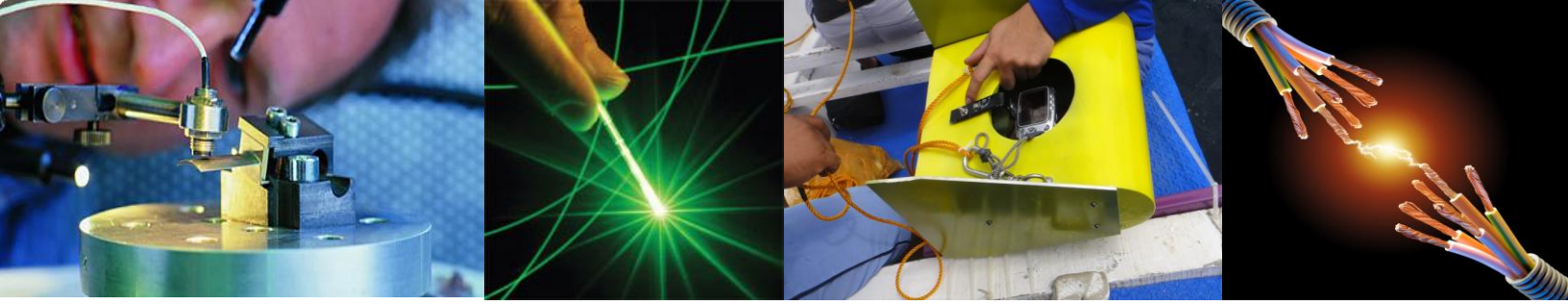

PHOTONICS SECTORAL PLAN
(2014-2020)

Department of Science and Technology
PHILIPPINE COUNCIL FOR INDUSTRY, ENERGY AND EMERGING TECHNOLOGY RESEARCH AND DEVELOPMENT (PCIEERD)

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Department of Science and Technology
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PHOTONICS – AN EMERGING TECHNOLOGY

I. BACKGROUND

A. Definition

Optics and photonics is the science and application of light. More specifically, optics is a branch of physics that examines the behavior and properties of light and the interaction of light with matter. This includes the entire spectrum of visible light and other invisible light, such as microwaves and x rays. Photonics is the science and technology of generating, controlling, and detecting photons, which are particles of light[1].

The invention of the laser in 1960 started the field of photonics. Since then, photonics has played a crucial role in the rapid development of fast and reliable telecommunication systems and multimedia platforms that have resulted in a wide array of high quality yet affordable consumer products and services such as cellular phones, VCD players, high definition display systems, the Internet, and personal computers.

B. Significance

Photonics and the world today

The Harnessing Light Committee of the US National Research Council authored an overview report on ***"Optics, Photonics, Essential Technologies for Our Nation (2012)".*** The report cited Japan and Germany as countries that have advanced advanced their already strong optics and photonics industries during the past 14 years. While other countries rapidly developed technical expertise and manufacturing leadership. In many cases the successes were based on formal policy agendas. In 2010, the European Commission designated photonics as one of only five key enabling technologies for future prosperity (advanced manufacturing was recently added as a sixth focus area).

Eugene Arthur, CEO of the SPIE, the international society for optics and photonics, stated ín the report that:

> *"Education is inextricably linked to innovation. The importance to the nation of maintaining a strong educational infrastructure should not be understated. The optics and photonics industry is sizable on its own, but mastery of the technology also contributes to innovation in most other high technology sectors. This is because, as both reports show, photonics is a pervasive enabling technology. Advances in the field have a broad impact from health and energy to defense*

[1] National Academies booklet "Harnessing Light for America's Technological Future,". SPIE / 1000 20th St / Bellingham WA 98225 USA/ www.opticsandphotonics.org.

and manufacturing. Communicating that impact – to policy makers, heads of companies large and small, investors, and young people planning careers – must be a priority for each of us.

The Harnessing Light Report 2012[2] provided an overview how optics and photonics could be used for the nation, as follows:

1. Impact of Photonics on the National Economy

Optics and photonics are central to modern life; these technologies are needed to make and inspect the integrated circuits in nearly every electronic device we use. Moreover, optics and photonics technologies are used in the displays on smart phones and computing devices, optical fiber that carries the information on the Internet, advanced precision manufacturing and metrology, enhanced defense capabilities, and a plethora of medical diagnostics tools. New opportunities arising from optics and photonics offer the potential for even greater societal impact in the next few decades, including solar power, high-efficiency lighting, genome mapping, medical devices, and new optical capabilities that will be vital for supporting the continued exponential growth of the Internet.

2. Communications, Information Processing and Data Storage

Grand Challenges: invent technologies for the next factor-of-100 cost-effective capacity increases in optical networks. Develop a seamless integration of photonics and electronics components, as a mainstream platform for low-cost fabrication and packaging of systems on a chip.

Optics and photonics have increased the capacity of the Internet by nearly 10,000-foldover the past two decades, and bandwidth demand is expected to grow another 100-fold, possibly more, over the next 10 years. A technology wall is currently blocking the next factor-of-100 growth. Without optics, the Internet as we know it would not exist, and it may not be able to keep up with growing demands without a breakthrough.

Data centers, such as those used by Amazon and Google, are located overwhelmingly in the United States. These data centers will grow dramatically over the next decade, and they will be major consumers of new communications technologies.

[2] http://spie.org/Documents/AboutSPIE/PDF/HLII-OpticsandPhotonics.pdf

3. Defense and National Security

Grand Challenge: develop military platforms capable of wide area surveillance, exquisite object identification, high-bandwidth free-space communication, laser strike, and defense against missiles.

It is becoming increasingly clear that sensor systems will be the next "battleground" for dominance in intelligence, surveillance, and reconnaissance (ISR), with optics-based sensors representing a considerable fraction of ISR systems. Ubiquitous knowledge across an area provides a major defensive advantage, along with the ability to communicate information at high bandwidths from mobile platforms. Optical sensing technology can also identify chemical, biological, and nuclear threats, an ability fundamental for homeland security. Defense against missile attacks is a significant security need with laser weapons systems poised to cause a revolution in military affairs. Laser weapons can provide a substantial advantage to U.S. forces. There are also potential synergies from fully merging optical surveillance technology, laser weapons technology, and free-space laser technology.

4. Energy

Grand Challenge: achieve cost parity across the nation's electricity grid for solar power versus new fossil-fuel-powered electric plants by the year 2020.

Solid-state (SS) lighting is clearly the next step in lighting. It is more energy efficient, generates less heat than current options and is becoming increasingly cost-competitive for general lighting applications. The record efficiency for SS light today is 231 lumens per watt, compared to 4-15 lumens per watt for a conventional incandescent bulb. Cost is presently the main issue preventing widespread adoption of SS lighting: while lower electricity use and longer life result in a net savings, bulb cost is higher. Major progress is being made, however, and the U.S. needs to exploit its current expertise in SS lighting to bring this technology to maturity and to market.

5. Health and Medicine

Photonics technologies are already essential for delivery of effective and low cost diagnosis, treatment and prevention of disease. Applications in medicine span from elective sight correction and minimally invasive surgeries to characterization of the human genome and bedside clinical analyses in the future. Light-based technologies will also help optimize individual responses to medications while minimizing side effects: health care costs will be reduced as costly late intervention procedures are curtailed and hospital stays shortened. Medical imaging, which is widely used and is still a rapidly developing area, is key to many health-related needs, both for understanding the status of a patient and for guiding and implementing corrective procedures. Real-time images using

fluorescent biomarkers that selectively bind to tumor cells provide a clear demarcation between healthy and diseased tissue during surgery. Biophotonics research is driving advances that, together with improved medical instrumentation, will save lives and provide business opportunities. Optics and photonics (sources, materials, imaging, and microfluidics) provide unprecedented speed, sensitivity, selectivity and resolution for biomedical instrumentation to aid the physician. Opportunity lies in the development of new instrumentation for simultaneous measurement of all immune system cell types in a blood sample and instruments for detecting antibodies, enzymes, and important cell phenotypes. Remaining a world leader in medical innovation while simultaneously bringing down costs requires continued investment in R&D.

6. Advanced Photonics Measurements and Applications

Precise measurements (metrology) impact our daily lives. The ability to make precise and reliable photonics measurements is what underlies areas as diverse as global positioning systems (GPS), communications, and satellite and aircraft positioning and manufacturing.

Today's integrated circuits found everywhere from cellphones and tablets to automobiles could not be manufactured without optical sensing and metrology. The entire consumer electronics industry relies on optical sensing and metrology. Advanced metrology and precision laser printing have enabled continuing improvements in the level of detail (number of transistors) that can be built into new integrated circuits. Processor power and memory capacity have increased dramatically while cost has remained flat. Continued leadership in the field of nano/microelectronics among others will depend on further advances in metrology and sensing. The U.S. will need to support fundamental research in this area to remain at the forefront of applications in sensing, imaging, and metrology, which are all intertwined. The proliferation of mobile low-cost sensors connected to high-bandwidth data-transfer capability (e.g., cell phone cameras) will allow rapid growth of applications otherwise not economically viable like remote point-of-care diagnostics and environmental monitoring across large areas (distributed sensing). There are opportunities in niche applications based on combining consumer (high-volume low-cost) components with cutting edge research that could produce low volume but important products such as portable and/or remote health monitoring and diagnosis. Highly chemical specific and low-cost biochemical sensing will be a particularly important application.

7. Advanced Manufacturing

Grand Challenge: develop optical sources and imaging tools to support an order-of-magnitude increased resolution in manufacturing.

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8. Displays

12 of the 50 best inventions of 2011 listed by TIME magazine included optics as a key component.

Liquid-crystal displays (LCDs) have become ubiquitous, showing up in everything from cell phones and e-readers to computers and TVs. LCD technology consumes a substantial amount of energy: backlighting alone uses 25%-40% of total display power. Although they are less developed than LCDs, the use of organic light emitting diodes (OLEDs) is growing, and these devices promise much-reduced energy consumption. Flexible displays, made from thin polymer films or other thin-fi lm technologies, are an emerging technology with the potential to replace paper in media like newspaper, magazines, and reports. These lightweight, reusable displays could communicate with servers to download and display information. Flexible displays remain a relatively unexplored opportunity with considerable potential in consumer and defense applications. Although primarily used for military applications today, 3D holographic displays are another area where we expect to see strong growth in areas like entertainment and telemedicine as the technology becomes more widely available and costs decline. Traditional LCD display manufacturing has migrated outside the U.S., but future display technologies could provide new leadership opportunities, including energy efficient backlighting, OLED and flexible displays, and real-time holographic displays. While touch display technology has already reached the marketplace, significant innovations and improvements are under development that will create other opportunities. Future displays of all types will have to incorporate materials that are low-cost, durable, “green,” and easy to process.

C. Photonics Applications

C.1. Application Segmentation

The Australian Photonics Technology Roadmap laid out a long list of applications of photonics technologies and products. It states that there is hardly any industry that does not benefit from Photonics. It includes multiple diverse systems as part of an overall solution that could fuel economic growth in the years to come.

1. Health and Well-being
   - Diagnostics: non-invasive imaging
   - Treatment: laser surgery (drilling, cutting) light therapy
   - Drug delivery
   - Biometrics

2. Agriculture, Mining and Environment
   - Laser guidance (farm machine automation)
   - Imaging (water conservation, crop management and pest and livestock management)
   - Sensing (surveying)

3. Energy
    - Sensing for process automation
    - Photovoltaics
    - Fuel Analysis
    - Solid state lighting
    - Energy infrastructure security

4. Communications

5. Automative
    - Lighting
    - Navigation Systems
    - On-board communication systems
    - LIDAR for parking and highway cruising
    - On-board entertainment systems
    - Drive-by-wire

6. Logistics
    - Goods tracking
    - Traffic monitoring

7. Defense and security
    - Command, Control, Communications, Computers and Intelligence (C4I)
        - Secure Communication (Quantum Computing and Quantum Cryptography)
    - Surveillance, Targeting Acquisition and Reconnaissance
        - Visual sights and periscopes
        - Laser range finding
        - Laser imaging
        - Laser designation
        - Remote sensing (LIDAR) or a passive IR sensor
        - Forward looking Infra-red (Thermal) imaging systems
        - Image intensified (night vision) sights
        - Displays
        - Perimeter security (IR sensors, image processing)
        - Checkpoint / Airport security (Terahertz imaging, image processing)
    - Electronic warfare
        - Optical Fibre RF Signal processing and transmission
        - Electro-optical countermeasures (EOCM)
    - Smart Home
        - Computing, storage, communications, entertainment
        - Lighting
        - Sensing
        - Displays
        - Security

8. Manufacturing and Automation
        - Cutting, Welding and Micromachining
        - Surface reconstruction

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- Imaging
- Safety (e.g. light curtains)
- Lithography

Japanese Photonics Technology Industry, a defacto standard adopted internationally for the segmentation of the photonics industry at a systems level.

- Communications (all systems related to fibre optic and free space optical communications)
- Optical storage (CDs, DVDs, magneto-optic discs, future holographic storage: the media, and the devices that read and write on that media)
- I/O (printers, scanners, digital imaging)
- Displays (all displays with the exception of cathode ray tubes
- Energy applications (high power laser applications, photovoltaics)
- Optical sensing, test and measurement
- Others: solid state lighting, integrated optics devices, lithography

C.2. Component Segmentation

Photonics products are made from a combination of one or more basic components, as OIDA Japan has categorized as follows:

- Sources
- Detectors
- Fibre and cable
- Connectors
- Passives
- Displays
- Solar Cells
- Others

Variations in these components are shown in the table below

Mature Components	Emerging Components
MOEMs VCSELs RF photonics Light emitting diodes / laser diodes Photodetectors Passive Components Hetero Integration	Nanotechnology Terahertz imaging Micro resonators 3D imaging Photonic bandgap materials Quantum dot lasers Organic semiconductors Lasers: fs, high power, UV and visible, mode-locked Monolithic integration Organic light emitting diodes Silicon photonics

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D. Researchable Areas

Nature Photonics

Nature, a scientific journal identified the following as the emerging researchable areas in the field of photonics:

Researchable Areas:

a. **Disorder**
How light interacts with disordered, aperiodic and strongly scattering media to realize a variety of interesting optical phenomena. Recent developments include photonic quasi-crystals, random lasing, Anderson localization and hyper-transport of light as well as potential applications in imaging and next-generation light sources.

b. **Plasmonics**
Takes advantage of the coupling of light to charges like electrons in metals, and allows breaking the diffraction limit for the localization of light into sub-wavelength dimensions enabling strong field enhancements. Recent developments in the field including, non-linear plasmonics, acousto-magneto effects, plasmons on graphene and bio-sensor applications.

c. **Mid-Infrared Photonics**
The mid-infrared spectral region of 2-20 μm contains strong characteristic vibrational transitions of many important molecules as well as two atmospheric transmission windows of 3-5 μm and 8-13 μm, which makes it crucial for applications in spectroscopy, materials processing, chemical and biomolecular sensing, security and industry. Recent developments include sophisticated laser technologies such as quantum cascade lasers, fibre lasers and frequency combs, and plasmonics that can be exploited in the mid-infrared regime.

d. **Photovoltaics**
Photovoltaics is expected to provide the next generation of safe, secure, sustainable and affordable energy. The challenges now are to reduce costs and improve power-conversion efficiencies. This Focus Issue covers cutting-edge solar cell technologies such as polymer, dye-sensitized and intermediate-band solar cells, as well as advanced light-harvesting techniques based on plasmonics and quantum dots. Also included is an interview with the world's largest solar-cell manufacturer on the future of the photovoltaic industry.

e. **Optofluids**
Although the term 'optofluidics' is less than 10 years old, the combination of light and non-solids is being exploited by researchers who are finding applications in fields ranging from imaging, detection of chemical or biological agents and particle control, through to enhancing photonic circuits and energy generation.

f. **Optical Manipulation**
Since their invention 25 years ago, optical tweezers have become the method of choice for physical, chemical and biological experiments that require access to nanometre-scale distances and piconewton-scale forces. The June 2011 issue of *Nature Photonics*has a special focus on optical manipulation that describes how beam shaping, the orbital angular momentum of laser light, nano-optics and optoelectronics could help advance the field, as well as detailing the impact of optical manipulation in single-molecule biophysics.

g. **Next-generation Metrology**
The importance and latest progress of optical frequency combs, optical lattice clocks and quantum metrology, as well as techniques for measuring Casimir forces in complex microstructured geometries and ultrashort laser pulses — all of which are essential for realizing next-generation optical metrology.

h. **X-rays**
New X-ray sources that combine laser technology with novel imaging techniques promise to probe the world around us at atomic spatial and temporal scales. This month, *Nature Photonics* presents a special focus issue dedicated to the latest advances in X-ray optics.

i. **Silicon Photonics**
The field of silicon photonics is gaining significant momentum because it allows optical devices to be made cheaply using standard semiconductor fabrication techniques and integrated with microelectronic chips. This Focus Issue provides a comprehensive collection of articles that review up-to-date progress and the latest news in the field, as well as giving some ideas about what the future has in store and what challenges should be expected.

j. **Quantum Optics**
The optical world has long been the perfect playground for exploring quantum mechanics. Quantum dreams, from communications and teleportation through to computing and metrology, are shaping into reality. This special Focus Issue provides a glimpse into the tremendous progress that has been made and the challenges that remain for the bright future of quantum optics.

k. **Super Resolution Imaging**
Optical imaging beyond the diffraction limit of light is revolutionizing sample analysis in the biological and physical sciences. In this special Focus Issue, a collection of articles are presented, detailing the fundamental physics, the different approaches and the applications where super-resolution imaging can be of help.

l. **Slow Light**
Control over the velocity of light pulses leads to a host of exciting opportunities. In this special issue of *Nature Photonics*, we present a collection of articles that describe the evolution of the field, the fundamental physics and the different approaches that are developing.

III. STATUS OF PHOTONICS SECTOR IN THE PHILIPPINES

In the past five years, forecasted trends and technologies in Photonics revolved in interfaces of the traditional disciplines. R&D efforts in photonics are geared towards the development of photonics-based instrumentation and measurement systems for enhancing environmental monitoring and assessment, for developing a nice expertise (e.g. failure analysis) for the domestic semiconductor industry beyond assembly and improving the technical capability of the biomedical sectors.

A. Strengths

Photonics research is one area where Philippine-based scientists have been able to display creativity and technical expertise that are comparable with the best in the world particularly in laser microscopy, and image and information processing. Researchers at the National Institute of Physics, University of the Philippines Diliman are consistently publishing in the leading scientific journals in optics and applied physics (e.g. *Optic Letters, Applied Physics Letters, Optics Express, Applied Optics)* and some of their works are featured in widely-read technology magazines like *Photonics Spectra* (www.photonics.com) and *Laser Focus World* (www.pennet.com).

B. Past R&D Initiatives

Through the sustained financial support of the PCASTRD-DOST now known as PCIEERD and UP Diliman, the NIP has developed and acquired the technical competence and experience to mentor M.Sc. and PhD students with specialization in photonics.

In 2004, the International Commission for Optics recognized Dr. Caesar Saloma of NIP with the *Galileo Galilei* Award for significant contributions in optics that were achieved under unfavorable socio-economic conditions. Dr. Saloma is the first ASEAN scientist to receive the prestigious award.

NIP Photonics researchers have performed collaborative research with engineers from Intel Technology Philippines on the development of functional infrared emission spectral microscopy for analyzing transistor defects in flip-chip microprocessor samples that are operated under actual field conditions. They have also collaborated with engineers from the Philippine Long Distance Telephone Corporation to analyze the performance of PLDT domestic fiber optics network.

Some of the growth areas in Photonics research include Graduate Programs in the Natural Sciences and Engineering, Semiconductor industry and the convergence of communication and computing.

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C. R&D Projects funded from 2006 to 2013

1. Smart systems for accurate and precise environmental monitoring

   - LIDAR research for detection and measurement of various atmospheric pollutants. ***An Improved Ambient Air Pollution Sensor Utilizing DOAS Technology*** (Dr. James Simpas, Manila Observatory and the Department of Physics, ADMU)
   - ***Automated Rapid Reef Assessment (ARRAS) Program:***
     Project 1. Multi-sensor Reef Assessment (MSRA), Dr. Cesar Villanoy, UP Marine Science Institute (UP-MSI)
     Project 2. Computerized Reef Assessment & Visualization (CRAV) by Dr. Maricor Soriano, National Institute of Physics, UP Diliman

2. Materials and Semiconductors Industry

   Optical processing techniques: holographic data storage, variable elastomeric optical devices. ***Multiplexed Holographic Data Storage Using Elastomeric Phase Masks*** Dr. Raphael Guerrero, Department of Physics, Ateneo de Manila University

3. Biomedical Industry

   Quantum-Dot-Labeled Mouse Embryos Multi-Dimensional Spectral Microscopy
   Dr. Carlo Mar Blanca, National Institute of Physics
   Dr. Cynthia Palmes Saloma, National Institute for Molecular Biology and Biotechnology

   Micro-fabrication and Optical Actuation of Microdevices Using Tailored Optical Landscapes, Dr. Vicente Daria, National Institute of Physics.

   Fluorometric Chemosensor for the Detection of Tuberculosis, Dr. Regina So, De La Salle University

   99mTc and 99mTc Radiopharmaceuticals: Preparation and Quality Control for Nuclear Medicine Application, Dr. Alumanda dela Rosa, Philippine Nuclear Research Institute (PNRI), Department of Science and Technology

D. Infrastructure: Institutions and Human Resources

In the Philippines, R&D efforts in photonics are carried out in UP-NIP and the Physics departments of the Ateneo De Manila University (AdMU), De La Salle University, and University of San Carlos (Cebu), and the Chemistry Department, University of Santo Tomas (UST).

To date, most ISI publications in photonics are based on research works that have been done at NIP, some involving the participation of researchers from other universities. The NIP is the primary producer of MSc. and PhD graduates in photonics in the country today. There are about a hundred PhD's in physics and applied physics and about 15% of those are specializing in photonics ***(Figures still for updating)***.

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The following lists the different Philippine Universities offering Physics Programs:

Schools with BS Physics Degree Programs

- State (8)
  - University of Northern Philippines (Region I)
  - Cagayan State University – CAR (II)
  - Western Mindanao State University - (Region IX)
  - Mindanao State University – Iligan Institute of Technology (Region XII)
  - Mindanao State University - Marawi (Region XII)
  - Polytechnic University of the Philippines – (NCR)
  - University of the Philippines – Diliman (NCR)
  - University of the Philippines – Baguio (CAR)
- Private (5)
  - Silliman University (VII)
  - University of San Carlos (VII)
  - University of Mindanao (XI)
  - Ateneo de Manila University (NCR)
  - De La Salle University (NCR)

Schools with BS Applied Physics Degree Program

- State (2)
  - University of the Philippines – Diliman (NCR)
  - University of the Philippine – Los Baños
- Private (2)
  - Ateneo de Manila University (Computer Engineering - NCR)
  - De La Salle University (Medical Physics – NCR)

Schools with MS Physics Degree Program

- State (3)
  - University of Eastern Philippines (VIII)
  - Mindanao State University – Iligan Institute of Technology (XII)
  - University of the Philippines – Diliman (NCR)
- Private (2)
  - Silliman University (VII)
  - University of San Carlos (VII)
  - Ateneo de Manila University (NCR)
  - De La Salle University (NCR)
  - University of Santo Tomas (NCR)

Schools with PhD Physics Degree Program

- State (2)
  - University of the Philippines – Diliman (NCR)
  - Mindanao State University – Iligan Institute of Technology (XII)
- Private (2)
  - Ateneo de Manila University (NCR)
  - De La Salle University (NCR)

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E. Threats

The biggest threat in Photonics research is the migration of young talented college graduates to foreign countries as revealed by the experience of the different institutions undertaking photonics research.

IV. PHOTONICS TECHNOLOGY AND MARKET

Photonics Industries in the Philippines

1. Perkinelmer Optoelectronics Philippines
2. Avago
3. Others (please identify)

V. PRIORITIES

Given the limited resources that are available from the government, it is both wise and prudent that future investment in scientific R&D be concentrated in areas where Filipino scientists have already developed the capability to compete with their counterparts abroad. Substantial financial support is strongly advised in the photonics R&D sector because it has shown the capability to attract the best BS graduates and encourage them to pursue graduate studies. The availability of high-quality graduate programs is the most effective way of stopping the migration of young talented college graduates to foreign countries as revealed by the experience of NIP in the last ten years. This will likewise help the country towards global competitiveness in the years to come.

VI. ACTIONS TO BE TAKEN

This year 2013, PCIEERD needs to initiate the promotion and gathering of all stakeholders to develop short and long-term plans for the Photonics sector. The government, public and private sectors as well as the academe are expected to contribute towards the implementation of research and development, commercialization and promotion of Photonics products and services. This could be done through well-developed curriculum and scholarship programs, world-class facilities and infrastructures as well active networking with regional and international counterparts.

One of the greatest gaps that can be clearly identified at present is market understanding. Several activities should be done prior to the development of a roadmap for the photonics sector:

1. Documentation of its participants and capabilities. Identifying the companies, its capabilities and the photonics-related market areas in the Philippines;

2. Develop a framework to match the current capabilities with market opportunities;

3. Form multiple public and private partnerships to open new opportunities.

VII. LITERATURE CITED

National Academies Booklet "Harnessing Light for America's Technological Future". SPIE / 1000 20th St / Bellingham WA 98225 USA/ www.opticsandphotonics.org.

The Harnessing Light Report 2012. SPIE / 1000 20th St / Bellingham WA 98225 USA http://spie.org/Documents/AboutSPIE/PDF/HLII-OpticsandPhotonics.pdf

PCASTRD Sectoral Plan (2004-2010)

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