Optics and Photonics:

Driving US Competitiveness through Investment in Public-Private Partnerships and Workforce Development

Look around you — your phone, computer, TV — all modern-day technologies made possible largely by photonics. Optics and photonics are the science and application of light, detecting, generating and harnessing light to advance manufacturing, health care and medicine, defense and national security, communications, energy and many other industries.

Without photonics, the world as we know it would not be possible.

Optics and photonics research and technologies are essential to our nation's leadership in global markets in nearly every industry sector. US leadership in optics and photonics research and technologies is paramount for economic growth, American jobs and continued commercial success in the global marketplace. Historically, the United States has been the world leader in deploying photonics research to power cutting-edge technologies, but global competition has put our leadership position at risk, causing a substantial loss of global market share to overseas competitors as well as thousands of US jobs.

New opportunities arising from photonics, such as 3D printing, solar power, nuclear threat identification, cancer detection and the growth of the Internet, offer the potential for even greater societal impact in the next few decades. US investment in photonics-driven fields will create jobs and grow our economy, protect and improve the lives of our people, and position the United States as a global technology leader.

To this end, concerted efforts by United States industry, academia and the federal government are needed to work in partnership to invest in critical optics and photonics research and technologies that would enhance innovation in private and public sector laboratories and promote the nation's continued competitiveness in sectors across the global economy. Concerted investment is especially needed to bridge the existing gap between basic research and the development of technologies. Further, while maintaining US technological leadership can be accomplished in the near-term through public and private investment in infrastructure and research, the greatest challenge is our nation's ability to sustain a well-trained workforce into future generations.

The National Photonics Initiative (NPI), a collaborative alliance seeking to raise awareness of photonics and drive US funding and investment in key photonics-driven fields, is committed to working with the federal government to reposition the United States as a leader in photonics research and development by driving funding and investment in the five areas of photonics critical to maintaining US competitiveness and national security, as well as to developing federal programs that encourage stronger partnerships between US industry, academia and government labs. A recent example of this collaboration is best demonstrated by the NPI's work with federal agencies, congressional leaders, industry and academia on the recently announced Integrated Photonics Institute for Manufacturing Innovation (IP-IMI).

But private and public sector investment in optics and photonics does not end with the establishment of the IP-IMI. With current demand exceeding the supply of a trained workforce and the forecast calling for an increased demand for optics and photonics research, technologies and its commercial applications,

the NPI identifies a need for and an opportunity to invigorate technical, hands-on learning in the United States.

Additionally, advanced optics and photonics research and technology underpin many large-scale technological challenges such as mapping neurons in the brain, monitoring energy and the environment and developing next generation high performance computing. The NPI encourages collaboration between government and optics and photonics industry to identify and strive for joint technology goals that ensure development of critical technologies and lead to commercialization.

Specifically, the NPI recommends:

1. *Establishing an education-to-workforce pipeline* with increased industry internship opportunities for optics and photonics technicians in community colleges, and modernizing educational laboratories for optics and photonics in four-year universities.
2. *Co-developing photonics technology road maps* to advance common interests and goals between public and private institutions.

Concerted efforts around these two recommendations will dramatically improve the translation of federal research results into innovative commercial applications for the benefit of the nation's economy, security, health and competitiveness. For more detailed information about these recommendations, please review Attachment I: NPI Recommendations for advancing next generation technologies and ensuring a technically trained US workforce.

Proposed Legislation

The US Senate Committee on Commerce, Science and Transportation has jurisdiction over key civilian research and development agencies. The NPI proposes legislation to facilitate private and public collaboration on priority optics and photonics research and technology; enhance opportunities for optics and photonics applications across agencies and for multiple uses; establish a hands-on education to workforce pipeline; and help to ensure US competitiveness in optics and photonics.

TITLE I. ROLE OF OPTICS AND PHOTONICS TECHNOLOGY IN TECHNOLOGY INNOVATION.

SEC. 1. FINDINGS.

Congress makes the following findings –

i. Optics and photonics is the science and application of light, serving as the backbone for modern national security applications, industrial controls, manufacturing, medicine and consumer and business products;
ii. Optics and photonics are fundamental, enabling technologies critical to our nation's leadership in nearly every industry sector including energy, telecommunications and information technology, defense and national security, health and medicine and manufacturing;
iii. Public companies focused on optics and photonics in the United States enable more than $3 trillion in revenue annually and create more than 7 million public company jobs;
iv. Optics and photonics are recognized globally as critical technologies and governments including Germany and China have aggressively directed funding to advance their optics and photonics industries which have resulted in a number of critical energy

manufacturing jobs and companies moving from the United States to overseas markets; and

v. Partnerships between US industry, academia and the federal government are needed to invest in vital optics and photonics research and development, enhance innovation in private and public sector laboratories and promote continued US competitiveness.

SEC. 2. AUTHORIZATION AND REPORT TO CONGRESS.

(a) The Secretary of Commerce, the Director of the National Science Foundation and the Administrator of the National Air and Space Administration separately shall –

i. Survey and identify photonics, and optics and photonics-related programs, within their respective agencies;
ii. Make available surveys undertaken in Sec.2(a)(i) to other agencies for the purpose of investigating the application of advanced optics and photonics technologies for multiple purposes;
iii. Work in partnership with the private sector to leverage knowledge and resources to maximize opportunities for optics and photonics innovation including the development of high-value technology road maps;
iv. Explore priority research and development opportunities including but not limited to federal and private sector-sponsored internships to ensure a highly trained optics and photonics workforce in the United States; and
v. Assess existing programs and explore alternatives to modernize photonics laboratory equipment in undergraduate institutions in the United States to facilitate hands-on learning.

(b) The Secretary shall report to Congress results of SEC. 2(a) within one year after enactment of this Act.

SEC. 3. AUTHORIZATION OF APPROPRIATIONS.

No separate appropriations will be authorized to carry out this Title.

Conclusion

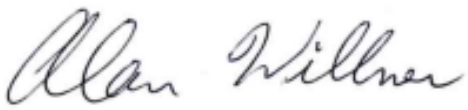
On December 20, 2013, the United Nations General Assembly 68th Session proclaimed 2015 as the International Year of Light and Light-based Technologies (IYL 2015). Much of the world has long recognized the promise of light and many countries have significantly increased their national commitments to the optics and photonics industries, threatening our nation's historic leadership in this field. By uniting the public and private sectors to develop critical technology road maps, and by creating educational opportunities that will inspire a more skilled workforce, our nation can regain its leadership position in this critical, enabling technology.

The NPI was created in 2013 to unite our nation's experts in industry, academia and government to identify and advance areas of photonics critical to saving lives, improving the economy, creating jobs and sparking innovation for future generations. Led by a coalition of scientific societies, including the American Physical Society (APS), the IEEE Photonics Society, the Laser Institute of American (LIA), the Optical Society (OSA) and SPIE, the NPI seeks to raise awareness about photonics; increase collaboration

and coordination among US industry, academia and government; and drive US funding and investment in areas of photonics critical to maintaining US competitiveness and national security.

On behalf of the NPI, we welcome the opportunity to strengthen dialogue with the federal government and jointly develop sustainable solutions for improving the translation of photonics research results into innovative commercial applications to improve our nation's competitiveness. With reach to experts in both academia and industry, and across all fields from defense to medicine, the NPI seeks to be a resource to the federal government as it explores the best path forward. For more information on the NPI, please visit www.lightourfuture.org. For any questions about the proposals and recommendations in this submission, please contact Laura Kolton at lkolto@osa.org, or Krisinda Plenkovich at krisindap@spie.org.

Respectfully submitted,



Alan Willner, PhD
Chair, NPI Steering Committee

Attachment I: NPI Goals and Recommendations for Ensuring a Technically Trained US Workforce and Advancing Next Generation Technologies

Ensure a Trained Photonics Workforce

While maintaining US technological leadership can be accomplished in the near-term through targeted public and private investment in infrastructure and research, the greatest challenge is our nation's ability to sustain a well-trained workforce into future generations. The current demand for hands-on learning at the community college and undergraduate levels to meet industry needs will increase dramatically with the application of optics and photonics technologies in next generation products and services across economic sectors.

The National Photonics Initiative (NPI), a collaborative alliance among industry, academia and government seeking to raise awareness of optics and photonics' foundational role in advancing technology, identifies a demand for and an opportunity to invigorate technical education in the United States by championing programs that support applied and hands-on learning opportunities for students.

- **Increase Community College/Industry Partnered Technician Training.** The preparedness of the American workforce in the physical sciences and engineering has become a matter of national security and economic competitiveness. Further, according to a 2012 study by the national Center for Optics and Photonics Education (OP-TEC), only 300 optics and photonics programs focus on the optics and photonics industry across economic sectors. The NPI anticipates further growth in demand for specialized optics and photonics technicians in the United States and worldwide.

  The NPI recommends that targeted private and federal investment be made to establish and fuel an optics and photonics-focused, nationally networked, public-private partnership in technician education. Successful but isolated individual programs currently exist between community colleges and the optics and photonics industry in a few areas of the country. Providing federal internship grants to companies or community colleges across a national network will facilitate a nationwide employment pipeline and bring together qualified optics and photonics technical students with US industry. In addition, the expected reduction in the size of the military services — particularly the planned reduction of 40,000 soldiers in the Army — creates a natural pool of qualified candidates available to enter into the optics and photonics industry. The result will be increased opportunities for hands-on apprenticeships and a workforce pipeline that keeps both well-trained talent and critical technology in the United States.

  Federal programs offering millions of dollars for the improvement of the nation's community college system exist with hundreds of millions more proposed. Initiatives such as the National Science Foundation's (NSF) Advanced Technological Education (ATE) program, the Department of Labor's (DOL) Trade Adjustment Assistance Community College and Career Training (TAACCCT) program, and DOL's Ready to Work program show the government's commitment to improving the effectiveness of the US community college system. The Department of Defense

(DOD) and the Department of Veterans Affairs (VA) have a number of programs designed to provide military personnel and veterans with the resources and support they need to attain advanced degrees and technical certification. In addition, there are various scholarship programs from students in key science, technology, engineering and mathematics (STEM) fields, including DOD's SMART (Science, Mathematics and Research for Transformation) program.

While NPI's proposed industry-partnered technician training program could nest within an existing agency initiative, the NPI recommends a dedicated program to allow a geographically diverse vocational optics and photonics internship model to grow and thrive. The NPI believes that the DOD and VA should work with inter-agency partners, military and veteran support organizations, and the optics and photonics communities to ensure military personnel who are separating from DOD are aware of career opportunities within the optics and photonics industry. In turn, the NPI is prepared to support a stand-alone optics and photonics vocational program by leveraging its scientific societies' established platforms and resources.

- **Modernize University Laboratory Education.** The United States was known around the world for its culture and practice of "hands-on" problem solving introduced to undergraduate students and a critical link in a well-trained and technically proficient workforce. However, today, nearly 70 percent of US physics departments offer two or fewer laboratory courses after the first year of introductory curricula and nearly 20 percent are unable to offer any. The downward trend of funding and course offerings in four-year colleges across the nation impacts the optics and photonics community disproportionately because of the industry's demand for employees at all levels with sound optics and photonics laboratory skills. If the United States is going to compete globally in high-tech areas like optics and photonics, the American culture of hands-on problem solving must be restored.

  The NSF Improving Undergraduate STEM Education (IUSE) program is tasked with funding research and tracking pedagogies in undergraduate STEM laboratory curricula. This focus emerged from a program that previously had been dedicated to funding hardware updates and maintenance, but unfortunately lost favor and vanished from the NSF budget line. The equipment purchased using this phased-out NSF funding allowed small science departments, which graduate the majority of students nationally, to offer a fully equipped curriculum competitive with large, elite departments. Undergraduate physical sciences departments, regardless of size, need to adequately prepare their students to contribute at a high-level as they pursue their careers — and this includes hands-on, laboratory training.

  The NPI recommends the restoration of critical laboratory equipment and instrumentation funding through the IUSE program. In order to strike a balance between funding for pedagogy and infrastructure, the NPI recommends an even split of this allocation with 50 percent matching funds required for infrastructure grants. The NPI also recommends exploring other agency programs that can fund optics and photonics lab equipment for undergraduate study. Hands-on experience with modern equipment at the undergraduate level will help to ensure that the high-tech talent pipeline, particularly in optics and photonics, is open and robust in the United States.

Identify and Facilitate Public-Private Collaboration to Advance Next Generation Technologies through Optics and Photonics

We live in an era in which (a) advanced technology affects many aspects of our lives nearly every minute; (b) many of these technologies did not exist until recently; (c) technological advances occur on ever-shrinking time scales; and (d) many countries around the world are investing aggressively to secure their role in the next technological breakthroughs and subsequent commercialization.

Defense and national security, data centers, high performance computing (HPC), personal electronics, medical applications and energy monitoring and extraction impact trillions of dollars within the US economy. All of these key application areas rely on the integration of optics and photonics with electronics. To date, the United States has held a leadership position in this area, with renowned industrial companies and academic institutions recognized for their excellence in innovation. However, strategic planning and investment are crucial for us to remain at the forefront of the latest technology revolution. New approaches to optoelectronic integration have developed over the past decade. These technical advances, combined with better visibility on the demands of the end-user applications, create an urgent need to develop the advanced manufacturing capability for making commercial products that meet both the price and performance criteria demanded by these diverse markets.

- **Support the newly announced Integrated Photonics Institute for Manufacturing Innovation (IP-IMI):** Established to bring government, industry and academia together, the IP-IMI will advance state-of-the-art photonics technology and better position the United States relative to global competition in this vital field. The IP-IMI was awarded to the Research Foundation for the State University of New York (RF SUNY) who was joined by a consortium of 124 companies, nonprofits and universities across the United States to secure the IP-IMI from DOD. The public-private partnership will bridge advanced research and commercial product development, yielding critical defense and telecommunications advances — while also investing in education and workforce development to train and position the next generation of manufacturers in integrated photonics. At a total investment of $610 million — $110 million in federal funds and $500 million in non-federal contributions — the IP-IMI is the country's largest public-private commitment for the President's National Network for Manufacturing Innovation (NNMI).

  Well before the IP-IMI selection process began in June 2014, the NPI worked with the administration and federal agencies to develop a roadmap ("National Photonics Prototyping and Advanced Manufacturing Facility") outlining critical technology challenges and recommendation for strategic investments in infrastructure to support a vertically integrated photonics manufacturing institutes that bridges the gap between research and development. As the project now moves from idea to reality, the NPI is prepared to help the IP-IMI, and by association work with DOD, by leveraging the platforms, programs and resources of its scientific societies, and will continue to serve as an advocate for the photonics community and a private sector resource for DOD.

  To ensure the long-term success of the IP-IMI and future photonics Institutes for Manufacturing Innovation (IMIs), additional investment must be made. As a result of the enabling capabilities

of photonics, numerous technology areas outside of those supported through the IP-IMI would benefit from research and development investment. Selected highlights of such areas that would benefit include:

- Health: remote diagnosis of traumatic injury, field-deployable treatment, field assessment of biological and chemical threats, portable personal health monitors, early diagnosis of many life-threatening diseases.
- Manufacturing: optical elements with enhanced focusing resolution, machine-vision technology for low-cost, high yield of mass-produced devices, 3-D printers for rapid prototyping, high power laser systems for welding and cutting of high-strength, light-weight materials.
- Sensors: low-cost, environmental and climate sensors, down-hole monitoring of oil and gas wells for exploration and efficient and safe energy extraction.
- Energy: efficient energy transfer/switching devices, materials that maintain performance at high temperatures, highly efficient energy generation from solar sources.
- Displays: cost-effective high-resolution heads-up displays, next-generation 3-D, 4K displays.

Much like the nature in which the IP-IMI came to be, the NPI encourages the federal government to partner with industry and academia to develop roadmaps for the advancement of those fields listed above.

- **Identify and support development of new photonics technologies to advance the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative:** On April 2, 2013, President Barack Obama launched one of his flagship programs, the BRAIN Initiative, to "accelerate the development and application of new technologies that will enable researchers to produce dynamic pictures of the brain that show how individual brain cells and complex neural circuits interact at the speed of thought." In response to President Obama's charge, the National Institutes of Health (NIH) convened a panel to recommend how best to proceed. The panel recommended a focus on accelerating the development of technology necessary to acquire fundamental insight into how the nervous system functions in health and disease. Photonics forms the basis of almost all medical diagnostic imaging devices: CT, MRI, X-ray imaging, microscopy, cell sorting and most devices used in ophthalmology. Further, photonics will play a pivotal role in achieving the goals of the BRAIN Initiative.

  In 2014, the NPI founded an innovative multidisciplinary industry cohort, the Photonics Industry Neuroscience Group, to work collaboratively with the research community and federal government on next generation imaging technologies in support of the federal government's BRAIN Initiative. The NPI united industry leaders across optics and photonics fields to offer strategic guidance and recommendations for federal, private and joint funding opportunities in key optics and photonics areas where advances in technology and training would significantly accelerate progress toward achieving the BRAIN initiative goals of mapping neurons and circuits.

Current technology allows monitoring of only several dozen neurons simultaneously of the 100 billion neurons present in a human brain. Researchers have been able to use existing imaging instruments to locate portions of the brain that respond to simple stimuli (such as different aromas or a bright light) and in a few cases map connections between these regions and other important regions of the brain, showing their relationships. As we expand the volume of the brain and the number of monitored neurons to several thousand we can begin to understand how the neural networks respond to more complicated sensory stimulus patterns, learning how the brain deciphers language and intricate visual images, acquires complicated new skills, and forms complex memories — all at the fundamental neural network level.

The development of new optics and photonics technologies is critical to realizing the translational value of the BRAIN Initiative. Once mapping and neuron control are achieved, the neuroscience community should be able to better understand the disruption of traffic caused by a stroke or traumatic brain injury and accelerate the redirection of neural signaling or traffic around these damaged regions to speed recovery from injury. We will be able to pinpoint the location and potentially prevent the explosions of local neural activity that cause epileptic seizures or the pulsation in neural signaling causing the tremors of Parkinson's disease. We can better understand the hyper neural activity that may be related to autism and the origin of many learning disabilities such as dyslexia. And, when the capability of controlling neural traffic is fully realized, we will be able to insert interface devices that can connect external sensors directly to the nervous system, restoring sight in certain types of blindness through artificial retinas or regaining muscle movement and providing prosthesis control to paralyzed patients.

The NPI Photonics Industry Neuroscience Group believes federal, private and joint road mapping and investment will significantly accelerate the progress toward translating science into applications to treat the complexities of the brain. Further, educational investment is needed to facilitate the transfer of technology and know-how from academic to commercial environment. This can be accomplished through the sponsored intern programs for students and sponsored visiting industrial scientist programs to support academic/industry collaborations. The NPI Photonics Industry Neuroscience Group is currently exploring opportunities through the Grant Opportunities for Academic Liaison with Industry (GOALI) program and the Intergovernmental Personnel Act (IPA) as avenues to bridge the gap from academia to application.

- **Identify and support the development of photonics architecture in next generation High Performance Computing (HPC):** HPC is of critical importance to the worldwide economic competitiveness of our nation, enabling advances from discovery in basic and applied sciences to product design and simulation and underlying efficiency advances in everything from the delivery of optimal medical treatments to socio-economic networks. Furthermore, the role of HPC in addressing threats to our national and economic security, whether physical or cyber in nature, cannot be overstated.

  While HPC systems and data centers have many similarities in employing large numbers of processing nodes connected through a network, and some of today's mega-data centers have node counts that exceed that of most supercomputer systems, there are significant differences.

HPC systems are usually intended for running a single large application at a time while data centers run many small computations concurrently. This results in key differences in network bandwidth and latency requirements. Large-scale data centers with specific applications have made great progress in scaling out massive numbers of small workloads on highly parallel but lower performance compute nodes. However, there are many existing and evolving workloads for which these techniques simply do not work. This includes not only today's scientific workloads, but new, dynamically changing, big data workloads that will be of critical importance in areas such as cybersecurity, fraud detection and data analysis. Maintaining highly connected, low-latency systems is critical to continued progress in HPC on these workloads. However, inter-node communication is expensive in terms of latency and power as well as cost, requiring a leap in technology capabilities to feasibly meet the needs of HPC.

The United States has dominated the HPC landscape in the past, but this can no longer be said, with five of the top 10 HPC systems operating outside the United States. For the second time, China's top computer, the Tianhe-2 supercomputer, has captured and retained its position as the world's number one system. China has invested heavily in HPC through its National University of Defense Technology. It is also investing in the "1000 Talents Repatriation Program," as well as in silicon photonics and interconnect technologies. Japan has historically had a very strong HPC program as well, rivaling that of the United States since the mid-1990s, and continues to have coordinated efforts in the design of HPC processors, systems and optical interconnects. Additionally, the European Union (EU) typically has programs that mirror or exceed the United States, with a continuing presence on the world's top 10 supercomputer list.

As of June 2015, the only new entry to the top 10 HPC was Saudi Arabia's Shaheen II (number seven in the top 10). Furthermore, the other nine systems in the top 10 were all installed in 2012 or earlier, reflecting a slowing trend in HPC, and particularly in US HPC, that began in 2008. Examining the top data analytics of HPC machines from the most recent Graph 500 list, one finds three of the top 11 systems reside in Europe, two in the United Kingdom, three in the Pacific Rim, and two in the United States. This again emphasizes increased importance of such applications on a global level and further evidence of waning US dominance.

It is worth noting that all of the top 10 computing systems use US-designed processors and commodity memory, highlighting the relative importance of interconnect and system-level integration. They also incorporate photonic interconnects in the design, but simply as "better wires" — point -to-point links formerly connected with copper cable that have been replaced with fiber-optic cables without any significant changes to the high-level architecture. As a result, the NPI believes that there is a rare and significant opportunity to harness current and future innovations in optical interconnect components and infrastructure that could transform HPC and restore our nation's competitiveness in the global arena.

To achieve strong gains in cost, power and latency, the NPI recommends targeted private and public sector investments in photonics. Embracing photonics as the primary physical-layer communication can provide the massive and flexible bandwidth needed to both scale existing workloads and address emerging workloads, as well as preserve existing high-level programming

models as the underlying technology scales. Taking advantage of these new photonics technologies will require a significant investment in new network and system architectures and their corresponding control structures as well as considerable co-design. It is worth noting that all of the current top 10 HPC systems incorporate photonic interconnects in the design, but simply as "better wires," replacing copper cable with fiber-optic cables without significant changes to the high-level architecture. As a result, the NPI believes that there is a rare and significant opportunity to harness current and future innovations in optical interconnect components and infrastructure that could transform HPC and restore our nation's competitiveness in the global arena. A US Center of Excellence or other mechanism to bring together private and public resourced dedicated to the research and development of HPC system architecture and software that incorporate integrated photonics at a fundamental level would inspire and enable revolutionary applications of information technology to advance national security and economic competitiveness objectives in the United States.

- **Explore new applications of existing photonics technologies and support development of advanced optical sensors for monitoring energy and the environment**. Advanced light-based (photonic) detection and monitoring systems can be used to increase reliability and efficiencies of renewable and nonrenewable energy at all stages of coal, oil and natural gas life cycles; hydroelectric dam safety and efficiency; wind farm safety, and much more. Significant reductions in energy costs and remarkable improvements in performance can be achieved through the use of advanced photonic sensor technology.

  Partnerships between US industry, academia and the federal government are needed to invest in vital optics and photonics research and development, enhance innovation in private and public sector laboratories, and promote continued competitiveness in the energy sector. Technologies already in development in non-energy fields such as light-based radar (LADAR), an electro-optic based technology that can map vibrations rapidly, remotely and without attaching equipment to structures, could be advanced for use on hydroelectric dams for structural health on demand and tune flow rates for maximum efficiencies. Similarly, fiber optic bragg grating (FBG) could be advanced to more reliably measure stretching, bending, vibration and other physical changes in large wind power blades. Concerted private sector and federal investment in the United States is especially needed to develop next-generation optical sensors for life cycle monitoring of all energy sources including solar, wind and hydropower in areas of efficiency, infrastructure, supply and accountability and to contribute to the modernization of energy delivery infrastructure in the United States.

  Currently, public companies focused on optics and photonics in the United States enable more than $3 trillion in revenue annually and create more than 7 million public company jobs. Investment in next-generation photonic sensing would strengthen United States' leadership in this field, reduce the burden of energy costs through improved efficiency and greater resource availability in energy production and use, and spur job creation and economic growth.

  Early adoption of photonic sensing technologies has already begun to bring marked improvements in energy extraction and transportation applications. The NPI sees an opportunity

for the United States to leverage this promising start to bring significant reductions in both energy costs and environmental impact and to establish the nation as the global leader in energy sensing. The NPI recommends pursuing private-public collaborations to ensure investment is made in priority optical sensing technologies. Utilizing current advanced photonics technologies and developing next-generation sensing technologies will be critical to protecting energy sources, increasing efficiencies, and contributing overall to domestic energy independence and environmental sustainability goals. At the same time, determining a baseline of optics and photonics-related research within the Department of Energy (DOE) and working with the private sector will help direct private and federal investment in needed areas and keep optics and photonics research and technologies in the United States.

The potential rewards of a broader public-private undertaking in sensor development for energy are enormous. With large savings in exploration costs, dramatically improved safety in production and storage, and lowered emissions at stake, investing in a public-private initiative to develop these critical photonic technologies will make the United States the leader in monitoring energy extraction and utilization from the oil and gas fields to the engine.