing the visibility of Corning Display Futures group and establishing a dialogue with key thought leaders in the industry.

Prior to Corning, Dr. Mioc spent 8 years in the medical devices industry in both technical and business development roles. She worked in Colorado for the pulse oximetry division of Datex-Ohmeda, a Finnish company that became part of GE Healthcare in 2003.

In parallel, she has been involved with the Colorado Photonics Industry Association (CPIA), a non-profit organization dedicated to enhancing the environment for optical technologies in Colorado. She has been active in the organization since 2001, being its president from 2003 to 2006. She spearheaded expanding program reach to strategically exploit synergies with biotech, medical devices, nanotech and defense/homeland security sectors, and formed numerous win-win partnerships with service providers to increase member benefits. Under Silvia's leadership, CPIA steadily grew its impact, visibility, and reach at state level, nationally and internationally. Additionally, she led the transition of the association from an all-volunteer base to employing an executive director through funding secured via a grant from the state of Colorado.



**Stephen D. Hersee**  
**ERC Associate Director and Materials Thrust Leader**  
**Professor, Electrical and Computer Engineering**  
**University of New Mexico**

Dr. Hersee is an IEEE Fellow and a Professor of Electrical and Computer Engineering at the University of New Mexico. He graduated from Brighton University in the UK then spent 6 years with Plessey Research in the UK. From 1980 to 1986 he worked at the Central Research Laboratories of Thomson CSF in France, where he established several world records for quantum-well laser performance. In 1986 he joined GE's Electronics Laboratory in NY State. He has been a faculty member of the ECE Department at the University of New Mexico since 1991.

During his international career in industry and academia, Dr. Hersee has worked on advanced III-V materials and many types of electronic and optoelectronic devices. His current research focuses on the nanoscale epitaxial growth of semiconductors and especially the use of nanostructures for defect reduction in GaN and for advanced photonic and electronic devices. He is the inventor of a scalable GaN-nanowire process that promises to move nanowire-based, semiconductor devices out of the laboratory and into production. This research has been highlighted in *Nature Nanotechnology* and cited by the National Research Council of the National Academies in their 2008 report on "Nanophotonics". He is currently collaborating with other universities, with Sandia National Laboratories and with industry to develop the intellectual property associated with this nanowire work and to transfer this process into industry.

Dr. Hersee has published and presented over 170 papers and has been awarded 10 patents. His research has been funded by NSF, DARPA, AFOSR, ARO, DOE and by industry. He has graduated 11 Ph.D and 4 MS students and has received awards for his research and for his teaching. In 2002 he was named the University of New Mexico's "2001/2002 Teacher of the Year".



**Thomas D.C. Little**  
**ERC Associate Director**  
**Professor, Electrical and Computer Engineering**  
**Boston University**

Dr. Little is the Associate Chair for Graduate Studies for the department and is director of the Multimedia Communications Lab where he is involved in the development of enabling technologies and applications for networked and distributed systems. Dr. Little is also the Associate Director of the Smart Lighting Engineering Research Center -- a collaboration of Rensselaer Polytechnic Institute, the University of New Mexico, and Boston University. His

recent efforts include research in video sensor networks and streaming in wireless settings, ubiquitous optical networking with visible light, vehicle-to-vehicle/infrastructure (V2X) communications, and the application of wireless sensors in health monitoring.

Dr. Little received his BS degree in biomedical engineering from RPI in 1983, and his MS degree in electrical engineering and PhD degree in computer engineering from Syracuse University in 1989 and 1991.



**Arthur C. Sanderson**  
**ERC Interim Deputy Director**  
**Professor, Electrical, Computer, and Systems Engineering**  
**Rensselaer Polytechnic Institute**

Dr. Sanderson received his B.S. degree from Brown University and the MS and PhD degrees from Carnegie Mellon University. Dr. Sanderson held faculty positions at Carnegie Mellon University from 1973 to 1987, where he was Co-Director of the Robotics Institute, and has held a number of international visiting positions in Europe, Latin America and Asia. In 1987, he joined Rensselaer Polytechnic Institute as Professor and served as Department Head of the Electrical, Computer and Systems Engineering Department. He was instrumental in establishing the IEEE Robotics and Automation Society in 1989, and served as its first President. He is a Fellow of the IEEE. From 1998-2000, he was Division Director of Electrical and Communications Systems research at the National Science Foundation in Arlington, VA.

From 2000 through 2004, Dr. Sanderson served as Vice President for Research of Rensselaer Polytechnic Institute. Dr. Sanderson is the author of over 250 publications and proceedings and five books in the areas of biomedical signal processing, robotics and automation systems, and sensor-based control. In 2005, Dr. Sanderson was on sabbatical leave as a Visiting Distinguished Professor in the College of Engineering, University of South Florida, and a Visiting Research Fellow of the Autonomous Undersea Systems Institute. His most recent book *Adaptive Differential Evolution, a Robust Approach to Multimodal Problem Optimization* was published in October, 2009. He currently serves as Interim Deputy Director of the NSF Smart Lighting Engineering Research Center.



**Shawn-Yu Lin**  
**ERC Device Trust Leader**  
**Constellation Professor, Physics, Applied Physics & Astronomy**  
**Rensselaer Polytechnic Institute**

Dr. Lin received his doctoral degree from Princeton University in 1992 and joined IBM T.J. Watson research center the same year. At IBM, he first worked on the wave-function symmetry of high temperature superconductors and then on ultra-fast photo-conductive optical switches. In 1994, Dr. Lin joined Sandia National Laboratories, working on photonic crystal structures and its application to solar conversion efficiency. In 2004, Dr. Lin assumed his new job at Rensselaer Polytechnic Institute as a Wellfleet Constellation professor in Future Chips and Professor of Physics.

Dr. Lin is a fellow of American Physical Society, a fellow of Optical Society of America, a distinguished member-of-technical-staff at Sandia National Laboratories. Dr. Lin's research interest is in sub-wavelength optics that includes nano-photonics, integrated optoelectronics, silicon photonics, solar

collection/absorption, and quantum optics. For the past decade, Dr. Lin leads Sandia's multi-million efforts in developing photonic-crystal devices for communication, defense and energy applications. From 2001-2003, he also headed a US Department-of-Energy multi-laboratories initiative in Nano-Structural Photonics.



**Michael Ruane**  
**ERC Biosensors Application Area Leader**  
**Professor, Electrical and Computer Engineering**  
**Boston University**

Dr. Ruane received his PhD from MIT in 1980. Prof. Ruane is the B.U. Education Coordinator for the Smart Lighting Center, and has also served as the B.U. Education Coordinator for the NSF Bernard Gordon Engineering Research Center for Subsurface Sensing and Imaging Systems, Gordon-CenSSIS. He has been Associate Chair for Graduate Studies for ECE and Associate Dean for Research and Graduate Studies, ad interim. He is the Smart Lighting Center Biosensors Application Area Leader and co-directs the Biological Sensing and Imaging Lab. His interests include photonic materials and devices, biosensing, engineering design, education and outreach.

Dr. Ruane was Chair of IEEE Lasers and Electro-Optics Society, Boston Chapter, during 1996-98, and received the ASEE New England region Outstanding Professor award in 2004. He is the Faculty Outreach Director for the College of Engineering.



**Mark Rea**  
**ERC Lighting & Health Application Area Leader**  
**Director, Lighting Research Center**  
**Rensselaer Polytechnic Institute**

Dr. Mark Rea is the director of Rensselaer Polytechnic Institute's Lighting Research Center, the leading university-based research center devoted to lighting. Since 1988, under his guidance, the Lighting Research Center has built an international reputation as a reliable source for objective information about lighting technologies, applications and products.

In addition, Dr. Rea is a professor in Architecture and Cognitive Sciences. He teaches courses in leadership and in visual and circadian processes, and supervises graduate students at master's and PhD levels. He conducts research in many areas including circadian photobiology, mesopic vision, psychological responses to light, lighting engineering and visual performance. He is the author of more than 200 scientific and technical articles related to vision, lighting engineering, and human factors and was the editor-in-chief of the 8th and 9th editions of the IESNA Lighting Handbook. Dr. Rea is a recipient of the IESNA Medal.



**Kenneth Connor**  
**ERC Education & Outreach Director**  
**Professor, Electrical, Computer and Systems Engineering**  
**Rensselaer Polytechnic Institute**

Dr. Connor teaches courses on plasma physics, electromagnetics, electronics and instrumentation, electric power, and general Engineering. His research involves two primary topics: 1) The application of heavy particle beam -based diagnostics to plasmas of interest to the thermonuclear fusion community, for which he was made a Fellow of the IEEE in 1997; and 2) The study of electromagnetic phenomena, especially those associated with high frequency waves. Dr. Connor also maintains an interest in other plasma physics and electromagnetics topics, photonics, engineering education, diversity in the engineering workforce, and technology enhanced learning. Since joining the Rensselaer faculty in 1974, he has been continuously involved in research programs at such places as Oak Ridge National Laboratory and the Universities of Texas and Wisconsin in the US, Kyoto and Nagoya Universities in Japan, the Ioffe Institute in Russia and Kharkov Institute of Physics and Technology in Ukraine. He was ECSE Department Head from 2001-2008 and served on the board of the ECE Department Heads Association from 2003-2008.



**Kevin Dowling**  
**Member, ERC Scientific Advisory Board**  
**Vice President of Innovation**  
**Philips Color Kinetics**

Dr. Dowling joined Color Kinetics in early 1999 as Director of Engineering, and was integral to the research and development fueling many of Color Kinetics' successful products, technologies and market applications. He is an inventor and co-inventor on many Color Kinetics patents. He also leads the company's government programs. Beyond his work at Philips, Dr. Dowling actively engages with many industry organizations to advance adoption of LED lighting, including the creation of much-needed industry standards. He currently serves as Chairman of the National Electrical Manufacturers Association (NEMA) Solid-State Lighting Section, and formerly served as Chairman of the Next Generation Lighting Industry Alliance (NGLIA). He was instrumental in the formation of the Solid-State sub-committee within the Illuminating Engineering Society (IES) Testing Procedures Committee (TPC). Dr. Dowling is also active within the education community, teaching lighting at the New England Institute of Art and lecturing at many lighting and design programs. He is a well-known industry advocate with numerous published articles and speaking engagements to his credit.

Prior to Color Kinetics, Philips, Dr. Dowling was Chief Robotics Engineer for PRI Automation, the leader in advanced factory automation systems and software for the semiconductor industry. He has over 15 years of experience in advanced robotics engineering at the Field Robotics Center of Carnegie Mellon University, where, as a scientist, he led a number of projects including a Lunar Rover demo, robots for Space Shuttle Inspection and Shuttle ground operations at NASA's Kennedy Space Center, and the Mars Rover Project. Dr. Dowling has also consulted for many companies, including Shell Oil and Apple Computer, and was a founding principal of a medical robotics company. Dr. Dowling received his undergraduate degree in Mathematics and masters and PhD degrees in Robotics from Carnegie Mellon University.



**Thomas Bifano**  
**Photonics Center Director**  
**Boston University**

Dr. Bifano directs the Boston University Photonics Center (BUPC), a core facility and academic center of excellence comprised of thirty-five faculty members from seven academic departments, eighty graduate students, and ten staff members. He leads BUPC programs for education, scholarly research and development of advanced photonic device prototypes for commercial and military applications. He oversees a state-of-the-art facility that includes more than a dozen special-purpose and shared research laboratories and a large business incubator.

Dr. Bifano has been a Professor of Mechanical Engineering at Boston University since 1988, and was Chair of the Manufacturing Engineering Department from 1999-2006. Dr. Bifano's research in Mechanical Engineering focuses on modeling, design, production, and use of micro-electro-mechanical systems (MEMS) in optical applications, and he has supervised more than forty graduate students in his Precision Engineering Research Laboratory. He is a member of the Center for Space Physics, where his work includes development and launch of space-based instrumentation and a project to launch the first space-based civilian AO system using deformable mirrors developed in his laboratory. He is also a member of the Fraunhofer Center for Manufacturing Innovation, where he helped initiate a Global MS degree program in Manufacturing Engineering, in collaboration with RWTH in Aachen, Germany.

Dr. Bifano has organized and led international symposia and technical conferences in photonics, precision engineering, and MEMS, has authored more than a hundred publications, and is named as inventor on six patents. He is a founder and CTO of Boston Micromachines Corporation, of Cambridge, MA, a leading producer of deformable mirrors for applications in astronomy, bio-imaging, and defense. His technology has received two R&D100 Awards for innovative product development.



**Majeed Foad**  
**Chair, ERC Industry Advisory Board**  
**Manager, Advanced Thin Films, Advanced Technology Group CTO Office**  
**Applied Materials Corporation**

Dr. Majeed Foad is currently the manager of Advanced Thin Films Group at the CTO office of Applied Materials. He joined Applied Materials in 1995 in England as a Development Engineer with the Implant Division. He held several positions with increasing responsibilities. In 2006 he was appointed as a General Manager of the Plasma Doping Product Line where he led the P3i product through an aggressive program that exited the Alpha and Beta phases in 15 months.

Majeed holds a BS in Physics, MS in Chemistry and a PhD in Electronic Engineering from the University of Glasgow, Scotland.



**Douglas Castor**  
**Member, ERC Industry Advisory Board**  
**Member of Technical Staff, R&D**  
**InterDigital Communications Corporation, LLC**

Douglas Castor is a member of the Technical Staff at InterDigital Communications Corporation at its headquarters in King of Prussia, Pennsylvania. Doug has been with InterDigital since 2000 supporting the innovation and development of third generation cellular phone technology which is used in millions of handsets and data cards today. He currently manages a system engineering team with a charter to investigate and develop future generation air interface technologies for cellular and non-cellular systems. Doug heads InterDigital's research in Visible Light Communications and represents the company at the IEEE 802.15 committee for developing an international standard for this technology.

Prior to InterDigital, Doug was a Communications Systems Engineer at General Atronics in Wyndmoor, Pennsylvania and at Lockheed Martin in King of Prussia, Pennsylvania where he worked on various military and satellite communications systems. At Lockheed Martin, he completed the Leader Development Program (formerly General Electric Edison Engineering Program). Doug received a B.S.E.E. degree from the Pennsylvania State University in 1992 where he graduated with honors from the University Scholars Program (currently the Schreyer Honors College). In 1995, he received an M.S.E.E. degree from The University of Pennsylvania. Doug holds three U.S. patents and has authored several additional patent applications. In 2006, he was awarded the Delaware Valley Young Engineer of the Year award from IEEE in recognition of outstanding productivity and professional accomplishment.



**Matthew (Matt) A. Stough**  
**Member, ERC Industrial Advisory Board**  
**Research Manager, Solid-State Lighting**  
**Osram Sylvania**

Dr. Matthew Stough is the Research Manager for Solid-State Lighting and Materials Science within OSRAM's Central Research and Development organization. From the lighting company perspective, his group services all levels of the solid-state value chain- from growth and deposition to product concept realization. Matt has lead this group since 2003, transforming most of the basic materials science resources towards solid-state activities while securing a \$5M investment to expand capabilities at the Beverly, MA facility. Prior positions in OSRAM SYLVANIA included master black belt in design for six sigma and ceramic component product development engineering. He joined OSRAM SYLVANIA in 1997 after completing his PhD work from Penn State at Oak Ridge National Laboratory.

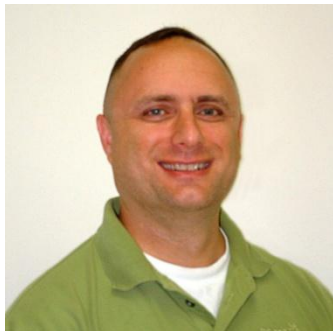
Our interest in the Smart Lighting Engineering Research Center demonstrates our continuing pursuit of innovative solid-state lighting technology. By collaborating as an Industrial Partner, we will help guide the research and project portfolio of the ERC, engage with faculty, students, and staff of the ERC on specific focus areas, and when appropriate foster scientist/student exchanges. Our interest covers all levels of the ERC's mission-Materials, Devices, and Systems.





**Leo J. Schowalter**  
**Member, ERC Industrial Advisory Board**  
**CTO, Crystal IS**  
**Visiting Professor, Rensselaer Polytechnic Institute**

After receiving his PhD in Physics from the University of Illinois (Urbana-Champaign), Dr. Schowalter was employed by the GE Research and Development Center in Schenectady, NY. He joined Rensselaer Polytechnic Institute (RPI) in 1987 and was chair of the Physics Department from 1997 to 2000 at which time he resigned to work with Crystal IS and is currently on a leave of absence from RPI. He has over 25 years experience in crystal growth and nano-probe technologies for which he has received international recognition and has focused his efforts on AlN crystal growth for the last eight years. He has published over 140 articles, co-edited four proceedings volumes, given over 50 invited talks, and holds three US patents (with 5 pending). He has co-chaired several international symposia in the areas of thin film crystal growth and nano-probe technologies. He was a co-instructor for the 1999 and 2000 Fall MRS Tutorials on nitride semiconductors and a tutorial instructor on nitride semiconductor substrates at the Gorham Compound Semiconductor Outlook Meetings of 2000 (San Diego) and 2002 (Taiwan). Dr. Schowalter also won the Tech Valley Business Plan competition for Crystal IS in 2003.



**John Taranto**  
**Member, ERC Industrial Advisory Board**  
**Senior Research Engineer**  
**Advanced Energy Group, Thorlabs**

John Taranto received his MS in Electro-Optical Engineering from the University of Dayton and has been working in the photonics industry for 23 years. After graduating from the University of Dayton John initially worked as a government contractor. He monitored government funded focal plane array reducibility programs for the Strategic Defense Initiative Organization (SDIO). He was also part of a team that built a 100+kW quasi-CW CO<sub>2</sub> laser at the Laser Hardened Materials Evaluation Laboratory (LHMEL) facility at Wright-Paterson Air Force Base, OH. As part of this group he gained experience integrating large scale systems and managing government projects. John joined Thorlabs early in its history, 1994, as a design engineer and has been responsible for many product designs; these include opto-mechanical components to electro-optical systems, such as their polarimeter (a polarization analyzer) and their omega-meter (a laser beam diameter measurement system). John has enjoyed various roles within Thorlabs over the years, including that of their Fiber Optic Business Unit leader. In this role John lead a team of people and was responsible for new product development, manufacturing, inventory control/management, and customer support. He increased sales for the group by >20% annually. After leading the Fiber Optic Business Unit, John took on his current role as a member of the Advanced Imaging Group. He has been focusing on adaptive optics based imaging systems. In September 2007 Thorlabs teamed with Boston Micromachines Corporation to help offer advanced MEMS based deformable mirrors to the photonics research community. John helped to incorporate the MEMS-DMs into a fully functional affordable Adaptive Optics kit, which integrates BMC's Multi-deformable mirror, Thorlabs' wavefront sensor, a pre-aligned opto-mechanic system, light source, and a software development kit. This kit provides an affordable means for users to get started in AO and minimize their time to realize an operational AO system. Additionally, Thorlabs committed to offering two DM designs, resulting in a cost effective solutions for OEM applications.