



TOWARDS A BRIGHTER MEXICO: OPTICS AND PHOTONICS ROADMAP

ISBN: 978-607-92394-5-5
9 786079 729455



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OPTICS AND PHOTONICS ROADMAP

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INDEX

PRESENTATION	9
PROLOGUE	17
INTRODUCTION	19
CHAPTER 1 Conceptual Framework	20
CHAPTER 2 Current Situation	24
CHAPTER 3 Photonics in the World	30
CHAPTER 4 SWOT Analysis of Photonics in Mexico	36
CHAPTER 5 Trend Analysis	42
CHAPTER 6 Milestones and Projects	48
CHAPTER 7 Action Plan	54
CHAPTER 8 Summary of Technological Needs	78
CONCLUSIONS	82
REFERENCES	90

PRESENTATION

The proper utilization of the assets of Mexico has allowed its consolidation as one of the most important and open economies in the world, one of the most attractive countries to invest, as well as to become the largest exporter in Latin America. Particularly in the technological sector, Mexico has several factors in its favor. With a median age of 27 years, the tripling of university enrollment over the last thirty years, a long-standing entrepreneurial culture and technological clusters on the rise, the growing interest from large companies in related industries is not surprising.

These qualities place the country in a privileged place to grasp the opportunities that the flourishing optical and photonic industry offers: both, its economic potential (since it has tripled its value in less than a decade) and its transforming character of other important sectors such as automotive, aerospace, health and advanced manufacturing with high added value.

The optical and photonic industry could lead Mexico towards a more competitive, clean, safe, energy efficient, and even a healthier future due to advances in medical equipment that allow better diagnostics.

That is why ProMéxico, in collaboration with the International Commission for Optics (ICO), represented by the Mexican Optical Academy (AMO), produced this joint proposal with the objective of determining the course to follow in order to prosper in the sector, to apprehend its virtues, and thus ensure the regional leadership of Mexico through competitive companies with high quality standards.

Based on strengths, opportunities and current resources, a meticulous plan is presented to locate Mexico as the Latin American leader of the industry, which outlines the strategy and concrete actions of the triple helix: government, industry and academia. By taking advantage of the opportunities it will be possible to turn Mexico into a pole of technological development applied in the field of photonics.

In this way, Mexico places the optical and photonic industry as strategic to strengthen its position at a global level, and as a leader in sectors with high added value.

— *Francisco N. González Díaz*
CEO of ProMéxico

The International Commission for Optics (ICO) was established in 1948 with the mission of contributing, on an international basis, to the progress and diffusion of knowledge in the field of optics. Since the discovery of the laser, optics and the closely-related field of photonics have become core enabling sciences for the development of other sciences and technology in our modern society. The economic impact of optics & photonics has grown immensely in the last 50 years. The global photonics market grows at a 6% annual rate and is expected to exceed 677 billion US dollars in 2017. The photonics components market comprises 2,750 companies in 46 countries. Major players include material processing as additive manufacturing (3D printing), optical communications, medical and cosmetic applications, lighting and displays, and security.

In 1998 the USA National Research Council (NRC) published a report “Harnessing Light: Optical Science and Engineering for the 21st century”, that inspired the European Photonics 21 initiative, launched in 2005. It recognized that many important European Industries, ranging from chip manufacturing to health care and life sciences, rely on the mastery of light science and light-based technologies. With 2,500 members, Photonics 21 represents the industry and research organizations in photonics throughout Europe. Currently the European optics and photonics components industries generate more than 40 billion euros and employ a quarter of a million people.

In 2013 the ICO USA Territorial Committee (USAC/ICO) in collaboration with the NRC National Materials and Manufacturing Board (NMMB) launched the updated report “Optics and Photonics: Essential Technologies of Our Nation”, which contains an assessment of the current state of optical science and engineering and is intended to recommend actions for the development and maintenance of USA global leadership in this area. The updated report highlighted new areas with potential for even greater societal impact in the next few decades, including solar power, high-efficiency lighting, genome mapping, high-tech manufacturing (including 3D printing), cancer detection, and new optical capabilities vital to supporting the Internet’s growth. The information-based sector already occupies 15% of the total U.S. economy. The report was widely advertised and supported by academic research institutions, government, and industries, and originated the USA National Photonics Initiative.

As the world strives toward becoming more energy-efficient, the solar, photovoltaic (PV), and energy markets will grow worldwide. Solar PV is already commercially competitive with fossil fuel alternatives and will become a major part of the electricity system, delivering clean and affordable energy for all. The global market for PV is expected to grow to nearly 350 billion by 2020. Photonics is also a key enabling technology for the emergence of most new “smart” systems, including “smart grid” applications. Lighting consumes approximately 20% of total electricity generation. LED lighting provides energy-efficient solutions and contributes to reducing energy demand. In the past 5 years, the global LED lighting market has become a 30.5 billion US dollars market. Solar energy, efficient lighting, and the use of lasers and LEDs in communications, sensing, and transportation applications will allow people living in isolated regions to have a telephone that broadcasts warnings for disaster risk, a satellite-driven GPS location device, and sophisticated sensors near the ground.

The Mexican Photonics Initiative has been formulated by the ICO Mexican Territorial Committee in collaboration with ProMéxico and with the support of the Iberian American Network of Optics, an international society member of the ICO. The ICO is aware of the great potential this initiative has to enhance well-being and economic prosperity not only for Mexican people but for people in other countries in the region. The ICO congratulates the Mexican research and entrepreneur communities on Optics and Photonics for taking this huge step towards the construction of a better future for all.

— *Prof. Yasuhiko Arakawa*
ICO President

The Optical Society (OSA), as part of its centennial celebration in 2016, is recognizing the many innovations and solutions optics and photonics technology has provided to the world. Most importantly, we are focused on how this technology will impact our future. That is why it is our privilege to review the IMF Optics and Photonics Route Map, which eloquently describes an exciting plan for real, future growth for the optics industry in Mexico. The strategic sectors supporting this high tech growth include: energy, telecommunications, health and advanced manufacturing.

To give some perspective on what is possible, this technology currently enables the entire world economy of 78 trillion US dollars. The Photonics in the World section of the Route Map provides a comprehensive region-by-region summary of the various optics and photonics initiatives successfully adopted into policies. Many of these regional plans take aim at similar grand challenges noted in the Route Map: the revolution of technology in medicine and healthcare, the expansion of international broadband communication, increases in energy efficiency via photonic materials enhancements and advances in manufacturing initiatives utilizing photonic integration. In all cases, the strategic coordination of industry, academia and government is essential.

OSA estimates that the global manufacturing of optics and photonics products exceeds 400 billion US dollars per year, and North America has approximately 20% market share of the global production. Mexico has a tremendous opportunity to grow its market share in Latin America if the proper policies can be implemented and government funding can be provided at effective and sustained levels. The country will also increase its competitiveness through a focused set of key research goals, development objectives and dedicated production facilities in Mexico. One of the strengths of this initiative, for example, is the realization that there is a requirement for workforce training, multiple levels of education for each market segment and quality metrics to be competitive through Latin America.

OSA endorses this national call to invest in and grow Mexico's research enterprise in photonics. The ProMéxico initiative, through this Route Map, offers an organized action plan that will enrich and transform Mexico's photonics industry. OSA supports our colleagues within the International Commission for Optics, of which Mexico has a very visible leadership presence with its México Territorial Committee for Optics. Many of our members from Mexico will be participating in this important endeavor. We commend your efforts and look forward to your successes.

— *Elizabeth Rogan*
Chief Executive Officer of the Optical Society

Today, light and numerous light-based technologies are present everywhere in our daily lives and yet, in many cases we are not even aware of it. It is clear that the light emitted by the sun plays a fundamental role in the development of life on Earth and is the main source of energy for our planet. However, just by looking around us and reflecting for a moment, we can realize that the applications of light have revolutionized our current society via science, technology, culture and education.

Meanwhile, the industries related to optics and photonics are authentic drivers of today's economy, as they respond to an ever greater number of humanity's needs, contributing new solutions through advanced technologies for medical imaging and endoscopy, global communication networks via optical and submarine cables and fibers, highly efficient photovoltaic panels, materials technology applied to new sources of highly efficient illumination that combines light-emitting diodes (LEDs) of different compositions, and the nano-processing of materials with ultra-high intensity lasers. Here, at the dawn of the XXI century, all of this makes for a glimmering future for photonic technologies and the like, in their numerous facets, as a key element in the comprehensive and sustainable development of humanity, contributing solutions to world challenges in energy, agriculture, communications and health, among many others.

An excellent corroboration of all of the aforementioned was the United Nations' declaration of 2015 as the International Year of Light and Light-Based Technologies around the world, whose closing ceremony was in fact held in Merida, Yucatan.

The European Union affirms that photonic technologies already have a very significant impact on the world economy with a current global market of 300 billion euros and more than 600 billion euros in commercial activity foreseen for 2020. Within the Horizon 2020 Framework Program, which determines the research actions for the European Union for the 2014-2020 period, Key Enabling Technologies (KETs) are a priority for the European industrial policy within its Europe 2020 strategy. The European Commission has identified lasers and photonics as one of these six enabling technologies that are key for sustaining European growth. In the same way, photonics technologies applied to the Life Sciences and Health, as well as nanotechnology, are considered strategic areas in the Horizon 2020 Roadmap for European Photonics developed by the technological platform Photonics 21.

Despite all of its long history, never before have optics and photonics experienced a moment as exciting nor with such a promising future. For this reason, we can conclude that without a shadow of a doubt, the first half of the XXI century is optics' time. The Red Iberoamericana de Óptica [Ibero-American Network on Optics], (RIAO, acronym in Spanish), completely backs the Iniciativa Mexicana en Fotónica [Mexican Photonics Initiative] as well as the consequent Mexican Photonics Cluster and considers it to be very sound, in particular because of the opportunity it offers. It is undeniable that the study of light and the corresponding development of its numerous associated technologies have become a key transverse discipline in current technology and science. Thus, this action must necessarily drive foreign investment in Mexico, national production of technological products of great value added, the internationalization of Mexican companies that are formed in this framework and the export of their products.

Even more, given the pioneering character of this initiative in all of Latin America, aside from its economic and technological implications, the Roadmap promoted by ProMéxico can serve as a beacon and reference point for future similar actions that other countries in the Latin American region undertake with the consequent influence and hegemony.

For these reasons, we fully trust in the success of the Photonics and Optics Roadmap sponsored by ProMéxico.

— *Prof. Pedro Andres*
University of Valencia, Spain
President of the Ibero-American Network on Optics

Optics and photonics are increasingly recognized as fundamental to progress in the 21st century. The UN declared 2015 International Year of Light and Light-based Technologies, which was global recognition of the importance of something we take for granted, light. Light from the sun makes life on our planet possible. Photons provide the energy to warm our planet, for plants, for life in the seas. Fossil fuels are stored solar energy.

Man has learned how to use light in increasingly sophisticated ways. Microscopes revolutionized our understanding of life and led to an ongoing productive relationship between optical technology and medicine. Telescopes continue to expand our understanding of our glorious universe. Eyeglasses allow billions to see clearly. Electric light was crucial to industrial production, and of course is now so common it is taken for granted in most parts of the world. Yet sadly, still not available for everyone. Powerful tiny digital cameras and tiny screens have changed human interaction in less than two decades.

Since a comprehensive 1998 study by the US National Academy called “Harnessing Light”, light has been recognized as an enabling technology, crucial to medicine, communication, science and industry. An updated study in 2012, aptly titled “Optics and Photonics, Essential Technologies for our Nation” identified the importance of optics and photonics to future economic competitiveness.

Similar studies of the impact of optics and photonics have been produced by nations like Germany, the UK, and Canada. In 2010, the European Union identified photonics as one of only five key enabling technologies crucial to future economic competitiveness.

The information transmission systems of today, and those of the future rely on photons. Fiber optic transmission of laser beams around the world, and high resolution displays are essential components of information systems. With the information explosion has come a growing demand for datacenters where information is stored and retrieved. These are the physical manifestation of “the cloud”. As these have proliferated, the limitations of the traditional electronic processors and memory have grown increasingly apparent: energy efficiency and speed. In North America, Europe and Asia, companies and nations are competing to introduce photonics to datacenters, likely the first comprehensive integration of photonics into the silicon world. Visionaries expect that, after a hybrid world where the advantages of photons over electrons ensure this integration, we will see all photonic computation as we move towards an era of quantum devices.

Non polluting direct capture of energy from the sun, whether with solar panels or concentrator is rapidly becoming a significant part of global energy production. Costs are falling so quickly that electricity from solar will soon make water desalination affordable. A transformation of electric lighting which consumes about 20% of generated electrical power is getting underway with efficient and long lasting LEDs. The properties of these light sources will allow a shift to “human centric” lighting that takes into account what we are discovering about the impact of lighting on our biology.

The processors and memory chips that allow us to carry around a smartphone, with thousands of times the capability of the Apollo mission computers, were all printed and inspected with light. Without laser lithography and optical metrology we would not have the computing power that underpins modern commerce, scientific modeling, medical analysis and entertainment. The dramatic miniaturization of electronic devices is only possible with precision laser manufacturing.

In medicine, imaging grows ever more sophisticated with improved sensors and high resolution displays. It has transformed the battle against cancer and other diseases. The genetic revolution which is helping us understand life and health, and better personalize medicine is enabled by lasers and optical sensors, and by light enabled advances in computing power. Imaging at many different wavelengths will play a vital role in the next frontier of medicine, understanding the brain. Optogenetics has already shown promise for therapy.

Many advances in the sciences are tied to photonics technologies. Particle physics, for example, relies on optical sensors to detect particle flight and behaviors. Optical instruments are essential tools for analytical chemistry and geoscience. Synchrotron radiation is a widely used tool in the discovery of new pharmaceuticals. New optical microscopies are providing nanoscale imaging for

science and medicine. Powerful lasers generate extreme conditions of matter in the laboratory that are leading to a new frontier involving lasers and particle physics. Laser generated proton beams will soon see therapeutic use. In its Extreme Light Initiative (ELI) Europe is investing heavily in extreme light, very high intensity laser facilities. These will open new areas in physics.

Our studies of the global market for products that are photonic in nature such as displays, optical communication hardware solar panels and lighting hardware, give us a figure of about US 500 billion for 2015. This is close to the EU's 2015 market number, which the EU projects will exceed US 1trillion by 2025. These are factory gate prices for manufactured products. US Department of Commerce data suggest that Mexico is the largest exporter of optoelectronics (another name for optics and photonics) products to the US, some 55 billion US a year. However, the Mexican added value in the global supply chain from Asia is limited. Than should and can change.

These large numbers do not capture the impact of optical technologies on an economy. The reliance on photonics powered information transmission and processing will be ever more pervasive. The fourth industrial revolution (Industry 4.0) with its emphasis on digital technologies will have heavy dependence on photonics technologies. Medical practice will become more cost effective through improved photonics based diagnostics, monitoring and data sharing. In other areas, optical sensors, whether embedded, in drones or piloted planes or in space are already providing data to improve current agricultural practices, identify climate impacts, improve recovery of fossil energy sources, active pipeline monitoring and providing ever better information on our environment.

Advanced manufacturing is rapidly absorbing vision sensors for automation, lasers in production and sophisticated on-line optical metrology. The automotive and aerospace industries are becoming serious about 3D manufacturing where additive laser (and electron beam) techniques are bringing both unique capabilities and materials savings.

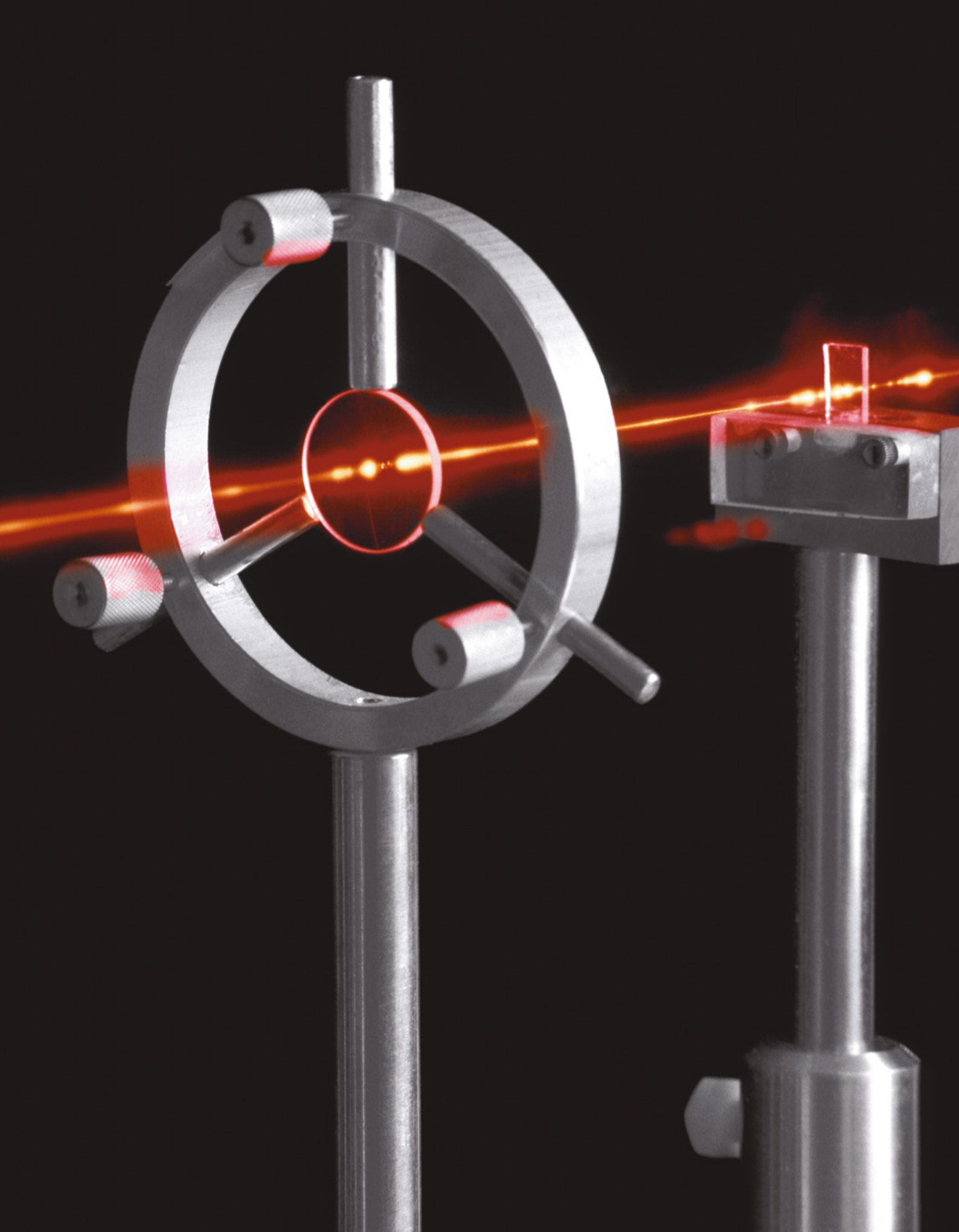
This century has been called the “century of the photon” and for a good reason. Progress in electronics which revolutionized the human condition during the 20th century is running into some fundamental limitations. Photonics offer new options. It is widely recognized that nations with skills in optics in photonics will be better positioned for the increasingly technological future. Industries such as automobile manufacturing, whether producing conventional or optical sensor enabled driverless vehicles, will employ more laser based manufacturing. Photonics skills will increasingly be needed to be a competitive manufacturer in any major sector.

Separately, I believe that Mexico has the foundation for a photonics industry, based on both of inward investment and synergistic indigenous companies. SPIE has seen a growing involvement from Mexico with very impressive Mexican student chapters. We have not yet seen the industrial activity that we would expect from such a well prepared and creative talent pool. Mexico has not established itself as a known destination for the multinationals seeking such talent, nor as a home for start-up companies in this field (SPIE has a database of some 70,000 companies in optics and photonics, many of which are successful small innovative companies, constantly replenished by start-ups.)

It is timely and vital that Mexico reviews its capability in optics and photonics and plans to ensure it is well prepared to support an industrial future where photonics will determine competitiveness.

— *Dr. E.G. Arthurs*

CEO, SPIE, The International Society of Optics and Photonics.



PROLOGUE

Optics and photonics play an increasingly important role in the lives of the population around the world, since they are the technologies on which the processes that allow communication between people, power generation, detection and diagnosis of diseases, as well as advanced manufacturing in many industrial sectors are based on. The declaration of the United Nations as “International Year of Light and Light-based Technologies 2015” has highlighted the importance of optical and photonic technology in the current global environment. In recent years, major economies of the world, such as the United States of America, the United Kingdom, Germany and Canada, have recognized optics and photonics as key technologies in their future development. This recognition has led to the development of various national and regional mechanisms geared to the use of optical and photonic technologies, such as the National Photonics Initiative of the United States of America, the European Technological Platform Photonics 21 of the European Union, and the UK Photonics Leadership Group, among others. In Mexico, ProMéxico and the International Commission for Optics, through its Mexican Territorial Optics Committee –represented by the Mexican Optical Academy–, started in 2014 the collaboration that now gives birth to the Mexican Initiative of Photonics.

The Mexican Initiative in Photonics will promote synergies between industry, government, academia and society, which will facilitate the recognition of optics and photonics as key technologies for the consolidation of Mexico as one of the main economies in the world and the leader in Latin America. Through the contribution of broad and deep proposals for the design and implementation of specific policies and programs in the various areas of the life of our society, the Mexican Initiative in Photonics will seek to place optics and photonics as priority technologies for Mexico, so that a favorable ecosystem for innovation can be established in productive sectors (telecommunications, energy, health and medicine, as well as advanced manufacturing), that are able to take advantage of the young talent of the country through their involvement in these disciplines at different levels of production as highly skilled manufacturing, specialized technical services, innovative design. With this, it is hoped that in the near future Mexico will be able to advance in the world market of photonics until becoming an important player with the participation of technologically innovative companies in optics and photonics, basing their efforts in a solid scientific base in which the optical and photonic community of Mexico will contribute to the formation of highly specialized young talent and to the design and construction of the necessary infrastructure for high level scientific research and the development of new products and services, such as the Mexican Cluster of Photonics, the first ultra-high intensity laser of Mexico, or the various certification centers for photonic technologies.

As the first product of the Mexican Initiative in Photonics, the Trust Group delivers this launch edition of the Technological Routemap for Photonics in Mexico, which presents the current scenario of optics and photonics in the world and within the country, and proposes milestones, programs and actions that Mexico can and should achieve in the near future in the sectors already mentioned. ProMéxico and the International Commission for Optics are sure that with this first Technological Routemap for Photonics in Mexico, more actors and industry leaders, Mexican government, academia and society will soon join the Mexican Initiative in Photonics to promote and translate its results into new public policies, programs and actions in areas such as education, science, technology development, innovation, economics, health, poverty alleviation, gender equality and environmental care.

— Eric Rosas

*Trust Group Coordinator of the Mexican Photonics Initiative
RIAO appointed Vice President, International Commission for Optics*

INTRODUCTION

Photonics is the basis for great technological breakthroughs, radically transforming various aspects of society and ushering in excellent opportunities for technological, scientific and economic development.

Few industries have enjoyed such explosive market growth. In just under ten years, photonics has tripled in value, with annual worth exceeding 182 billion dollars in 2015. Additionally, applications have been found in strategic sectors as automotive, energy, health, military, advanced manufacturing and precision sensors, creating a transverse industry of added value that enables new technology development with increased cost efficiency in similar and different areas.

The world's large economic blocks have prioritized photonics as a strategic sector that can ensure improved economic, social, environmental and technological leadership. As a developing economy, Mexico must take advantage of the juncture to position itself as a world leader in the field and thereby set in motion all the concomitant opportunities. That is precisely why ProMéxico has been collaborating with the International Commission for Optics (ICO), through its Comité Territorial de Óptica de México (Territorial Committee on Optics in Mexico) –represented by the Academia Mexicana de Óptica (AMO, Mexican Optics Academy)– to develop a joint proposal that allows Mexico to benefit from worldwide progress within the sector: the Iniciativa Mexicana en Fotónica (IMF, Mexican Photonics Initiative).

This document is the first outcome of these coordinated efforts to spark unprecedented growth in photonics and optics by means of a Technological Roadmap, and it exploits the greatest potential value for applications in a range of industries. The goals are to propose a plan that puts Mexico in a leading position within Latin America and to produce sustained intense promotion to attract the sector's triple helix: government (to support and create the necessary conditions), industry (as an engine for investment in the sector with an eye toward generating major commercial development) and academia and educational institutions (to develop and facilitate technological breakthroughs). Both research and the commercial application of a sector that operates as an advanced enabling technology would thus be covered.

Furthermore, this text is meant to outline a highly efficient and viable path through which to develop a favorable ecosystem for optics and photonics nationwide. It also proposes high value applications for establishing a solid link with the industry to thus ensure a strong triple helix presence and attract investment, technological development and industrial application of cutting-edge technologies, so that Mexico secures a leading position within the photonics community.

A strong push forward in this enabling industry will lead to vitality in various strategic sectors, manufacturing, energy, medicine, telecommunications and electronics among them. The idea is for such strides to have high added value by avoiding the cheap manufacturing model and highlighting the potential value of high technology, certifications, design and specialization.

CHAPTER 1

CONCEPTUAL FRAMEWORK

Recent technological developments within optics and photonics have led to innovations based on an understanding and the manipulation of phenomena of light. As defined by the Commission International de l'Eclairage (CIE),¹ the latter is understood as the portion of electromagnetic energy perceived by the human eye (visible light), in addition to the ultraviolet (UV) and infrared (IR) portions.

Electromagnetic radiation can be defined as the dispersion of energy or radiation in the form of electromagnetic waves, as a result of the overlap of electric and magnetic fields at different frequencies and wavelengths.²

The scientific community now accepts duality in the nature of light, as wave and particle. In other words, it can disperse in the form of electromagnetic waves but also in a discrete, quantized way in the form of particles known as photons.*

OPTICS

Optics is the branch of physics that studies the behavior and properties of light in visible IR and UV wavelengths. The study of optics dates back to ancient times –both in China (Mo Zi)³ and in ancient Greece (Euclid of Alexandria)– and encompasses the observation, analysis and manipulation of phenomena such as reflection, refraction, interference, dispersion and polarization, among others.

An enabling technology, optics contributes to the design and manufacture of components for instruments such as mirrors, glasses, microscopes, telescopes, optical sensors, measurement systems, lasers, fiber optic communication systems and optical disk systems, which use optical phenomena to move forward and improve technology in other sectors.

22

PHOTONICS

Photonics is the branch of optics that deals with photon generation, guidance, control and detection. It focuses particularly on the visible and near IR spectrum but it also includes other regions of the electromagnetic spectrum such as UV, long wavelength IR and distant IR.⁴

The semiconductor light emitters invented in the early 1960s at General Electric, MIT's Lincoln Laboratory, IBM and RCA and put into practice by Zhores Alferov and Dmitri Z. Garbuzov at the Ioffe Institute are among the early photonic developments.

The term photonics⁵ was introduced as an analogy of the word electronics, to emphasize replacement of the electron by the photon in typical electronic operations (such as data processing, transmission and storage). Photonics has been established as an autonomous discipline and is currently present in everyday technologies such as optical sensors and telecommunications.

Applications^{6,7,8}

Just as electronics applications have grown substantially since the first transistor was invented in 1948, new and specific uses for photonics keep being found.

Among the uses for semiconductor photonic devices that are considered solid and economically sound are: optical data storage, fiber optic telecommunications, laser printing (based on xerography), viewers and optically pumped high intensity lasers. The potential use of photonics is practically limitless and will advance at the enormous pace of technological development.

From the perspective of applications for optics and photonics, three of the four main areas that can be defined influence current research, while the other is being developed: optical instrumentation; optical communications; optical metrology,** and frontier optics and optogenetics. These four

*The term "photon" (from the Greek, "light") was originally coined by Lewis to explain an idea of Einstein.

**Here "optical metrology" is used as a synthetic reference for the concept of metrological methods assisted by optical phenomena.

groups are closely interrelated. For example, optical instrumentation applications are connected with those in optical communications and metrology, and new concepts and discoveries that are being made bring frontier optics closer to optical instrumentation.

Optical Instrumentation

This includes the study and design of optical systems and elements that are used primarily to form images. As examples, we can cite glasses, prisms, mirrors, microscopes, telescopes and so forth.

Optical systems are used in many areas of daily life (smartphone devices) as well as in scientific research and technological and military applications.

Optical Communications

Here, light is used to carry information and optical systems to transmit, amplify and receive signals.

Topics that relate to this application area include special crystals, optic fibers, detectors, light sources (lasers), optical amplifiers, signal processing, holography and non-linear optical phenomena, among others.

Optical Metrology

This is the monitoring of physical, chemical or biological parameters through non-contact methods and systems that use light or IR or UV radiation to carry out non-destructive, non-invasive tests.

Topics related to this area of applications are: optical systems, polarization, interference, light emitters, light detectors, image processing, etc.

Optical metrology has had a great impact on solving medical, industrial and engineering problems based on metrological techniques such as photometry, radiometry, colorimetry, spectrometry, spectrophotometry, spectroradiometry, turbidimetry, and refractometry.

Frontier Optics and Optogenetics

Research is being done on phenomena related to high power light radiation, rapid detection and transmission of light-generated information, new optical materials, sources of radiation and light detection.

Developing fields encompass quantum optics, photonic fibers and non-linear optical phenomena. These studies are aimed at using new materials and techniques for unconventional applications such as the design, manufacture and use of quantum dots to create new technologies. An example of this is the production of third-generation photovoltaic cells that enable increasing energy extraction efficiency, which considerably reduces the cost and facilitates energy transportation in nanometric structures for curing superbug infections immune to traditional medicine or designing new solid-state lighting systems, among others.

Optogenetics

It investigates the interaction of light at the quantum level with molecules that control some biological responses, such as the behavior of certain mammals when illuminated with different wavelengths of light. Furthermore, the principle of photosynthesis may be used to separate proteins and create energy through the electron transmission process.

CHAPTER 2



CURRENT SITUATION

THE PHOTONICS INDUSTRY

Optics and photonics are basic to modern life, enabling the manufacture and inspection of all the integrated circuits in the electric and electronic devices we use, contributing to breakthroughs in countless sectors, creating screens for electric and electronic devices, producing the fiber optics that transport information through the Internet, enabling advanced manufacturing of precision instruments and medical devices, among many other applications.

Potentially, photonics and optics can have a large social impact in the coming decades by transforming the energy sector through the use of efficient lighting and new renewable energy generation methods, such as solar. Even communications will be affected by the use of new optical and photonic capacities that support developments such as the Internet, allowing for greater connectivity penetration.

In recent years, expansion of optic and photonic technologies has increased all over the world. On the one hand, it offers encouraging trends for the world economy and general wellbeing, and on the other, it represents a challenge for the regional (Latin America) leadership of Mexico in these economic sectors where there is an abysmal difference between the neighbors to the north and those to the south.

The United States, primarily, has designed strategic documents such as **Harnessing Light**⁹ that aims to place the country in a position of world leadership within this industry. According to this report, they are aware that exploiting trends in optics and photonics will open doors to the creation of new industries, jobs and substantial growth in existing industries.

ProMéxico and ICO are confident that this study will help political, academic and industrial leaders defining courses of action that will promote the economy of Mexico in an area that could still make noteworthy and competitive progress. This document aims to provide visionary guidance for future growth of optics and photonics, as well as support with the arduous task of designing applied technologies that will ensure Mexico's regional leadership.

VALUE OF THE INDUSTRY

Proclaimed by the United Nations (UN) as the International Year of Light and Light-Based Technologies¹⁰, 2015 falls within a wave of growth for the world photonics market. According to figures from the 2013 photonics industry report¹¹ by Photonics21, the photonics market—which includes industries such as light source producers and manufacturers of displays, optical components and systems, among others— will be worth 670 billion dollars in 2020—while just ten years ago, it was valued at 260 billion dollars¹².

Photonics industry growth for the period spanning 2014 to 2020 is expected to be more than double the percentage it represented of the world Gross Domestic Product (GDP) between 2005 and 2011. The value of sales of photonics components has grown to more than 182 billion dollars annually, according to an analysis by the International Society for Optics and Photonics (SPIE)¹³. Between 2012 and 2014 alone, the number of active photonics companies grew more than 18%, going from 2,750 to 3,194 units¹⁴.

Additionally, the growth of jobs in such companies grew 26%, reflecting the industry's rapid development¹⁵. In the United States, the proportion of generated sales was 260,000 dollars per employee working in the photonics industry in 2014, which reflects the enormous performance efficiency in the companies¹⁶.

SENSORS

Growing at an annual compound rate of 16.9% during the 2014-2020 period¹⁷, the global market for photonics sensors is expected to reach 15.2 billion dollars in 2020. This market is segmented

by types (fiber optic, image and biophotonic sensors), technology and applications (military, industrial processes, factory automation, civil structures, transportation, biomedicine, renewable energy, petroleum and gas, among others)¹⁸.

Globally, the market lacks technological and industrial standards, heavy initial investments in projects and awareness of the sector, which has prevented exponential growth¹⁹.

FIBER OPTICS²⁰

With growth at an annual compound rate of five percent for the 2014 - 2020 prospective period, the fiber optics market value is expected to exceed three billion dollars by 2020. Over 90 percent of the market is in the telecommunications industry, for which demand is ever growing due to the constant development of network use in the Asia-Pacific regions.

Additionally, the major economies in the world are creating fiber-to-node and fiber-to-home networks, intensively connecting citizens in ever faster networks that have greater data transmission capacity and a particular focus on the Internet of Things (IoT). With this combination, global demand for fiber optics will keep growing until reaching close to 400 million kilometers of fiber by 2020.

Currently, fiber optics is the most frequently used technology in detection applications, given that it is well established and possesses powerful capacities in this sphere. Many manufacturing companies worldwide offer sensors that can withstand harsh environmental conditions such as extreme heat, noise, corrosion, explosion and vibration. Fiber optic sensors are compact and lightweight.

ENERGY

Photonics increases both the efficiency and security of energy production and consumption. Not only is the clean renewable energy sector a growing area in terms of jobs, but photonics research could reduce energy consumption and foreign oil dependence, which would be a boom to the national economy.

This is a particularly attractive sector due to its growth rate in the face of the widely used fossil fuel energy sources, with the social, environmental and economic implications derived thereof. Additionally, solid-state lighting – primarily based on LEDs (light-emitting diodes)– could slash electricity consumption in half by 2030 if appropriate programs and means are used. Exporting renewable energy could even be considered, given the great demand around the world.

Companies wishing to enter this sector will need research and development investment, as well as structural support, to guide the world towards a clean, safe and energy-efficient future.

HEALTH

Photonics is responsible for medical breakthroughs that have set new standards for modern medicine: from the use of fiber optics (occasionally laser assisted) in laparoscopic surgery to X-ray and UV radiation based imaging, which leads to immeasurable benefits for millions of patients throughout the world. The use of photonic devices is also beginning to be more widespread for measurement and diagnostics, for example, in determining the amount of oxygen or other substances in the blood.

Photonics plays a significant role in new generation medical advances, in terms both of increasing the capacity to observe and measure symptoms and the ability to treat patients with innovative, less invasive techniques, in addition to improving the cost-efficiency ratio.

Photonics-based health devices offer sensitivity, speed and accuracy, which, together with rapid diagnosis and effective therapy, are key to high quality care with a good cost-efficiency ratio.

Biophotonics research will eventually lead to smaller, automated medical devices with diagnoses at point of examination, which will mean substantial improvement in medical outcomes for patients, as well as greater accessibility to health services.

ADVANCED MANUFACTURING

Advanced manufacturing is vital for the economy of the country, being a sector that tends to contribute major job growth. The world trend is to create a new generation of high power, low cost ultrashort pulse lasers; as well as photonics-based additive manufacturing (3D printing), which enables machines to produce a series of personalized products transmitted directly from an electronic design, saving time, costs and materials in the process. These advanced printers, called “the future of manufacturing”, can produce a broad range of objects, from prostheses, functional human tissue and jet turbine parts to shoes. To maintain a position of regional leadership, the country should seek not only low-cost mass manufacturing but also to compete in high value added, precision and technologically advanced manufacturing.

BIOPHOTONICS

Photonic sensors have multiple applications, as they have greater capacity to provide profitable solutions for accurately detecting images, compared with conventional sensors.

Among the range of sensors, biophotonic ones will have the largest market share as they have a 16 percent annual compound growth rate. By 2018, the biophotonics industry will have exceeded 99 million dollars, according to information from Markets & Markets²¹.

Biophotonics can enable technologies that will improve the cost-efficiency relationship in medical diagnosis and therapeutic tools for the detection and treatment of critical illnesses. It can be used in microscopy, cytometry and spectroscopy, disciplines where significant strides in diagnostic techniques are foreseen.

Other medical uses of biophotonics focus on the demand for laser applications for specialized therapies such as surgeries, pain treatments and skin cancer therapies. This is extremely important given demographic projections, as the population is inclined to seek higher-quality and more efficient health services as it ages.

In the near future, biomedical imaging is expected to replace both biopsies and current mechanical medical imaging equipment. Biophotonics will also play an important role in the food science sector, to improve quality and more safely identify possible contaminants in foods²².

LASER TECHNOLOGY²³

By 2020, laser technology market value will surpass 17 billion dollars. Photonics is one of its most solid segments due to the sustained growth of its technological and economic value (its annual rates go up more than six percent), as well as the wide variety of application fields.

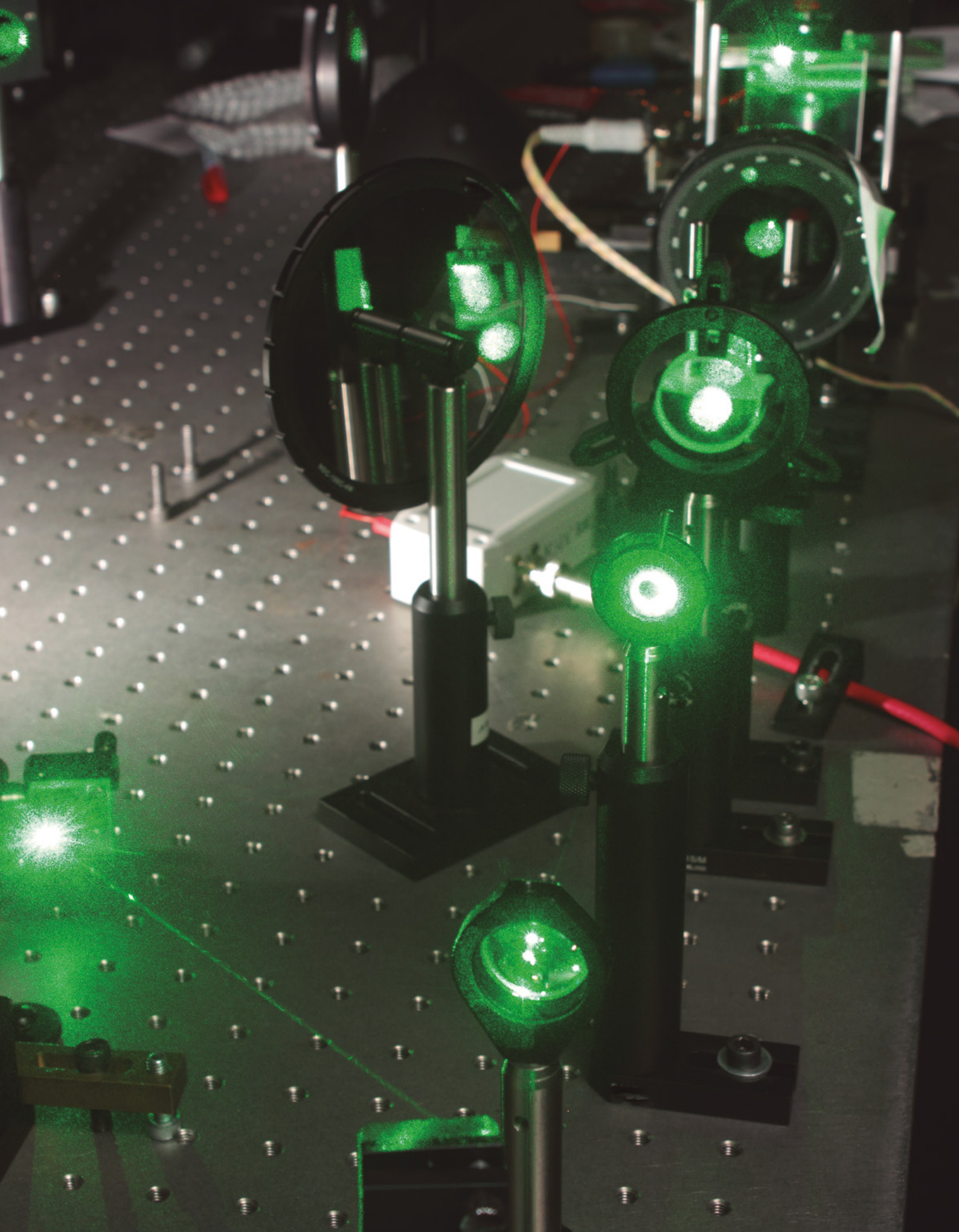
The technologies enabled by the use of diverse lasers continue to multiply, exceeding expectations in the heavy manufacturing industry (in accuracy and power) and have even reached new applications such as advanced 3D manufacturing, cutting-edge aesthetic and medical tools, high precision sensors and telecommunications²⁴.

OPTICAL INTEGRATED CIRCUITS

In chip development, optical integrated circuits are beginning to compete with electronic ones. They make it possible to miniaturize multiple applications that use laser light to process and transmit information with greater energy efficiency and speed.

They can work in specialized chips such as temperature, pressure, chemical and biomedical sensors or via light change detection when light interacts with what is being measured. Optical integrated circuits will create a very broad niche market given their diversity of use, although they are currently restricted to basic devices with specific functions (primarily in the telecommunications field) rather than being utilized to full potential²⁵.

CHAPTER 3



PHOTONICS IN THE WORLD

To be fully utilized, photonics requires favorable conditions, shaped by society, industry, academia and government. The latter is a major actor in establishing the appropriate ecosystem for sector development. This section will document the efforts of several leading economies to create environments that foster progress in photonics, with an eye to exploiting its commercial applications.

The countries that are at the forefront of photonics technology are the United States, the United Kingdom, Germany (along with the European Union) and Japan. Each of them has designed strategies for growth according to its own features and interests. The strategies presented vary in scope, but they all focus on providing a conducive environment with a stable platform from which optics and photonics can take off. It has also been suggested that photonics should have appropriate environments, such as technology platforms and strategic international alliances, known as clusters.

To approach the (proven) best practices of the leading economies, we present the most significant actions that those countries have taken, along with worldwide trends, as a way of gathering valuable information about the steps that Mexico could take to become a leader in the sector, following general paths in the world photonics development and collaborating to open new routes.

General Focus

Within the overall trends, some applications of photonics have drawn the attention of particular sectors:

- The energy sector is oriented toward self-sufficiency, sovereignty, national security and rational use of natural resources.
- With regard to telecommunications and information and communication technologies, national security, increased competitiveness and environmental protection are the primary goals.
- Advanced manufacturing focuses on market leadership, growth in competitiveness and national security.
- Medicine and the health sector are most interested in national security, increased competitiveness and protection of the population.
- The area of security and defense is concerned with national security, self-sufficiency and sovereignty.

United States

The objective of this country is to produce a comprehensive initiative that involves the triple helix in developing a focus centered more on the management of photonics with regard to research and development for its applications in industry, government and related investments.

By fostering this sector, the United States aims to progress and maintain world leadership in the industry. It is the largest photonics market in the world and the second largest producer, after China.

In 1998, the National Research Council (NRC) of The National Academies, developed the report *Harnessing Light, Optical Science and Engineering for the 21st Century*, aimed at providing recommendations for sector development. The report presents an overview of the real and potential impact of optics and photonics in the largest U.S. sectors.

In 2013, the NRC published the report *Optics and Photonics, Essential Technologies for Our Nation*²⁶, a review of important breakthroughs in the fields of optics and photonics. As a result, the United States established its National Photonics Initiative (NPI)²⁷ in 2013, to identify other major areas for progress and thereby recover U.S. competitiveness and maintain national security. The following topics stand out:

- advanced manufacturing
- communication and information technologies
- defense and national security
- energy
- medicine and health

The NPI will lead a collaborative effort to improve data collection and presentation on research, development and economic strides in this sector. The project will gather statistical data on jobs, production, private investment, federal investment and development of support for local photonics analysis programs.

Following the NPI's recommendations, the Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) was created in 2014. It is a regional hub geared to creating a positive ecosystem for photonics in the United States, thereby paving the way for greater collaboration between applied research and commercial product development through triple helix alliances.

European Union

As part of its New Horizon 2020 program, the European Union has allocated over two billion dollars to photonics research and development for a period of more than seven years.

It published the study **The Leverage Effect of Photonics Technologies: The European Perspective**²⁸, which examined the structure and dynamics of the European value chains in key photonics technologies and how they can be developed in the future. Six value chains were also analyzed, taking into account economic, demographic, political and technological factors in order to understand the European position:

- Systems for scanned images and illness detection and treatment
- Data transmission, storage, communication and networks
- Screens and monitors
- Advanced lighting (limited to solid state lighting)
- Photonic energy systems
- Laser systems

Comprising over 20 percent of the world photonics market, Europe has about 5,000 active companies active in the field and more than a thousand research organizations expanding knowledge in the area.

The Photonics Public-Private Partnership initiative aims to align with public and industrial strategies. It brings together academia, industry and public resources to provide sufficient know-how, thereby achieving the essential investment for making strides in the sector.

Germany

In 2011, Germany committed to allocating approximately one billion 300 million dollars to photonics research and development over a period of ten years. It launched the financing program Photonics Research Germany: Light with a Future, through the Federal Ministry of Education and Research (BMBF).

United Kingdom

Regional photonics clusters are compatible with and/or are coordinated by government, for example, knowledge transfer networks on plastic electronics such as PPE KTN. Furthermore, the counterpart to the NPI in the United States, the Photonics Leadership Group (PLG), was created in 2013.

Photonics Innovation Clusters

Photonics clusters were the first regionally organized entities. Members in such places include large companies, small and medium-sized enterprises (SMEs), start-ups, public and private research centers, universities, specialized suppliers, investors, consultants and regional and governmental agencies. In particular, such agencies, together with cluster networks, often act as intermediaries between the cluster and national or regional governments. Generally, group members work under a common interest and development strategy aimed at generating synergy in research, development and innovation (R+D+i) in one or more markets.

Clusters in Europe –perhaps the best example of directed collaboration– are based on cooperation among educational, research and investment institutions as well as governmental support with the objective of:

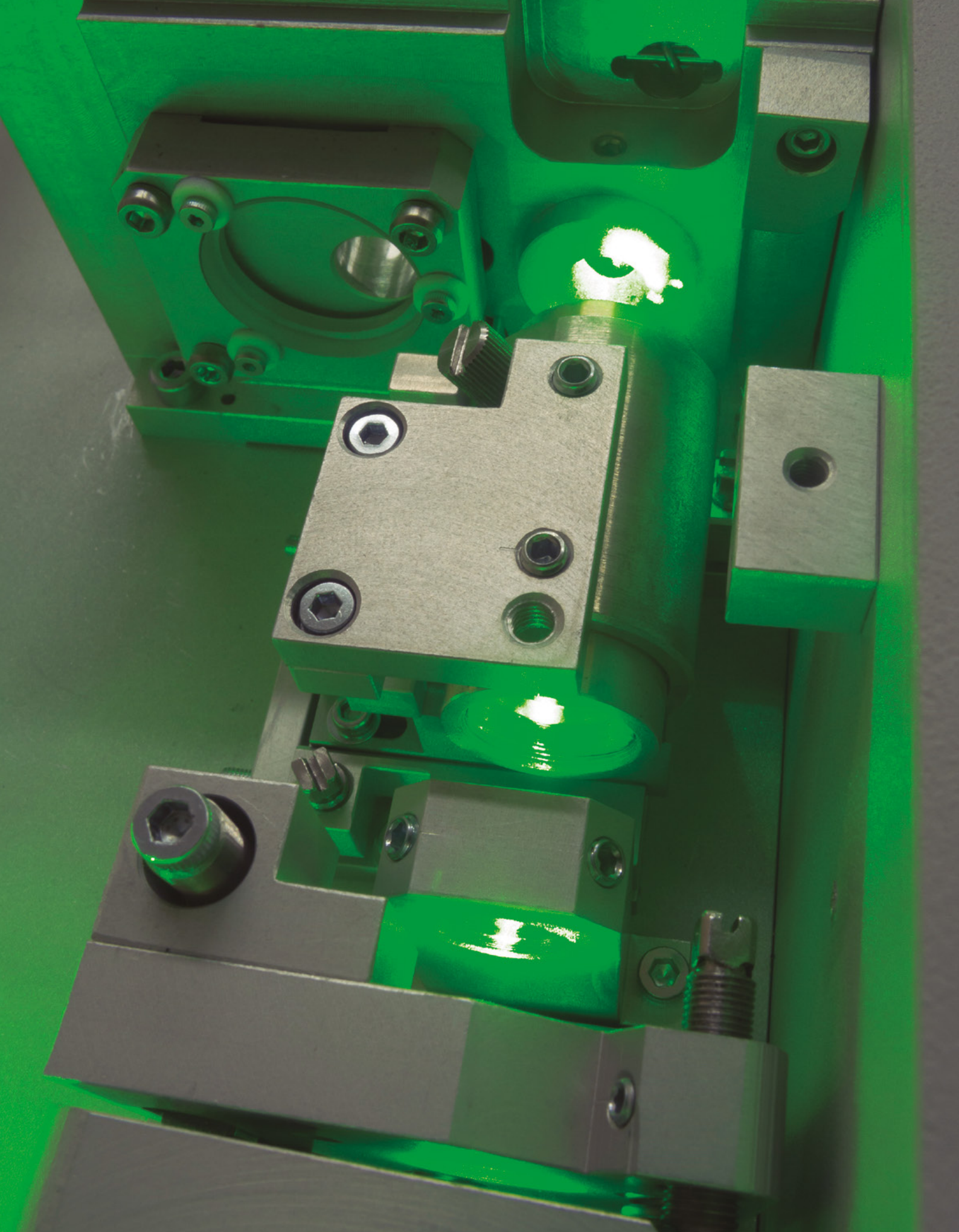
- triggering interaction and exchange of knowledge,
- redirecting R+D resources toward new innovative actors,
- increasing productivity and innovation,
- promoting photonics solutions for members/users,
- stimulating the formation of new businesses, development of new markets, products and services; and
- promoting photonics excellence (local, national, European) for potential foreign partners.

Photonics clusters primarily operate locally or regionally, although their activities sometimes extend to the European level. This is evident through their participation in international research and development programs and in European projects related to transnational cooperation among clusters.

National Technology Platforms

National technology platforms for photonics have existed since 2005, following the successful launch of the European Technology Platform (ETP) Photonics²¹. Such national consortia are networks of public and private actors who share strategic topics on photonics and work together to overcome resource fragmentation, define a common strategy and achieve political visibility. Possible follow-up activities to national platform activities are national research and development funds, as well as political measures for specific innovation that would expand the national and international visibility of photonics.

CHAPTER 4



SWOT ANALYSIS OF PHOTONICS IN MEXICO

Part of the methodology for producing a Technological Roadmap requires knowing the history, current situation and future trends of a topic to be able to foresee correct decisions within a systematic strategy of action.

The SWOT matrix is a current situational analysis tool that provides us with a description of the photonics industry, and the Technological Roadmap is a flexible instrument that adapts to the different circumstances and trends, thus requiring constant monitoring. Successive diagnostics should be conducted periodically, to maintain a situational analysis that is applicable to the strategy. The initial one is used as a reference, to review whether the strategy is achieving the objectives, given that external and internal conditions are dynamic and some factors change over time, while others undergo minimal modifications.

Internal Analysis

This part of the SWOT identifies factors in the project itself that affect it. In a way, we are talking about a self-evaluation in which the strong and weak points of the industry have to be defined.

STRENGTHS

Among the own capabilities of photonics in Mexico, we found that:

- More than 43 million people²⁹ (37% of the population) in Mexico have access to smartphones (with camera) or other devices that use photonics-based components. The population that uses this type of device is growing, and as a market, it potentially reaches 120 million Mexicans.
- Thanks to new technologies, there is a great amount of young talent that can be attracted to the area of science and technology through a smartphone or other devices with Internet access.
- Research in optics and photonics is consolidated in Mexico by diverse institutions throughout the country (in addition to those interested)^{***}.
- Because Mexico has a large number of free trade agreements with key regions in terms of world development and growth, such as North America, Europe and the Asia-Pacific region, it is a very important convergence point for technology and standardization.
- The skills to manufacture “special” optical components exist in Mexico, and they have lessened in other countries.

The photonics industry in Mexico presents itself as a developing sector. It has various strengths to help it grow in the country and numerous opportunities to achieve regional leadership. The strengths presented by the Group of Trust reveal a possibility for industry growth. In other words, we have the capacity to achieve the primary objective of the Technological Roadmap project: to use current resources to enable a developing industry to take root and progress explosively past the point of no return.

The fact that numerous people have devices that use photonics-based components is a major indirect strength, as it will increase the population’s understanding of this branch of optics and will generate greater interest in its study and use. The idea is that –via the corresponding IMF-derived plans– the same population will support photonics consolidation in Mexico.

The foundations are established: talent, companies’ photonics enabling environment, interest on the part of actors in academia and industry. However, it is still essential to have a strategic plan such as the one presented here to manage efforts directed at achieving great milestones in optics and photonics.

^{***}This marks the moment to establish photonics manufacturing centers that develop devices via contracts with private initiatives or government entities such as SEDENA, SEMAR, SSA, SEP, SENER, SEDESOL, etc.

WEAKNESSES

Some factors that contribute to an unfavorable competitive position are:

- A large percentage of the relationships made between higher education institutions, public research centers and the industry focus on providing low value added services and technological content, in addition to offering them at lower costs than potential competitors.
- We do not have solar-grade silicon factories.
- A comprehensive national plan for the development of optics and photonics is non-existent in Mexico.
- Academic programs are mostly oriented toward training academics without direct ties to industry.
- We do not have an ultra-high intensity laser –known in the trade as petawatt lasers³⁰– that would allow the country’s scientific community to conduct research on the new frontiers of knowledge.

The weaknesses of optics and photonics in Mexico lead to the lack of capacity to develop projects that should be strategic for positioning the country in this sector. Academic and industrial skills must be improved.

In the academic setting, the main weakness is the lack of connection between academia and industry. Training plans tend to produce more researchers because at all levels, from beginners to the most versed in photonics and optics, those who publish an article or conduct a research project are supported while those who link up with industry are not, except for projects with little added value and technological content. That is why interest in the study of these areas has dwindled. Plans that effectively link academia to industry need to be created, as they can combine resources to achieve benefits at new levels.

Despite the foregoing, on the industrial side there is still a need (which presents an investment opportunity) to create supply chains both for the entire photonics industry and for solar-grade silicon factories and other manufacturers. Insufficient production in other industries such as metallurgical-, chemical- and electronic-grade silicon, could possibly be covered by these factories.

Hand in hand with solar-grade silicon is the development of a petawatt laser system, given the most recent scientific discoveries and the particularities of laser use in modern physics (such as cooling with laser).

Making the most of the strengths of both photonics and optics, as well as the abilities of Mexico in creating competitive companies with high quality standards, has become one of the main objectives of this technological roadmap. The purpose is to position the country as the leader in photonics and optics in Latin America.

EXTERNAL ANALYSIS

This section identifies the key factors that are external to the project, as they are generated by other actors or circumstances that do not directly affect the project, such as those related to international competition, market changes, technology, economics and politics.

OPPORTUNITIES

Among the positive, beneficial and exploitable contextual factors from which competitive advantages may be derived, are:

- Use/implementation of photonics in development centers for electronics (for example: Intel and microprocessor production and development) and for the lighting, automotive, chemical, pharmaceutical, food industries and others.
- Designing curricular programs to train engineers and technicians in diverse fields of photonics, for example: medical laser system operating technicians, maintenance technicians for fiber optic lines, LED lighting photometry and radiometry technicians and new biophotonics applications.
- Optics and photonics are enabling technologies for the development of other industries, which can lead to deep and intense interaction among them.

- Certain initiatives supported by international scientific societies such as the ICO, The Optical Society (OSA), SPIE, and the American Physical Society (APS) interact vigorously with their Mexican counterpart, AMO, and can help foster the development of specific fields of optics and photonics in Mexico.
- The North American Free Trade Agreement has encouraged foreign investment in Mexico and will be boosted even more with the Trans-Pacific Partnership (TPP). Although a large portion of the investments target the maquiladora industry, the presence of foreign companies in Mexico enhances the possibilities for interaction with academics through design centers in which research and innovation can be conducted.

The opportunities listed by the Group of Trust revolve around international initiatives for the development of photonics and optics, as well as the ability of the country to cooperate with other actors through free trade agreements. This is precisely where the International Year of Light and Light-Based Technologies, 2015 has played a major role in consolidating international collaboration to strengthen the photonics sector. Countries such as the United States, Germany and Japan lead the technological development of applied photonics by creating high-value technologies that empower other industries such as telecommunications and manufacturing.

Moreover, it is worth noting the willingness of numerous investors to support programs to train talent, create new manufacturing industries in the country and develop research that could contribute to high added value to the photonics industry in Mexico .

By taking advantage of the opportunities, Mexico can become a center of applied technological development in the field of photonics.

THREATS

Some external situations that could endanger our project are:

- Brazil and Chile (direct competitors of Mexico in Latin America) have invested heavily in training talent and installing infrastructure.
- Mexico has a manufacturing society without its own technology.
- Other countries develop technologies rapidly.
- Some large laboratories have the support of their governments to develop new technologies (such as the American Institute for Manufacturing Integrated Photonics, in the United States, and Germany's Fraunhofer-Gesellschaft).

Threats are external situations that can obstruct a project. In this case, the main threats to Mexico becoming the leader of photonics and optics in Latin America are Brazil and Chile, given that they have invested more in the industry. However, we are not far from them and we can still get ahead thanks to the regional power of Mexico. One important factor is that certain governments actively support laboratories to develop, apply and market new technologies. This benefits our competitors internationally, as they accelerate the development of impactful photonics-based technological applications.

On the other hand, there is a risk of incorrectly directing investments, studies and production of photonics-based technological goods, which would encourage a manufacturing society without its own technology. If this path is followed, the country could not only lag in the photonics industry but also in the industries enabled by it, which would cause technological stagnation by favoring only low-cost manufacturing and assembly. New technologies must be developed in order to keep up the pace to secure a regional leadership position.

CHAPTER 5

TREND ANALYSIS

The trend analysis is based on the work done by the Group of Trust, which has closely followed the main forecasts that could affect photonics and optics in Mexico, by researching the strategic plans of countries that stand out in the sector.

Some of the industrial trends are merely proposed in this document, given that national industry has not developed significantly, yet the global outlook gives us an idea of the direction that such enabling technology is taking. Moreover, the comprehensive outlook on trends that could directly or indirectly affect photonics and optics presents us with technological, trans-industrial, political, social, environmental and economic situations that will also be studied.

Medium- and long-term views specific to the type of proposed trend are discussed.

Overall, the trends of the Internet of Things (IoT), connectivity, industrial improvements in manufacturing production guided by Industry 4.0, and of medical advances with hybrid technologies to improve artificial organ processes and integration, point to the need for new photonics technologies that facilitate communication among devices, integration of hybrid technologies and progress in specialized sensors, whether for security, geo-location or advanced production. All of these expansive trends in different industries can and must be enabled by photonics, which is responsible for efficiently facilitating the steps that lead to their specialized and generalized (common use) application. It thereby becomes a transversal technology that participates in high-value projects in various sectors. For example, energy improvements through approaches to clean electric energy use and generation, thermodynamic efficiencies for environmental benefit and energy optimization for electronic proceedings based on silicon circuits go hand-in-hand with progress in photonics and optics.

To analyze trends in photonics more specifically, we have grouped them into six sections according to their field, each one relating to other industries or sectors.

Technology Field

- Increase in data transmission speed and bandwidth: fiber to the home.
- Generation of capacities for the development of new technologies.
- Modern self-sufficient devices.
- Development of new materials.
- Fiber optics for connectivity in biological beings.

Inter-Industrial Field

- Integration of the photonics industry.
- Consolidation of manufacturing with photonics technology.
- Use and manufacture of international-quality photonics components (for example, LEDs, panels and sensors).
- New disruptive technologies (such as 3D printing and advanced manufacturing).

Political Field

- Decrease of civil expenses.
- Improvements in techniques and materials for lighting and energy generation.
- Development of regulations and certification programs for photonics-based technologies.

Social Field

- Demographic bonus in growth.
- Demand for human capital with advanced specializations.
- Intelligent urban systems.
- National security systems.

- Constant connectivity (Internet).
- Growing culture of health in diverse areas.

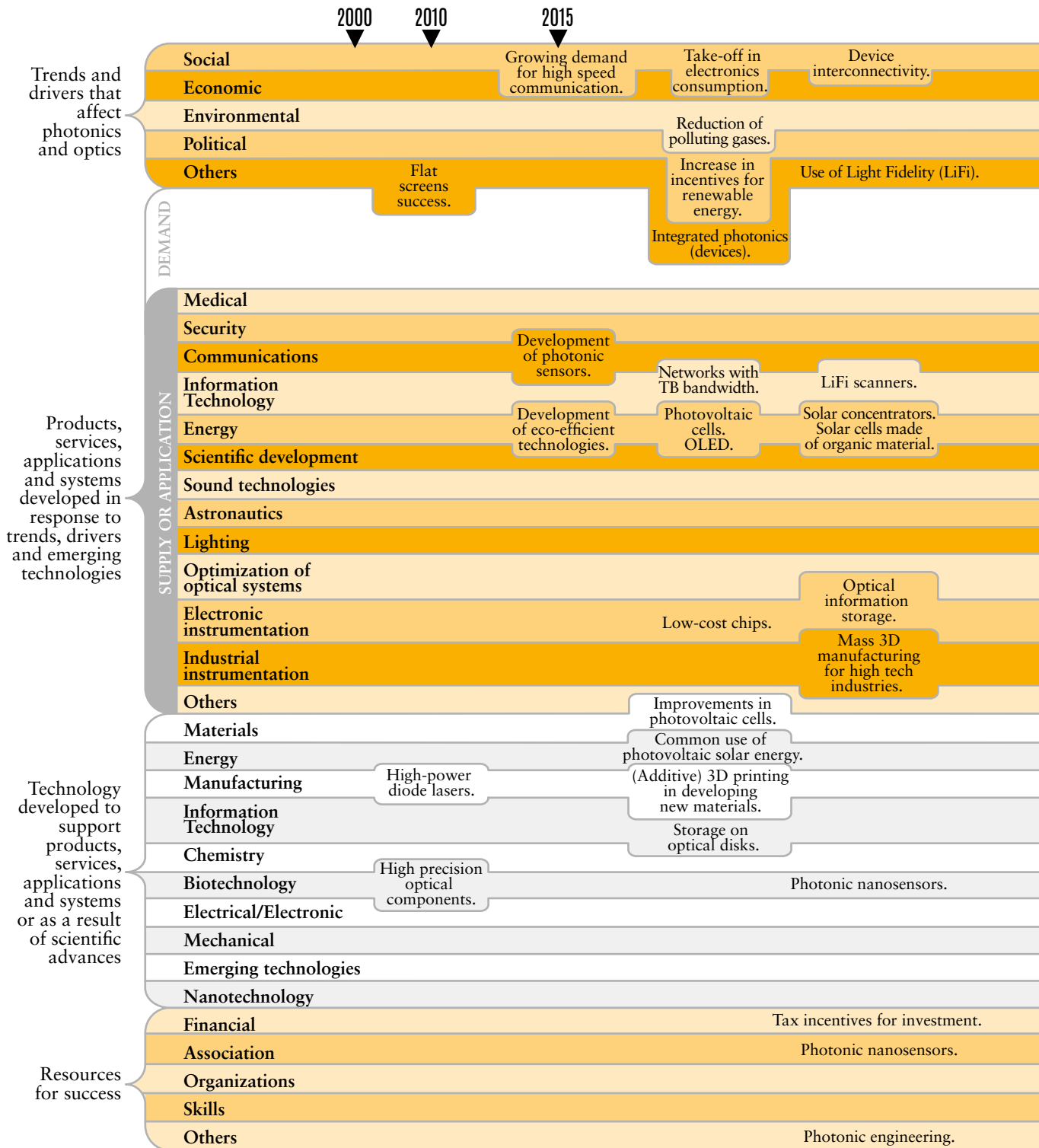
Environmental Field

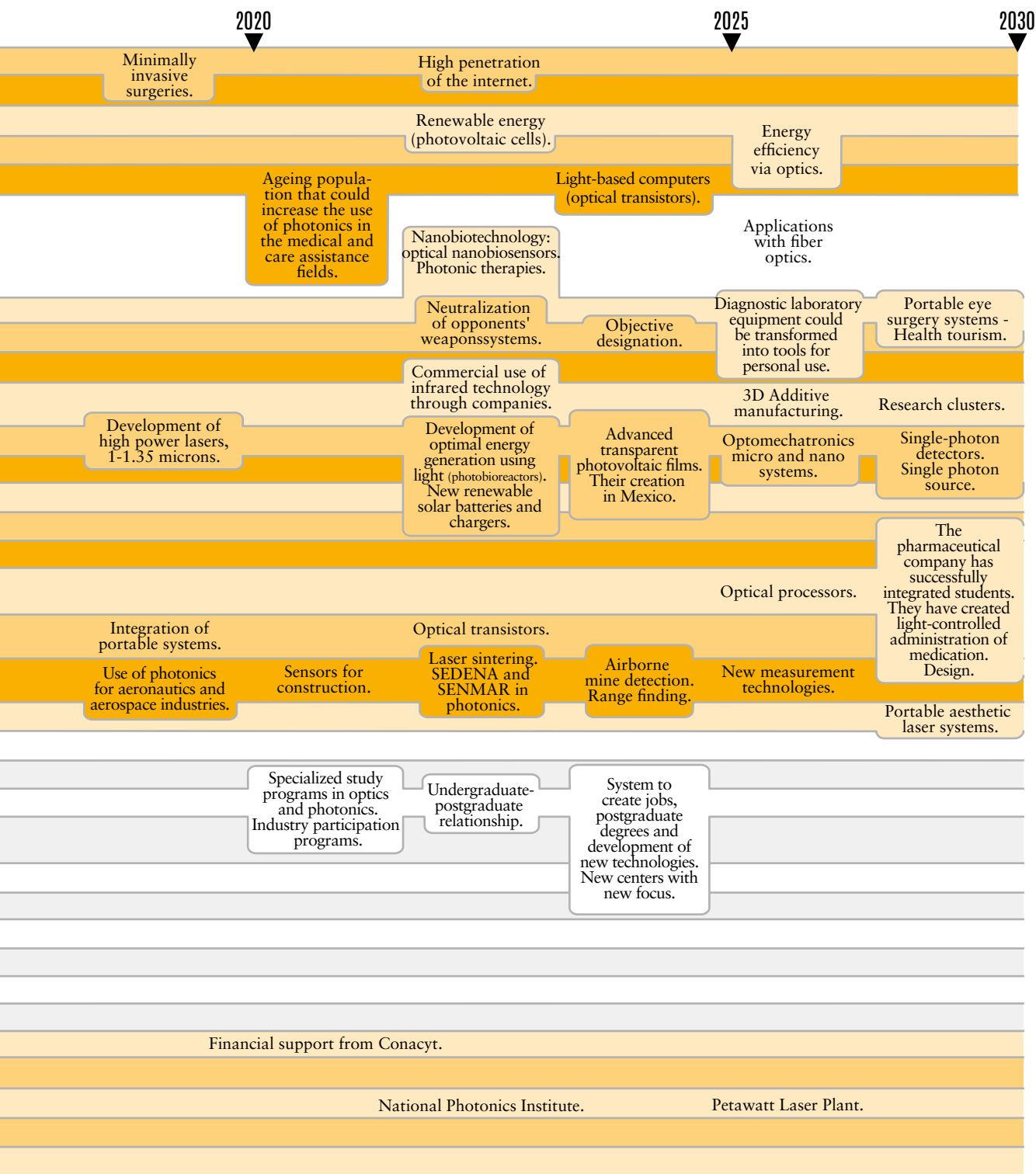
- Energy efficiency (Paris Protocol).
- Generalized environmental awareness.
- Search to increase renewable and efficient energy sources, as well as materials for energy self-sufficiency.

Economic Field

- Development of supports for kickstarters and start-ups.
- Government support for the development of high-value technological industries.
- Economy of scale in reducing production costs.
- Development of the national blue ocean strategy to increase leadership in investment at the regional level (Latin America).

STRATEGIC OVERVIEW OF OPTICS AND PHOTONICS





CHAPTER 6



MILESTONES AND PROJECTS

The next step after reviewing the current situation and trends of the sector is to define the strategic actions required to achieve our objective of developing photonics in Mexico.

This section and the action plan are based on “drivers” geared toward future societal and sector needs. Such strategic projects, defined after extensive analysis, may well be the very core of the technological roadmap. The idea is to determine, not only where we intend to get, but also the steps to take, as well as the existing capabilities and those that still need to be created in order to fully carry out every project within the master plan.

The milestones and strategic projects defined for the national optics and photonics industry are the result of the contributions and consensus of the Group of Trust that took part in the exercise. In turn, they present a comprehensive development proposal that should spark other sectors. The dates that appear are feasible yet not binding, since they were proposed prior to the active participation of the industry.

MILESTONES

2016 - 2020 MILESTONE 1
Achieve urban lighting with Smart LEDs to improve efficient energy use in an Urban Operating Systems (UOS) environment.

2016 - 2020 MILESTONE 2
Mexico will achieve an energy efficiency increase (use and production) through photovoltaic cells to produce electricity and efficient liquid fuels.

2016 - 2020 MILESTONE 3
Achieve urban connectivity with high-quality national fiber optics, and thus enable the corresponding industry in the country.

2016 - 2020 Mexico will design and produce 2-20 μm photonic sensors, as well as developing an ultra-high intensity laser (petawatt), and will control the quality of the processes through appropriate certifications.

Strategic Milestones

Strategic Projects

1. Achieve urban lighting with Smart LEDs to improve efficient energy use in an Urban Operating Systems (UOS) environment..

1.1 Improve energy efficiency and develop the industry via a project for widespread use of nationally manufactured LEDs for public lighting.

1.2 Develop studies and proposals for direct and indirect incentives to support manufacturers focused on photonics, especially LEDs.

1.3 Develop projects to bolster the supply of photonics materials and the business ecosystem so that a complete logistical mechanism can be developed.

1.4 Support the development of design and innovation centers for photonics materials for LEDs (preferably in the Mexican Photonics Cluster) and a strategy for specialized certifications.

2 Mexico will increase energy efficiency (use and production) by means of photovoltaic cells to produce electricity and efficient liquid fuels.

2.1 Promote research, collaboration, and investment to develop companies that produce photovoltaic cells and advanced silicon.

2.2 Conduct a study on the current state of silicon and advanced photonics materials production in order to propose a way to develop the country's competitiveness.

2.3 Develop production and research centers for silicon and photovoltaic material, focused on organic, inorganic and hybrid technologies, in cooperation with the AMO³¹.

2.4 Promote the creation or strengthening of agencies focused on standardization, certification and accreditation of laboratories and factories, jointly with the Mexican Photonics Cluster.

2.5 Create strategic alliances to form supplier and production networks that will give Mexico a head start in the race for photonics-enabled energy sources.

Strategic Milestones

Strategic Projects

3. Achieve urban connectivity with high-quality domestic fiber optics.

3.1 Design the Urban Connectivity project to satisfy the constant telecommunications demand, which will help to increase network penetration among the different users, thereby improving civil and business communications³².

3.2 Articulate incentives and regional and national strategic projects, taking advantage of the actions taken during the International Year of Light and Light-Based Technologies, 2015, focused on generating and integrating technological know-how³³.

3.3 Develop the industrial foundation and production know-how for specialized and technologically advanced fibers through alliances with major producers for their inclusion in the Mexican Photonics Cluster.

4. Mexico will design and produce 2-20 μm photonic sensors and an ultra-high intensity (petawatt) laser and will control process quality through appropriate certifications.

4.1 Design incentives for research and production of 2-20 μm photonic sensors and construction of an ultra-high intensity laser, leading to program development for frontier research and advanced photonic component manufacture.

4.2 Establish a network of strategic alliances that reinforces the role of Mexico in the development of revolutionary technologies such as 2-20 μm sensors, ultra-high intensity laser and optically connected optical network clocks³⁴.

4.3 Create the Mexican Photonics Cluster focused on research, development and production of specialized materials, ultra-high intensity laser and commercial applications of photonics, maintaining international quality management throughout the various processes by means of a national certification center or international alliances and certifications.

CHAPTER 7

ACTION PLAN

This section describes in greater detail each one of the objectives, benefits and action plans and identifies the leaders responsible for comprehensively developing the projects so as to reach the strategic milestones. Based on the various situational and trend analyses already carried out, investment opportunities in developing technologies and businesses in the photonics and optics sector can be seen clearly.

Participation by a sound industry brings development opportunities with it, which is why the milestones show current capabilities as well as the interests of some of the actors involved in the sector to attract investment (among them the government and the AMO).

MILESTONE 1

Achieve urban lighting with Smart LEDs to improve efficient energy use in an Urban Operating System (UOS) environment

Urban lighting in several pilot cities is an effective way to promote the Mexican photonics industry and the development of advanced materials, which are the means to creating a project with high social, economic and environmental impact. The first milestone is supported by the creation of the Mexican Photonics Cluster (which will be central to research, production and promotion of photonics and optics in Mexico), efficient organization of the logistics chain (focusing in particular on procurement) and the alliances that will enable the UOS to function efficiently with LED lighting applications.

PROJECT 1.1: Improve energy efficiency and develop the industry via a project for wide-spread use of nationally manufactured LEDs for public lighting.

OBJECTIVE

To promote the benefits of using national LEDs in public lighting systems in pilot cities.

BENEFITS

- Energy use efficiency.
- Cost reduction.
- Synergy between the LED lighting systems and the UOS.
- Increase in jobs and generation of wealth through national production.
- Conditions established to attract direct foreign investment that supports national production.
- Environmental impact reduction.
- Coordination of the procurement chain.

ACTION PLAN

1. Select pilot cities.
2. Promote the concepts of the project in regions that could produce the material and the LEDs.
3. Develop an action plan in the pilot cities that facilitates systematic application of LEDs in the Smart lighting of the cities.
4. Invite the companies needed for the procurement chain.
5. Support the development of Mexican companies and application of their quality LED products.

Execution period 2020.

PROJECT 1.2: Develop studies and proposals for direct or indirect incentives to support manufacturers focused on photonics, especially LEDs.

OBJECTIVE

To strategically attract companies, researchers and leaders to develop processes primarily focused on LED production in national projects.

BENEFITS

- Creation of a group of trust for the studies and generation of incentive proposals for the new manufacturers.
- Attraction and execution of new projects aimed at researching LED materials and/or processes.
- Positioning the region as an environment conducive to the development of new business projects (preferably in the Mexican Photonics Cluster).

ACTION PLAN

1. Specify the value proposition that could be enjoyed through studies on new photonics materials and products.
2. Define public policies for attracting companies and investment, and develop national promoters of photonics material production, primarily to manufacture LEDs.
3. Propose direct and indirect incentives for those mentioned in the previous point, based on the creation of a consistent ecosystem for business development in the sector.
4. Support and care for new projects, by placing greater emphasis on technology production and design companies.

Execution period 2016 – 2020.

PROJECT 1.3: Develop projects to bolster the supply of photonics materials and the business ecosystem, so that a complete logistical mechanism can be developed.

OBJECTIVE

To have a development program for the value and supply chain and thus keep up with the various photonics production companies.

BENEFITS

- Appropriation and application of specialized knowledge on topics of interest for the sector.
- Solid network of material and knowledge suppliers among different major actors within the sector.
- Increase in companies' competitiveness and productivity.
- Important part of the business ecosystem.

ACTION PLAN

1. Identify national companies with the capacity and sufficient technical knowledge of photonics production topics or of industry-compatible materials, as well as production capacity with high-quality certification elements.
2. Expand the expert buyers for supply of materials, components, equipment and tools.
3. Draw up agreements with academic institutions, public research centers and domestic and international companies to form a consortium of specialized photonics and optics materials and techniques.

Execution period 2016 – 2018.

PROJECT 1.4: Support the development of design and innovation centers for photonics materials for LEDs (preferably in the Mexican Photonics Cluster) and a strategy for specialized certifications.

OBJECTIVE

Create specialized photonics centers that focus primarily on materials for LEDs (thus collaborating on carrying out project 1.5), complemented by a photonics certification center operating within the Mexican Photonics Cluster.

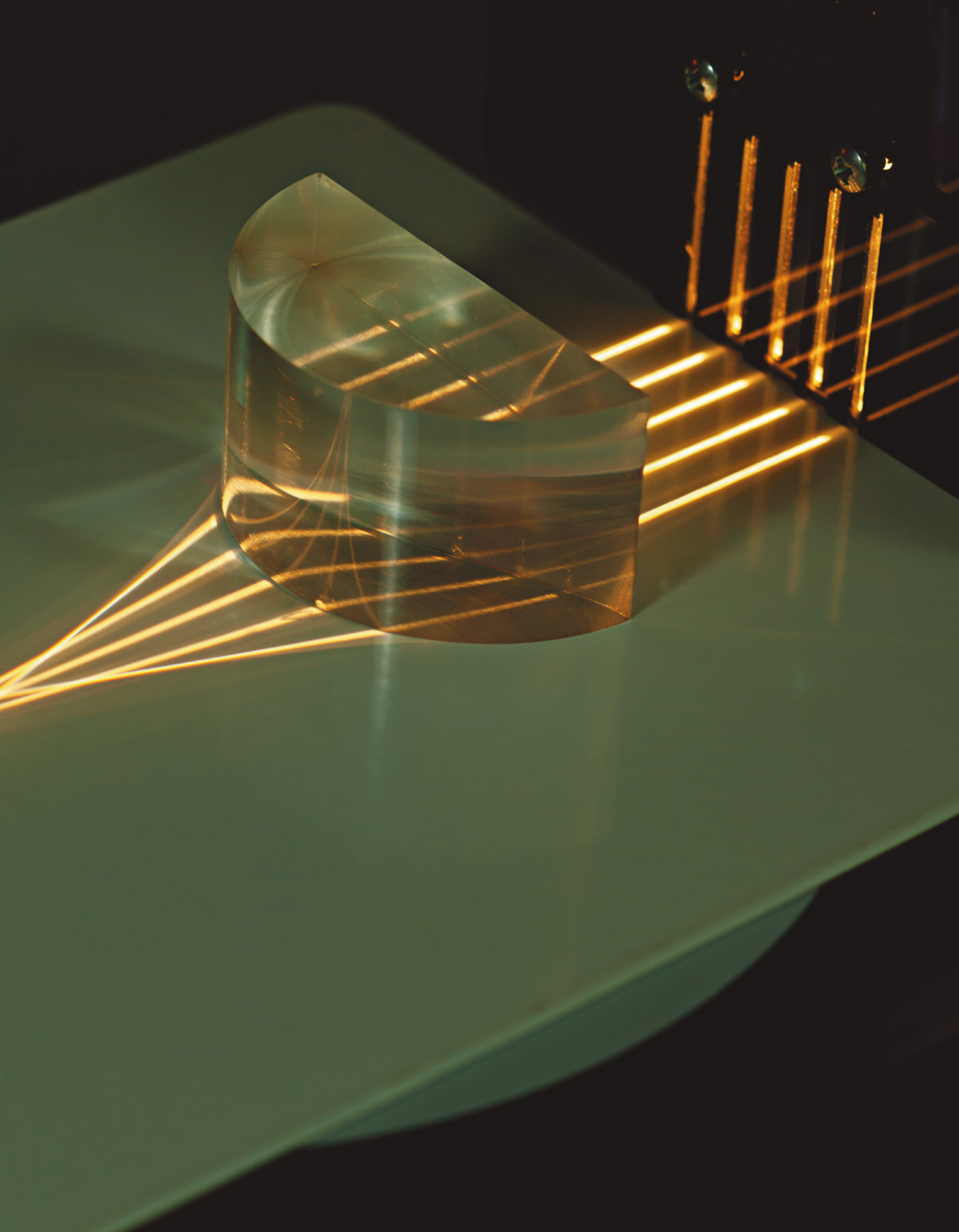
BENEFITS

- Having state-of-the-art centers for the design of materials, projects and innovation production for LEDs and other materials for the sector.
- Development of sector technology in Mexico so as to be a regional leader.
- Decrease in costs of production, know-how and intellectual property for developing advanced optics and photonics products.

ACTION PLAN

1. Define sector needs in order to achieve the technological advances to carry out the projects described herein, as well as a future vision for photonics in Mexico.
2. Select the materials, necessary technologies and required know-how for which we should focus the efforts of the innovation and design centers, according to the Group of Trust.
3. Design a medium-term certification plan for the research and production of such photonics materials, with a view to making it the cornerstone of the specialized certification center within the cluster.
4. Establish the bases and evaluation mechanisms for compliance of products, systems and services required by the industry in the country.
5. Secure the required permits and licenses for the specialized photonics and optics certification center.

Execution period 2020.



MILESTONE 2

Mexico will increase energy efficiency (use and production) by means of photovoltaic cells to produce electricity and efficient liquid fuels

Photonics also plays an important role in high-value strategic sectors such as energy. Much research has been done on the production of renewable energy as well as reduced energy consumption for illumination, and photonics brings technological advances such as high efficiency solar cells and the creation of efficient and renewable liquid fuel, which could revolutionize the energy market.

An innovative system based on renewable energy will be used to transform electric power production in the country. The goal of the first phase is to increase photovoltaic cell efficiency and to extend their application so that they become a viable source of energy that leads to economic, environmental and social benefits.

In the second phase, the idea is to use the benefits of the photovoltaic cells together with a bacteria with which hydrogen can be transformed into a more controlled liquid fuel (because unlike hydrogen, its volatility is low), which is a sustainable way to produce renewable energy, and it can be transported within the country through the liquid fuel network that already exists. This project also shows the enormous interaction of photonics with other disciplines, which creates new technologies.

The challenge is to strengthen and consolidate collaboration with industry and participate in projects and programs of greater added value and impact, from research to application of spear-heading technology in this energy branch of photonics.

PROJECT 2.1: Promote research, collaboration, and investment to develop companies that produce photovoltaic cells and advanced silicon.

OBJECTIVE

To create an ecosystem conducive to promoting research and production of advanced, photovoltaic grade silicon.

BENEFITS

- Development of the early stages of a legal framework for the establishment of a fertile environment for national photonics.
- Design of support plans among the main actors of the sector that converge in the creation of competitive hubs such as the national photonics cluster.
- Creation of alliances that drive research, development and investment in areas related to the photonics energy sector.
- Attraction of investors due to the security that the regulation of the sector provides, as well as the governmental and academic support underlying it.

ACTION PLAN

1. Propose the legal framework within which the photonics industry will operate, with an emphasis on innovation technologies.
2. Define policies to attract companies, investment and national promoters of production of photonics material for the energy sector.
3. Propose direct and indirect incentives for the above.
4. Secure a strategic alliance plan with national and international institutes to foster research and investment.

Execution period 2020.

PROJECT 2.2: Conduct a study on the current state of silicon and advanced photonics materials production in order to propose a way to develop the competitiveness of the country.

OBJECTIVE

To propose a development plan based on market, business, cost reduction verification, possible incentive and subsidies for the development of sustainable energy studies, as well as a national supplier matrix.

BENEFITS

- To have the capacities matrix.
- Development of a supply strategy focused on establishing a national value chain.
- Increase in the country's competitiveness and business environment.

ACTION PLAN

1. Create a commission leader for the project, to determine the scopes and points to be studied regarding the state of photonics in Mexico.
2. Conduct an in-depth analysis prior to laying the foundations for the design of a competitiveness development plan for the photonics sector, as well as the country's current and desired capacities.
3. Direct the study to the commissions, which will propose necessary actions to achieve the objectives for optics and photonics in the country. Add it to the industry capacities matrix.

Execution period 2016 – 2020.

PROJECT 2.3: Develop production and research centers for silicon and photovoltaic material focused on organic, inorganic and hybrid technologies, in cooperation with the AMO.

OBJECTIVE

To develop a main production and research center for silicon for photovoltaic applications with the objective of enabling the creation of solar panel farms in the country, as well as progress in efficient energy sources.

BENEFITS

- Design and development of know-how for the use of photovoltaic cells that generate sustainable energy.
- Regional leadership in the research of advanced materials with a focus on the energy sector.
- Utilization of liquid fuel distribution capacities.
- Remain at the energy, environmental and scientific forefront with high-potential developments at a moderate cost.

ACTION PLAN

1. Identify national companies that have the capacity, sufficient progress in technical knowledge of photonic production topics or industry-compatible material production and production potential with high-quality certification elements.
2. Create a team to evaluate possibilities, needs and costs for the production and research centers to be designed, keeping in mind the silicon production industry of Mexico.
3. Define the measurements for creating material that can be certified within proper quality control.
4. Design the plan for researching, patenting and developing liquid fuel by using photovoltaic energy and bacteria on hydrogen residues.
5. Draw up agreements with academic institutions, public research centers and domestic and international companies to form a consortium of specialized photonics and optics materials and techniques.

Execution period as of 2016.

PROJECT 2.4: Promote the creation or strengthening of agencies focused on standardization, certification and accreditation of laboratories and factories, jointly with the Mexican Photonics Cluster.

OBJECTIVE

To have an entity that certifies international quality standards for photonics in the country, in support of the Mexican Photonics Cluster work guidelines.

BENEFITS

- Establishment of solid bases to start accreditation processes on more national bodies.
- Decrease in costs of production, know-how and intellectual property for developing advanced optics and photonics products.
- Creation of a leading national certification and accreditation center that will be the regional model to follow.

ACTION PLAN

1. Establish a council that monitors certification and accreditation processes according to a list proposed and approved by the corresponding commission (preferably from the Mexican Photonics Cluster).
2. Research knowledge and methodologies related to international certifications, to choose those that are more closely related to the projects mentioned in this document.
3. Select an international center or organization to create a strategic alliance aimed at accelerating the creation process for the Mexican certifying entity.

Execution period 2017 – 2019.

PROJECT 2.5: Promote the creation or strengthening of agencies focused on standardization, certification and accreditation of laboratories and factories, jointly with the Mexican Photonics Cluster.

OBJECTIVE

To have a development program for the supply and value chain to keep up with the various photonics production companies.

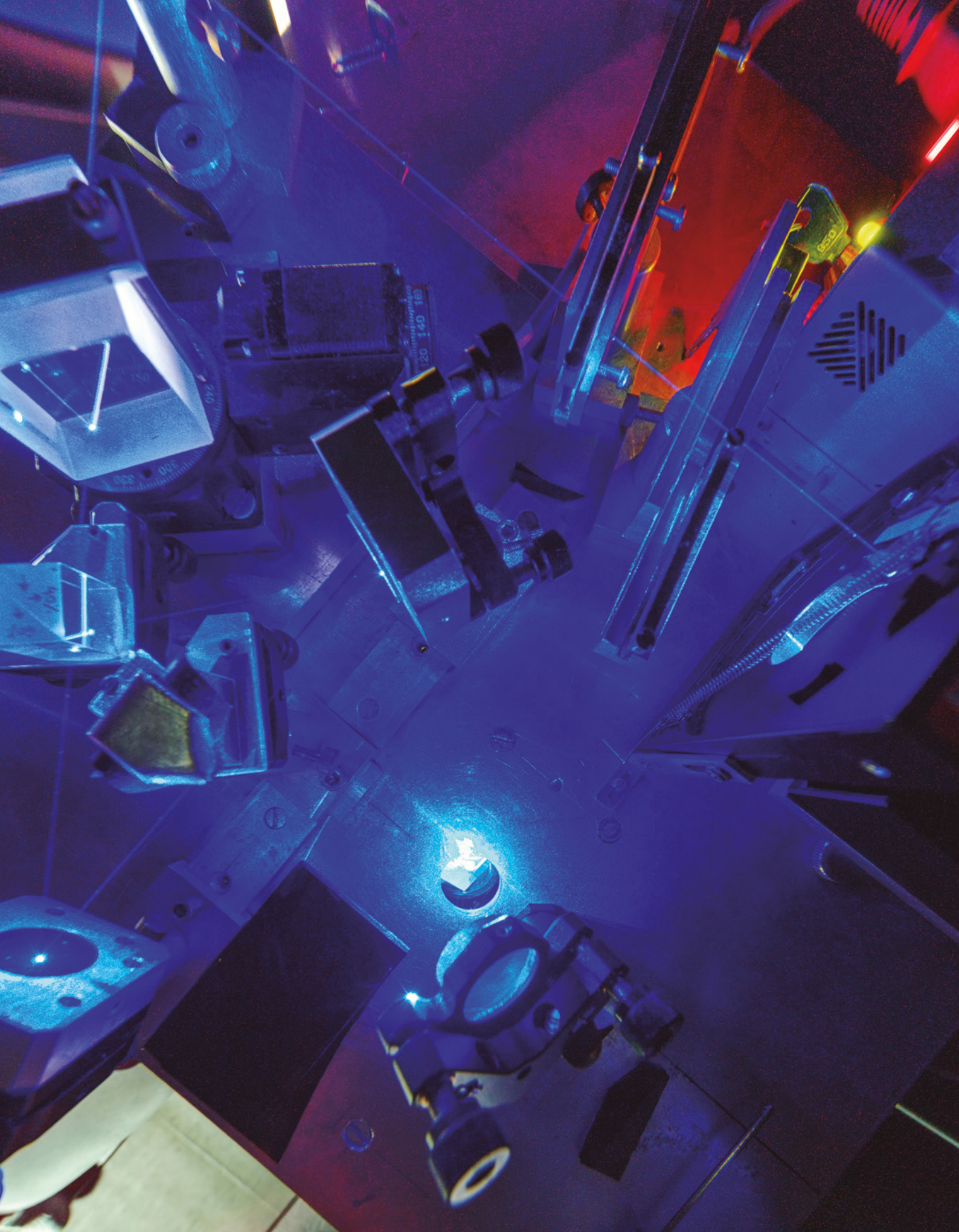
BENEFITS

- Appropriation and application of specialized knowledge on topics of interest to the sector.
- Solid network of suppliers of materials and knowledge among several major sector actors.
- Increase competitiveness and productivity of the companies.
- Support in certification processes thanks to the quality of the materials.
- Create and strengthen the photonics business ecosystem with regard to renewable energy.

ACTION PLAN

1. Identify national companies that have the capacity, sufficient progress in technical knowledge of photonic production topics or industry-compatible material production and production potential with high-quality certification elements.
2. Develop a current supply capacity matrix and a capacity development strategy for companies, according to market forecast needs marked on this roadmap.
3. Develop expert buyers in supplying materials, components, equipment and tools.
4. Build alliances with academic institutions, public research centers and domestic and international companies, to form a consortium of specialized photonics and optics materials and techniques.

Execution period 2016 – 2018.



MILESTONE 3

Achieve urban connectivity with high-quality domestic fiber optics and thereby enable the corresponding industry in the country.

This milestone aims to further buttress the national photonics industry in another one of its main areas: connectivity. To stay at the forefront of telecommunications, data transmission networks must be the fastest, most efficient and have the widest bandwidth possible, which can be accomplished with fiber optics.

The drivers that can justify a connectivity network project in the main urban centers of Mexico go hand-in-hand with the technological breakthroughs that mark the path for the development of the digital era. Among them are the continuous digitalization of methods, processes and contents at all levels and strata (both economic and social), and the widespread use of the Internet of Things (IoT), which requires an uninterrupted exchange of digital information in order to be able to get the most out of its applications. IoT is also widely used for the modern development of industries (for example, in the new trends of these technologies such as the Industry 4.0 movement).

Additionally, there is a social driver: the intensive use of cell phones, computers, electronic, domestic or work devices and consoles that people adopt not only as a tool but as a lifestyle.

Immediate and Direct Benefits.

Some immediate benefits of the urban connectivity milestone center around the development of the country's photonics industry:

- Creation of photonics know-how to maintain regional leadership.
- Development of viable photonics applications with possible commercial outcomes.
- Boost of national industry by supporting it.
- Generation and use of the own patents of Mexico.
- Bolster the Mexican Photonics Cluster by means of a national development plan in a specific photonics-enabled sector.

Whereas some indirect advantages derived from this important milestone are:

- Participation of scientific, industrial and commercial alliances for industry development, establishing the premises for future collaborations.
- Increase in public and private investment in research and development.
- Creation of specialized jobs in advanced communications industries.
- Interaction with programs such as the Internet of Things, UOS and Industry 4.0 via the widespread use of data transmission media in bandwidth.

PROJECT 3.1: Design the Urban Connectivity project to satisfy the constant telecommunications demand, which will help to increase network penetration among the different users, thereby improving civil and business communications.

OBJECTIVE

To exploit and develop coverage, transmission and security of national fiber optics networks so as to remain at the technological forefront of telecommunications, as well as provide a constant bandwidth to major cities with telecommunications-based projects (Internet of Things) interested in developing the country as a regional leader in the information age.

BENEFITS

- Profound synergy with the technological and social advances that require stable connectivity to the data network.
- Development of projects that involve UOS, the Internet of Things, Industry 4.0 and the like for use of smart applications continuously connected to the network.
- Establishment of efficient communications links in the country's major cities.
- Strategic alliances with governments (and entities responsible for national security), industrialists, academics and researchers.
- Being at the forefront of technological advances that, in this information age, revolve around the development of the Internet.

ACTION PLAN

1. Create a specialized commission to study, analyze and design the strategy, projecting to 2025.
2. Research and define photonics communication technologies to be used and their manufacturing method.
3. Select the pilot cities and make alliances with the local governments to create the necessary infrastructure.
4. Develop the central fiber optics communication network.
5. Begin applying the project in major cities that have Internet of Things programs or UOS, to create the necessary synergy to trigger joint success.

Execution period 2025.

PROJECT 3.2: Articulate incentives and regional and national strategic projects, taking advantage of the actions of the International Year of Light and Light-Based Technologies, 2015, focused on generating and integrating technological know-how.

OBJECTIVE

To strategically attract project leaders for the development of technological communications know-how, exploiting the commercial and international advantages of Mexico and possible technological and industrial alliances to promote various initiatives.

BENEFITS

- Support for the telecommunications business ecosystem through photonics and optics.
- Creation of communication channels among diverse actors and leaders in the sector; the possibility of designing initiatives focused on business development and enabling new projects, which would interest new actors such as the navy and the army.
- Development of complex projects –otherwise not feasible to carry out– that will put Mexico in a regional leadership position.
- Enabling of alliances that can focus on other sectors of photonics with a strong industrial boost.

ACTION PLAN

1. Together with the Group of Trust and the main actors that can be located for the national photonics cluster, specific alliances of high strategic value must be made according to the contacts made and objectives to be met.
2. Define special projects according to the institutions that can collaborate on them.
3. Propose direct and indirect incentives for alliance formation, based on possible benefits for the country and the IMF institutions.

Execution period 2016 – 2020.

PROJECT 3.3: Develop the industrial foundation and production know-how for specialized and technologically advanced fibers through alliances with major producers for their inclusion in the Mexican Photonics Cluster.

OBJECTIVE

To create alliances geared toward production and advanced research on optical communication technologies, such as LiFi³⁵, for industry development in the country.

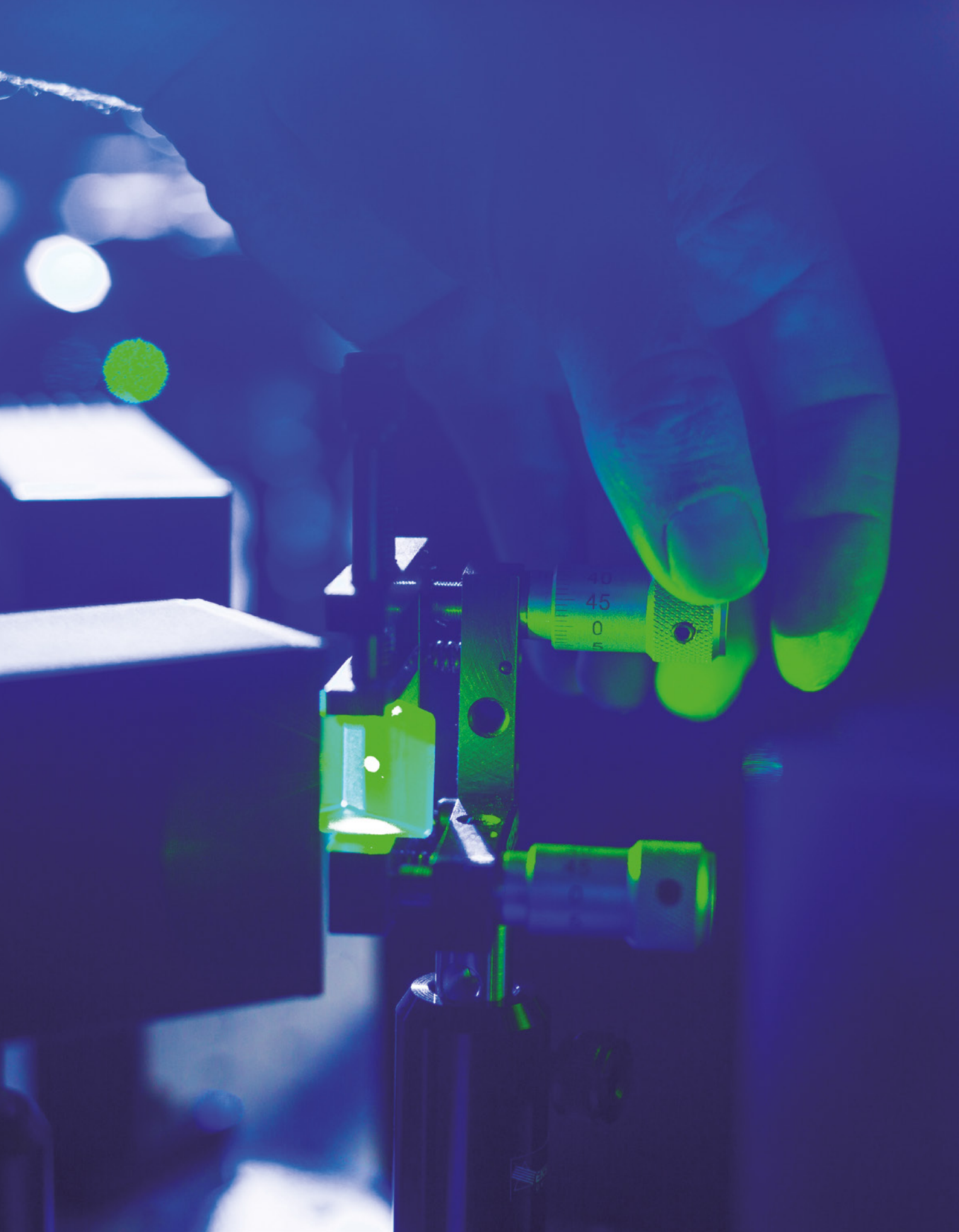
BENEFITS

- Development of a conducive environment for creating the necessary know-how in cutting-edge optical technologies within telecommunications through research and development.
- Generation of the alliances needed to create the appropriate ecosystem and develop the photonics industry and Mexican Photonics Cluster.
- Definition of the strategy for including the largest specialized fiber optics producers in the Mexican Photonics Cluster.
- The opening of closer communication channels with the different research hubs on topics of optical telecommunications for the development and dissemination of various strategic projects.
- Growing interest in the market that will open in Mexico and business opportunities and development possibilities in the telecommunications, medical and industrial sectors, which will lead to attracting foreign and national investment.

ACTION PLAN

1. Establish the committee to define necessary projects to achieve urban connectivity and maintain Mexico's position as a regional leader in the field, together with the projects that require connectivity such as: Internet of Things, digital creative cities and Urban Operating Systems.
2. Define –together with the photonics cluster leaders– the requirements and conditions for the cluster and suppliers to cover their needs.
3. Establish the general plan for contacting the most representative leaders and taking the first steps toward the necessary national and international alliances.
4. Steer the alliances toward new emerging high-value sectors within photonics, optics and the Mexican Photonics Cluster.

Execution period 2016 – 2018.



MILESTONE 4

Mexico will design and produce 2-20 μm photonics sensors and an ultra-high intensity (petawatt) laser and will control process quality through appropriate certifications.

The ultra-high intensity (petawatt) laser is a source of laser light capable of reaching extraordinary space-time energy concentrations. Typically, it can concentrate the equivalent amount of energy to that generated by a thousand hydroelectric plants in a few nanoseconds and in areas of just a few square millimeters. This means that extreme natural conditions can be simulated, so it can act as a laboratory to test designs, materials, and technologies whose performance would otherwise be impossible to determine.

A tool like this is necessary to stay at the technological forefront in diverse productive sectors, but due to its demanding technical characteristics, it is not feasible for companies to build them. That is why countries must develop and maintain them and offer them to companies, higher education institutions, research centers and design and development centers as a valuable input for the technological development of the production plant relying on them.

Among the applications of the tool is the generation of new materials with special and extreme characteristics (hardness, flexibility, etc.), demanding test environments (testing of accelerated aging, exposure to high levels of irradiance, transmission in electromagnetically hostile environments, material welds in extreme conditions); special physical conditions that encourage manifestation of nonlinear phenomena (induction of energy transfer processes and of chemical processes in ultra-rapid reactions) that enable identifying potential applications of new technologies in sectors such as energy, telecommunications, defense and security, manufacturing and pharmaceuticals.

PROJECT 4.1: Design incentives for research and production of 2-20 μm photonic sensors and construction of an ultra-high intensity laser, leading to program development for advanced photonic component manufacture.

OBJECTIVE

To foster investment in industrial projects for 2-20 μm sensor production and the development of specialized technologies such as the ultra-high intensity laser to enable technological progress in optics and photonics in the medium term.

BENEFITS

- Establishment of a fertile environment for the specialized sensor and advanced laser production industry via private and public actions developed within the framework of the sector.
- Attraction of international leaders and actors in the sector via the strategies of the national photonics cluster and the weight this cluster will hold.
- Creation of alliances that drive research, development and investment in photonics for ever more ambitious future projects.
- Enabling of new opportunities in the sector via sensors, ultra-high intensity lasers and certified quality processes that can increase the appeal of the sector.

ACTION PLAN

1. Create a commission that integrates triple helix actors to establish the necessary legal framework to drive the industry, research and application of specialized sensors, as well as the construction of the ultra-high intensity laser.
2. Identify and validate the technologies involved.
3. Create the country's capabilities matrix to determine the specific strategy for developing such technologies internationally.
4. Establish strategic alliances for the creation of the advanced certification center, keeping in mind the use of intellectual property assets at the research level, but above all, for national and international marketing.
5. Propose incorporating such projects in the Mexican Photonics Cluster.

Execution period 2020.

PROJECT 4.2: Establish a network of strategic alliances that reinforces the role of Mexico in the development of revolutionary technologies such as 2-20 μm sensors, ultra-high intensity laser and optically connected optical network clocks.

OBJECTIVE

To position Mexico among the countries developing advanced technologies intended to revolutionize photonic applications and thus create a network of strategic contacts for large-scale projects.

BENEFITS

- Enabling of high-level academic and industrial alliances to establish strategic joint projects in keeping with the vision proposed in this document.
- Positioning Mexico in the scientific forefront in the field of optics and photonics by exploiting the great talent in this country.
- Foreign and national investment incentivization for the development of projects that address the sector's new needs in a business-conducive environment.

ACTION PLAN

1. Set up a council to select the institutions with which to collaborate on strategic alliances for research and development of optical network clocks in keeping with milestone 3.2, taking advantage of many already-established alliances.
2. Produce knowledge and methodologies connected to international certifications to choose those that are most related to the projects mentioned in this document.
3. Select an international center or organization to establish a strategic alliance with the aim of accelerating the process of creating the country's certifying entity, as mentioned in milestone 4.1.
4. Propose –together with research and industry leaders– international projects on uses for optical network clocks and their applications in other disciplines, in order to be pioneers in such breakthroughs together with other institutions.

Execution period 2018 – 2025.

PROJECT 4.3: Create the Mexican Photonics Cluster focused on research, development and production of specialized materials, ultra-high intensity laser and commercial applications of photonics, maintaining international quality management throughout the various processes by means of a national certification center or international alliances and certifications.

OBJECTIVE

Design, plan and build the Mexican Photonics Cluster, to function as a competitive hub, a magnet for project investment and sector development center in order to attain and maintain the regional leadership of the country.

BENEFITS

- Enabling of the different strategic projects mentioned in this document.
- Generation of high-value initiatives for the development of photonics and optics in the country.
- Coordination of influential triple helix actors for the design and development of strategic projects as well as an efficient intercommunication platform.
- Ease of creating strategic alliances, attracting investment, and applying technology to the national market.
- Help in defining the lines of action that can update the national photonics strategy with interdisciplinary knowledge that will determine the direction of the strategies.

ACTION PLAN

1. Design the specific plan of the Mexican Photonics Cluster, divided into strategic phases, as discussed in this document and in subsequent plans.
2. Seek out proposals for geographical location, as well as project participants for the different phases.
3. Develop the national supply network in the context of the Mexican Photonics Cluster.
4. Attract primary investors and actors with a development plan for the national photonics cluster to promote the greatest strategic participation possible.
5. Identify missing resources and their suppliers.
6. Create a strong international promotional campaign to secure the role of Mexico in the region.

Execution period 2018.

CHAPTER 8



SUMMARY OF TECHNOLOGICAL NEEDS

This section describes the specific technologies to be developed and the primary needs detected by the IMF Group of Trust. They will be attached in a list, together with the slated dates according to the strategic plan.

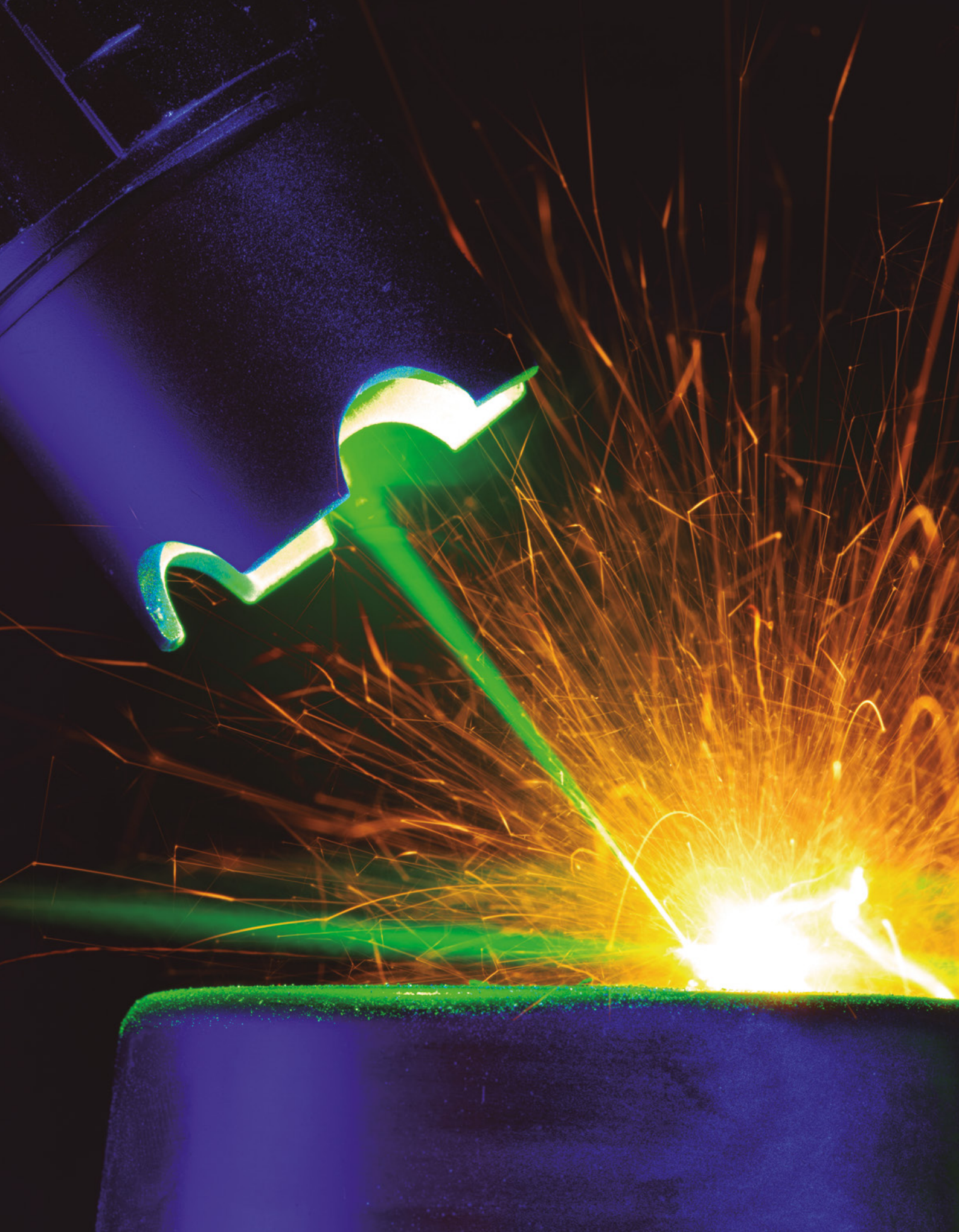
Technologies:

- Fiber optic sensors.
- Sensors for biological (medical) use.
- Heat management.
- Single-photon detectors.
- Fiber optics with less performance error.
- 2-20 micrometer lasers.
- Specialized medical silicone.
- Means and technologies for reducing transmission errors.
- Manufacturing of silicon and high quality organic compounds.
- Common and advanced organic compounds and silicon.
- Second and third generation solar cells.
- Advanced LEDs.

Points to consider:

- Part of the investment is resolved with the involvement of federal and private resources for kick-starters and by attaining venture capital.
- Allocate federal resources to large scientific complexes that collaborate for the common development of the sector in the country.
- Establish the technological alliance for the development of high range electric/electronic devices.
- Consolidate the projects through Intellectual Property rights.
- Research alliances for certifications.

CONGRESSIONS



CONCLUSIONS

Photonics is playing an ever-greater role in global development, given that it enables creating new scientific and technological applications for high value sectors, thereby securing dominance of the leading countries in cutting-edge technology. It is an enabling technology that has begun an inter-sectorial innovation race in the new century. Together with other disciplines, it is able to bring substantial changes in strategic sectors to geopolitics and society, such as energy, telecommunications, health, defense, advanced manufacturing and integrated circuits.

The major economies are wagering –individually and in strategic blocks– on the research and development of the double sector of photonics and optics. That is precisely why it is so important to join the global trend and achieve comprehensive photonics development in our country, by seeking areas where we can compete internationally.

Exploiting Strengths and Getting a Head Start on Opportunities

It is best to accelerate the creation of an ecosystem conducive to the development of photonics, making the most of current capacities and promoting the creation of opportunities that allow for efficient interaction and exploitation among sectors.

Therefore, the country's strengths must be exploited, such as the quality of researchers, national talent in innovation and design, demographic pluses, infrastructure, geographical location, penetration of digital device use, fostering of business creation in the country, free trade agreements and international institutions for the promotion of science, photonics and optics. Mexico also has advantages in the size of the market and in the technological race in manufacturing, which position it as a key partner for sector investments in Latin America.

Likewise, business and development opportunities must be promoted. They are mentioned in the SWOT, but particular emphasis must be put on the creation of a fertile ecosystem for sector development through short- and medium-term actions that incentivize the involvement of triple helix actors. It is worth emphasizing that the role of each of the actors is essential for the provisions in this document to function properly.

Government

Its role is to attract foreign investment and promote the national environment so that such investment triggers development of the photonics industry in the country. In this sense, the establishment of the Mexican Photonics Cluster is a priority.

Similarly, support of pure and applied research (depending on market needs) must continue and grow, which will lead to increased investment generation, otherwise research will lack momentum over the long term. Additionally, the support must procure cutting-edge tools, such as the ultra-high (petawatt) laser and the interconnection of optical network clocks so that it is efficient and collaborative.

Industry

Industry can be considered the engine of the roadmap, as it promotes market-focus technology application.

Development of the photonics industry in Mexico must concentrate on two main points: consolidation and growth of ties between the electronics and photonics industries (through co-investment agreements) and the support of high-risk investment in small industries (start-ups).

Constant generation of new participants will also create the backbone of the value chain for the photonics industry in Mexico, which will expand the horizon in projects and facilitate access to materials, technologies and infrastructures needed for industrial development.

Academia

The academic sector is crucial to accelerating the incorporation of qualified personnel into the nascent industry without waiting for traditional degrees, and it should also develop professional programs for those interested in the sector.

It is the job of academia to strengthen the specific talent pool by training engineers and scientists who can be incorporated into photonics. Solid education in engineering and physics is essential to solving the industry's future problems, for example, with electronic and mechatronic engineers with terminal options in photonics and physicists specialized in optics and photonics.

Furthermore, academia needs to coordinate to conduct research that will allow for industry progress, which will also foster the nation's regional leadership. Some of the research needed for new technologies is mentioned in this document.

AMO's role is to be the primary promoter and coordinator in the initial phases (while a strong industry presence is generated), actively fulfilling its role in integrating the national development plan for the sector. Therefore, AMO will approach the various industrial chambers to promote collaboration between academia and industry, with support of the government, enabling specific initiatives by laboratories, institutions and companies to better connect the triple helix.

Besides utilizing strengths and exploiting opportunities, it is necessary to prepare the future of photonics in Mexico. For this, a strategic plan must be designed that considers the joint effort of the triple helix—according to the roles of each one—joined with the social trends of each region, using the provisions of this document as the foundations. It must be a plan for the medium and long term, given that the most important goals (termed “milestones”) require prior essential steps in order to achieve them. The general strategy is oriented to achieving the technologies that lead to the milestones and to integrating the efforts in large-scale projects that serve as paradigms for their design, planning and application. A Mexican Photonics Cluster must be created that enables models such as the FabLab and incorporates state-of-the-art research facilities, such as the petawatt laser, the generation of academic or commercial alliances and participation in international certifications as a fundamental part of the value added process. In this way, the means needed to maintain regional leadership will be created through the application of new technologies and the strengthening of innovation, collaboration and competitiveness.

Industry and Collaboration

It is worth emphasizing that once a strong industry is formed in the sector, a series of circumstances will be triggered that will quickly multiply the value of the market in Mexico. The country will have a greater international reputation in fields such as research and regional leadership both with its own technological contributions as well as with high value contributions (specialized inputs, advanced technological applications and design).

Cooperation with other actors at the national level will help to explore new opportunities for the Mexican Photonics Initiative and incorporate it into the international environment, which will lead to the country's regional leadership and its participation in international projects with other powers.

Final Considerations

A roadmap involves a process of continuous improvements and constant evaluation and determines the areas of convergence where the main actors can add value. It is, therefore, a tool that requires ongoing updates to achieve its objectives as strategic actions move forward. Updating the agenda with projects and strategic alliances related to the strengthening of the industry in the sector remains pending. Mexico has the opportunity to establish a global presence in photonics, which demands coordinated actions by the main agents of change in Mexico: industry, State and academia.

The future of Mexico will only be guaranteed insofar as society optimizes the intelligence of its inhabitants, its best resources. The solution to the growing problems in the world will require appropriate coordination of technical and scientific knowledge with economic, social and environmental balance. Only then will there be a better quality of life for everyone.

MILESTONE 1 - PROJECTS

2020	Project 1.1: Improve energy efficiency and develop the industry via a project for widespread use of nationally manufactured LEDs for public lighting.
2016 - 2020	Project 1.2: Develop studies and proposals for direct or indirect incentives to support manufacturers focused on photonics, especially LEDs.
2016 - 2018	Project 1.3: Develop projects to bolster the supply of photonics materials and the business ecosystem, so that a complete logistical mechanism can be developed.
2020	Project 1.4: Support the development of design and innovation centers for photonics materials for LEDs (preferably in the Mexican Photonics Cluster) and a strategy for specialized certifications.

MILESTONE 2 - PROJECTS

2020	Project 2.1: Promote research, collaboration, and investment to develop companies that produce photovoltaic cells and advanced silicon.
2016 - 2020	Project 2.2: Conduct a study on the current state of silicon and advanced photonics materials production in order to propose a way to develop the competitiveness of the country.
2016 en adelante	Project 2.3: Develop production and research centers for silicon and photovoltaic material focused on organic, inorganic and hybrid technologies, in cooperation with the AMO.
2017 - 2019	Project 2.4: Promote the creation or strengthening of agencies focused on standardization, certification and accreditation of laboratories and factories, jointly with the Mexican Photonics Cluster.
2016 - 2018	Project 2.5: Create strategic alliances to form supplier and production networks that will give Mexico a head start in the race for photonics-enabled energy sources.

MILESTONE 3 - PROJECTS

2025 Project 3.1: Design the Urban Connectivity project to satisfy the constant telecommunications demand, which will help to increase network penetration among the different users, thereby improving civil and business communications.

2016 - 2020 Project 3.2: Articulate incentives and regional and national strategic projects, taking advantage of the actions of the International Year of Light and Light-Based Technologies, 2015, focused on generating and integrating technological know-how.

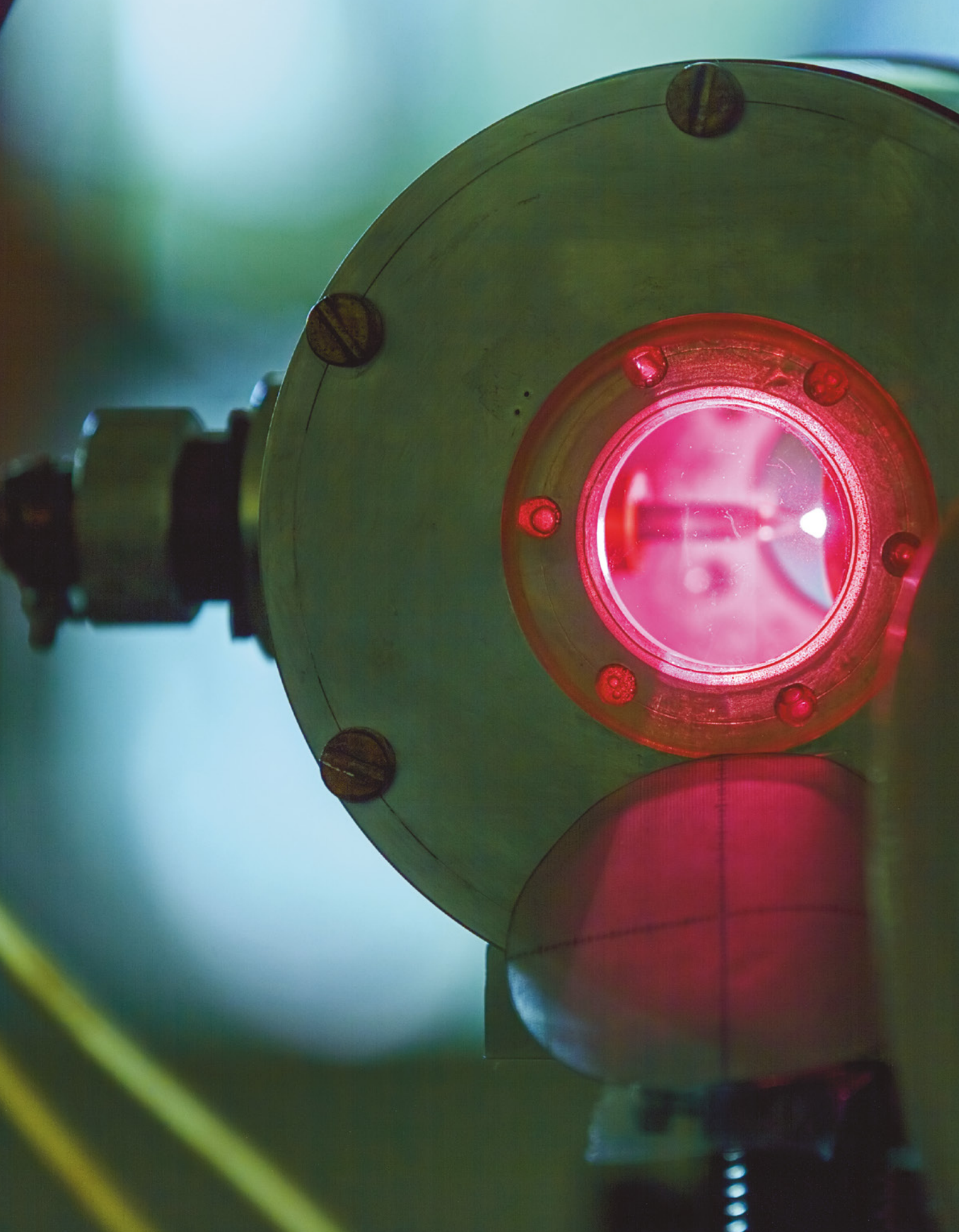
2016 - 2018 Project 3.3: Develop the industrial foundation and production know-how for specialized and technologically advanced fibers through alliances with major producers for their inclusion in the Mexican Photonics Cluster.

MILESTONE 4 - PROJECTS

2020 Project 4.1: Design incentives for research and production of 2-20 μm photonic sensors and construction of an ultra-high intensity laser, leading to program development for advanced photonic component manufacture.

2018 - 2025 Project 4.2: Establish a network of strategic alliances that reinforces the role of Mexico in the development of revolutionary technologies such as 2-20 μm sensors, ultra-high intensity laser and optically connected optical network clocks.

2018 Project 4.3: Create the Mexican Photonics Cluster focused on research, development and production of specialized materials, ultra-high intensity laser and commercial applications of photonics, maintaining international quality management throughout the various processes by means of a national certification center or international alliances and certifications.



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