

Market Data and Industry Report 2020



PHOTONICS PUBLIC PRIVATE PARTNERSHIP



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Key findings

The global photonics market has grown by 7% per year since 2015 exceeding global GDP growth

The global market for photonics components and systems accounted for \$733 billion (€654 billion) in 2019. The market grew at a CAGR (Compound Annual Growth Rate) of 7% during the last four years (2015 – 2019) exceeding both global GDP growth and the growth rate of the overall industry in the OECD (1.3% per year). Photonics is a fast-growing industry compared to other high-tech industries like Microelectronics.

The global photonics industry addresses major challenges and concerns for the future

Besides Components and Materials, the major application segments are Photonics for Consumers IT, Medicine & Biology, Environment, Lighting & Energy, and Industry 4.0 showing that photonics is participating directly in the challenges for the future such as Digitalisation of production and society, Health and wellbeing, Sustainable development and Environment. Other main segments (Mobility, Defence & Security, Food and Agriculture) address major concerns shared by citizens in Europe and elsewhere.

Europe was able to maintain its market share and defend its #2 global position in the last years

The European photonics industry accounted for €103 billion in 2019, comprised more than 5,000 companies and contributed around 3% of the total manufacturing within Europe. The size of the photonics industry in Europe exceeds the size of the microelectronics industry, which was worth 75 billion euros in 2019.

The European photonics industry has grown from €76 billion in 2015 to €103 billion in 2019 with a growth rate of 7% per year and a share of 16% of the global market, maintaining its market share over the last 4 years and keeping its # 2 global position.

EU photonics growth is 3 times the growth of EU GDP and almost 5 times of the whole EU industry

For the period 2015–2019, the growth of the European photonics industry in terms of revenues (7% per year) is 3 times the growth of the EU GDP (2.3%/year) and almost 5 times the growth of the European industrial production (1.5%/year). It is also growing faster than many other high-tech industries (for example, the IT industry: 4.5%, Medtech: 4.9%, Microelectronics: 4%). The European photonics industry is therefore a sector with remarkable dynamism.

EU photonics employment growth is twice that of the entire European Industry

From 2015–2019, the European photonics industry created over 30,000 jobs, reaching a total of 390,000 employees – an annual growth rate of 2.1%. This growth is much higher than that of employment in European Manufacturing as the whole (about 1% CAGR for EU28). This difference in growth of European photonics in terms of revenue and employment is due to its significant productivity gains. European photonics is currently seeing the transformation of its manufacturing processes with significant impact on jobs and skills. The growth of European photonics employment is, however, not without recruitment problems, particularly among SMEs.

Four important segments together represent two-thirds of the European photonics industry

The largest segment in Europe – Photonics Systems for Industry – was worth €19.2 billion and accounted for the largest share in the global markets: more than 40%. Europe is well positioned in the field of photonics systems for production i.e. industrial laser systems, semiconductors manufacturing and machine vision.

Three further segments account for a significant production volume and at the same time a substantial global market share well above average. The segment covering photonic components and materials was worth €16.6 billion in 2019; staying strong in this segment is important as it consists of the building blocks used for all the photonics systems. Photonic devices and systems for Healthcare and wellness accounted for a European production volume of €15.9 billion. Europe is well placed in medical instruments and systems with a global market share of 26% in 2019. In photonics systems for environment, lighting and energy, European production accounted for €16.7 billion in 2019. Europe has a significant market share in the field of lighting (25%) and Environment monitoring (30%).

Finally, with a market share above 30%, Europe is also very well positioned in optical instrumentation and in photonics for space.

Research and innovation are key to maintaining the competitiveness of European photonics

Although lagging in the two biggest photonic markets (displays and PV), the European share has been maintained, stressing the huge dynamism of other photonics segments in Europe especially those described above. Photonics is an important key enabler for many applications. Serving those application markets requires constant innovation and being at the forefront of technology. Thanks to a strong research capacity, European companies can maintain and expand their businesses and catch their share of this fast-growing market.

If the same level of innovation is preserved, the European photonics industry will maintain or even increase its global market share.

R&D spending is high in the European photonics industry: on average, 10% of turnover is devoted to Research and Development, which is essential considering the competition in this highly innovative industry. The average ratio of total investment in the European photonics industry (R&D + Capex/turnover) was around 15% in 2019 – well above the EU Industrial Investment average. The level of investment in research and innovation from companies and public authorities is key to the successful development of European photonics. This investment will not only further strengthen the core segments but also launch win-back strategies for other segments when possible and appropriate. Recent successes of AMS and ST-Micro in modules for smartphones demonstrate that European photonics can produce high-volume products and make a significant contribution to the sovereignty challenge towards reindustrialisation.

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Implementing the European Photonics21 PPP strategy

Instrument: Coordination and Support Action

Industry Report 2020



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1 What is photonics?

Harnessing light is one of our oldest technologies and has played a significant part in science and the development of human history.

By mastering fire, our ancestors not only gained the ability to protect themselves, cook their food and make better tools, but, they could also extend daylight, allowing them to talk after sunset or tell stories around a fire or craft objects. Without light in the form of grease lamps, our ancestors could not have produced the magnificent works of cave art in Lascaux France, created over 10,000 years ago, or the renowned charcoal drawings in Altamira Spain that are over 36,000 years old.



Figure n°1: More than 500 grease lamps dating from 36000 to 10000 years B.C. have been found close to sites showing parietal art like Lascaux. Illustration: recent pottery oil lamp.

In the Middle Ages, Ibn al-Haytham (965–1039), an Arab scholar, laid the foundations of modern optics. Since then, Galileo, Kepler, Newton, Maxwell, Einstein, Bohr and almost all the scientific giants of history have pushed forward our scientific knowledge and understanding of light.

Questions about the propagation of light were fundamental to the 20th century revolution in physics, the invention of the theory of relativity and the emergence of quantum physics.

Two discoveries opened considerable fields of application: first, that light can be understood as both a flow of particles (called photons) and also an electromagnetic wave, and this wave-corpuscle duality is at the origin of lasers or digital cameras; second, the spectrum of wavelengths extends far beyond what the eye sees in the form of ultraviolet rays (which make us tan and sterilise), X-rays (the basis of radiography), and gamma rays (which come from space or are produced by radioactivity). There is also infrared radiation, which carries information in fibre optics and allows us to see at night.

To embrace these disruptions, “optics”, a thousand-year-old science, had its name changed to “photonics”, or the science of the photon, in the same way that electronics is the science of electrons.

Photonics, the science of harnessing light to benefit humankind, encompasses technologies that generate, detect, measure, transmit and manage light, from infrared through the visible spectrum to x-rays.

1 What is photonics

Behind this definition lies a constellation of applications that fulfil fundamental every-day life needs that are not immediately apparent.

Lighting is so familiar to us, we can almost take it for granted: we switch on a light and it illuminates our rooms; we can walk the streets at night, and drive cars or ride a bike safely. Lighting, especially advanced lighting based on LEDs, is photonics!

Do you need glasses to read this text? According to the Vision Council of America, over 50% of all women worldwide and 42% of all men wear glasses. Maybe you need a specific optical correction for long distances and another one for short distances; ophthalmologic glasses modify the light coming to the eye to compensate for the imperfections of our vision and allow us to see clearly. They are adjusted specifically to each of us. Progressive glasses show very advanced shapes to let many of us wear the same glasses all the time. Ophthalmic glasses are photonics devices!



Photonics is the science of harnessing light to benefit humankind.

Are you reading this text on a screen? A display is made of millions of pixels, with each one a light source that is activated and tuned in real-time to produce images in a fraction of a second. Displays are photonics devices! In the same way, digital cameras catch light, allowing us to take millions of professional, medical, artistic or simply personal pictures.

Did you receive this document through the Internet? This file was previously transformed into binary and transmitted as infrared light through fibre optics. Fibre optics are photonics devices!

When did you last go to a laboratory for medical analysis? When did you pass your last X-ray scanner imaging? Did one of your relatives undergo laser surgery recently? Many medical devices that help us to diagnose and cure diseases are based on photonics.

When you go shopping tomorrow, the shop assistant's laser barcode scanner may remind you that photonics has become so ubiquitous that we may not notice it. But, photonics is capable of doing so much more! Light is fast, precise and clean – three unique and useful properties that make photonics key to advancing human knowledge and understanding.

Almost all our understanding of the universe comes from observing the sky through the light caught by telescopes seeing billions of light-years away.

Photonics is also the only way to observe large areas. Satellite imaging has revolutionised meteorological forecasts, the detection of hurricanes, our understanding of climate change, measuring ocean levels and the impact of forest fires. Photonics has enabled researchers to transform guesses and hypotheses that emerged in the 1980's into scientific evidence about global warming.

In the 21st century, photonics is at the heart of the second quantum revolution. It has already given rise to discoveries such as laser-cooled atoms, which give ultra-stable clocks, or "twin" photons, paving the way to ultra-secure communications through quantum cryptography, and the eagerly anticipated quantum computers.

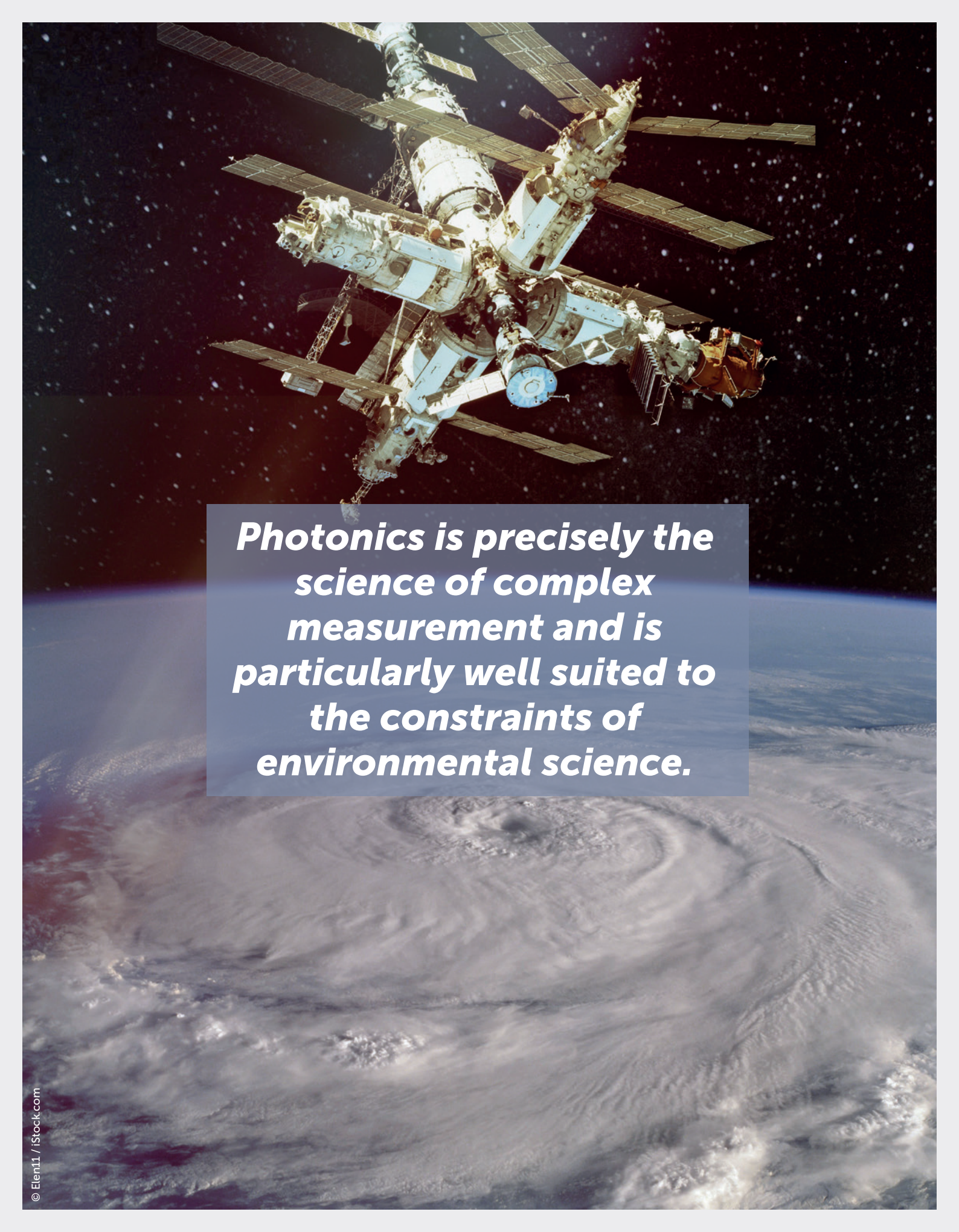
Photonics, as a key-enabling technology for a very broad range of applications, features two remarkable and paradoxical characteristics: the first paradox is, as will be shown in this study, that photonics is an important asset that will address grand challenges such as the Green Deal, Sovereignty, Digitalisation of production and society, Health and Well-being, while also remaining a “discrete technology”. It is most often a critical and enabling component of technical solutions but also mostly embedded or simply too familiar to be noticed.

The second paradox is that on one hand, the photonics industry – if evaluated by size or revenue – is smaller than many others like automotive, aerospace, oil & gas, consumer, but on the other hand, (and this study will show) it is crucial to precisely all these industries. They all rely to a greater or lesser extent on photonics to implement their innovative ideas and thus maintain their jobs and competitiveness. The use of photonics brings a strategic advantage to a non-photonics industry.

And, fortunately, the European photonics research industry is competitive, generating hundreds of start-ups and showing higher growth than many other industries. The photonics industry is specific in terms of jobs. Photonics is a high-tech industry and requires PhDs and people with a higher educational background. But apart from some big submarkets like displays or automotive headlamps, photonics is made of thousands of niches that need hundreds or no more than a few thousand devices. These niches can be very profitable, especially for SMEs, but the fabrication volumes of these niches are too small for being intensively automated. As a consequence, photonics, one of the most deep tech fields, is in great need of motivated technicians and skilled workers.

Photonics produces mainly hardware products meaning it not only requires a higher capital intensity, but it also takes longer to build large companies than with software technologies. This higher risk means that many European investors are less inclined to get involved in photonics companies. Many emerging European photonics companies are then acquired by US groups or Asian investors. It must therefore be part of the ambition for more sovereignty in Europe to set an example here and ensure sufficient risk and venture capital as photonics is one of the major assets to increase our industrial sovereignty.

Investing in photonics is very profitable for European states and regions. Through this document, the photonics community wishes to give genuine evidence that it can provide solutions to the great societal challenges that lie ahead while strengthening the reindustrialisation of Europe and creating many jobs.

A high-resolution photograph of the International Space Station (ISS) in orbit above Earth. The station's complex structure, including multiple modules and large solar panel arrays, is clearly visible against the black background of space. Below the station, the Earth's surface is shown with swirling cloud patterns and the blue horizon of the planet. A semi-transparent blue rectangular box is overlaid on the lower half of the image, containing white text.

Photonics is precisely the science of complex measurement and is particularly well suited to the constraints of environmental science.

2 Photonics is critical for Europe's strategic value chains

2.1 Green deal

Global warming and its consequences – the medical impact of air pollution in urban areas, the death of beehives or the future of plastic particles in oceans – are issues that pose immense challenges to science. Contrary to other major historical scientific advances (antibiotics, electricity, etc.), environmental issues are much more complex to address because it is necessary to deal with massively multidisciplinary phenomena, diffuse in space and time, and where each parameter interacts with all the others.

Despite numerous studies, the scientific community has not yet succeeded in gaining unanimous acceptance of some of its diagnostics. The reasons given by detractors are often less scientific than ideological, religious, or driven by economic interests. And in good faith or not, many exploit the uncertainties and numerous questions raised by the scientific approach, which evolves to the limits of knowledge on these subjects. Moreover, even once the diagnostic is accepted, solutions to environmental issues are intrinsically complex because they affect society in all its facets: scientific, political, economic, demographic, social, health, regulatory and even spiritual.

Photonics is precisely the science of complex measurement and is particularly well suited to the constraints of environmental science. Photonics is the “eye”, the unique means to look and observe at all scales. On a planetary scale, advanced cameras and instruments embedded in satellites can measure winds, clouds, detect hurricanes and tsunamis, monitor the expansion of vegetation, and monitor forest fires.

On the ground, a global network of hundreds of photometers installed all around the world called AERONET measures the number of microparticles in all layers of the atmosphere. Photonics instruments provide ultra-sensitive, portable and non-contact detectors, less and less energy-consuming, suitable for on-field or “point of use” measurement. They can detect pollutions in rivers or sea waters, detect diseases of crops, detect leaks on pipelines, measure air particles and pollutions in urban areas. IR cameras help for the thermal diagnostic of buildings. And yet another object so familiar that we forget it: binoculars. They are one of the most useful on-field tools for zoology and wildlife protection.

In the laboratory, Photonics instruments reveal the small scale. Microscopes are everywhere, including the most advanced multifocal, high-resolution, two-photon, multispectral devices. Along with fluorescence techniques they allow us to observe living cells or bacteria in vitro and in vivo. Spectroscopy techniques identify and measure chemicals. Photoacoustic enable contactless and harmless monitoring of organ functions or disease progression in living animals.

But photonics can go much deeper: highly advanced instruments make use of light to study surfaces at the nanoscale. For example, atomic force microscopes use a laser to measure the displacement of a nanotip made of few atoms. Such instruments are very useful for developing advanced materials to be used for batteries or hydrogen fuel cells.

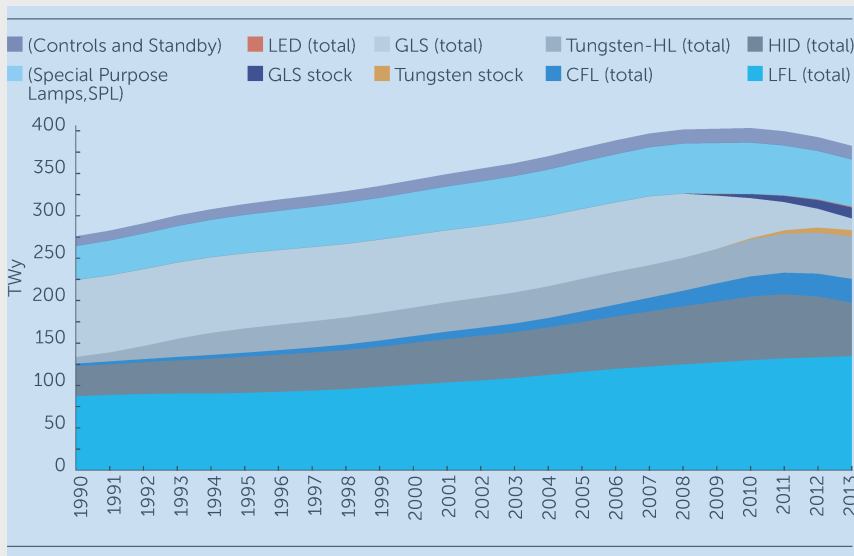
2 Photonics is critical for the strategic value chains

Photonics not only provides diagnostic tools at every scale, it also invents solutions. Photovoltaic cells collect light and turn it into electricity. Estimates by the International Energy Agency show that photovoltaic could avoid the emission of more than 350 MT of CO₂ in 2019. LIDARs – which are like radars but use light rather than radio waves – measure the wind in front of wind turbines and improve their efficiency by 5%. Spectroscopic or LIBS¹ systems sort wastes at high speed and can discriminate different kind of plastics whatever their colour. Photonics offers solutions for cleaning and inactivating pollution without using chemicals. It is thus a valuable asset in nuclear monitoring and dismantling.

For agriculture, cameras enable phenotyping studies, which search for the optimum conditions for growing crops and reduce chemicals. On-field equipment analyses soil or measure the quality of a fruit or the comfort of animals contactless. Photonics is also critical for indoor and urban farming where artificial light allows lettuces or strawberries to be grown without any phytosanitary product. The photonics community shows great creativity to develop solutions, but photonics engineers are not farmers, and farmers and agronomists are not physicists. So, it takes intensive joint discussions and also some “translation help” to understand the complexity of growing crops or livestock and translate it into appropriate photonics parameters. The meeting of these two communities takes time and is the current bottleneck for faster adoption of photonics solutions in agriculture. But, there is no doubt a bright future lies ahead as more and more photonics companies and start-ups enter the agriculture market. Along with their interactions with agriculture experts, artificial intelligence and deep learning bring new ways to much faster translate agricultural requirements into physical parameters to be handled by photonics sensors and instruments.

Photonics can provide a solution for fulfilling the EU’s commitment toward a carbon-free economy and a greener society. But what about the impact of photonics itself? In 2008, low energy lamps demonstrated their efficiency and reliability. The EU was able to adopt a directive for the gradual replacement of old incandescent lamps by low consumption sources. As the installed capacity continued to grow, the replacement of old bulbs by low-energy lighting (fluorescent lamps and now LED lamps) had a significant effect. The energy consumption for lighting in the EU began to decrease after a peak in 2010 and was more than 5% lower in 2013 (fig. n°2). For the residential sector, the peak was observed in 2008, decreasing by 13% in 2013.

¹ LIBS: Laser-Induced Breakdown Spectroscopy



Prospective studies estimate that the adoption of low-energy lighting can avoid the emission of around 50MtCO₂eq² from 2014 to 2030 and up to 290 MtCO₂eq in 2050.

	2030	2050
Annual energy savings (EU28)	20–29 TWh/y	48–56 TWh/y
Savings (%) of electricity use (BAU)	9%	18%
Cumulative energy savings	110–180 TWh	900–1,000 TWh
Cumulative GHG reduction	40–60 MtCO ₂ eq	270–300 MtCO ₂ eq
Energy expenditure reduction	€3–5 B/y	€21–25 B/y

Figure n°3: Energy savings for optimised lighting systems (both indoors and outdoors) with controls. (Source: Lighting Europe, Position Paper on lighting in the smart grid, 13 November 2014).

2.2 Digitisation of manufacturing and society

When describing the history of personal computers, which began in the early 70s, the focus is often on microprocessor capacity, memory size, and floppy disc drives. Displays, along with keyboards, were not regarded as critical since they did not contribute to the calculation capacity of the computer; they were simply "interfaces" for commanding processors and reading results.

The fact that displays were essential subsystems, without which a computer could not function at all, has never been a strong talking point. Because they were based on electron tubes, displays, as well as TV sets, were considered to be "just" electronic devices, in the same way that photonics was not yet considered a scientific discipline in its own right. Even though displays are electronic devices, this sole consideration detracts from another main function of a screen: that it is there to display of information, i.e. sending meaningful photons to our eyes.

² Carbon dioxide equivalent (CO₂eq) stands for a unit based on the global warming potential (GWP) of different greenhouse gases. The CO₂eq unit measures the environmental impact of one tonne of these greenhouse gases in comparison to the impact of one tonne of CO₂.

2 Photonics is critical for the strategic value chains

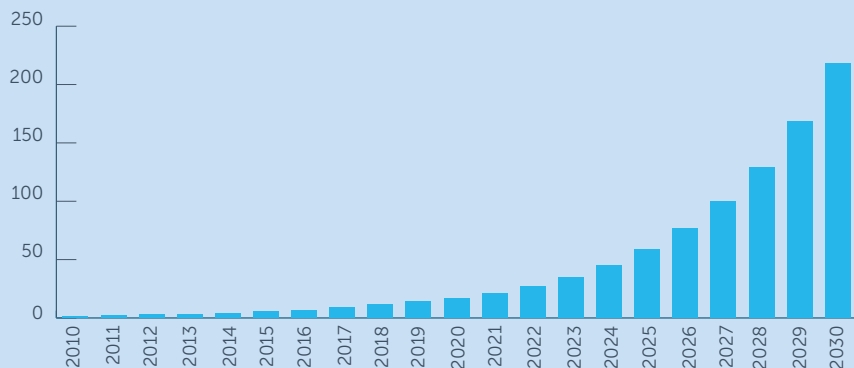
Displays are the best illustration that electronics and photonics are “sisters” and need each other to achieve progress. Displays cannot work without an electronic driver, and vice versa, electronics need displays as an essential interface between a human and the processors. The digital ‘boom’ came out of this intimate combination of electronics and photonics. While electronics was steadily improving and following Moore’s law, photonics led to four breakthroughs: chip lasers, fibre optics, flat screens and digital cameras. In the mid-90s, chip lasers along with fibre optics paved the way to the exponential increase of telecommunication, while flat displays enabled the development of portable devices, especially mobile phones. By the mid-2000s, higher-end cell phones had an integrated digital camera. By the beginning of the 2010s, almost all smartphones had an integrated digital camera.

Smartphones are the iconic device of the global digitisation, but, they are only the tip of the iceberg: almost all mobile applications are based on cloud computing. They rely on rapid interaction with data centres i.e., fast telecom connections. The core components of telecom networks are photonics: fibre optics and chip lasers. And yet, telecom networks would not work without clocks that synchronise all connected devices. These incredibly precise clocks that still give the correct time after several million years are based on a photonics phenomenon, which is another example of an understated but critical function of light science.

Datacentres benefit from another indirect but significant contribution of photonics. The traffic of data in datacentres is expected to increase from 17 ZB/y in 2020 to almost 220 ZB/y in 2030.

Figure n°4: IP Traffic Datacenter, CISCO Global Cloud Index, 19 November 2018.

Traffic data centre IP (Cisco Cloud index: ZB/year)



This is a major challenge, not only in terms of capacity but also in terms of energy consumption which amounts to around 240 TWh in 2020. A medium-sized data centre consumes as much energy as a city of 40,000 inhabitants. Microprocessors have become more and more efficient every year and assuming that data traffic will multiply by a factor of 13 in 10 years, it is more likely that the energy consumption will only multiply by a smaller factor – around 3³. Nevertheless, this will still be a huge quantity of electricity

³ Source: TEMATYS 2018

and datacentre companies are aware of this issue. Along with the improving efficiency of electronics, photonics contributes thanks to two solutions. Datacentres consist of several hundred thousand servers, each needing to be connected by thousands of kilometres of wires. Today, these cables are no longer made of copper wire but are increasingly replaced by fibre optic cables. The energy savings from such cables account for 5% of the total energy consumption. A far greater impact however comes from the policy of datacentre companies to compensate for the required energy by producing electricity through renewables sources, mainly photovoltaics. In 2018, the leader AWS claimed to have used more than 50% renewable energy through a mix of wind and solar (i.e. photonics) power plants.

Digitisation occurs in every sector, from industry, automobile, medicine, aerospace, defence, or services, for example.

In industry, major transformations are underway. Simulation is now used at almost every part of the value chain, from conception to machine command. Thermal, mechanical, optical simulations, the appearance of surfaces, even the assembly process can be simulated. As a result, equipment, as complex as aeroplanes, exists as a "digital twin" before a prototype is built.

In this digital environment, photonics will provide motion capture systems, 3D displays, and augmented or virtual reality glasses or masks. When a component is manufactured, photonics instruments control its dimensions, surface and integrity through X-ray imaging. Machine vision systems control their quality and track potential defaults. When integrated into a system, AR/VR glasses allow a technician to mix the digital twin with the real component for simplifying maintenance.

Another major transformation of industry comes from the emergence of additive manufacturing which constructs a three-dimensional object from its digital twin. Many machines are based on photonics as they use lasers to melt plastics or metal or to sinter ceramics.

Massive automation is also one of the major transformations of the industrial sector. It has been several decades since the first robots were introduced in manufacturing processes. However, thanks to advanced sensors, faster computers and improved software, new generations of robots are now emerging, which perform more than simple heavy or repetitive tasks; they can now also cooperate, help and protect or even operate fully autonomously. This state-of-the-art robot generation is enabled by new cameras, LIDARs, 3D sensors i.e. photonics sensors that bring a more precise perception of the local environment, especially when humans are working close by. It is now well understood that for most industrial processes, the "dream" of 100% automation is an inadequate illusion. Robots and humans working together are much more efficient, and competitive!

The use of advanced technologies for increased safety and security is also an expectation of European citizens. Photonics technologies provide solutions with CCTV⁴ and advanced processing that can extract meaningful

⁴ CCTV: Closed-Circuit Television, television network used for tele surveillance.

2 Photonics is critical for the strategic value chains

information, like suspicious behaviour in a railway station hall. Cameras operating in infrared light will be critical in defence and aeronautics, as they allow us to see in the dark. They are now also being used in cars, boats or trains for night vision, which provide an increased level of security. And for cybersecurity, the quantum photonics community is currently developing the most advanced cryptography systems based on a spectacular physical phenomenon called Quantum Entanglement.

In certain conditions, two or several photons, particles or even atoms together can act as one quantum entity. This phenomenon is the heart of quantum computers concepts. They use the specific behaviour demonstrated by particles when they are entangled to enable a new way of computing. These quantum computers will not replace regular devices which are already so versatile and powerful, but they are capable of instantly solving complex problems that a regular computer would take centuries to process.

Building a quantum computer is not an easy task and a lot of research is needed, which is why the US, China, Japan, Korea, Canada, the UK and of course the European Union and other member countries are investing enormous sums in development. Currently, some companies like IBM or Google claim to have built functioning prototypes. Besides, there are several ways under exploration to build quantum computers as a hardware set-up. For almost all of them, photonics technologies will be either the core heart or at least a critical enabler of these concepts. A survey of over 40 quantum organisations in the United Kingdom⁵ showed that many of them consider photonics as essential and indispensable to quantum technologies.

2.3 Health and well-being

Modern healthcare systems are facing new challenges. Over 30 million people worldwide die each year from the top ten medical conditions, which include heart disease, lung cancer, strokes and chronic obstructive pulmonary disease (COPD). Richer diets and sedentary lifestyles have gone hand in hand with the spread of obesity and other health risk factors, contributing to 10 million early deaths from type-II diabetes and other nutrition-related causes. Last but not least, the COVID-19 pandemic reminded us that a new deadly virus can appear anytime anywhere and how international travel can spread a contagious virus fast.

In Europe, these challenges are compounded by rapid population ageing: The number of EU citizens aged 65 and older is expected to double by 2030. This is an undeniable success of biological science and medicine, but this will create immense additional pressures in medical and nursing care, not at least due to dramatic growth in age-related diseases like Alzheimer's, dementia, macular degeneration, kidney failure, osteoarthritis and cancer.

These shifts have dramatic consequences for European citizens and their healthcare systems. Healthcare spending has already reached nearly 10% of the EU's GDP, equivalent to almost €1.5 trillion a year. In the years ahead, this

⁵ Internal study for UKRI by Anke Lohmann (Anchored In), 2020.

expenditure is expected to grow much faster than the over-all economy as the European population ages. New technologies and concepts are therefore needed not only to maintain health and treat disease but especially to do so more effectively and at a lower cost.

Few other fields rely more on photonics than medicine and biology. Below are four major and historical examples from the constellation of all systems and applications enabled by photonics. And the good news is that European companies are playing a leading role in these fields.

Ophthalmology, almost half of humanity wear glasses!

A study published in 2016 showed that in 2000⁶, 22.9% of the global population was affected by myopia (fig. n°5); this percentage is increasing steadily for reaching 34.0% in 2020, i.e. 2620 million people. In 2050, half of the global population (49.8%) will need glasses because of myopia only. And taking into account all eye conditions, in 2020 according to the Vision Council of America, over 50% of all women worldwide and 42% of all men wear glasses.

No other field relies more on photonics than medicine and biology.

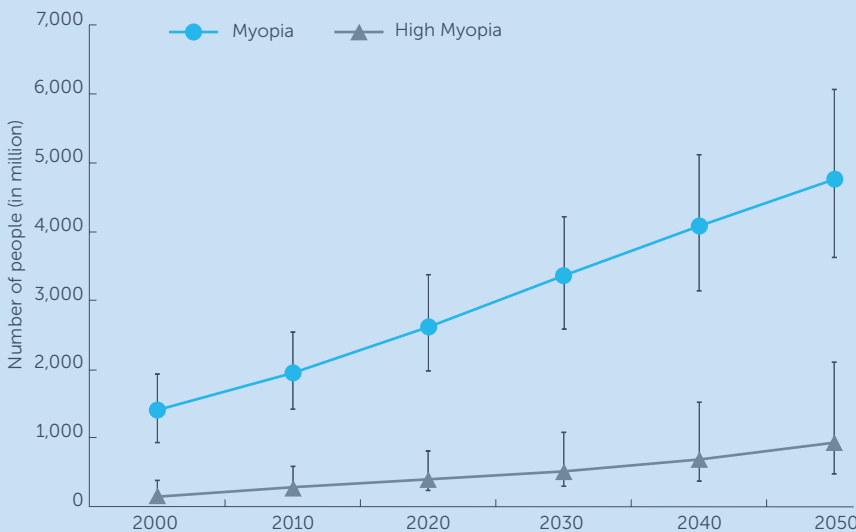


Figure n°5: Number of people estimated to have myopia and high myopia for each decade from 2000 through 2050. (Source: Holden et al. 2016⁶).

Ophthalmic glasses are so common and necessary to all of us that we forget they are such high-tech product. The material, the shape, the coatings, applied to harden them and to add more protection, is all the result of highly advanced science and technology. Complex shapes, called freeform, allow us to personalise ophthalmic glasses to each one of us and to include several types of correction in one progressive glass. ESSILOR and ZEISS are respectively the first and second world leader in that market.

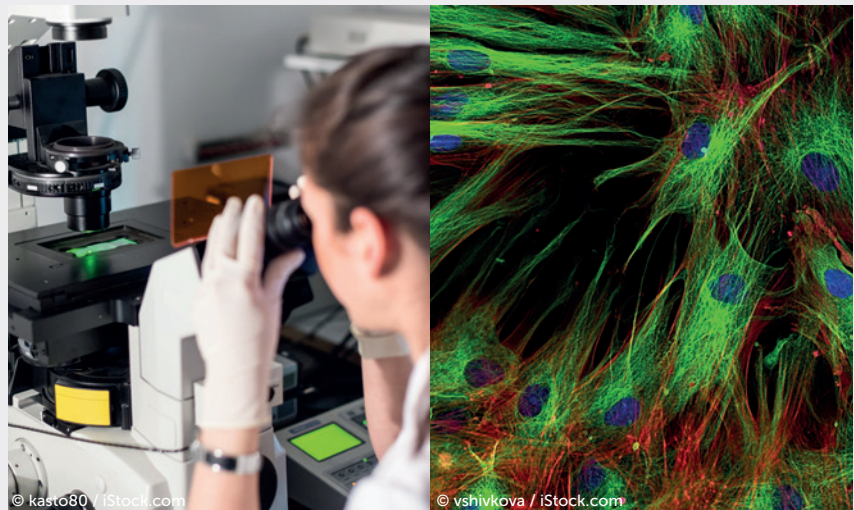
⁶ Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050, Brien A. Holden, PhD, DSc, Timothy R. Fricke, MSc, David A. Wilson, PhD, Tien Y. Wong, MD, Thomas J. Naduvilath, PhD, Serge Resnikoff, MD, February 11, 2016, DOI: <https://doi.org/10.1016/j.ophttha.2016.01.006>

2 Photonics is critical for the strategic value chains

No biological laboratory and advanced diagnostics without advanced microscopy techniques.

Today, anyone who wants to represent a laboratory uses an icon showing a microscope. Since the first observation of bacteria by Antonie van Leeuwenhoek in the 17th century, microscopes have improved tremendously; they are no more a simple optical instrument made of several lenses through which small objects can be seen. Bright field, dark field, dispersion staining, phase contrast, interference, fluorescence, confocal, two-photon, wide field, a multitude of advanced techniques allow to observe inside living cells in 3D, diagnose diseases and even manipulate living material such as in in-vitro-fertilisation. Besides LEICA MICROSYSTEMS and ZEISS as the main players, a large number of European laboratories and smaller companies are also developing special solutions for this market.

Fig. n°6: A multitude of advanced techniques allow to observe inside living cells in 3D, diagnose diseases and even manipulate living material like for in-vitro-fertilisation.



Radiography, X-rays are also photons.

Most of us have had an x-ray at some point, whether it's for a dental examination, a broken bone, mammography or any other reason. Radiography uses the capacity of x-rays to penetrate a body and show its internal structure. Looking at mammography alone, radiography is crucial for the early detection of breast cancer. In 2018, nearly 2 million new breast cancer cases were diagnosed⁷ and it has been proven that these mammography screening programmes can reduce breast cancer mortality by about 20%⁸.

European companies Siemens and Philips are among the top 5 in the diagnostic imaging market along with General Electric, Canon and Fujifilm in first and third place respectively.

⁷ Source: Globocan 2018 <https://gco.iarc.fr/>

⁸ "WHO position paper on mammography screening". World Health Organization, ISBN 978 92 4 150793

Endoscopes allow in vivo observation and minimise the impact of surgery.

Endoscopy is the fourth example where photonics has revolutionised medicine. The first endoscope was invented by Antonin Jean Desormeaux in 1852. Today, endoscopy makes use of many fields of photonics: micro-optics, fibre optics, imaging, lasers, smart lighting. They not only allow to see inside the body but also to interact with the organs: surgery with lasers, advanced in vivo detection of tumours etc. Thanks to endoscopes, many surgeries no longer require large incisions, which is not only more patient-friendly and reduces anxiety – it also helps patients recover much faster, which in turn has a positive impact on recovery costs.

Europe is also highly competitive internationally in this area thanks to companies like Karl Storz or Mauna Kea

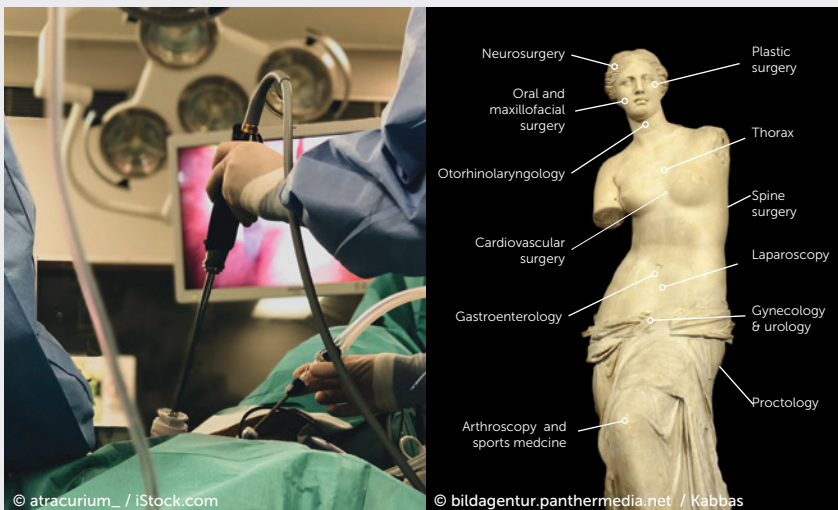


Fig. n°7: Medical applications of endoscopy.
Endoscopy is vital to many fields of medicine.

These four examples show applications invented more than 100 years ago. But, thanks to intense R&D efforts, they are making progress every day for the benefit of patients. Such continuous efforts of photonics research have brought many other breakthroughs in medicine. To list and detail all of them would take far too long but here are some that could have been selected in our shortlist: PCR⁹ testing, is used for detecting infected people are based on advanced photonics colourimetry techniques; Optogenetics dramatically accelerated our understanding of the brain; Photoacoustics combine the best of photonics and ultrasound to develop a new way of imaging a living body part in 3D. Chip size spectrometers along with microfluidic technologies pave the way too many advanced point-of-care devices that will allow immediate diagnostics for diabetes or cancer. Cameras, even those embedded in smartphones, perform so well that they can be used for dermatology diagnostics, thanks to advanced image processing based on deep learning.

⁹ PCR: Polymerase Chain Reaction

Regarding health, the ability for photonics to detect and monitor pollutions and risks in air or water has already been mentioned. Photonics is often the only way to prevent accidents through the detection of dangerous or unwanted bacteria in food. And, energetic ultraviolet light, UV-C, will kill bacteria or viruses on any surface. In other words, with UV sanitisation and the already mentioned PCR tests, photonics provides major tools for controlling pandemics.

Photonics not only plays a role in the diagnosis of various conditions, but also provides an important element of *therapy* for a broad range of conditions, for example, laser therapy for the treatment of cancers, or, of laser myopia surgery – to name but a few. Furthermore, light therapy is a recognised and evidence-based approach for treating several mental disorders as well as for promoting mental health. Controlling lighting intensity and colour can produce great benefits for end users. Light therapy, or the exposure to intense light that mimics sunlight, can be a great help to people suffering from seasonal affective disorder or having mild or moderate depressive symptoms. Even more, success has been recently achieved in using bright-light therapy for the treatment of Alzheimer's disease.

Furthermore, many studies have shown that the elderly benefit from improved sleep efficiency when exposed to bright white light in the evening.

2.4 Sovereignty

About Sovereignty.

"Sovereignty consists of not depending on the benevolence of others to satisfy certain needs and in being able to act without being subject to the will of another State or company."¹⁰

When it comes to the sovereignty of a state or a political entity such as the European Union, several aspects should be considered.

- First, the political aspect means the ability of citizens to organise their way of life and their future through governmental structures that are sufficiently free from external pressures.
- Second, there are aspects of security and defence – an extension of the political aspect, as it were. They refer to the precautionary measures to protect citizens and democratic institutions from any threats that might exert unacceptable pressure.
- The third important aspect concerns the economy. This refers to the ability to choose the orientation of economic policies – especially in terms of innovation, industrial structure and sustainability – that will help maintain employment and a decent standard of living for citizens while addressing environmental challenges and problems for the long-term sustainability of all inhabitants on the planet.

¹⁰ Translated from "De la souveraineté industrielle aux relocalisations: de quoi parle-t-on ?", Sonia Bellit, Caroline Granier, Caroline Mini, La Fabrique de l'industrie, 2020

Economic and industrial sovereignty is an important part of President von der Leyen's Political Guidelines. It was a response to a request from the European Council and was approved by the European Parliament. In a "Questions and answers" document, the Commission says: "the Commission is setting a clear direction for a globally competitive, climate-neutral and digitalised industry. The Strategy is about enabling Europe's industry to do what it has always done best: drive our economies forward, provide a fair living for millions and stay at the cutting edge of innovation. It is about supporting industry to lead on the green and digital transitions and stay competitive at a time of geopolitical uncertainty."¹¹

The risks related to dependency in value chains have been demonstrated by the covid-19 pandemic: the pandemic itself – as well as the political decisions applied in various countries all over the world to cope with the covid-19 pandemic – led to the collapse of global value chains in a very short time. No one would doubt today that the fragmentation of value chains can create highly problematic situations of dependency, namely related to the access to raw materials, the supply of critical technologies or components within a specific value chain, external policies or standards which may prevent trade or limit access to goods.

The emergence of new businesses, not yet fully organised by law and fair regulations, have also enabled dominant positions from major companies, like the digital giants, which prevent the emergence of local champions and set new social issues and threats. Economical sovereignty does not imply autarchy but to find balanced solutions for dealing with these issues while maintaining an open approach for trade and capital investments from and into Europe.

As a key enabling technology, photonics is undoubtedly connected to the sovereignty challenge set by European institutions.

Defence – photonics as a strategic asset. Photonics is essential for the defence sector. No advanced equipment can operate without at least one photonics module: IR detector and cameras, counter-measures, analysis devices for NRBC threat, head-up displays, IR sensors, advanced imaging cameras embedded on satellites or drones, LIDARs, rangefinders, inertial sensors, and many more.

The military landscape is changing and Europe is facing new potential threats like **the acceleration of an arms race by countries outside Europe.** Furthermore, recent events have shown that the supply of some critical high-tech components is not guaranteed, in particular, due to the export rules and policies applied by allied states¹². Whether we like it or not, the ability to locally develop and manufacture all these vital photonics technologies is now a strategic issue.

A sovereignty strategy aims to maintain trade and cultural exchange with outer countries while limiting the risk and/or consequences of dependency.



¹¹ European Commission – Questions and answers: EUROPEAN INDUSTRIAL STRATEGY PACKAGE, 10 March 2020

¹² <https://infoguerre.fr/2018/11/enjeux-de-reglementation-itar-blocage-de-vente-missiles-scalp-a-legypte/>

Civil Security – opportunity to enforce a European approach. Photonics is also critical regarding civil security. There are many of examples where photonics acts as an enabler: on-site sensors and satellite imaging help detect wildfire, floods, earthquakes; fibre sensors monitor the health of infrastructures like bridges or dams; embedded sensors detect leaks on pipelines or water networks; CCTV networks limit urban delinquency or regulate traffic jams. All these technologies are of great benefit to citizens across the world. But the use of such great abilities and versatility also brings a great responsibility. Democracy and privacy of information can be at stake, and the European data privacy approach in the form of the General Data Protection Regulation (GDPR), is not shared by all. 5G telecom technologies show how different views can pose major sovereignty issues to Europe.

On October 20 2020, Sweden banned Huawei, China's telecommunications giant, and ZTE from participating in its 5G networks. Along with the United States, Australia, the U.K., and France, Sweden joined to impose a ban on using Huawei and ZTE equipment in 5G networks. In mobile telecommunication, the signal exchanged between the antenna and the phone is based on radiofrequency rather than photonics. But behind the antenna is the telecommunication network, which is largely based on fibre optics and photonics components. These serious state decisions are directly related to sovereignty concerns.

Facing Climate change – building trustworthy knowledge helps to become more persuasive. Photonics is not only well suited to assessing climate change or the impact of human activity on nature but is also the only technology capable of taking measurements at a planetary level thanks to satellite or aerospace imaging. Photonics instruments help us to understand global phenomena such as global warming, which depend on many complex interactions.

While there may be a refusal to accept the scientific evidence of climate change and environmental challenges, it is important to provide trustworthy scientific evidence to relevant decision-makers and supporting the decision-making processes of governments and representatives in negotiations in multilateral institutions (UN, IPCC, IEA...) .

Europe is a major player in advanced satellite imaging and spectral instrumentations – two key photonics technologies for environmental observation. It is also a major player in medical analysis, which enables impact studies of human activities on human health. When scientific findings are controversial the European Union can rely on European technologies to build its decisions and actions on trustworthy information.

Combating counterfeiting – for maintaining fair economic competition. Instruments like spectrometers are essential for analysing materials and they are great tools for combating counterfeiting. Fake olive oil, unauthorised plastic additives, false automotive spare parts, counterfeit luxury goods, for example, can be detected thanks to photonics, which helps to prevent counterfeited goods from entering Europe. Photonics is, therefore, a tool



to assess the extent of dishonest behaviour, where it exists, by foreign companies – information that can be crucial for negotiating trade agreements with other countries.

One possible answer to the above concerns and challenges, regarding the risk vulnerability of global value chains, is to locally produce the most critical components, systems and technologies to make it more self-sufficient. Fibre optics, sensors, spectrometers, IR detectors, laser accelerometers, atomic clocks, industrial lasers and many other technologies are integrated into many value chains of high-tech equipment and systems reaching from medicine, automobiles, planes, satellites, telecom networks to smartphones and the emerging AR/VR sector. Manufacturing them within Europe makes even more sense given that the majority of these technologies have been invented here, thanks to creative European research.

While local manufacturing may be considered too difficult, and Europe no longer able to return to areas of industrial mass production, Chapter 4 will show that it is not necessarily the case. In recent years, Europe has maintained its global share in many segments, even if it has lost the competition for some high-volume products like displays or photovoltaic-panel manufacturing. For example, the Austrian AMS is providing a face recognition module for the Apple iPhone, and the Franco-Italian ST Micro has co-developed a 3D imaging sensor with Apple for the same device. With fair support and fair markets rules, the European photonics community can contribute greatly to the sovereignty challenge towards a “reindustrialisation”.

A man and a woman, both wearing lab coats and lanyards, are looking at a large digital display. The woman is pointing at the screen, which shows a complex neural network diagram with many nodes and connections. The man is standing next to her, looking at the screen. The background is a dark, industrial-looking space with some red lights.

***Photonics has
experienced a large
boom, leading to
thousands of inventions
and new applications.***

3 The specificities of the photonics industry

3.1 The origin of the photonics industry

Considered an extension of optics, today photonics is one of the oldest industries in the world. Although the manipulation of light by humans began with the mastery of fire, the take-off began on an industrial scale before the first Industrial Revolution. The “Manufacture Royale des Glaces de Miroirs” (Royal Mirror Glass Manufacture) was founded in 1665 in France, after discovering the secret of mirror fabrication from the Venetians. The company supplied all the mirrors for the Hall of Mirrors of the Palace of Versailles. It still exists today through SAINT-GOBAIN. SOLEIL, later known as JOBIN-YVON and now HORIBA Scientific was registered in France in 1819. ESSILOR was founded in 1849, the same year as LEICA in Germany.

Until the twentieth century, the glass industry was divided into two categories: flat glass – windows and mirrors for example – and optics, which would manufacture devices based on lenses like ophthalmic glasses, microscopes or telescopes. The revolution of quantum physics led to an industrial revolution. The invention of lasers in the 1960's, along with the expansion of micro-electronics, enabled the development of a new industry, not only based on lenses and optical components but technologies that would exploit and manipulate all the properties of light. The recognition of photonics as an extension of optics began worldwide in the early 2000s, as the conclusion of three successive dynamics:

- A dynamic driven by R&D that began in the 1960s around fibre optics and lasers and reached technological maturity 40 years later.
- A dynamic driven by technology maturation initiated in the 1970s and 80s, linked to the development of products in the defence and security sectors, which has improved the reliability and miniaturisation of technologies.
- A dynamic driven by markets started in the 1980s and fully implemented in the 1990s related to the deployment of photonics solutions in the telecommunications markets that allowed industries to develop the right industrial manufacturing tools, lower costs and address mass markets, like compact disc players, and spread to all sectors of the industry.

Since then, photonics has experienced a large boom, leading to thousands of inventions and new applications until it was recognised as a “key enabling technology” for the H2020 European research framework program. Photonics appears to be a key enabling technology with several specificities.

3.2 First specificity: photonics is deeply transverse

A photon is a vehicle that represents the interaction between two distant objects; one is a source and the other a receptor. This interaction is a transfer of energy, but photons are much more than mere grains of energy. Light also carries information about its source and about the interactions it has had with the materials it has passed through before reaching the receptor. In other words, they have many other properties which can be exploited for making countless applications, from common lighting lamps to immensely

3 The specificities of the photonics industry

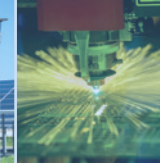
complex quantum computers; thermal solar heating systems use the basic property of light to collect solar energy and convert it into heat and hot water; photovoltaic cells convert light into electricity.

All photons do not have the same energy, i.e. the same colour. Some objects, like a lamp, for example, will send many more photons to the eye or a camera than any other place in a scene being captured; they are more intense sources. Both the colour and the intensity is information collected by our eyes and then transferred to our brains, which interpret, process and enable us to see. In a camera, the photonics energy and the information it holds are converted into electricity by the camera detector to produce a digital image (the expression "shooting with a camera" is a misnomer as a camera collects photons and does not send anything).

When analysing all the information held by photons through their physical properties, more advanced sensors, instruments or cameras can be made. Producing photons in a specific way – with lasers, for example – can allow us to take advantage of special properties of light and transfer information thousands of kilometres away, cut metal, read a DVD or make automotive lighting. Putting together millions of tiny sources, for example, allows us to develop displays.

Since light, as an energy transfer between a source and a receptor, is a fundamental physical phenomenon, it is understandable how deeply transverse photonics, the science of light, really is. Figure n°8 below shows all the functions that can be accomplished with photons."

Figure n°8: All the functions that can be performed by photons.

Types of Photonic Systems	Sensors & instruments	Camera & imaging systems	Communication systems	Screens, displays, projectors	LED, OLED, smart lighting	Photovoltaic systems	Laser & production systems
Photonic functions	Measure monitor	Acquire information	Transmit information	Deliver information	Provide light	Collect energy	Manufacture
Examples	 	 	 	 	 	 	 

Top row images from left to right: © 4X-image, djedzura, Ceneri, Thomas-Soellner, Sakan Piriyaongsak, vlbentley, Phuchit / iStock.com
Second row images from left to right: © danlogan, atracurium_, BrianAJackson, pixdeluxe, lovelyday12, DiyanaDimitrova, tiero / iStock.com

3.3 Second specificity: photonics is a slow maturing market

Thanks to the endless ways of using photons, numerous new applications and innovations are emerging from research laboratories every day. Many aspects of our lives and many economic sectors benefit from this effervescent creativity.

However, experience shows that it takes an average of ten years for a photonics start-up to take off. There are several reasons for this phenomenon.

First, as in any “hardware” industry, the development of a product requires capital and a higher initial investment than in purely digital activity. For a successful innovation development, it is imperative to bring together different interdisciplinary players in a value chain, from photonics experts, electronics engineers, software developers, to precision mechanics and, experts for the targeted application areas, like medicine, environment, mobility, energy, agriculture, etc. Such a highly multidisciplinary project is never easy to carry out, even when every partner shows strong willingness. Technical languages are different, habits and ways of doing varies. A large amount of energy and effort is required, but it is highly rewarding as long as the needs of the end-users are shared collectively as the common target. Due to their interdisciplinary nature, photonics-based projects can benefit greatly from the support of the European Research programmes, which bring together partners in pan-European value chains.

Secondly, photonics barely exists by itself: photonics serves or addresses application areas where end-users, such as doctors, chemists, materials engineers, telecom engineers and also consumers still need to be convinced of the performance and added value of photonics. If a photonics product shows a unique feature and allows us to do something hitherto impossible, end-users will have to invest time and effort to learn how to use it. If a photonics product is new to an existing market, end-users will need time and money to compare it with available substitutes and existing technologies used. For example, how many technologies compete with photovoltaics and need to be compared by the producers and end-users? Wind power, fossil fuels, hydroelectricity, nuclear power, geothermal energy, hydropower, biogas and many others. This learning curve in comparing performance and efficiency at the end-user level is inevitable and can be a hurdle for deploying innovative photonics products. This is especially true in areas where new and innovative photonics technologies are not yet known, such as agriculture. Many call it the “Death-valley”; Geoffrey Moore, in a reference book on the adoption processes of innovation¹³, called it the “Chasm”.

¹³ Geoffrey Moore, “Crossing the Chasm: Marketing and Selling High-tech Products to Mainstream Customers” (1991)

3.4 Third specificity: the emergence of mass customisation – an opportunity for Europe

Mass customisation processes enable end-users to customise products to their need or their wish and get them at a cost of a standardised product¹⁴. The recent emergence of three factors: simulation, AI, especially deep learning, and miniaturisation of photonics components, enables photonics to implement mass customisation approaches to the benefit of their customers and end-users. This is not entirely new but it can be brought to a new level. Along with this trend, photonics technologies like AR/VR devices or laser-based additive manufacturing machines become essential assets for tomorrow's mass customisation of products of any industries.

This could be highly profitable for the European photonics industry as these solutions are mainly applied in areas where Europe is competitive. Even more, they could pave the way to a come-back of Europe into the game of mass production if the mistakes that led to the relocation of the electronics manufacturing outside Europe are not repeated. Let's first have a closer look at these solutions, and then explain why it is a great opportunity for the European photonics industry.

The best example of mass customisation of a photonics product is ophthalmic lenses. Almost half of the human population wears glasses. But each one of them needs to be adapted to the specific impairment of each patient. And yet, Ophthalmic lenses companies like ESSILOR and ZEISS can produce huge amounts of fully customised and individual lenses. Their solution: to combine flexible processes and the comprehensive digitisation of the whole production steps, including design, metrology, manufacturing and even the final fitting into any shape of an eyeglass frame.

Automotive headlamps are more and more complex. They can use different types of light sources – bulbs, LEDs, lasers – and they are becoming smart with new function like range finding or focusing on specific objects of the road (a hole, stone, animal, any hazard...) or limiting the glare to oncoming drivers. But at the same time, automotive manufacturers want more flexibility in terms of car shape design and multiply the options offered to customers. In that case, the same core components, like the light sources, are used but it is their integration that is adapted, thanks to a comprehensive simulation. This approach was already used in the past in a basic way, but it can now be adapted to a much wider extent.

Machine vision is expected to have a great potential in agriculture as it can check every plant of a field to analyse their growth or detect diseases. Besides, Machine vision can also sort fruits according to quality. Hyperspectral imaging, i.e. imaging not only in the visible light but also in infrared, allows detecting even more details invisible to the human eye. But the problem is that each plant variety is different. Not only every species. Every variety of every species! And there are more than 20,000 varieties of apples, 3,000 tomatoes, 5,000 potatoes! Even more complex,

¹⁴ B Joseph Pine II, "Mass Customization: The New Frontier in Business Competition", Harvard Business Review Press, (1992)

there are around 160 diseases that can affect potatoes! To become useful to farmers or agro-food companies, a machine vision system must be trained to process the specific varieties of plants that they grow. Here, deep learning can change the game. Previously, it was necessary to study in detail the symptoms at each stage of a disease that appeared on one variety to analyse the molecules that are produced and their trace on the crop. Using deep learning, training is much simpler. Few hundreds of samples are passed to train the system and it becomes capable of sorting the fruits or the vegetable. The hard-ware is still the same and the deep learning software provides the flexibility and the ability to be trained with a limited and affordable effort¹⁵.

These three examples are powerful illustrations of mass customisation, but there are so many more. They show how the above mentioned factors of simulation, deep learning, and miniaturisation of photonics components can be combined and exploited to speed up the integration of components in customised systems. With such an approach, the generic hardware component can be developed and reused in many different situations. The photonics hardware core stays the same, the specific adaptation is enabled by software and the integration is facilitated by a thorough simulation: photonics, thermal, mechanical, integration, manufacturing processes, product assembly etc.

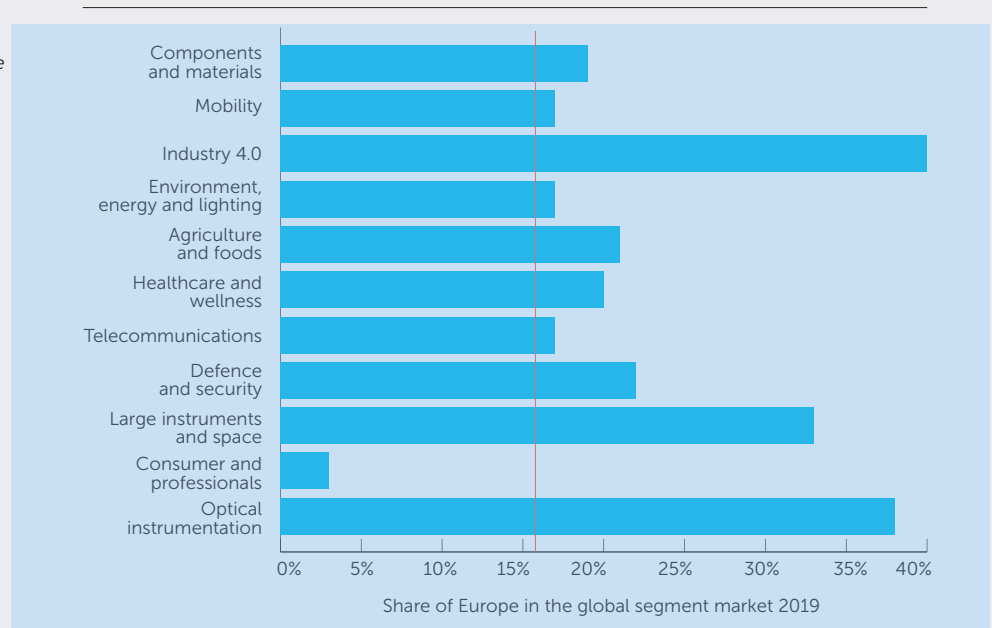
These examples deal with markets where European companies are leaders and can greatly increase their competitiveness with this approach. Figure n°9 shows the market share of the European photonics industry in each major market segment. Europe is a leading or a significant player in instrumentation, space, defence, healthcare and industry.

These segments are "Mid-size", with manufacturing series between 2,000 and 100,000 units per year, "short series" or "custom" (from unique piece to 2,000 units per year). Because of mass customisation, applied to photonics, this an efficient way to use the same hardware for many different applications. It can be manufactured in larger series at a lower cost and with a higher profit margin.

¹⁵ <https://www.wur.nl/en/newsarticle/Better-detection-of-diseases-thanks-to-deep-learning.htm>

3 The specificities of the photonics industry

Figure 9 – European Photonics Industry – Market share by segment. (The vertical red line indicates the average market share of European Photonics).
(Source: Photonics21 / TEMATYS).



Finally, photonics is essential for simulating a user's experience in the course of the design of a product, a service or the combination of both. Using digital simulation, VR and augmented reality allows the inclusion of – and taking into account clients' expectations from the very beginning – the design process of new products or product-services. This generates more added-value for the user, ensuring they receive the exact product they were expecting, which is important from a marketing perspective, compared to "standard" mass products, which follow a 'one-size fits all' approach.

This trend is already underway. It is reasonable to expect it to step up and reach a stage comparable to the current electronic industry. Generic electronic chips are developed and produced in large series and they are implemented on circuits board designed for specific applications. In the same manner, an industry of chip-size photonics components, called photonic integrated circuits (PIC) is emerging. European universities and companies have great expertise in these fields. During the 1980's and 90's, Europe had missed out on the expansion of the mass manufacturing of the electronic industry. Perhaps this is an opportunity for Europe to get back into the game.

3.5 Fourth specificity: no strong photonics industry without a strong photonics research

In 2014, a statistical study on the French photonics industry revealed that 40% of the photonics companies surveyed were less than 10 years old (figure n°10). Twice as many companies had been created between 2004 and 2014 as in the previous 10 years (between 1994 and 2004).

40% of French photonic companies are less than 10 years old (2014)

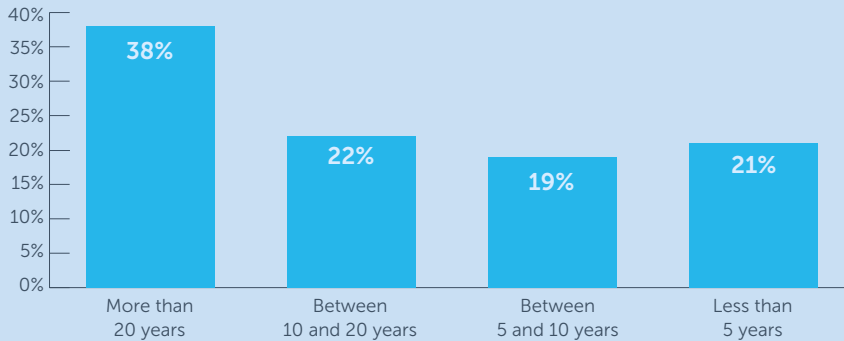


Figure n°10: in 2014, 40% of the French photonics companies were less than 10 years old. Twice as many companies were created during the last 10 years than during the previous 10 years. (Source: French Ministry of Industry/TEMATYS/ERDYN, 2014).

Photonics as a hardware-based technology did not emerge from "nothing". Most of the entrepreneurs who went on to become companies were spin-offs from research labs and universities. They have all proven the creativity that goes into photonics research and how many new ideas over time have become jobs and also thriving companies or business sectors.

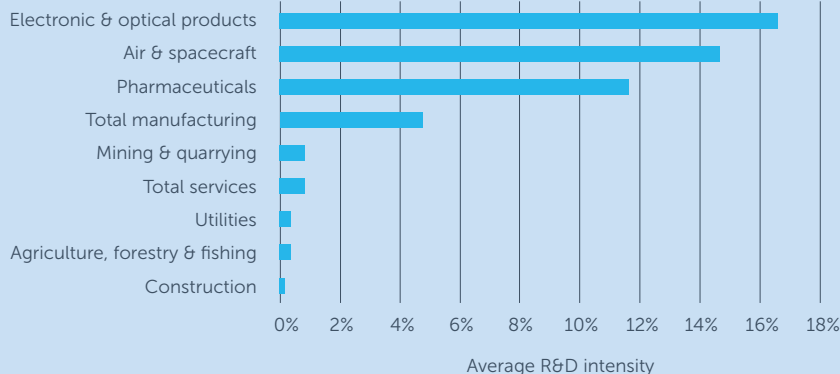


Figure n°11: R&D intensity by industry: business enterprise R&D expenditure (BERD) as a proportion of gross value added (GVA), 2014 or nearest year. (Source OECD¹⁶).

Further evidence of the close link between photonics companies and research comes from OECD statistics on research intensity of companies (figure n°11). Electronic and optical companies invest more in research than any other sector. This was also confirmed by an online survey made by Tematys on behalf of Photonics21. Among the 320 answers, larger companies announced an average research investment of around 12% of their revenue, except in ophthalmology where it is lower (around 4%). SMEs showed an average R&D investment of 18%.

In conclusion, investment in public and private research is the main driver for strengthening the photonics industry.

¹⁶ OECD (2019), Health at a Glance 2019: OECD Indicators, OECD Publishing, Paris, <https://doi.org/10.1787/4dd50c09-en>

A close-up photograph of a hand holding a white smartphone. The phone's screen is dark and reflects the surrounding environment. A semi-transparent green rectangular box is overlaid on the upper part of the phone, containing white text. The background is blurred, showing what appears to be a modern interior with blue and white architectural elements.

***Photonics is a key enabler
for many different
applications and is made
of a constellation of
thousands of markets.***

4 The European photonics industry is growing fast and is competitive

The global Photonics industry is growing faster than many other industries. The global photonics market (€ billion) accounts for €690 billion in 2019 and should reach €900 billion in 2025 (figure n°12). It is a fast-growing industry compared to the more traditional ones. Figure n°12 shows the growth of the overall industry in the OECD. While it was growing at an average of 1.3% per year between 2015 and 2019, the photonics industry showed a CAGR of 7%. The photonics industry grew even faster than the entire Chinese industry, and is estimated to have grown at a pace of 6% per year in the same period.

Photonics worldwide market size

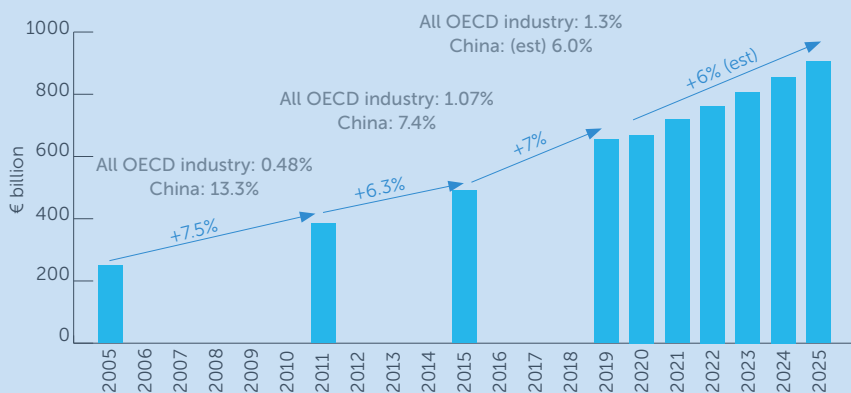


Figure n°12: the global photonics market (€ billion) accounts for €690 billion in 2019 and should reach €900 billion in 2025. (Source: Photonics21 / TEMATYS).

The European photonics industry revenue was €103 billion in 2019, amounting to 16% of the global market. This represents more than 390,000 jobs. But what is to be noticed is that the recent growth of the European photonics industry for the period 2015-2019 was the same as the global one: 7%. This is three-times the growth of the EU GDP (2.3%/year) and five-times the growth of the EU industrial production (1.3%/year).

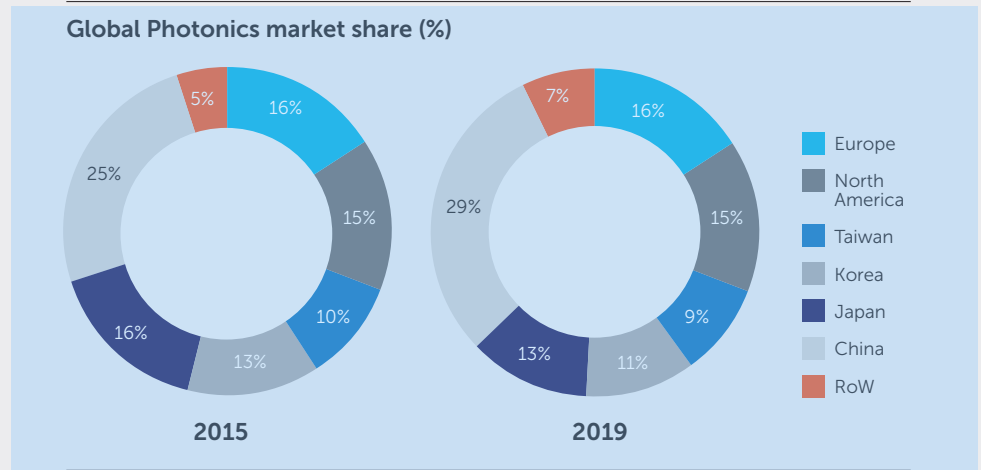
Key figures about European photonics industry

Photonics production (2019)	€103 billion
Number of employees (2019)	> 390,000
Growth since 2015	~ 7% / year

A paradox can be drawn in two of the biggest photonics markets. While many display technologies were invented in Europe, this market became dominated by Asian companies, in Japan, Korea and China. It is also true that in the last 20 years, the Chinese industry caught the photovoltaic market through a policy so aggressive that the EU introduced anti-subsidy and anti-dumping duties in 2014 on solar glass imported from China. In short, Europe is not a leader in the two biggest photonics markets, yet, for the last five years, the share of the European photonics industry has been maintained at 16% of the global market (figure n°13), for which there is a very good reason.

4 The European photonics industry is growing fast and is competitive

Figure n°13: from 2015 to 2019, the share of the European photonics industry has been maintained at 16% of the global market thanks to the creativity of the European Research and the dynamism of companies active in "mid-size" markets. (Source: Photonics21 / TEMATYS).



Photonics is a key enabler for many different applications and is made of a constellation of thousands of markets. Some are tiny niches, but profitable for SMEs, whereas others are medium-sized with volumes of several thousand. Serving those applications markets, and to remain at the fore-front of technological change requires constant innovation. **Research and innovation are key to maintaining competitiveness.** And, thanks to a European strong research capacity, companies can maintain and expand their businesses and catch their share of this 7%/year fast-growing market¹⁷. These companies are leaders in markets like technologies for Industry 4.0 (Lasers machining, Semi-conductor Production machines, Machine Vision...), Instrumentation, microscopy and Optical Measurement, medical and healthcare photonics-based technologies (fig. n°9). And if China has increased its share during the period 2015–2019, it came from the growth of its inner market and production transfer from Japan and Korea (which respectively lost 3% and 2% of the global share, figure n°13) to China.

¹⁷ More detailed statistics about the European photonics industry are available in the "WP1 report" (add the right title, reference and download link)

4 The European photonics industry is growing fast and is competitive



***Photonics is playing a
part in the great
challenges facing Europe:
a greener world and
economy, accelerating
the digitisation of
manufacturing and
society, improving our
health and well-being
and adopting a new
approach to sovereignty.***

5 Conclusion: Investing in photonics is very profitable for Europe, states and regions

European photonics companies are successful. Photonics is both essential for producing a broad and varied range of products, and is an enabling technology for the most advanced high-tech products and objects that have become so essential for daily life that we almost forget they are there.

Photonics is playing a part in the great challenges facing Europe: a greener world and economy, accelerating the digitisation of manufacturing and society, improving our health and well-being and adopting a new approach to sovereignty.

Photonics presents several specificities, making it more and more essential for our economy and for our everyday lives:

- ✔ Photonics, as an extension of optics, is one of the oldest industries
- ✔ Photonics is deeply transverse
- ✔ Photonics is a slow maturing market
- ✔ The photonics application markets can be sorted by production volume: unit or small series, mid-size and mass market. But within the last category, a sub-category is emerging, based on mass-customisation, where every single product is unique even produced by large volume processes, like ophthalmic lenses.
- ✔ No strong photonics industry without strong photonics research.

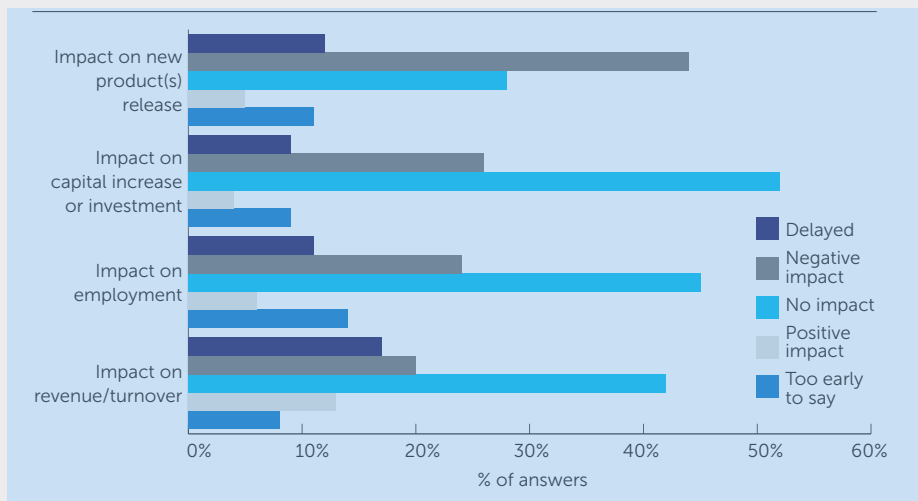
Fortunately, Europe is competitive. Thanks to strong and creative research, and to public support at all levels in many countries and regions, European companies can keep on growing and start-ups are being created every day.

Europe's Photonics industry is resilient. Another specificity is worth being stressed: the photonics industry is highly resilient. Because it serves so many different application markets, and because it is high up in value chains, the photonics industry manages to sustain an economic crisis with perhaps less damage than other sectors.

A survey conducted between July 15th and September 30th, 2020, (Figure n°15) showed that the majority of European photonics companies were not seriously impacted by the COVID-19 virus crisis in terms of business and employment. However, they faced production bottlenecks caused by lock-downs and postponed investments, as their clients are often waiting for a better understanding of economic perspectives.

5 Conclusion: Investing in photonics is very profitable for Europe, states and regions

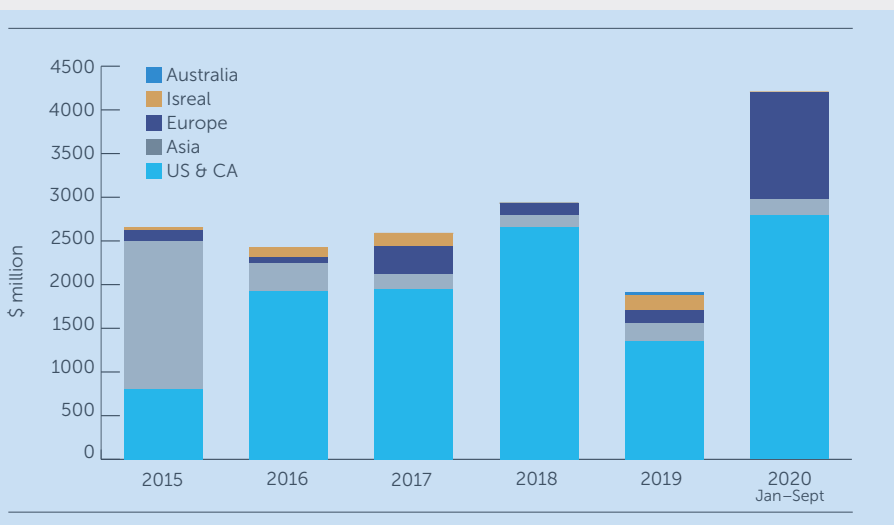
Figure n°15: a survey done between July 15 and September 30, 2020 by Tematys on behalf of Photonics21 showed that only 20% of survey participants reported a negative impact on revenues and 25% a negative impact on employment. (Source: Photonics21 / TEMATYS).



European funds have not identified photonics companies as good investment opportunities.

Strangely, given the fast growth of the photonics sector (see above chapter 4), one could imagine that investors and venture capital funds would regard photonics as an attractive field to invest in. While this is the case in the US, it is not the same in Europe. Figure n°16 shows the geographical breakdown of the funds raised by photonics companies over the past 5 years. American and Canadian companies could raise almost \$11.490 million (69%), Asia \$2.698 million (16%) and Europe \$2.019 million (12%). But, 60% of the total amount raised in Europe comes from one single operation finalised in 2020 (Infineon). The remaining amount of funds raised by European companies during the 5 and-a-half-years is €819 million. In parallel, Israeli photonics companies could raise €478 million during the same period! European photonics companies build lucrative businesses, maintain their world market share, but struggle to secure support to grow and develop. Is it because of European investor strategies, or because photonics companies do not make themselves attractive as investment opportunities? A more comprehensive analysis of the reasons for this situation was done by the

Figure n°16: funds raised by photonics companies between 2015 and 2020, geographical breakdown. (Source: TEMATYS 2020 – investment database, OWler).



5 Conclusion: Investing in photonics is very profitable for Europe, states and regions

European Investment Bank in 2018. But a much bigger effort might be necessary to put Photonics under the spot-lights¹⁸.

However, the success of European companies has not gone unnoticed everywhere. There are some funders from the US or Asia who are happy to invest, and a significant part of this €819 million raised by European companies actually came from foreign investors. This is a demonstration of European excellence, and also evidence that photonics could be a major asset to increase European industrial sovereignty. But the multiplication of foreign investment reduces also the control over technologies that were invented and matured in Europe, often through public support.

This trend situation has heightened the public authorities' concern. Claiming military sovereignty reasons, the French government had set up so strict condition for the takeover of the company Photonis that the American Teledyne gave-up¹⁹. In the Netherlands, the company Smart Photonics was struggling to attract financing to scale up the production of its next-generation chip. The Dutch government stepped in the company Smart Photonics along with the government-backed agency PhotonDelta as only Asian funds would show interest²⁰.

States and regions have good reasons for investing in photonics. Beyond the sovereignty reasons, states and regions have good reasons for investing in photonics. With an expected CAGR of 6% for the coming years (see chapter n°4), photonics companies generate jobs. When France decided to build its first intense laser facility near Bordeaux in the 90s (Laser Megajoule), the region Nouvelle-Aquitaine decided that photonics would be a strategic priority. After 20 years, the local photonics cluster claims 94 start-ups, 49 established companies and 3,000 direct and more than 10,000 indirect jobs.

Last but not least, the photonics industry not only employs highly qualified persons including PhDs and engineers. In our days, photonics companies in many parts of the world report on difficulties²¹. It may seem unthinkable that many production lines of one of the most deep-tech hardware sector struggle to find personnel for assembling their products. They are often too complex and produced at too small a volume and automation is not a good solution. To make a photonics product requires care and attention at a level shown by craftspeople who would spend months hand-polishing a perfect lens, decades, or even centuries ago.

¹⁸ Financing the digital transformation Unlocking the value of photonics and microelectronics" and "Financing the Deep Tech Revolution: How investors assess risks in Key Enabling Technologies (KETs) March 2018

¹⁹ https://www.challenges.fr/entreprise/defense/affaire-photonis-comment-la-france-a-pris-les-etats-unis-a-leur-propre-jeu_729446

²⁰ <https://www.bloomberqint.com/global-economics/how-china-made-the-netherlands-question-its-free-market-beliefs>

²¹ Alexis Vogt, "Your precious engineers will be increasingly disabled by a shortage of optics technicians. What can be done?," Proc. SPIE 11143, Fifteenth Conference on Education and Training in Optics and Photonics Photonics: ETOP 2019, 111431U (3 July 2019); <https://doi.org/10.1117/12.2523596>
Patricia Daukantas, "The Optics Workforce: Looking to the Future", Optics and Photonics Photonics, 2017 https://www.osa-opn.org/home/articles/volume_28/july_august_2017/features/the_optics_workforce_looking_to_the_future/

6 Appendix A: Green deal

Environment	
Needs and requirements	Expected technical functions
Monitoring: potable water, sewage water, air, rivers, oceans, soils, subsoils, plants and crops, landscapes, biodiversity	Chemical and molecular analyses (metals, Reach, Endocrine Disruptors, pesticides, drugs, etc.).
Atmosphere monitoring: greenhouse gas, ozone, atmospheric boundary layer	Biological analyses (bacteria, viruses, ...)
Treatment and decontamination of contaminations (all types)	Dust and particle detection
Monitoring the climate and its evolution	Low-energy sensors and systems
Carbon-free energies	Color analysis
Waste sorting and treatment	
Data for environmental policies, international program (COP21, IPCC, Paris Agreement...)	
Constraints	Photonics technologies and solutions
Regulation	Multi and hyperspectral all-band cameras and imagery
Complexity of ecosystems and the chain of living organisms	Spectrometers (Mini, micro...), cytometers, granulometers...
Sociological factors and resistances	Lasers and all-band diodes
Carbon market	Image processing: detection, recognition, 3D reconstruction...
Hydrocarbon markets	Artificial and semantic intelligence
	UV (LED), RX, Gamma sources
	Biosensors

6 Appendix A: Segmentation of photonics applications

Agriculture	
Needs and requirements	Expected technical functions
Sustainable Agriculture	Geolocation (equipment, animals...)
Precision Agriculture	Performance measurement
Maintaining biodiversity	Phenotyping
Feeding the population	Seed characterisation
Phytosanitary reduction	Production characterisation, chemical analysis "on field": Colour, sugars, oxidants, proteins...
Input reduction	Detection of pathologies and pests
Adaptation to climate change	Behavioural monitoring
Rise in quality	
Limiting soil depletion and soil erosion	
Health monitoring and traceability	
New practices (organic, above ground, vertical farms)	
Sustainable Aquaculture	
Animal Welfare	
Constraints	Photonics technologies and solutions
Regulations and standards	Multi and hyperspectral all-band cameras and imagery
Size of farms	Spectrometers (Mini, micro...)
Technological skills of the operators	Business databases
Purchase price	Multi-sensor hybridisation: coupling inertia vision...
Fragmentation of needs	Lasers and diodes: continuous and pulsed LIDAR
Variability of living matter	Image processing: detection, recognition, 3D reconstruction...
Climatic hazards	Artificial and semantic intelligence
Investment capacity of the sector	Animal tracking
	Artificial lighting

7 Appendix B: Digitisation of manufacturing and society

Digitisation of manufacturing and society	
Needs and requirements	Expected technical functions
Exponential increase in data to be stored and shared	Higher capacity of telecom networks (fibre optics)
Sensors for any parameters, at all scale, working in any conditions	More secure transfer technologies (less easy to be tapped)
Exponential increase of calculation capacity	Cryptography
All data available anywhere, anytime, at high speed and low latency.	Low consumption components and devices
Exponential increase of the number of connected objects	Advanced imaging technologies
Protection of privacy, copyright etc	High-performance computing (quantum)
Safe storage, transfer and use of data	Photonics sensors
Easy access by anyone	
Easy use by anyone	
Limitation of energy consumption	
Fair competition and a fair share of value between value chain stakeholders	
Protection against fake news etc.	
Development of AR/VR	
Constraints	Photonics technologies and solutions
Lack of rigidity of global standards	Transceivers
Political use of digital means (security, commercial, privacy issues...)	Fibre optics, telecom components
Size disparity of stakeholders (GAFAM)	Free space telecommunication, LIFI
Protection of privacy	Detectors, cameras, advanced imaging techniques (medical etc.)
	Displays, micro-displays
	LIDAR, rangefinders, 3D sensors
	Freeform optics, advanced optical components
	Coating technologies
	Lasers, fibre lasers
	Cryptography, quantum computing technologies
	Ultra-precise clocks

8 Appendix C: Health and well-being

Health and well-being	
Needs and requirements	Expected technical functions
Diagnostics	Biological analysis: haematology, bacteriology, oncology, biopsy, glucose...
Personalised medicine	Imaging and microscopy: X-ray, NMR, ultrasound, endoscopy, OCT, microscopy, full-field imaging...
preventive medicine	Surgery: cutting, cauterisation, refractive
Point of Care	Therapy: visual correction, chemotherapy, radiotherapy, proton therapy
Home medicine	Well-being: depilation, tattoo removal...
New therapies	
New surgery technologies (safer, less invasive, faster recovery etc.)	
New vaccines and new antibiotics	
More knowledge on the human body as well as the impact of its environment (nutrition, pollution, behaviours and habits)	
Strategies and methods for impaired and disabled, especially seniors	
Decrease of animal use for research	
Constraints	Photonics technologies and solutions
Regulations and standards (CE Marking/FDA approval...)	Corrective lenses, crystalline implants, artificial retina, adaptive optics, OCT
Clinical trials	X-rays, particle sources
Reimbursement policies	Flow Cytometry
Costs (age of population...)	Spectroscopy: UV-Visible, Raman, SPR, FTIR, SERS
Quality and durability	Lasers (fluorescence, excitation, cutting, ablation, photocoagulation, molecule dissociation)
	PDT
	All Microscopy and fluorescence techniques
	Endoscopy, full-field imaging
	DNA sequencing
	Photoacoustics
	Visible and IR Imaging: detection, data analysis, 3D, ...

9 Appendix D: Sovereignty

Photonics as an enabling technology
As a Key Enabling Technology, photonics covers all fields of the industry and people's life. The current document illustrates this statement, focused on the great challenges to be taken up during the new framework program 2021-2027. Further details and information can be found here: "Europe's Age of Light! How photonics will power growth and innovation", Photonics21 Multiannual Strategic Roadmap 2021-202, VDI Technologiezentrum GmbH – Photonics21, March 2019 https://www.photonics21.org/download/ppp-services/photonics-downloads/Europes-age-of-light-Photonics-Roadmap-C1.pdf "Photonics – a critical Key Enabling Technology for Europe, Role and impact of Photonics in H2020", VDI Technologiezentrum GmbH – Photonics21, December 2017 https://www.photonics21.org/download/ppp-services/photonics-downloads/Photonics-in-Horizon-2020-finaldigital-C1.pdf "Europe's age of light! Leverage the unbroken innovation potential of Photonics", vision paper, VDI Technologiezentrum GmbH – Photonics21, https://www.photonics21.org/download/ppp-services/photonics-downloads/Photonics21-Vision-Paper-Final.pdf

Fight against counterfeiting, contraband and drug-trafficking	
Needs and requirements	Expected technical functions
Detect drugs and substances	Chemical and molecular analyses.
Analyze chemicals and compositions in material and biomaterial	Biological analyses (bacteria, viruses, ...)
Identify material and biomaterial origin	Dust and particle detection
Detect additives and not authorised blending (wine, honey etc.)	"Artificial nose"
Identify vehicles and persons	Imaging, vision and night vision
Detect biohazard (parasite, pest, bacteria, viruses, fungi, invasive animals and plants)	Scanner
See through packaging, inside containers, under a pile of goods	Shape recognition
Find hidden goods or substances	
Constraints	Photonics technologies and solutions
Regulations and standards (CE Marking/FDA approval...)	Multi and hyperspectral all-band cameras and imagery
Volumes of goods to control	Spectrometers (Mini, micro, chip-size...), Raman, FTIR, SPR, SERS, TDLAS, LIBS
Storage and packaging techniques	Microscopes and fluorescent detection techniques
Regulation management	UV (LED), RX, Gamma, Nir, SWIR, MIR and LWIR sources and detectors
Intentional concealment of goods or substances	Biosensors

Defence and security	
Needs and requirements	Expected technical functions
See in all conditions including night	Vision in all conditions, night vision
Detect threat in any condition	Threat detection in any condition
Designate target	Target designation systems
Guide missile and ammunition	Missile and ammunition guidance
Deceive or destroy threatening missile and ammunition	Countermeasure and flare, incoming missile and ammunition destruction
Stay undetected	Camouflage
Measure distances and adjust strikes	Range finding
Communicate safely	Encrypted communication, Free space high-speed communication
Detect and protect against NRBC threat	NRBC detection
Monitor structures	
Constraints	Photonics technologies and solutions
"Harsh and all conditions" Operations	Multi and hyperspectral all-band detectors and cameras
Standards (ITAR etc.)	Image processing: detection, recognition, 3D reconstruction...
Dual-use regulations	Lasers and all-band diodes
	Spectrometers (Mini, micro...)
	LIDARs, range finders
	Metamaterials
	Advanced optical components (diascope, periscope...)
	Free space and fibre communication systems
	Cryptography (see appendix C)
	Fibre sensors
Technologies for an autonomous survey and monitoring of environmental challenges	
See Appendix B	
Cryptography	
See Appendix C	

NextPho21

Implementing the European Photonics21 PPP strategy

Instrument: Coordination and Support Action

Market Data Report 2020



PHOTONICS PUBLIC PRIVATE PARTNERSHIP



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1 Segmentation and methodology

Photonics as a Key Enabling Technology (KET) of Europe intended to play a major role within Horizon 2020. As this framework program has now come to an end, it is time to provide evidence that the objectives of enabling and leveraging growth for the EU industry and society have been achieved.

Moreover, accurate dimensioning of the photonics industry is crucial for positioning and sustaining the technology as well as the industry towards strategic stakeholders such as value chain partners, public and private investors, governmental and non-governmental representatives as well as supporting agencies, associations and citizens.

The broad range of photonics technology applications, the diversity of photonics products and systems in varied application fields – and in very different customer industries – make it difficult to precisely determine the economic impact along the value chains, as well as to quantify the importance of the photonics industry.

While the photonics industry is global with many large organisations, most of its companies are SMEs. Photonics as a newer technology is a powerful fuel for the global and European economic growth engine and has increasingly gained significance in the global economy over the last two decades.

This report strives to deliver an in-depth quantitative assessment both of the size of both the global and European photonics industries based on solid methodologies and recognised data sources. The methodologies used are designed to extract the contribution of photonics from dispersed (and sometimes hidden) industry data. This report also provides a detailed analysis of both the various industrial photonics applications and of the different sectors impacted by these technologies.

1.1 Introduction and definitions

What is photonics?

Photonics is the science of harnessing light to benefit humankind. This field encompasses sciences and technologies that generate, emit, detect, collect, transmit, modulate, amplify photon beams, from the terahertz band (from 300 Gigahertz or 1000 μm) to gamma and X-rays¹. From this definition, Optics and Optoelectronics are parts of photonics.

Behind this definition lies a broad range of applications: the extent to which photonics technologies fulfil fundamental everyday needs may not be immediately apparent as they are used in almost all industrial sectors. This report will describe and quantify the applications of photonics technologies.

¹ European Technology Platform Photonics21 c/o VDI Technologiezentrum GmbH, Photonics21 Sekretariat (2017): Europe's age of light! How photonics will power growth and innovation", Photonics21 Vision Paper, Brussels / Düsseldorf / Berlin / Frankfurt am Main, 2017.

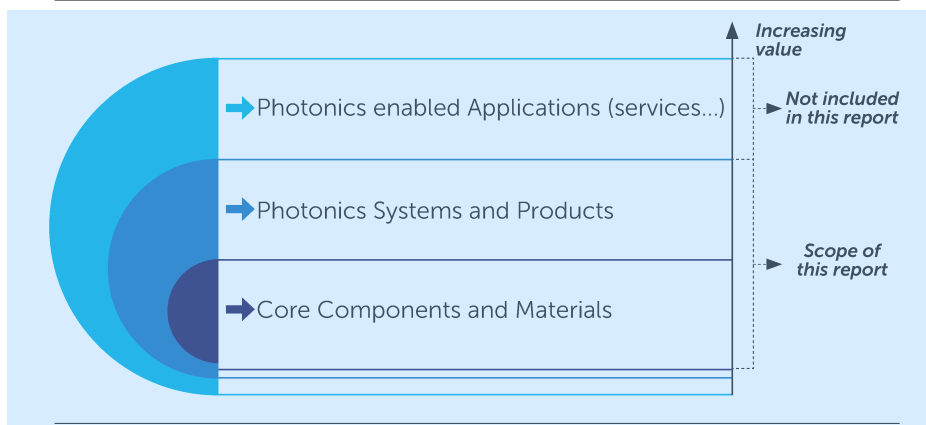
Other definitions used in this report:

- ▶ “Photonics Company”: company targeting the development and manufacturing of photonics core technologies (components and modules) as well as the development and manufacturing of whole products and systems that rely, for the most part, on photonics components.
- ▶ The term “photonics industry” refers to the collection of these photonics companies as described above (that develop, manufacture, and sell optics and photonics components and systems).
- ▶ EU27: current European Union
- ▶ EU28: EU27 + United Kingdom
- ▶ Europe (in this report): EU28 + Switzerland + Norway (European countries participating in H2020).

The Photonics Value Chain

The evaluation of the photonics industry must take into account the whole photonics value chain. This is the process of taking raw materials and adding value to them through various processes to create finished products that can then be utilised in end-use applications (see Figure 1).

Figure 1 – Global Photonics-related value chain including enabled applications.
(Source: Photonics21 / TEMATYS).



The photonics value chain starts with raw materials such as glass and semiconductor substrates and progresses through photonic components to photonic products and systems such as cameras or lasers.

The **global value chain** is based on both photonics products and systems (hardware type of products such as laser machines, medical devices, etc.) and a wide range of **further services and products enabled by photonics**, such as the internet, which relies on optical fibres to transmit its data or smartphones which include various photonic modules.

Each level of the value chain has a higher value than the previous one, so that the total revenues associated with enabled services, for example, are much higher than those of the basic components. All along this value chain, other industrial sectors can therefore benefit and develop thanks to the related opportunities.

**Along the value chain,
many other industrial
sectors benefit and
develop thanks to the
opportunities related
to photonics.**

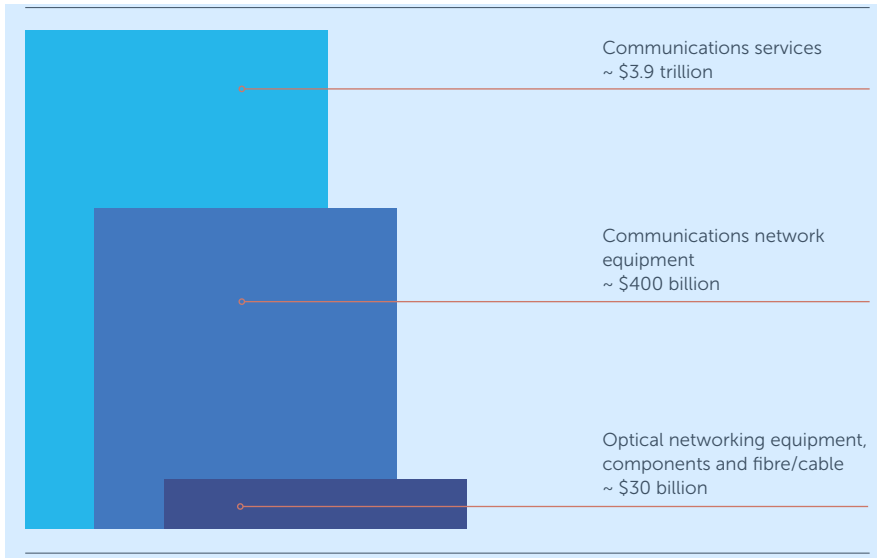


Figure 2 – Example of global value chain including photonics-enabled products and services. (Source OSA²).

It is important to note that this report focuses on quantifying the market and production of Components & Materials and of photonics systems (or modules in the case of smartphones). The final market value of photonics-enabled products and services like smartphones, communications services, e-commerce etc. is beyond the scope of the report.

Quantifying the Photonics Market and Industry

There is no single universally accepted definition of the photonics market or industry, even though thousands of entities use optical and photonic technologies. Conversely, many users of light-based technologies do not consider themselves as photonics companies.

Besides this, economic tracking codes in the US (NAICS) and in Europe (NACE) do not have a category for photonics. Therefore, we have to use more than 100 different NAICS or NACE codes to characterise photonics products and companies.

Although market estimates and economic impact assessments are an essential tool for understanding and promoting the photonics industry, these estimates can vary considerably – for the reasons just mentioned. It is therefore important to set out the methodology used in this report for estimating the photonics industry as clearly as possible.

It would be most appreciated if other organisations around the world would use similar types of segmentation and methodology as presented in the following. A major advantage of this approach of a common classification would be increasing comparability of studies performed by different institutions/organisations, allowing for an even more consistent assessment and representation of the industry on a global scale.

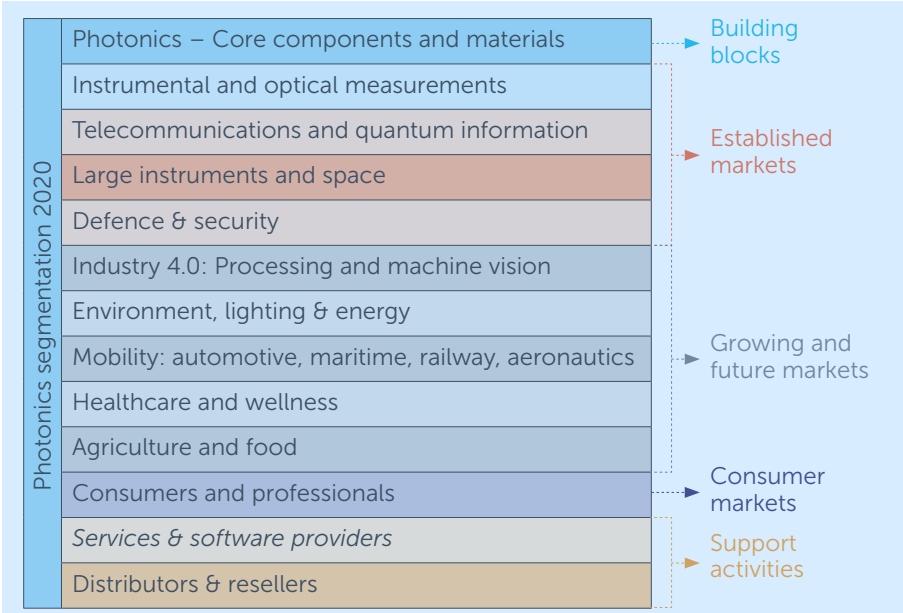
² Lighting The Path to a Brighter Future, How optics and photonics impact the global economy, OSA, 2018.

1.2 A new segmentation based on applications and usage

Why use a new segmentation?

To accompany, with exploitable data, Photonics21’s ambition to improve the visibility of photonics in its application markets, the former segmentation has been replaced by a new version (see Figure 3). The new segmentation is oriented towards end-users and application markets and is also adapted to the evolution of applications. Moreover, it is closed to the new workgroup’s structure of Photonics21.

Figure 3 – New Photonics Segmentation used in this Report.
(Source: Photonics21 / TEMATYS).



This segmentation makes it possible to define within the European photonics industry, the manufacturers who participate in the core development of photonic objects and products (optical components and materials, laser modules, optical surface treatment) and those who manufacture complete products with targeted application use. For example, a manufacturer of laser modules that can be integrated into the final manufacture of a LIDAR will be registered in segment “Core components and materials”, while a manufacturer of a LIDAR for a specific need will be registered in its application category (a manufacturer of “wind LIDAR” will be registered in “Environment” segment and a manufacturer of automotive LIDAR will be registered in the “Mobility” segment).

The complete details of what is included by segment can be found in Annex. There are 11 segments, 30 sub-segments and more than 125 product types.

The relationship between the previous and 2020 segmentation is presented in the following table.

Previous segmentation	2020 segmentation
Production technology	Included in "Industry 4.0"
Measurement and Machine vision	- Machine vision products are included in "Industry 4.0" - Measurement systems for process control are included in "Industry 4.0" - Measurement systems used out of factories are included in "Instrumentation and Optical Measurements"
Medical Technology & Life Science	Included in Healthcare and Wellness (almost identical)
Information Technology (Consumer Electronics, Office Automation, Printing)	- Included in the segment "Consumers and Professionals" - Except for the components like image sensors which are included in "Core components and materials"
Optical communications	Included in "Telecommunication and quantum information" (almost identical except for some Quantum related products but which represent a very small part of the segment)
Flat Panel Displays	- Included in the segment "Consumers and Professionals" "Consumers and Professionals" is almost identical to Information Technology + Flat Panel Displays (except for the part related to components)
Lighting	- Included in the segment "Environment, lighting & energy" - Except for car lighting (and other lighting for mobility) which were not taken into account and are now included in "Mobility: automotive, maritime, railway, aeronautics"
Defence Photonics (Including Security systems)	Almost identical to the segment "Defence & Security" except for the components like Image Sensors
Photovoltaics	Included in the segment "Environment, lighting & energy"
Optical Systems and Components (including optical glass)	- Optical components have a dedicated segment "Core components and materials" - Optical systems are included in their application segments. If they are instruments for various applications (e.g. FTIR systems) they will be included in "Instrumentation and Optical Measurements".

Table 1: Relationship between the previous and new segmentations.
(Source: Photonics21 / TEMATYS).

Besides this, there are small changes in the perimeter for the type of products versus previous reports. Car lighting (as well as other lighting for mobility) is now included in the statistics of European and global photonics – this is because most of these products have now evolved significantly and are real photonic systems with LEDs (or even lasers!), freeform optics and sometimes even cameras to adapt the lighting to the environment. Spectacle lenses and contact lenses are now fully included in the statistics in the “Healthcare” segment.

Note that for consistency, these changes were also made in the data for the previous years.

1.3 Methodology of the study

The photonics industry does not have a standard industry classification(s), presenting a challenge that complicates efforts to accurately quantify this industry.

Several other factors add to the complexity of analysis since many companies involved in manufacturing photonics products do so alongside producing non-light-based products. Furthermore, a large number of photonics companies are SMEs and often report only abbreviated accounts. To meet these challenges, the methodology used for this report was built on a similar study, initially developed for describing the French photonics industry and was slightly adapted to address the specificities of the economy and related databases in the various European countries.

The methodology used here is quite similar to that used in the UK for estimating the UK photonics industry³ and also to that developed and used for the photonics industry in Australia and New Zealand⁴. Apart from the selection of companies, it also has similarities with the method used by SPIE in estimating components industry size⁵.

This is good news because it provides a first step towards producing reliable, global, photonics industry statistics and facilitating international comparisons.

The methodology is outlined below.

³ https://photonicsuk.org/wp-content/uploads/2018/05/UK_Photonics_The_Hidden_Economy.pdf

⁴ Photonics in Australia and New Zealand – Lighting Economic Growth – An Industry Review 2020.
<https://optics.org.au/resources/Documents/Lighting%20Economic%20Growth.pdf>

⁵ https://spie.org/Documents/Industry%20relations/IR_Methodologies_2019.pdf

1.3.1 Methodology for the European Photonics Industry

The methodology for the “core study” is summarised in the following figure.

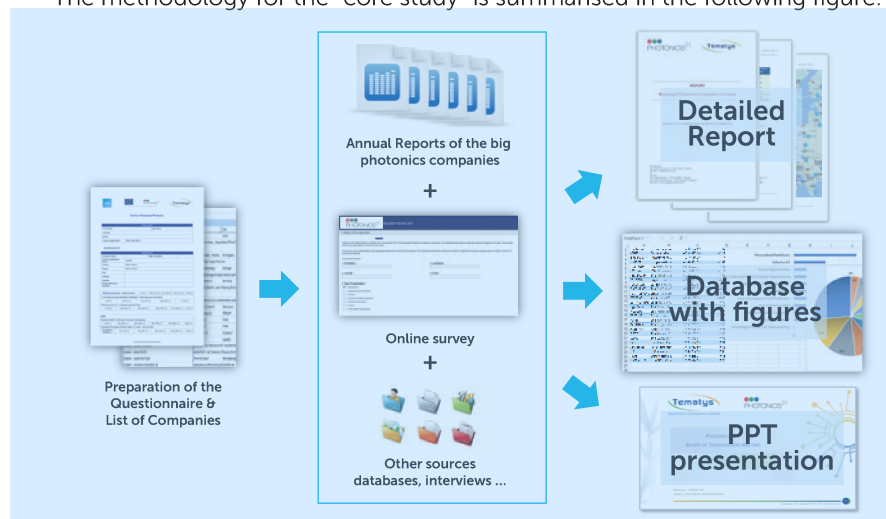


Figure 4– Overview of the methodology for the study.
(Source: Photonics21 / TEMATYS).

1 – Listing the European photonics companies

Data was gathered from sources including attendance in photonics-focused events, regional photonics clusters memberships, industry and academic experts and selected using knowledge of the local industry. This was augmented with keyword searches in databases like D&B (Dun & Bradstreet).

2 – Using annual reports, databases and interviews to evaluate the revenues of photonics companies

Data on revenues and employment for companies engaged in photonics manufacturing was obtained from annual reports and the D&B database based on matching the company name, city and country.

The reference sales figures are those for 2019 unless this was not available. To multiply the number of companies listed, in this case, the revenue for 2018 or 2017 has been used. Turnover before 2019 has been corrected with the turnover growth index.

For companies that do not report revenue, a methodology was used similarly to that used for Photonics France. The following assumptions were made: companies that do not report are mostly small. 100% of their turnover is photonics and is less than €10 million. The distribution of their turnover is identical to the distribution of the turnover of companies with a turnover of less than €10 million that have filled in their turnover.

Note: Companies considered to be photonics users but not explicitly photonics manufacturers were excluded from the analysis.

3 – Evaluating the proportion of photonics related activity for diversified companies

For diversified companies producing both photonics and non-photonics products, the reported total revenue and employment figures were then adjusted for the proportion of photonics related activity.

Average revenue per employee ratio for the photonics industry was calculated based on the same data. This ratio was then used for companies for which revenues or number of employees were not available.

Big companies

For this study, around 50 major companies were analysed – both through the publication of their latest annual report and through interviews with some of them to assess the size and dynamics of photonics in their group.

For doing that, the following list of European and international groups was used:

- Photonics components: AMS AG, Berliner Glas, Coherent, Corning, II-VI, Jenoptik, ST Microelectronics, Saint-Gobain, Schott
- Optical fibres: ASN, Leoni, Nexans, Prysmian
- Photonics for Industry: ASML, Bystronic, IPG Photonics, Sick, Trumpf
- Photonics for Automotive: Hella, Marelli Automotive Lighting, Valeo, Veoneer
- Lighting: Osram, Signify, Zumtobel
- Healthcare: GE Healthcare, Karl Storz, Philips, Siemens
- Ophthalmology: Essilor, Hoya
- Telecommunications: ADVA Optical Networking, Ericsson, Nokia
- Defence & Security: Airbus, BAE Systems, Diehl, Leonardo, Rheinmetal, Robert Bosch, Safran, Thales
- Instrumentation and diversified companies: Carl Zeiss, Horiba

Online Survey

To complete the collected data (regarding R&D investments, investments in production, export, expected growth, etc.), an additional online survey was performed.

The present method combines different approaches, produces a reliable assessment of the European photonics industry size and other characteristics, and is appropriate to industries for which no single applicable SIC code exists.

1.3.2 Methodology for Global Photonics Markets

In total, **128 different types of products** were taken into consideration to evaluate the global market. The methodology is presented in detail below.

Task 1: Breakdown in various product lines based on our segmentation

For example, split of category 6.1 (telecom components and systems) into subcategories:

- Telecom transceivers
- Datacom transceivers
- Optical switch
- Optical routers
- Datacenter Interconnects
- Others

Task 2: Compilation of public or purchased market data

The base year is 2019 and CAGR 2020–2025 (less than 20% of compiled studies have assessed the impact of COVID).

In our example (telecom), various market reports were compiled for each of the former items.

Task 3: Data reliability analysis

This task has the following steps:

- Listing of key players on each sub-segment (not necessarily European players)
- Analysis of Annual report of 1 to 2 key players to compare its revenue and estimated market share with market report data
- Analysis of Investors presentation of 1 to 2 key players to compare CAGR with market report CAGR
- In our example, analysis of II-VI, Huawei, Infinera ...

The following figure (Figure 5) displays the analysis made on photonics in Smartphones. It is amazing to see that now about half of the Bill of Material (BOM) in smartphone comes from photonics modules.

Mobile phones and devices	Product portfolio		Revenues (2020) \$ billion	CAGR (20–25)
	Displays for smartphones	Samsung displays, Japan displays, BOE, Sharp, LG displays, CSOT	59.9	7.30%
	2D cameras module for smartphones	LG Innotek, Semco, Foxconn (Sharp), Sunny Optical, Ofilm, Luxvision (Liteon)	25	7.80%
	3D cameras modules for smartphones	AMS, Sunny Optical Technology, Ofilm, LG Innotek, Samsung ElectroMechanics, LUXvision	3.2	20%
	Spectroscopic module for smartphones	AMS, ...	0.03	> 30%

Figure 5– Example of the result of our methodology on Photonics in Smartphones
*figures are estimates of major parts.
(Source: Photonics21 / TEMATYS).

Photonics business in smartphones \$77.4 billion in 2020

Price teardown of latest smartphones (in \$)

	Samsung Galaxy S20 5G	Apple iPhone 11 Pro Max	Samsung Galaxy A50	LG Q7
Display (touchscreen module, cover glass, controller)	75	100.4	26.32	18.4
Electro-mechanical elements	30.93	27.23	2.86	18.02
Chipset	5G chipset: 73.78 AP: 54.01	AP: 43.09	14.96	7.86
Memory (NAND, DRAM)	58.6	27	29.82	27.3
Camera modules	89.17	42.38	19.31	6.53
Battery pack	5.87	6.07	4.83	3.57
Launch	Feb 2020	Sept 2019	Aug 2019	June 2018
Retail price	\$1,399	\$1,099	\$350	\$404*

(Source: IHS Markit –
<https://benchmarking.ihsmarkit.com>).

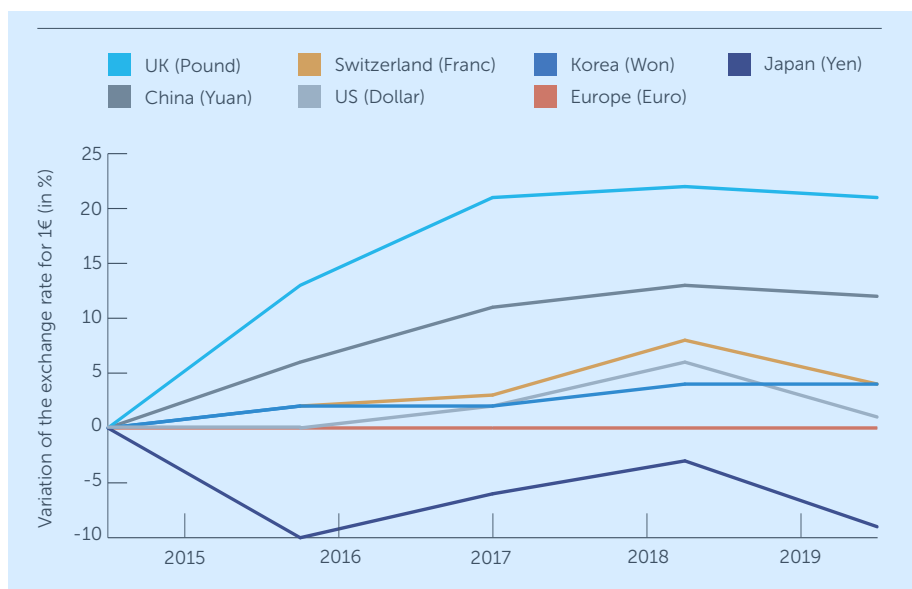
Photonics weight in smartphones' bill of material: Between 40 and 60% of BOM

2 Global photonics market

International market data are often reported in US dollars. Besides that, the photonics production in Europe will be reported in Euros. The exchange rates are important especially when looking at the annual growth rate (of a market segment or a country production) as it can be very different according to the used currency.

For the main period relative to this report (2015–2019), the variations of the exchange rates are given in the figure below.

Figure 6 – Exchange Rates of Major Currencies versus Euro from 2015 to 2019 (Variation in % of the exchange rate for 1€). (Source: OECD Data).



One major point is simplifying the analysis for the period: the variation of the USD/EUR exchange rate between the beginning and the end is less than 1%. The EUR/USD exchange rate was 1.11 in 2015 vs. 1.12 in 2019. So the variations in dollars or euros will be approximately the same over the period. For some of the other major currencies, the situation is very different.

From 2015 to 2019, the Japanese yen (JPY) appreciated by 9.1% vs. the euro after depreciating by 17% vs. the euro from 2011 to 2015. The EUR/JPY exchange rate was 134 in 2015 vs. 122 in 2019.

Vs the euro, the Chinese currency depreciated by 11.9% from 2015 to 2019, after appreciating by more than 30% from 2011 to 2015. The EUR/CNY exchange rate was 6.91 in 2015 vs. 7.73 in 2019.

The Korean won (KRW) didn't change greatly during the last four years. From 2015 to 2019, it depreciated by about 3.9% vs. the Euro. The EUR/KRW exchange rate was 1255 in 2015 vs. 1304 in 2019.

Finally, the most important change was for the British Pound (GBP) mainly due to the Brexit referendum in 2016. It depreciated by 20.8% from 2015 to 2019 vs. the euro. The EUR/GBP exchange rate was 0.73 in 2015 vs. 0.88 in 2019.

2.1 Overview – market size and growth

The global photonics industry has shown steady growth in the last 4 years with a CAGR of about 7%. The global photonic market accounted for €654 billion (\$733 billion) in 2019 and is expected to reach around €900 billion (approximately \$1,000 billion) in 2025 (See Figure 7). It is a fast-growing industry compared to the more traditional ones and even compared to other high-tech industries. Between 2014 and 2019, the global market for microelectronics grew from \$336 billion to \$412 billion, which corresponds to an average annual growth rate of 4.2%⁶.

Compared to the growth rate of the overall industry in the OECD, which grew at an average of 1.3% per year between 2015 and 2019, the photonics industry showed a CAGR of 7%. For comparison, note that the entire Chinese industry only grew at a pace of 6% per year.

The photonics industry has also grown in terms of the number of producers and employees. OIDA estimated in 2019 that more than 3.5 million people are employed in photonics companies.

Between 2015 and 2019, the global photonics industry has shown steady growth with a CAGR of about 7% exceeding global GDP growth (3.5%) and even entire Chinese industry growth (6%).

Photonics worldwide market size

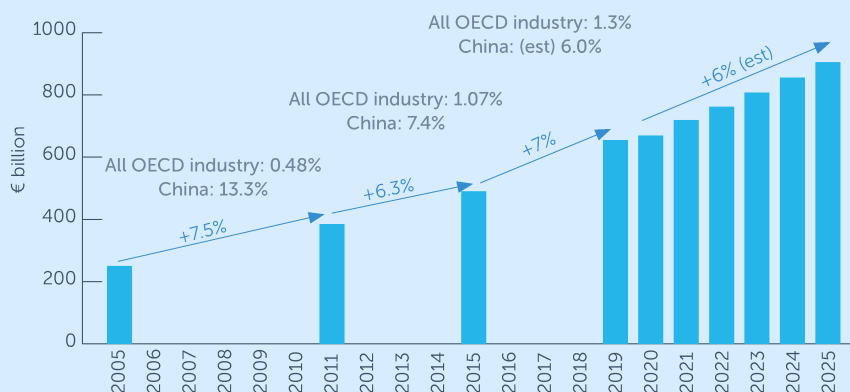


Figure 7– Photonics worldwide market (€ billion) from 2005 to 2025⁷. (Source: Photonics21 / TEMATYS).

Note that this result for the growth is in line with other studies (e.g. the last SPIE market study uses a different perimeter and focused on components but mentioned the growth of 7.6% in the last 6 years)⁸.

2.2 Global market by application segment

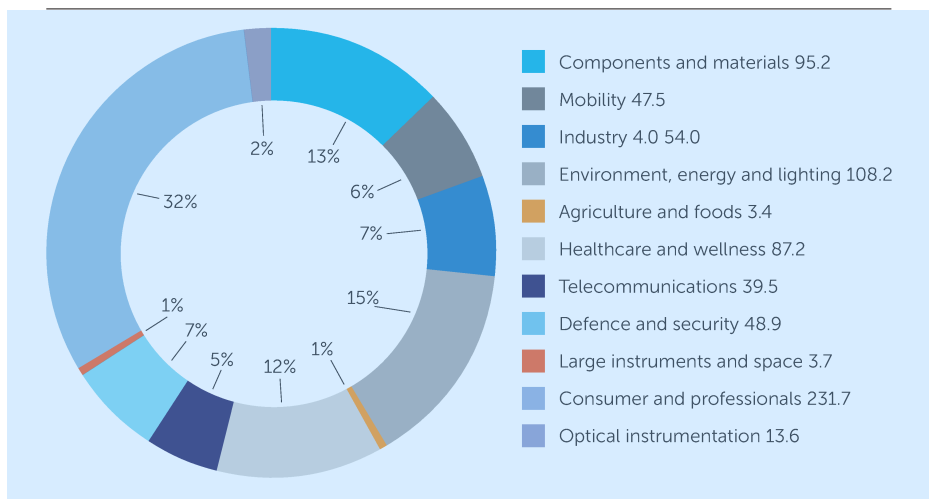
The global market for photonics totalling €654 billion (\$732 billion) in 2019 breaks out into application segments following the new segmentation. The breakdown for photonics components and systems is detailed in Figure 8 below.

⁶ The global microelectronics market, ZVEI study, www.electronica.de.

⁷ Note that the figure indicated for future growth is a forecast for mid-term growth. For a detailed discussion on the short-term forecast including assumptions on the impact of the Covid-19 crisis, see the next paragraphs.

⁸ <https://spie.org/news/2020-optics-and-photonics-industry-report>

Figure 8 – Breakdown of the global market (\$ billion – 2019) by application segment.
(Source: Photonics21 / TEMATYS).



A particular segment covers photonic components and materials and was worth \$95.2 billion in 2019. All other segments consist of photonic systems & subsystems and together accounted for \$638 billion or 87% of the total. Setting the market size of these two parts in relation, we can observe that the value-added ratio, defined as the ratio of the market size of all “photonic systems and subsystems” segments to the segment “photonic components and materials”, is 6.7 (\$638 billion / \$95.2 billion).

The largest segment consists of photonics products used mainly by consumers and accounted for \$231.7 billion or 32% of the total photonics market. This includes displays (\$172.3 billion), and IT (Information Technology) products for consumers and professionals (\$59.4 billion).

The segment of photonic devices and systems for Healthcare and wellness accounted for a total of \$87 billion in 2019 (12% of the total). It includes spectacle and contact lenses (\$43 billion) and Biophotonics devices and systems (\$44 billion).

Another major segment consists of environment, energy and lighting photonic systems. It accounted for \$108 billion (15% of the total) and comprises photovoltaics modules (\$46 billion) and lighting systems (\$54 billion).

Photonics products used in industrial manufacturing accounted for \$54 billion. This includes production technology products (industrial laser systems and semiconductor manufacturing systems) valued at \$34 billion and optical measurement & machine vision products valued at about \$20 billion.

Optical systems for telecommunications accounted for a total market of \$39.5 billion (5% of the total) and includes Optical network systems and optical cables.

The balance of 17% of the photonics market consisted of photonics products for Mobility (7%), Defence & Security (7%), Optical instrumentation (2%) as well as Large instruments and Space (<1%) and systems for agro-food (<1%).

Figure 9 below presents the evolution of the main application segments in the global market between 2015 and 2019.

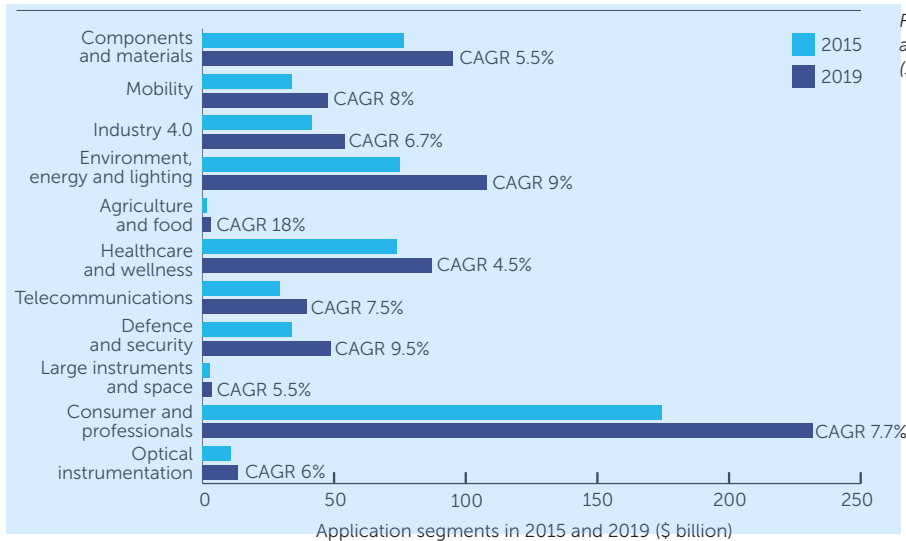


Figure 9 – Growth of main application segments (\$ billion).
(Source: Photonics21 / TEMATYS).

From 2015 to 2019, the market grew at a CAGR⁹ of 7%. The market for photonic components and materials increased at a CAGR of 5.5%. It should be noted that the value of the components increased at a slower rate than the total due to a strong decrease in the prices of some components over the period. In particular, laser sources saw their prices decrease due to competitive pressure. Optoelectronic components (LEDs, sensors, etc.) also experienced a sharp price decline. On the other side, the systems are becoming more and more precise, complex and "intelligent" resulting in greater added value.

The market for Consumers and Professionals (information technology and displays) has increased at a CAGR of 7.7% from 2015 to 2019 slightly above the global market but lower than in the previous period especially due to flat panel displays whose market started to saturate. This trend should be confirmed in the coming years depending on the rate of renewal from consumers.

The segment of photonic devices and systems for healthcare and wellness increased at a CAGR of 4.5% from 2015 to 2019. This relatively slight growth can be explained by the very different CAGR of the two major sub-segments: spectacle and contact lenses had a small CAGR (about 2.5%) but Biophotonics devices and systems grew at about 6.5% per year.

The market for Photonic products used in Industry increased at a CAGR of 6.7%, comprising production systems (CAGR 7.4%) and measurement & machine vision (CAGR 5%).

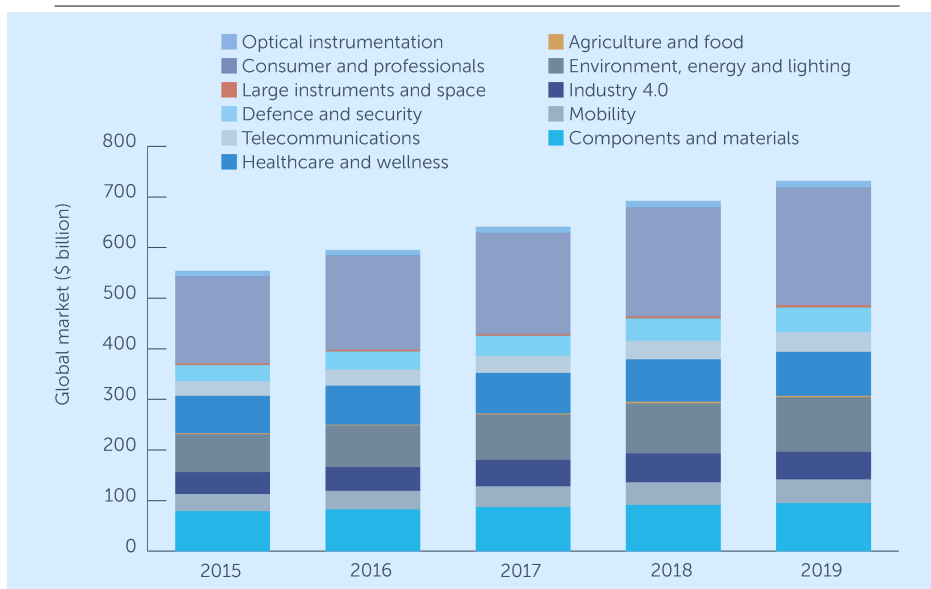
⁹ All CAGR and growth rates in this paragraph are related to markets in USD.

The segment of photonics for agriculture and food remains, at present, an emerging market but it is one experiencing the strongest growth with a CAGR of 18%.

The market for photonics products in other segments has increased as follows: Environment, Energy and Lighting (9%), Mobility (8%), Defence & security (9.5%). For details about the growth of segments and sub-segments, please see part 5.

Finally, the global photonics market progression from 2015 and 2019 is depicted in Figure 10 together with the breakdown by application segment.

Figure 10 – Global Photonics market progression from 2015 to 2019 (\$ billion).
(Source: Photonics21 / TEMATYS).



2.3 Production by geographical area

Photonics production is mainly located in Asia. More than 65% are accounted for by China, Japan, Korea, Taiwan, and a few other Asian countries including Vietnam, Malaysia, Singapore, Thailand and India. Europe and North America account for 16% and 15%, respectively. Other photonics producing countries include Israel, Turkey, Australia, New Zealand, and Brazil.

China is the leading producer with a share of almost 30%, ahead of Europe (16%), North America (15%), Japan (12%), Korea (11%), and Taiwan (9%). At present, Europe is the second-largest producer in photonics. These production shares are carried out taking into account the country of manufacturing of the products as opposed to a count using the nationality of the companies (location of the headquarters).

Asia is particularly strong in displays, PV and LED production whereas Europe leads in Optical components as well as Photonics for Industry and Healthcare. When Displays and PV products are excluded, **Europe leads with approximately 24% share in 2019.**

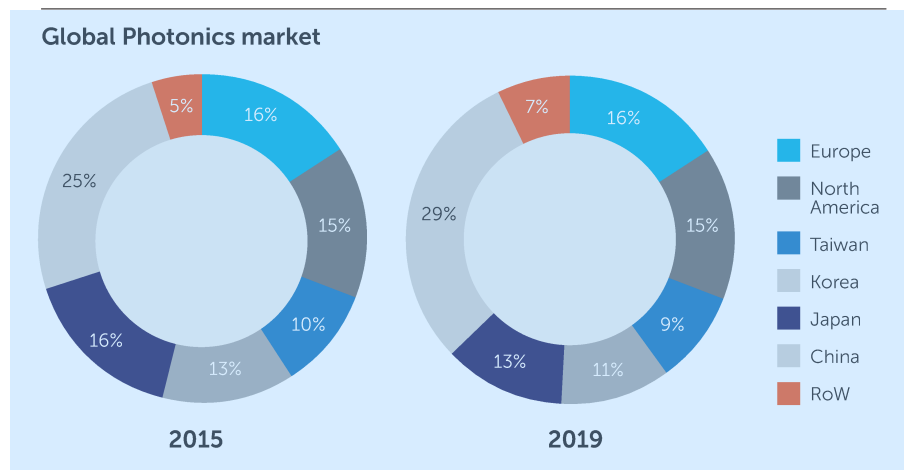


Figure 11 – Global Photonics industry – Breakdown by geographical area (2015–2019). (Source: Photonics21 / TEMATYS).

The market shares of most of the photonics-producing countries have changed during the last four years. While China continually gained market share, Japan, as well as Taiwan, began to lose their respective shares. In the previous periods (2005–2015), Europe lost its share mainly due to Photovoltaics and displays. However, Europe was able to maintain its market share in the last 4 years and then to maintain 2nd position.

In what follows, the market shares of the leading geographical areas in the main photonics segments (2019) are presented with details on their strengths and weaknesses as well as their evolution.

Europe maintained its market share and 2nd position in the last 4 years. When Displays and Photovoltaics products are excluded, Europe leads with approximately 24% share in 2019.

Overview of segment breakdown in leading geographical areas (2019)

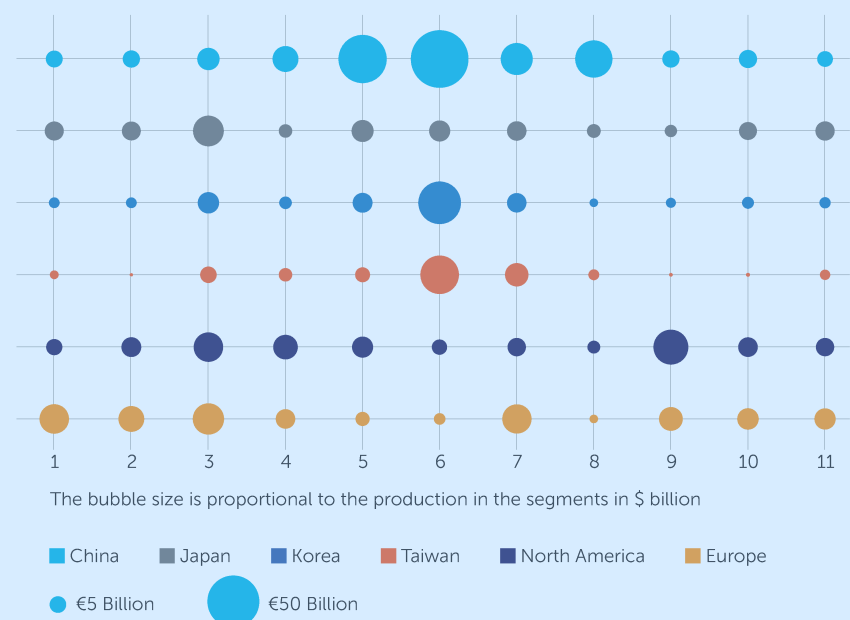


Figure 12 – Market shares of leading geographical areas in the main Photonics segments (2019). (The bubble size is proportional to the production in the segments in \$ billion). (Source: Photonics21 / TEMATYS).

1. Industry – Production systems
2. Industry – Machine Vision
3. Healthcare
4. Telecommunications
5. Consumers – IT
6. Consumers – Displays
7. Lighting
8. Photovoltaics
9. Defence & security
10. Automotive
11. Optical components & systems

Japan

The Japanese companies were pioneers in many segments of photonics, especially information technology and displays. Now, nearly half of the photonics production of companies headquartered in Japan is happening overseas, mainly in China. Fifteen years ago, in 2005, Japan was the major producer of photonics with a global share of 32%, not including overseas production. In 2011, that share shrunk to 21%, in 2015 to about 16% and in 2019 the share was only about 12%. It should be noted, however, that this trend has been even stronger for electronic products. Domestic Electronics Production, which was about 25 trillion yen in 2000, has decreased by a factor of more than 2 in 2019. During the same time, photonics production has remained roughly the same in yen in a rapidly growing market. This production increased until 2007 and has almost always decreased since then with a recovery in 2013–2014 due to photovoltaics. It should be mentioned also that the Japanese photonics industry has an impressive footprint in the main photonics segments and, if including overseas production, it is still among the leaders of global photonics. However, this position is seriously challenged by its Asian neighbours, especially China.

The domestic production volume reported by the Japanese Optoelectronics Industry and Technology Development Association (OITDA) accounted for JPY 6.3 trillion for 2019 compared to JPY 8.9 trillion in 2015 (see Data Sources). The figures reported by OITDA are based on a product range that is different from the one used in the present study. Based on the product range included in the new segmentation, the photonics production in Japan decreased between 2015 and 2019 and is estimated at \$85.7 billion (€76.5 billion) for 2019 vs. \$90 billion (€81.3 billion) for 2015. (Note that now car lighting and lenses for vision correction are included). During the last 4 years, Japanese photonics production increased in laser systems for production, measurement & machine vision as well as in Healthcare following the global trend. However, Japan lost revenues in information technology (input/output), optical components & systems, communications, displays and photovoltaics.

North America

The photonics production in North America for 2019 is estimated at \$107.5 billion (€96 billion) vs. \$80 billion (€72 billion) for 2015. This corresponds to a 2015 to 2019 CAGR of about 7% on a US dollar basis. In the past, the US was losing market share for many years. But since 2015, the US was able to stop this erosion due to industrial policy efforts to focus again on the production area and support important industries for the future. As an example, AIM Photonics is a government-backed initiative working to accelerate the transition of integrated photonic solutions from innovation to manufacturing-ready deployment in systems spanning various application markets¹⁰. The 3 major segments in the US have seen good growth since 2015: this concerns Telecommunication, Healthcare and Defence & Security. In the last years, production growth was strong in the segments of lasers systems and photonics components. In lighting and automotive, North America is home to several major manufacturers.

¹⁰ <https://www.manufacturingusa.com/institutes/aim-photonics>

China

Photonics production in China accounted for 197 billion Euros in 2019. In Euros, the production volume increased from 2005 to 2011 at a CAGR of 22%, from 2011 to 2015 at a CAGR of 12.4% and from 2015 to 2019 at a CAGR of 13%.

China has continued to gain market share in photonics over the last four years. The share of photonics made in China in the global market increased from 10% in 2005 to 21% in 2011 and 30% in 2019. Based on the actual production location, China now is the clear leader in the photonics industry, significantly ahead of Europe, North America, Japan, Korea, and Taiwan.

Photonics production in China comprises two major segments with an annual production volume of more than €20 billion: Energy (photovoltaics) and Consumers (displays and information technologies). In photovoltaics, the Chinese share in the global market is around 60%.

In photovoltaics, the overwhelming majority of the production plants are locally owned. The Chinese photovoltaic companies have dramatically gained market share due to aggressive product pricing. For displays, the share of the production in China in the global market is growing rapidly and reached almost 40% in 2019. This is partly due to locally-owned new production plants, and partly due to factories being built by display manufacturers headquartered in Japan, Taiwan, and Korea.

In optical communication, Chinese companies have steadily increased their market share during the last years. In the segment of Photonics for Industry, Chinese companies have gained market share in the area of laser materials processing systems, where they benefit from the rapidly increasing industrial manufacturing in China.

Korea

Photonics production in Korea accounted for €71.0 billion (\$79.5 billion) in 2019. This compares to a volume of €62.7 billion (\$69.6 billion) in 2015. Note that the evaluation from KAPID, the Korea Association for Photonics Industry Development (see Data sources) is \$53.3 billion which corresponds to Telecommunication, Information technologies, Lighting and Displays. Our scope is wider and we have included photonics components and systems for Healthcare, Defence & Security, Automotive ... The production of the Korean photonics industry is however strongly dominated by flat panel displays with a share of more than 50%. The two largest display manufacturers of the world, Samsung Display and LG Display are both Korean and manufacture most of their displays in Korea. Besides displays, the Korean photonics industry produces consumer and professional equipment such as digital cameras, optical printers, image sensors, and camera modules. Smaller contributions to Korean photonics production are provided by lighting, laser sources, optical components, and Healthcare.

Taiwan

The Taiwanese photonics production is dominated by the display segment which accounts for more than half of the total. The production volume decreased during the last four years on a US dollar basis. This results in a loss of market share in a globally increasing market. With the rise of the FPD industry in China, the FPD industry in Taiwan feels the pressure. In 2019, the FPD industry in Taiwan accounted for around \$30 billion, with 4.5% negative YoY growth. In the long run, Taiwan has not yet been capable of manufacturing OLED or Micro LED on a mass-production scale and that leaves LCD related industry in Taiwan going down in scale. On a positive note, the non-display photonics industry regained its growth due to enlarge applications of optics and photonics technologies on Automotive, Biophotonics, 5G communication, etc.

3 European photonics industry

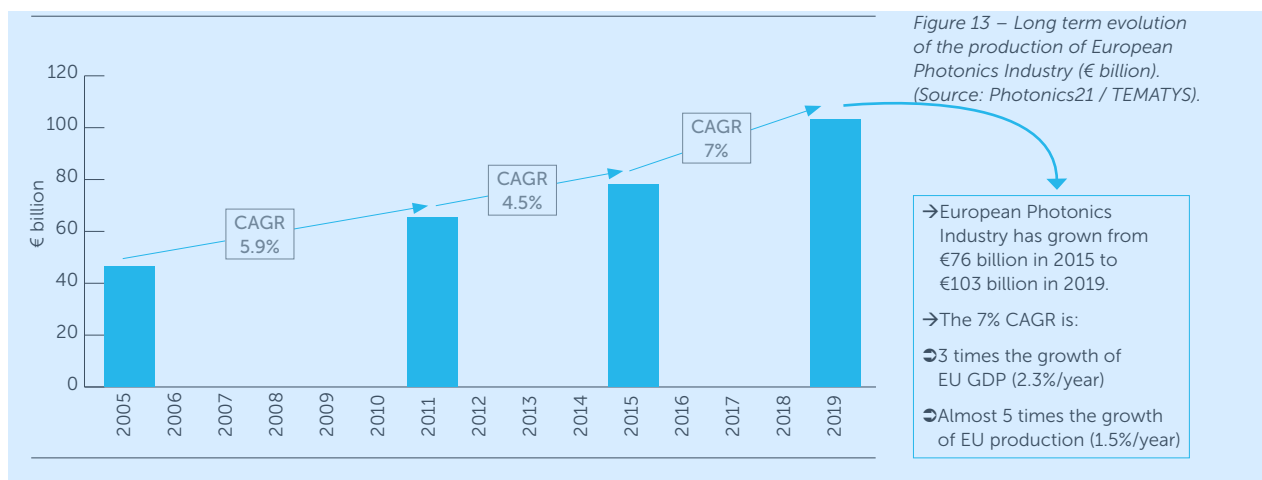
3.1 Introduction

The European photonics industry accounted for €103 billion in 2019, comprised more than 5,000 companies and contributed approximately 3% of the total manufacturing within Europe. It provides around 1.5% of the total manufacturing employment, with a revenue-per-employee of around €250 k. The size of the photonics industry in Europe exceeds the size of the microelectronics industry, which is worth €75 billion in 2019 (when including micro/nano-electronic semiconductors, components, materials and tools)¹¹.

European Photonics Growth: far exceeding GDP and overall industry Beyond size (which is the reference indicator for a traditional industry), a Key Enabling Technology (KET) is assessable by its dynamics.

The European Photonics Industry has grown from €76 billion in 2015 to €103 billion in 2019 with a growth rate of 7% per year and a share of 16% of the global market. It is growing faster than many other high-tech industries (for example, the IT industry: 4.5%¹², Medtech: 4.9%¹³, Microelectronics: 4%¹¹) and also much faster than the EU GDP (see Figure 13).

What is noticeable is that the recent growth of the European photonics industry for the period 2015–2019 is roughly in line with the global rate. Europe was able to maintain its market share over the last 4 years and defend its # 2 global position.



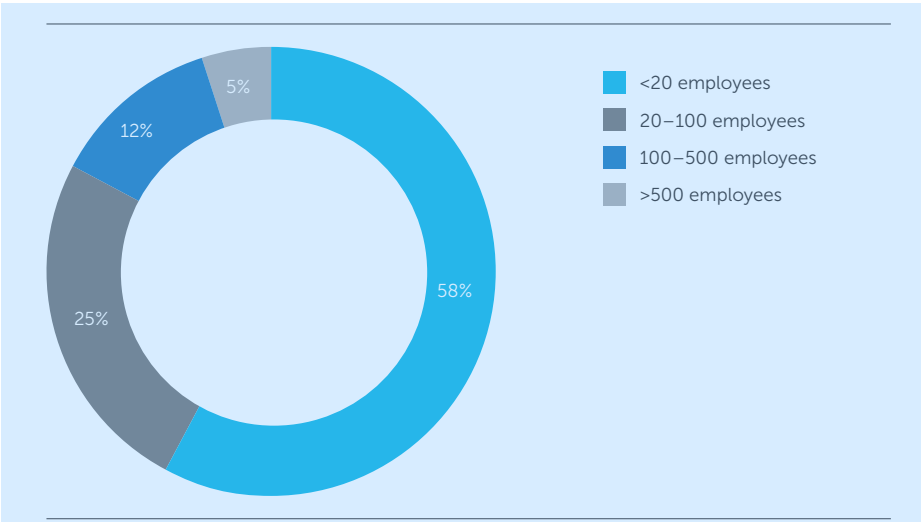
¹¹ Study on the Electronics Ecosystem, Publications Office of the European Union, 2020.

¹² From 2015 to 2019 – Source: IT Industry Outlook, CompTIA, 2020.

¹³ From 2014 to 2018 – Source: <https://www.medtecheurope.org/datahub/market>

The breakdown of the Photonics companies by company size is depicted in Figure 14.

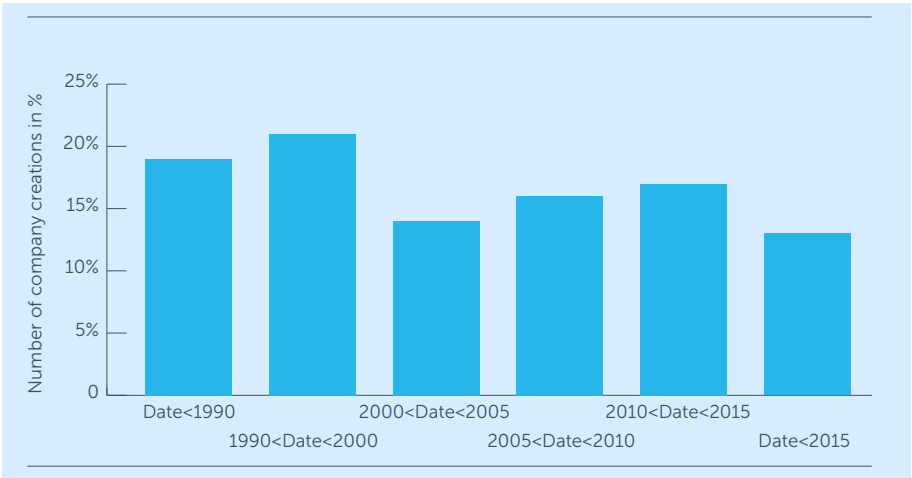
Figure 14 – Breakdown of the European Photonics companies by company size.
(Source: Photonics21 / TEMATYS).



Small companies (<20 employees) are the seed for the future: they represent 58% of the total number of companies, 5% of the total employment and are an important driver of the expected growth. Medium-size companies (20–500 employees) are the most important source for future growth: they represent 37% of the companies, 35% of the total employment and are responsible for around half of the expected growth. Big companies (> 500 employees) provide a stable base for the industry: they represent only 5% of the companies but account for almost 60% of the total employment.

The distribution of the dates of creation of photonics companies is presented in Figure 15 below.

Figure 15 – Distribution of the dates of creation of Photonics companies ¹⁴.
(Source: Photonics21 / TEMATYS).



¹⁴ These data are extrapolated from the survey and the study made on Photonics in France.

Long term, the photonics industry remains in a growing dynamic of business creation, with 60% of photonics companies less than 20-years-old. Since the industrial start of this activity and despite the crises of 2000 and 2008, a near continual growth of this industrial sector in terms of creation of new companies between 1990 and 2015 has been observed. (Note that the drop in creations after 2015 should take into account the total across 4 years and not 5 years for the previous periods).

3.2 Production value and growth of European photonics industry

The table below displays the production in different European countries in 2019.

Country	Domestic production (€ billion)
Germany	40.8
France	15.3
UK	15.6
Netherlands	6.2
Italy	5.1
Switzerland	4.3
Rest of Europe	16
Total	€103.3 billion

Table 2: Production in European Photonics industry (2019).
(Source: Photonics21 / TEMATYS).

Comparing the growth of the photonics industry with the growth of EU GDP and the growth of the whole European industry is presented in Figure 16 below.

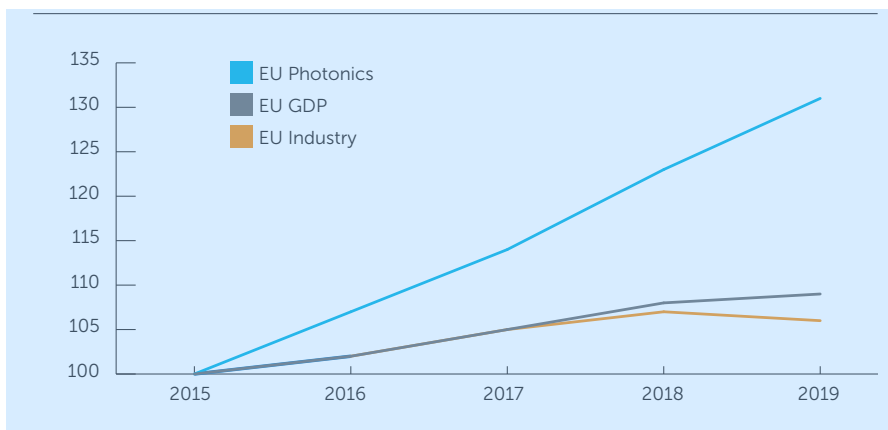


Figure 16 – Comparison of the growth of the photonics industry with the growth of GDP and the whole industry (base 100 in 2015).
(Source: Photonics21 / TEMATYS and OECD).



EU photonics growth is 3 times the growth of EU GDP and almost 5 times the growth of the whole EU industry.

What is noticeable is that the recent growth of the European photonics industry for the period 2015–2019 is three-times the growth of the EU GDP (2.3%/year) and almost five-times the growth of the EU industrial production (1.5%/year). The European photonics industry is therefore a modest sector in Europe in terms of size, but, its **dynamism is clearly remarkable**.

To maintain its competitiveness, research and innovation in Europe have been the solutions. A paradox can be drawn in two of the biggest photonics markets. Europe missed the market of displays which was dominated by Asian companies, in Japan, Korea and China. It is also true that throughout the last 20 years, the China captured the photovoltaic market through a policy so aggressive that the EU introduced anti-subsidy and anti-dumping duties in 2014 on solar glass imported from China. In short, Europe is not a leader in the two biggest photonics markets, yet, for the last five years, the share of the European photonics industry has been maintained at 16% of the global market (figure n°13), for which there is a very good reason.



Although lagging behind in the two biggest photonic markets displays and PV, Europe has maintained its share, stressing the huge dynamism of other photonics segments in Europe.

Photonics is a key enabler for many different applications and is made of a constellation of thousands of markets. Some are tiny niches, but profitable for SMEs, whereas others are medium-sized with volumes of several thousand. Serving those applications markets require to be constantly innovative and at the edge of the technology.

Thanks to a strong European research capacity, companies can maintain and expand their businesses and capture their share of this 7%/year fast growing market. They are leaders in markets like technologies for Industry 4.0 (Lasers machining, Semiconductor Production machines, Machine Vision...), Instrumentation, microscopy and Optical Measurement, medical and healthcare photonic based technologies.

3.3 Employment in European photonics industry

In general, it can be observed that the dynamics of European industrial employment remain weak despite the production growth. This applies to the whole industrial sector and might be exacerbated by the fact that the manufacturing industry is undergoing a structural shift towards digitalisation, creating new turnover with a lower impact on industrial employment. The photonics industry will not escape this trend, but its huge economic dynamism has a significant impact on employment growth, as shown in this paragraph.

Country	Number of Employees
Germany	160 350
France	60 680
UK	70 040
Netherlands	15 590
Italy	15 070
Switzerland	12 210
Rest of Europe	56 460
Total	390 400

Table 3: Employment in European Photonics industry (2019).
(Source: Photonics21 / TEMATYS).

The European photonics industry has created over 30,000 jobs in the period 2015–2019, representing an annual growth rate of 2.1%. This growth is much higher than the growth of employment in European Manufacturing as the whole (about 1% CAGR for EU28 from 2015 to 2019 according to OECD¹⁵).

The difference between the growth of European photonics in terms of revenue and employment is due to significant productivity gains. European photonics is currently seeing the transformation of its manufacturing processes and is moving from small workshops to industrial factories, with significant impacts on jobs and skills, but also digitalisation of the entire industry.

The growth of European photonics employment is not without posing recruitment problems, particularly among SMEs. In a survey commissioned in 2019, only 30% of photonics companies estimated that the skills and appropriate training already existed and were easy to access. Moreover, companies were looking for a broad variety of skills from R&D to production including IT and marketing; many have had to develop internal training programs to teach personnel who are not currently trained in photonics trades or skills.

**In the last 4 years,
the growth of
European photonics
employment was
twice that of European
Manufacturing as
a whole.**

3.4 European photonics industry R&D and Capex

Considering the competition in this highly innovative industry, R&D spending is substantial. Besides this, photonics companies have capital expenditures (Capex) which are investments in PPE (property, plant and equipment) mainly in expansion and modernisation measures relating to infrastructure, production plants and fixtures.

To obtain a clear picture for the R&D and Capex intensity statistics, two complementary means have been used:

- On one hand, fifty photonics companies from several different countries and operating in all segments have been selected and the information on R&D and Capex from the financial reports have been extracted. These companies are either large groups or medium-sized companies (there is

¹⁵ <https://data.oecd.org/emp/employment-by-activity.htm>

no published information on small companies). It should be noted that to ensure the statistics represent photonics, we have selected companies whose activity is mainly in photonics or large groups where we had figures on R&D in the predominantly photonics division, as it is the case for Philips for example.

- On the other hand, questions were introduced in the Internet survey about investments in Research and Development and production means. This enabled to have figures on small companies and start-ups and to compare them with larger companies.

On the selection of companies, an R&D intensity of 10.4% was obtained by making a simple average of the percentages. A weighted average by the turnover of the companies resulted in a value of 10.1%, which therefore corresponds to the R&D intensity on a total turnover of more than €60 billion and therefore is significant for the photonics sector in Europe in 2019.

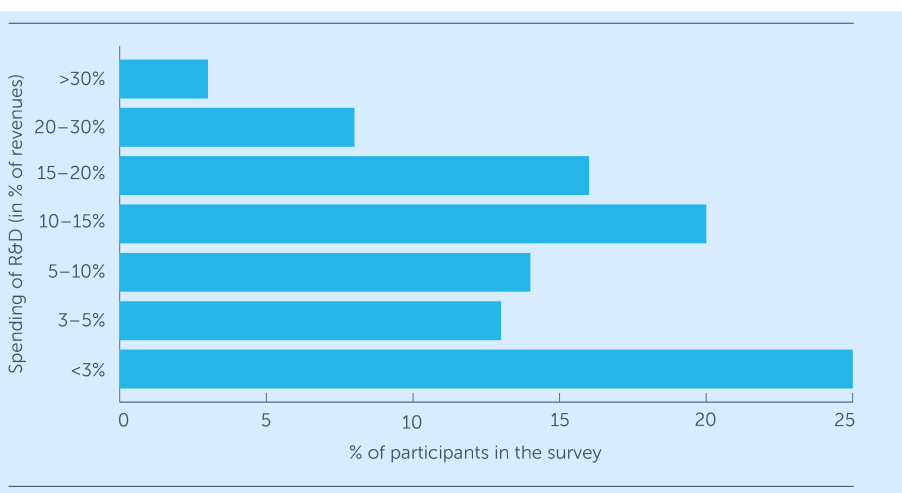
This figure is higher than that obtained in 2015 and to clarify this point the same work has been carried out on this set of companies with the figures taken from the 2015 reports; here a value of 9.2% was obtained. The intensity of R&D has therefore increased between 2015 and 2019.

Concerning Capex, the figures obtained are 5% in 2019 and 4.7% in 2015. There is an increase, but it is quite small.

Regarding the Internet survey, the results are given in Figure 17. It is astonishing to see a response rate of around 25% for an R&D intensity of more than 30%.

About a quarter of those surveyed reported an R&D intensity of more than 30%.

Figure 17 – Results of the survey about investments in R&D (as a percentage of the revenues).
(Source: Photonics21 / TEMATYS).



Examining the results in detail, this high figure comes from the responses of small companies and, in particular, start-ups. For a start-up, it is not surprising to have these figures and, especially at the beginning of the activity, the R&D rate can often be well above 30% (and sometimes even 100%!).

Taking into account the size of the companies, the following figures were obtained:

- For SMEs, the R&D intensity is around 15%.
- For large companies (turnover > €50 million), the R&D corresponds to 10.3% of the turnover.
- And, finally, the weighted average is 10.8% (the weight of large companies is much higher).

These results are in line with the figures obtained from our selection of companies. As far as Capex is concerned, the results are 6% for large companies and 9% for SMEs, with an average of 6.2% overall. These figures are higher than for our selection of companies and we believe that the reality is closer to a value of 5%.

In short, the average ratio of total investment in the photonics sector (R&D + Capex) is around 15% in 2019 compared to 14% in 2015, an increase of around one point, mainly due to the R&D intensity.

In comparison, for the 1,000 companies in the EU and the UK with the largest R&D¹⁶, the average R&D intensity is almost 4% and the Capex is 6.5%, i.e. a total investment of just over 10%. The photonics industry is well above in terms of total investment.

It should be noted that these average figures hide values that can be very different from one company to another. Due to the diverse end-use markets, the R&D intensity necessarily shows a wide range of values and varies from 3.2 to 18.7% for analysed companies.

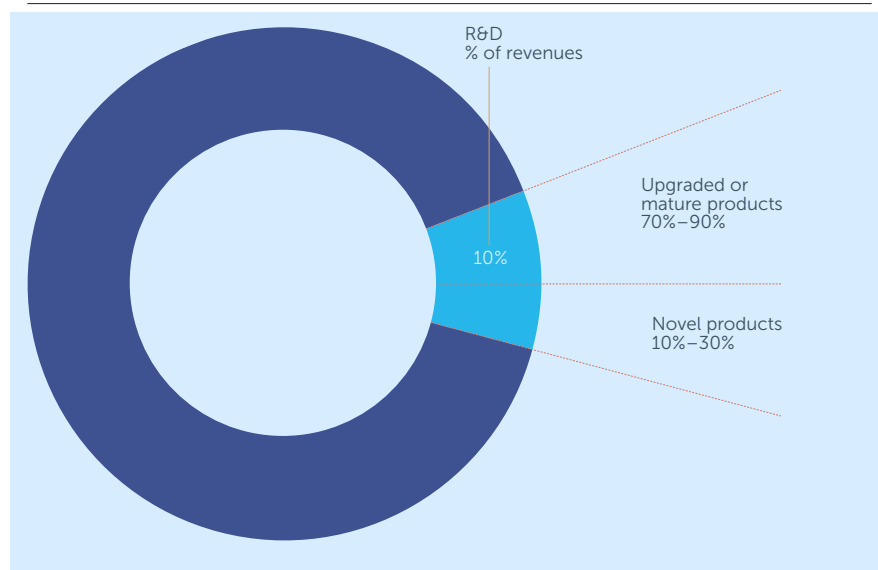
No link was found with the size of the company. The intensity of R&D depends mainly on the application segment, with extremes of around 3% in the segment of spectacle and contact lenses and around 17 to 18% in the photonics segment for the manufacture of semiconductors.

The intensity of R&D in other parts of the world is of the same order of magnitude as in Europe, as obtained from a selection of companies in the US and Asia. On the other hand, Capex is often higher, especially for companies that manufacture components such as CMOS sensors, which require very significant investments.

The figure below shows an evaluation of R&D Intensity for the photonics industry in the US.

¹⁶ The EU Industrial R&D Investment Scoreboard, European Commission, Joint Research Centre, 2019.

Figure 18 – Evaluation of R&D Intensity for Photonics Industry in the US¹⁷.



Concerning the impact of the Covid-19 crisis on R&D, expectations for R&D investments in the whole industry for the financial year of 2020 vary considerably depending on the sector, but, overall are flat. The good news is that a V-shaped recovery for R&D investment is expected for 2021 with an increase of around 7%¹⁸.

3.5 First analysis of the impact of Covid crisis

In 2020, the world economy was affected by an unpredictable and brutal recession caused by the Covid-19 pandemic. In many sectors, the pandemic and its direct and indirect effects caused an extremely sharp decline in both demand and production. This decline was followed by a gradual recovery. The impact has been very different depending on economic sectors, and the affected sectors are recovering at very different levels and speeds.

To make a first assessment (mid-January 2021) of the impact of the crisis on the photonics industry in Europe and worldwide, the quarterly reports of the main photonics companies have been used (or annual reports for an end of Accounting Year at 30 September). Of course, we will still have to wait several months to fully assess the impact of the crisis in 2020 and even more to evaluate its effects in the medium and long term.

Our initial assessment shows that the global photonics market is proving to be quite resilient to the effects of the Covid-19 crisis. However, there are very important differences between application segments.

¹⁷ Lighting The Path to a Brighter Future, How optics and photonics impacts the global economy, OSA, 2018.

¹⁸ Impact of Covid-19 crisis: 2020 EU Survey on Industrial R&D Investment Trends, 2020.

The results of the survey conducted on the Internet has also been used for this assessment.

General economic environment

As explained above, the economic environment suffered a sharp deterioration in 2020 with the arrival of a crisis without precedent. The COVID-19 epidemic that started just over a year ago has spread rapidly across the globe. Political decisions, including travel restrictions, export bans, lockdowns and production stops in many countries in the spring of 2020 (with huge consequences on global value chains in some important sectors of industry and economy), have thrown the entire global economy into crisis. The main factors that have weighed on businesses are:

- Confinements and plant closures,
- Problems with the supply of raw materials and components,
- The impossibility for salespeople to travel and meet customers,
- The general recession leading to cancellations and/or postponements of orders.

Impact on the various segments of the photonics industry

In the field of lasers, first evaluations have recently been presented (Photonics NEXT Summit, January 2021).

Surprisingly, the evaluation gives a market up by more than 8% for 2020 and forecasts for an increase of around 15% for 2021. However, it is worth noting two important factors: some segments had experienced a significant decline in 2019 (notably, lasers for materials processing) and a large part of this increase is taking place in Asia, particularly China.

Lasers used for sensors, and in particular 3D sensors (VCSELS in smartphones, etc.) have, unsurprisingly, had a very good year in 2020 with a growth of around 30%. AMS AG thus reports an increase of more than 22% for the first 9 months of the year.

Lasers for health and aesthetics, on the other hand, suffered a drop of around 20%.

This is counter-intuitive given the extent to which the health sector has been on the front line in 2020. But, apart from lasers for analytical instruments (sequencers, etc), all the others have been negatively impacted by the postponement of non-urgent procedures and interventions (ophthalmology, surgery, aesthetics,...).

The market for lasers for telecoms was positively impacted by the Covid-19 epidemic following the very significant growth in data exchanges on the Internet (+12%). II-VI, the largest manufacturer of transceivers even reported a 25% increase in revenues for the first half of the year.

All segments related to semiconductor manufacturing and more generally to the "digital world" have been largely spared from the effects of the crisis. Indeed, the semiconductor market remained strong in 2020.

Only 20% of survey participants reported a negative effect on income and 25% on employment.

Figure 19 – Online survey – Statistics on Covid-19 crisis Impact. (Source: Photonics21 / TEMATYS).

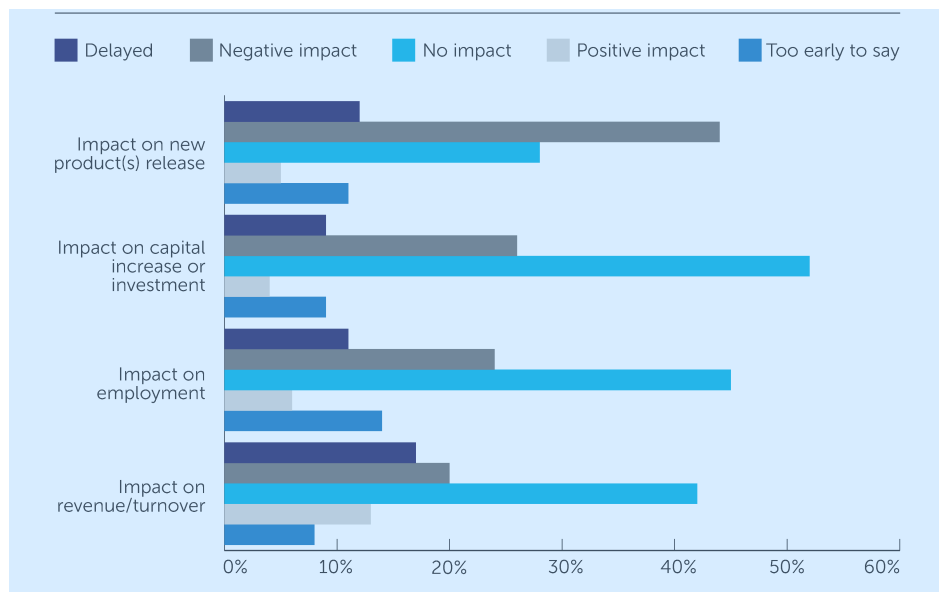
The market for lasers for material processing and lithography is relatively stable (+3%) driven mainly by lasers for lithography (mainly EUV) while materials processing, which had slowed down at the beginning of the year, resumed in the second part of the year, particularly in China. However, Trumpf reports a decline of 7.8% over its financial year (ending 30/06/2020) but this doesn't take into account the recovery in the second part of 2020.

Defence and research are two areas with budgets almost independent of the Covid-19 crisis (except for pharmaceutical research of course).

Unsurprisingly, the mobility segment is the one that has suffered the most during the year 2020. The stoppage of the car assembly lines in the spring and the extremely sharp drop in demand led the Manufacturers to drastically reduce their orders. Hella reports a drop of 17% over its accounting year (ending 31/05/20) and the situation is similar for other manufacturers.

On instrumentation, Horiba reports a decline of 5.3% over the period 01/01 to 30/09/2020 and Zeiss reports a decline of 6% over its financial year ending 30/09/2020.

The results of the survey about the Covid-19 crisis impact are presented below (note that this survey was online from 15 July to 30 September 2020).



Only 20% of participants reported a negative effect on income and 25% a negative effect on employment. The main impact is on the release of new products (negative effect: 45%; delayed: 12% for a total of 57%).

Another study shows that the impact on employment in high-tech industries (both R&D and non-R&D) for the financial year of 2020 is expected to be

small¹⁹. In the same study, sales are expected to show a decrease of about 5%. Companies that expect an increase in net sales are from the pharmaceutical, chemicals and ICT producers, typical sectors that might have been able to benefit from the pandemic.

All of these highly contrasting elements complicate the valuation of the photonics industry as a whole. We anticipate a decline of an order of magnitude of 2 to 3% over 2020 and a return to growth over 2021 with a slight offsetting effect of 7% (instead of 6%). This figure is given under the condition that the pandemic will gradually fade out from spring onwards, thanks to vaccination campaigns.

3.6 Forecast for global and European photonics industry growth

According to our evaluation, the global photonics Market will reach about \$975 billion (around €875 billion at 2019 exchange rate) by 2025. This evaluation is quite challenging as we are in the middle of an economic crisis. So, the figures for the market in 2020 and 2021 are difficult to evaluate precisely but we are confident about the mid-term and long-term growth (around 6% per year). The assumption for the short-term is a slight decrease in 2020 of the global photonics market (between -2 and -3%, so significantly less than the overall economy). For a deeper analysis of the impact of the Covid-19 crisis on global and European photonics, please see part 4.5.

The overall assessment shows that the Photonics industry is proving to be quite resilient to the effects of the Covid-19 crisis with a slight decline in 2020 and a return to growth in 2021.

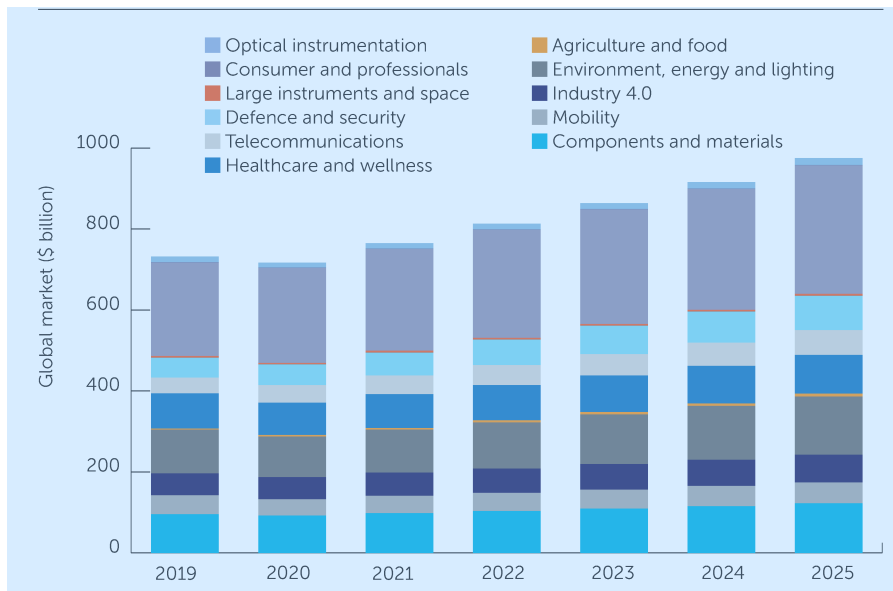


Figure 20 – Forecast for Photonics Industry global market by segment (\$ billion).
(Source: Photonics21 / TEMATYS).

¹⁹ 2020 EU Survey on Industrial R&D and Investment Trends

Table 4: Overview of revenues of photonics companies and expected growth.
(Source: Photonics21 / TEMATYS).

Regarding the perspective in Europe, again the short-term figures are quite challenging to evaluate but the same evolution as for the global market is foreseen.

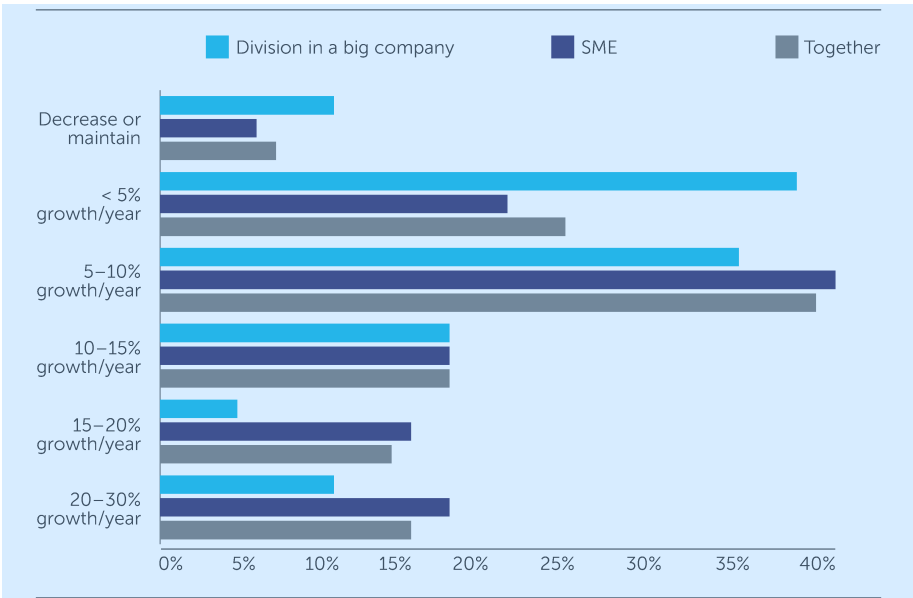
For mid-term evolution, the results of the survey have been used. There was quite a difference between the results from a big company (or more precisely a division in a big company) and SMEs (see Figure 21). Going a little bit deeper, we cross-referenced growth statistics with company size to calculate average growth as a function of company size. The results are as follows:

Revenues of the company	Average expected growth
€1–10 million	10.1%
€10–100 million	9.7%
€100–1000 million	6.5%
>€1000 million	6.0%
All sizes	6.5%

The expected growth is decreasing when the size of the company is increasing. And the average growth is of the same order as the expected growth of the global Photonics market.

So, **if the same level of R&D and innovation is preserved**, we forecast that European Photonics Industry will maintain or even increase its share in the global market.

Figure 21 – Results of the survey concerning the expected growth in the next years (in % per year).
(Source: Photonics21 / TEMATYS).



4 European photonics industry by application segment

Breakdown by Segment

The total European Photonics Production in 2019 was €103 billion with a CAGR of 7% from 2015 to 2019. The breakdown by segment is depicted in Figure 22 below. Comparing with Figure 8, it is clear that the distribution of the European photonics industry is very different from the global one. This leads to several comments below.

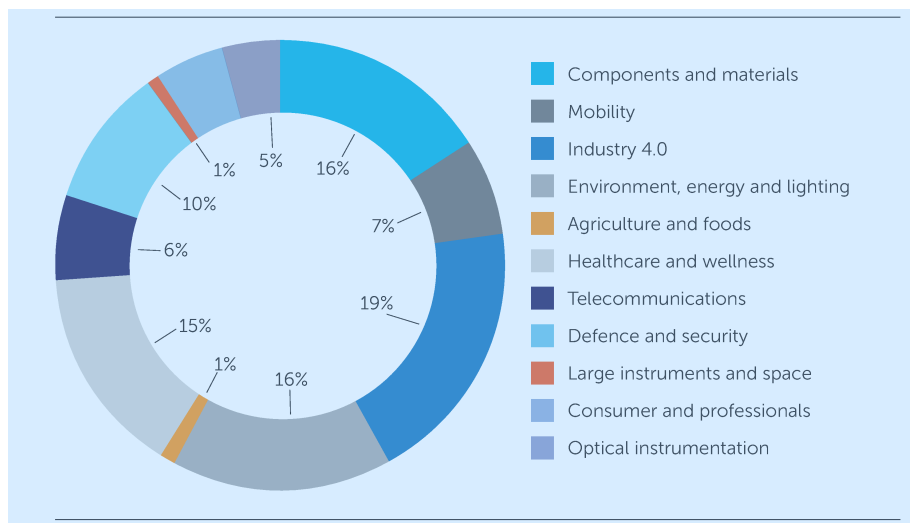


Figure 22 – European Photonics Industry – Breakdown by application segment.
(Source: Photonics21 / TEMATYS).

The segment covering photonic components and materials was worth €16.6 billion in 2019 (16% of the total). Europe needs to stay strong in photonic components and materials as they are the building blocks for all the photonics systems. This segment is directly connected with the Photonics procurement and the good result in terms of production leads to a purchasing rate for European Photonics companies of more than 50% in Europe.

The largest segment consists of Photonics products used in industrial manufacturing and accounted for €19.2 billion. This includes production technology products (industrial laser systems and semiconductor manufacturing systems) valued at €13.5 billion and optical measurement & machine vision products valued at about €5.7 billion.

The second segment consists of environment, energy and lighting photonic systems. It accounted for €16.6 billion (16% of the total) with lighting systems consisting of the major part.

The third segment, photonic devices and systems for Healthcare and wellness, accounted for a European production volume of €15.9 billion or 15.4% of the European Photonics production.

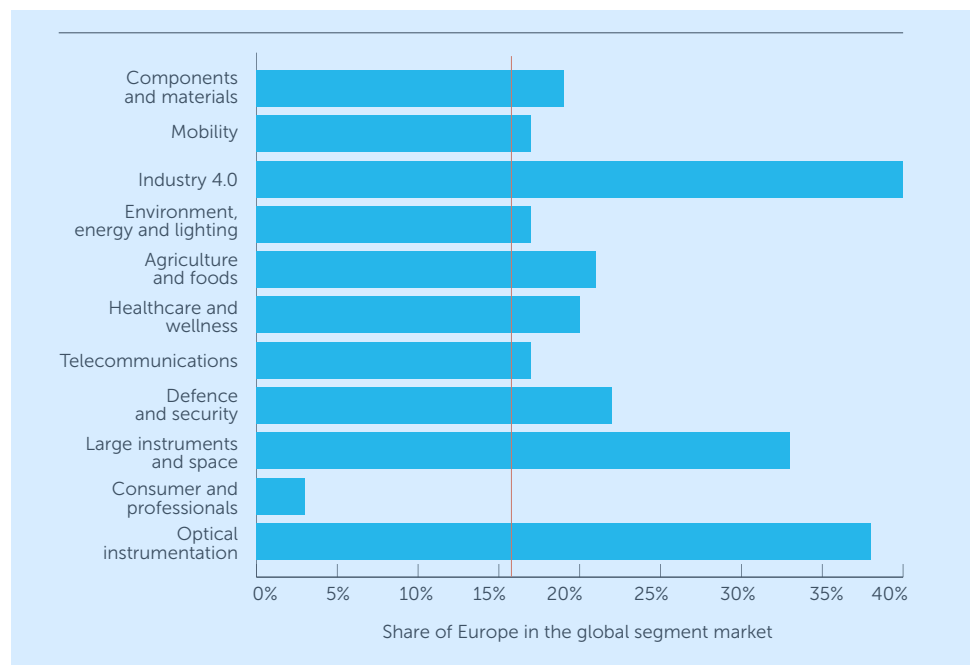
Optical systems for telecommunications accounted for a total market of €5.9 billion (6% of the total) and includes Optical network systems and optical cables.

4 European photonics industry by application segment

The balance of 28% of the European Photonics industry consists of Photonics products for Mobility (7%), Defence & Security (10%), Consumers (5%), Optical instrumentation (4%) as well as Large instruments and Space ($\approx 1\%$) and systems for agro-food ($\approx 1\%$).

Market share of the European Photonics industry by segments
After detailing the breakdown of the European Photonics industry by segment, it is of crucial importance to also identify the segments where European photonics has a large market share and where it is lagging behind the leaders. Indeed, it is this analysis that constitutes the first stone of a strategy for the successful development of European photonics: reinforcing the strong segments and launching a win-back strategy for the others when possible.

Figure 23 – European Photonics Industry – Market share by segment. (The vertical red line indicates the average market share of European Photonics).
(Source: Photonics21 / TEMATYS).



The largest segment in Europe, Photonics systems for Industry, also represented the largest share in the global markets. European production accounted for a global market share of 40%. Europe has a significant market share in the field of Photonics systems for production i.e. industrial laser systems and semiconductors manufacturing (45%) and in Machine vision (35%).

Three further segments accounted for a significant production volume and at the same time a substantial global market share: Healthcare and Wellness, Components & materials and Environment, lighting & energy. This can be seen in Figure 24.

4 European photonics industry by application segment

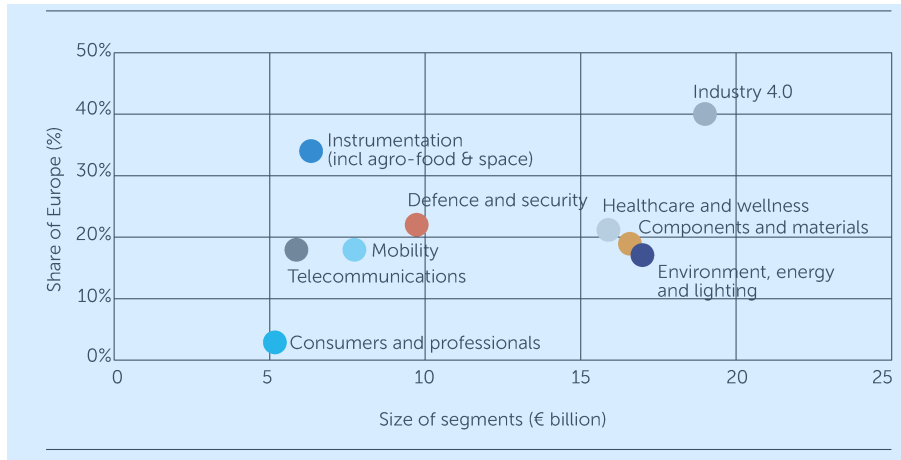


Figure 24 – Size of the main segments (€ billion) versus market share (%) of Europe. (Source: Photonics21 / TEMATYS).

With a 2019 production volume of €15.9 billion, photonic devices and systems for Healthcare and Wellness accounted for a global market share of 21% in 2019: 26% on instruments & devices and 14% on lenses for vision correction.

In the global market of optical and photonic components & materials, European production accounted for €16.6 billion, i.e. a market share of around 20%. Europe has a significant market share in laser sources, LEDs, infrared and 3D sensors. But European production of CMOS sensors is quite low.

In Photonics systems for environment, lighting and energy, European production accounted for a global market share of 19%. Europe has a significant market share in the field of lighting (25%) and Environment monitoring (about 30%), however, European market share in PV modules is less than 5%.

The communication segment accounted for €5.9 billion, corresponding to an 18% share of the global market. The European Photonics production only slightly increases between 2015 and 2017 but during the last 2 years, this segment has experienced a significant rebound and showed substantial growth mostly related to 5G in Europe.

In the global market of photonic systems for the mobility sector, European production accounts for €7.4 billion, i.e. a global market share of 17%. Of the top five international car headlights manufacturers (Koito, Valeo, Marelli Automotive Lighting, Hella and Stanley), three are European and the innovation in this segment in Europe is very high.

In the segments of photonics for consumers and professionals, the European industry holds small market shares and has the role of a niche supplier with products such as display materials, high-end digital cameras and high-end laser printers. Europe is not the leader in these large volume markets even if some examples show that the game is not over (ex.: AMS or STMicro on sensors for smartphones).

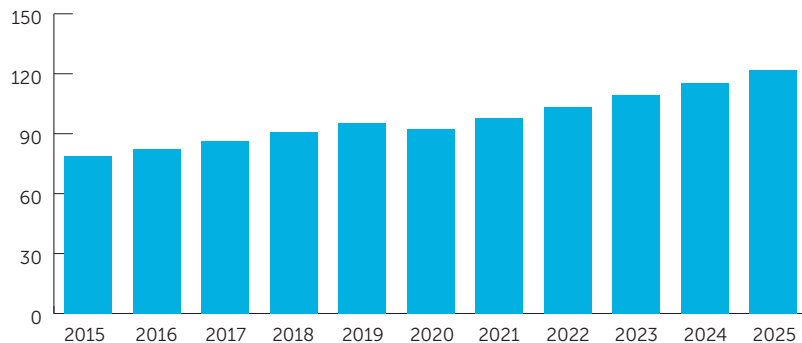
4.1 Photonics – core components and materials

World Market (2019)	\$95.2 billion
	€85 billion
CAGR 2015–2019 (\$)	5.5%
European production (2019)	\$18.5 billion
	€16.6 billion
% of Global Market (\$)	20%
Main sub-segments	
Passive Components	
Sources (LED & Lasers)	
Image sensors & detectors	
Fibres	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- ▶ The total market for photonic components, modules and materials was \$95.2 billion in 2019 with a 5.5% CAGR between 2015 and 2019.
- ▶ The market for passive optical components was \$19 billion in 2019. Of this total, components in the visible range take by far the largest share with 82%, infrared components account for around 15% and UV components for just over 3%.
- ▶ The total value of all sources is approximately \$28 billion including \$13 billion of LEDs and \$14.5 billion of laser sources.
- ▶ Optical fibres account for about \$8 billion (including preforms).
- ▶ Finally, sensors as a whole accounted for a market of \$29.6 billion, including approximately \$24 billion for CMOS image sensors.

European production summary

In the global market of optical and photonic components & materials worth €85 billion in 2019, European production accounted for €16.6 billion, i.e. a market share of around 20% (16% of total production in Europe).

Europe has a significant market share in the field of laser sources, LEDs, infrared sensors and 3D sensors. On the other hand, the European production of CMOS sensors is quite low.

Germany holds more than 40% share in European production due to a strong manufacturing base for optical components while France holds 15% and UK 20%. Other major producing countries include Italy, Switzerland, Netherlands, Sweden, and Austria.

The main producing companies include:

AMS AG, Berliner Glas, Coherent, Corning, Fisba, Gooch & Housego, Heraeus Quarzglas, IQE, Laser Components, Lumentum, Lumibird, Lumileds, Lynred, Osram, Prysmian, Qioptiq, Schott, Soitec, ST Microelectronics ...

Sub-segments and main products

Optical components comprise un-mounted and mounted components (lenses, prisms, polarisers, etc.). Applications range from consumer electronics to industrial laser equipment and measurement, imaging and analytical equipment. High-performance optics is used in applications such as astronomy. Also, we include in the present segment all optoelectronic components (LED, sensors, detectors ...) as well as all laser modules. For example, while laser systems for materials processing are included in the segment for Industry, we include here the laser sources in the present segment.

Note: Optical components for vision correction are included in the Healthcare segment.

The global market for Photonics components and materials was \$95 billion in 2019. The main component types are given below.

Categories	Components description	\$B (2019)
Materials and passive Components	Optical glass, ... Filters, prisms, lenses ...	19
Thin films	Optical coatings and films	8.8
Sources	LEDs chips	13.5
	Edge emitting laser chips (DL, QCL)	5
	Other laser chips (VCSEL ...)	1.6
	Laser sources (Solid State, fibre, ...)	7.8
Image sensors & detectors	CMOS image sensors	24.3
	CCD Image sensors	1.2
	Microbolometers	0.5
	Thermopiles, thermo-diodes, PIR, PD	0.8
	Non Si IR Image sensors (InGaAs, MCT ...)	0.9
	X-ray detectors	2.1
Fibres	Preforms & Optical fibres	8.3

Table 5: Types of components in the global Photonics market.
(Source: Photonics21 / TEMATYS).

Dynamics per sub-segment

A look at the dynamics of the basic components market shows that this is a reliable indicator of the growth of the industry as a whole.

As far as passive optical components are concerned, they are among the most mature products of photonics – however, innovation is stronger than ever. The business orients toward customized solutions. Many types and grades of materials are made into a wide range of optical elements, each specially designed for an end product (such as an image sensor or a laser) that is designed for a specific application. Hundreds of vendors offer tens of thousands of variations in product materials and designs. Long after the commercialisation of the legendary Polaroid SX-70 instant camera in the 1970s, freeform optics is a major trend in passive components.

Passive optical components will remain oriented toward customized products that serve niche customers. But the business will gradually consolidate in more mature markets and also continue to expand for elements used in innovative and exotic applications like space telescopes.

The market for laser sources (Diode, SolidState, Fiber ...) increased from \$6 billion in 2010 to \$15 billion in 2019, a multiplication by a factor of 2.5 in 9 years and a CAGR of nearly 11%. The year 2019 was a difficult year for laser source manufacturers, particularly in the field of industrial lasers with a decline of around 10% in revenues and showed a stagnation for all laser sources.

The market for optoelectronic components (LEDs, VCSELs, CMOS image sensors, photodiodes, etc.) grew from \$24.5 billion in 2010 to \$45 billion in 2019, a multiplication by a factor of 1.85 in 9 years and a CAGR of 7%. Besides, the impact of the Covid-19 crisis will be recovered as early as 2021 (-2.5% in 2020 and +10.2% in 2021).

In the fibre market, the number of kilometres deployed increased from 180 million in 2010 to 510 million in 2019, a multiplication by a factor of 2.8 in 9 years and a CAGR of 8% in revenue due to lower costs.

These figures show that the photonic components segment has experienced strong growth in terms of both units and revenues in the last years. However, the growth in units is much higher than the growth in revenues. This is due to a strong decrease in the prices of the main components over the period. In particular, laser sources saw their prices decrease due to competitive pressure. Optoelectronic components (LEDs, sensors, etc.) also experienced a sharp decline, especially at the beginning of the period. This also explains why the value of the components increased at a slower rate than the total.

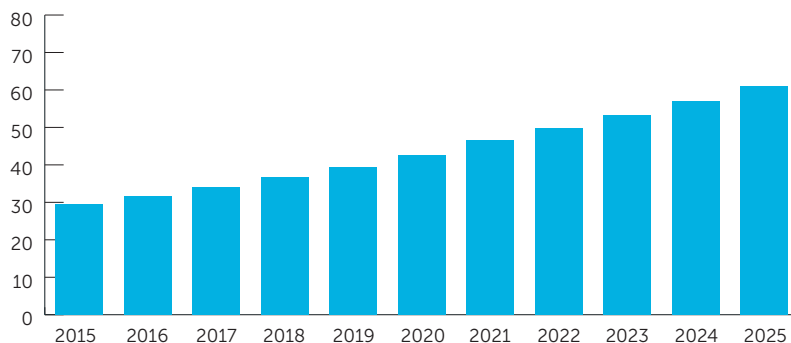
4.2 Telecommunication and quantum information

World Market (2019)	\$39.5 billion
	€35.3 billion
CAGR 2015–2019 (\$)	7.5 %
European production (2019)	\$6.6 billion
	€5.9 billion
% of Global Market (\$)	17%
Main sub-segments	
Wireline Telecom equipment	
Transmission equipment (fibres ...)	
Wireless optical communication	
Telecom instrumentation	
Quantum optics	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- Optical systems for telecommunications accounted for a total market of \$39.5 billion.
- Optical communications systems were worth \$17.5 billion and optical cables about \$17 billion.
- The free-space optical telecommunications market is growing rapidly: \$2.1 billion. It includes VLC and Li-Fi systems.
- The sub-segment of test and measurement instruments for telecommunications devices and networks accounted for \$2.7 billion.
- Quantum optics sub-segment is quite small and was worth about \$0.5 billion (including atomic clocks).

4 European photonics industry by application segment

On the supply side, China is the largest supplier, followed by North America, Europe and Japan. This segment is subject to intense competition and companies headquartered in China had an increasing share of the market.

European production summary

In the global market of telecommunication worth €35.3 billion in 2019, European production accounted for €5.9 billion, i.e. a market share of 17%.

The optical telecommunications industry has become highly concentrated. Today, a few manufacturers dominate in the market: Nokia & Ericsson in Europe, Huawei & ZTE in China and Ciena & Infinera in the US. In Europe, other major manufacturers are ADVA Optical Networking and Infinera (formerly Coriant). US manufacturer II-VI (formerly Oclaro) also produces in Europe.

France is leading in this segment with 35% of the European production. UK and Germany follow and together hold about 40% share of the production. Other major producing countries include Italy, Switzerland and the Netherlands.

Major players include:

Nokia, Ericsson, ADVA Optical Networking, Infinera (Coriant), II-VI, Prysmian ...

Sub-segments and main products

Optical telecommunications use light for the transmission of data in the long-range (wide area networks) and the short-range (local area networks). The long-range segment includes metropolitan to worldwide data transmission. The technologies used are wavelength division multiplexing (WDM/DWDM) and synchronous optical network/synchronous digital hierarchy (SDH /SONET). In the metro segment, Ethernet is used. Data centres increasingly use optical Ethernet. They account for an increasing share and offer substantial growth potential.

Systems and components include multiplexer/de-multiplexers, switches, optical amplifiers, transceivers, lasers, LEDs, detectors, splitters, connectors ...

Note that optical fibres are included in the component segment, but fibre cables are included in this segment.

Table 6: Sub-segments of the segment "Telecommunication and quantum information" and product typology. (Source: Photonics21 / TEMATYS).

Sub segments	Product typology
Wireline Telecom equipment	Switch, routers, OPP, Data Centre interconnects
	Optical Transceivers for Datacom
	Optical Transceivers for Telecom
Transmission equipment	Fibre cables, ETDA
Wireless optical communication	Free Space Optics (FSO), VLC, LIFI
Telecom instrumentation	Laser-based instrumentation
	DWDM tester, OTDR, Optical spectra analyser ...
Quantum Optics	Optical clocks, Quantum Key Distribution, Magneto-optical Traps ...

Market Evolution and Competition

The rapid digitisation of society is putting great pressure on communication networks around the world. It generates an ever-increasing demand for more universally available bandwidth and faster delivery of specialized communication services.

Internet content providers (ICPs) are companies whose primary business is the creation and distribution of digital content. The ICP community includes, for example, large Internet companies such as "GAFAM" (Google, Apple, Facebook, Amazon and Microsoft) but also Airbnb, Alibaba, HP, IBM, LinkedIn, Netflix, Twitter, Uber etc. These companies operate huge data centres often referred to as "hyper-scale" or "cloud" operators. Due to their size and purchasing power, ICPs are not only a relatively new but also interesting target group in the optical transmission equipment market, which promises strong growth potential.

Many large corporations, research and educational institutions, and healthcare providers have chosen to operate their own data centres connected via private fibre optic networks because of the criticality of data and the availability of applications.

Communication Service Providers (CSPs) are companies that build and operate large-scale networks that they use to provide communication services to end-users or other CSPs. In addition to the demand from enterprises and CSPs for data centre interconnection capacity, it is primarily the growing demand for bandwidth from private households that challenges CSPs, increasing the pressure to expand their network infrastructure. The drivers of bandwidth growth are mainly mobile devices, video-on-demand offerings from providers such as Netflix as well as the growing number of networked devices via the Internet of Things (IoT).

The competitive landscape for fixed access for CSPs has two major players, Nokia and Huawei, which hold the bulk of the market share. ZTE, in third place, has been affected by the component ban in the US, although to a rather limited extent. Smaller players such as Calix and Adtran in North America and Fiberhome in China have a limited footprint and have an estimated market share of less than 10%.

In October 2020, Sweden banned Huawei and ZTE from participating in its 5G networks. Sweden thus joined the United States, Australia, UK, and France, which have imposed a ban on using Huawei and ZTE equipment in 5G telecommunication networks. So, Huawei faces in some countries: product and 5G wireless network project bans, business contract restrictions, security scrutiny, and related pushback. However, the EU allows members to decide what part Huawei can play in its 5G telecoms networks²⁰.

In the context of new **5G technologies**, not only is the bandwidth of networks increasing but the number of antennas is also multiplying. This densification of radio heads requires a significant investment in the fibre optic network. The implementation of mobile broadband networks is stimulating the demand for a new generation of fibre-based solutions.

²⁰ Source: Reuters, January 29, 2020.

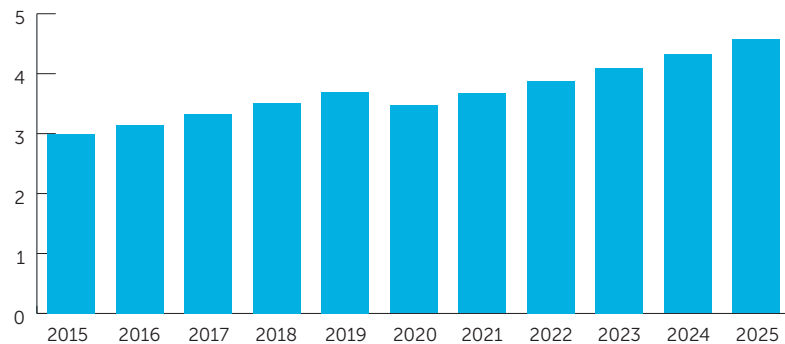
4.3 Large instruments and space

World Market (2019)	\$3.7 billion
	€3.3 billion
CAGR 2015–2019 (\$)	5%
European production (2019)	\$1.2 billion
	€1.1 billion
% of Global Market (\$)	33 %
Main sub-segments	
Ground large instrument	
Optronics space payloads	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- The large instrument and space segment accounted for a total market of approximately \$3.7 billion in 2019. This market is rather difficult to apprehend because it is largely made up of programmes lasting several years. Moreover, while budgets are usually known, the share dedicated to optical instruments is rarely mentioned and often drowned in the cost of infrastructure for large instruments such as ELI or in the total cost of satellites in the space sector.
- In the space segment, alternative solutions are beginning to emerge, including low orbit constellations with a high revisit rate, products complementary to satellites such as HAPS (High Altitude Platform) for example, and the trend towards the use of the hyperspectral domain.

European production summary

- In the global market, European production accounted for about €1 billion: a market share of 33%.
- European know-how (with the two leaders Thales Alenia Space and Airbus group) is recognised in the field of satellite optical payloads (often in combination with radar) for military, dual-use or civil missions. It covers a wide range of applications: intelligence gathering, target designation, meteorology, altimetry, oceanography, climatology, carbon cycle studies, cartography and crisis management. Satellites with optical payloads thus help to better understand and protect the Earth. In terms of countries, France leads with more than 40% of European production.
- In the field of commercial satellites, the main competitors outside Europe are Boeing, Lockheed Martin, Maxar, and Northrop Grumman. There is also the gradual arrival on the commercial market of new players from Russia, China, India, Japan, etc. in the fields of observation.
- In the institutional and military fields, the evolution of which depends largely on the budgetary environment of states and space agencies, the main European players are Thales Alenia Space, Airbus Group and OHB, and export competitors are mainly Boeing and Lockheed Martin.
- Large scientific instruments: France is well placed in the field of ultra-intense lasers with Thales and Amplitude (Thales and ELI-NP laser system reached a record power of 10 PW in 2019). Germany is also a player in this segment with the free-electron laser: XFEL even if other countries have participated in this project.

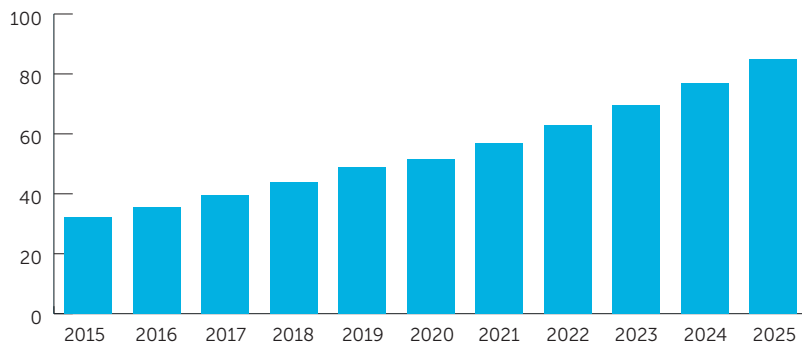
4.4 Defence and security

World Market (2019)	\$48.8 billion
	€43.7 billion
CAGR 2015–2019 (\$)	9.5%
European production (2019)	\$11 billion
	€9.8 billion
% of Global Market (\$)	22%
Main sub-segments	
IR Imaging, night vision & measures	
Security & dual cameras for surveillance	
Displays for avionics (including HUD)	
Biometric systems	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

➤ The segment of photonic systems for Defence and Security, was growing by about 10% per year and accounted for \$48.8 billion in 2019.

The main segments are as follows:

- Infrared systems account for around \$11 billion and are mainly intended for defence.
- Surveillance systems in the visible domain account for a \$30 billion market. The systems are known as “dual-use” systems and are intended for defence but also largely for the field of civil security: police, border control, surveillance of major infrastructures, factories, etc.
- Finally, the various biometric systems (AFIS: fingerprints, non-AFIS: iris, 2D or 3D face recognition, etc.) have a market of about \$4.5 billion.

European production summary

In the global market of photonic systems for Defence and Security worth €43.7 billion in 2019, European production accounted for €9.8 billion in 2019, i.e. a market share of 22%.

It represented about 10% of total production in Europe. Europe has a significant market share in the field of Infrared systems.

Major producing countries	The major producing countries in Europe are France and the UK (accounting for a combined share of 52% of the European production), followed by Italy, Germany and Sweden.
Main producing companies	With headquarters in France, Thales is the major producer of defence and security Photonics in Europe. Its production plants are mainly located in France and the United Kingdom. Safran is an important producer in this sector in Europe. Bosch Security Systems is a major player in video surveillance

Sub-segments and main products

This segment includes Optical and Optronics systems. Defence is by far the largest end market, but also the homeland and civil security market contributes to demand. Systems comprise sophisticated gated vision equipment, range finding binoculars as well as products like periscopic sights and cameras for satellites. Displays form another major market segment of defence and security photonics, including avionics displays and head-up displays. Other products comprise range finding and LIDAR systems, missile and munition guidance systems, countermeasure systems.

Sub segments	Product typology
IR Imaging, night vision & measures	Cameras and systems for day and night vision (for air-land-sea applications) Telemetry, laser vibrometry, countermeasures, CBRN measurements...
Displays	Avionics displays and head up displays for defence & security applications
Security	X-ray security detection
	Cameras for security & video surveillance
	IR cameras for surveillance and firefighting
	Biometry (Device for automated fingerprint identification systems – AFIS)
	Biometry (other non AFIS device – iris, 3D, veins)

Table 7: Sub-segments of the segment "Defence and security" and product typology.
(Source: Photonics21 / TEMATYS).

Main European production in the segment

In the field of Optronics, which combines optical and electronic systems, European companies design and produce components and systems that enable surveillance, reconnaissance, protection, threat detection and target designation, day and night, on all types of land, naval (surface and underwater) and air platforms for defence and security customers around the world.

Thales is the leading European supplier of multi-domain Optronics with no European competition in the field of airborne combat pods. Competitors in the latter field are Lockheed Martin and Rafael.

In land and naval applications, the leading European manufacturers are Thales, Safran and Hensoldt. Their main competitors in these segments are North American (Raytheon, Lockheed Martin and FLIR Systems) and Israeli (mainly Elbit) suppliers.

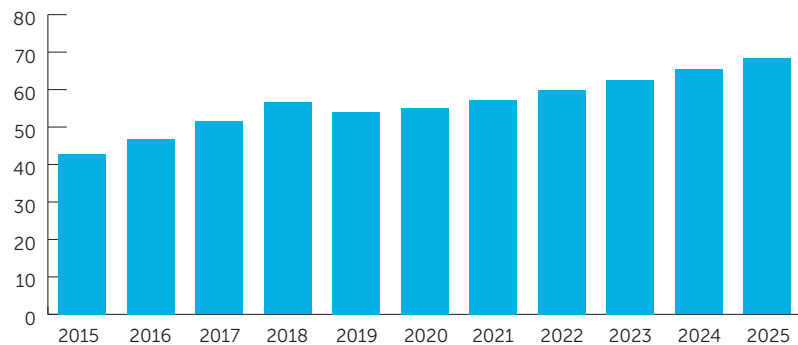
4.5 Industry 4.0: Processing and machine vision

World Market (2019)	\$54 billion
	€48,2 billion
CAGR 2015–2019 (\$)	6.7%
European production (2019)	\$21.4 billion
	€19.1 billion
% of Global Market (\$)	40%
Main sub-segments	
In-line control and measurement	
Machine vision systems	
Processing: laser systems	
Processing: semiconductor and displays manufacturing	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- The Photonics for Industry (mainly Processing and Machine vision) segment accounted for \$54 billion with a CAGR of 6.7%.
- Machine Vision Systems was worth just under \$10 billion with a growth of 5% per year.
- Sensors used in manufacturing processes have a total market of \$7.5 billion, to which barcode scanners must be added for approximately \$2.5 billion.
- The third sub-segment is made up of industrial laser systems: \$19.5 billion (including about 4 for micro-processing).
- All semiconductor and display manufacturing systems together accounted for \$14.3 billion.

European production summary

In the global market of Photonics systems for Industry worth €54 billion in 2019, European production accounted for more than €19 billion, i.e. a global market share of 40%.

It represented 18.5% of total production in Europe. Europe has a significant market share in the field of Photonics systems for production i.e. industrial laser systems and semiconductors manufacturing (45%) and in Machine vision (35%).

The major producing country in this segment is Germany with about 60% share in Europe.

The major producers in Photonics systems for production in Europe are the Netherlands (microlithography systems) and Germany (laser systems for materials processing, lasers and objectives for lithography). Italy and Switzerland follow.

Germany is also a leader in systems for sensing and imaging for Industry due to a large share for several major products (Machine Vision systems, optical sensors ...). The United Kingdom, France, Italy, Switzerland, the Netherlands, and Sweden follow. Many other countries host manufacturing of Machine Vision systems.

Sub-segments and main products

Photonics systems in this segment comprise equipment used in industrial manufacturing. This includes on one hand the systems used for processing: laser systems for materials processing, and systems for lithography, a major manufacturing process for semiconductors and flat panel displays. On the other hand, it comprises systems for in-line control and measurement: Machine vision, and on-line or final quality control like shape, colour, size, defects inspection. The most important user industries for Machine vision are the semiconductor industry, electronics industry and flat panel display industry. The most important tasks of imaging systems in industrial manufacturing are production monitoring as well as Quality Assurance & Quality Control (QA/QC).

Sub segments	Product typology
In-line control and measurement	Process Spectroscopy
	Optical Gas sensing
	Metrology for semiconductor
	In-line metrology (shape, colour, size, defects ...)
	Barcode Scanners
Machine vision	Cameras & visible-light imaging systems
	Coordinate Measurement Machines
	Non-conventional imaging systems (SWIR, MWIR, LWIR, THz)

Table 8: Sub-segments of the segment "Industry 4.0: Processing and Machine vision" and product typology.
(Source: Photonics21 / TEMATYS).

4 European photonics industry by application segment

Manufacturing & Processing	Laser systems for Macro-processing (cutting, welding, drilling, cleaning ...)
	Laser systems for Micro-processing
	Lithography systems for semiconductors and displays
	Laser annealing, etching, sputtering, lift-off for Displays
	LED/laser-based 3D printers

European industry in the segment

In the field of laser material processing, Europe is the leading producer of laser systems. The manufacturers of laser systems in Europe are, to a very large extent, local companies. The main producer in this segment in Europe is Germany (laser systems for material processing, lasers and lenses for lithography). Italy and Switzerland follow with large production volumes for laser material processing systems. Many other European countries also produce lasers and laser systems. Chinese demand for manufacturing equipment, which supports local production of laser systems and lasers, is expected to increase the market share of local suppliers compared to European suppliers.

In the field of lithography, the Dutch company ASML is the world's leading producer. The company is the clear market leader in microlithography, while Japanese companies dominate the market for lithography systems for the manufacture of displays.

After the slight decline in 2019, the German Association of Machine Tool Manufacturers (VDW) predicts a massive drop in production of -30% in 2020. In addition to weak global trade, the VDW cites the coronavirus pandemic as one of the reasons for this downward trend. For 2021, VDW forecasts a further increase in production of 9%.

For laser treatment, a further slight decrease is expected in 2020. EUV lithography, on the other hand, will see a further significant increase in sales. With Zeiss, ASML and Trumpf, Europe remains the only supplier for this highly innovative manufacturing process. The current positive trend will continue thanks to the growth of the semiconductor and microwave sectors in the coming years.

The intensity of competition in the market for industrial machine vision cameras increased in recent years. The competitive landscape has particularly changed due to takeovers and aggressive investments by Chinese competitors. The distribution landscape is also gradually becoming part of the consolidation trend. Regional distributors are being acquired by new entrants or by larger distributors or manufacturers.

The competitive environment is still highly fragmented and characterized by many small suppliers. The main competitors are Basler (Germany), FLIR (United States), Teledyne-Dalsa/e2V (Europe and Canada), TKH Group/Allied Vision (Germany) and Toshiba-Teli (Japan). Chinese competitors HIK Vision and Dahua, which currently have significantly lower sales for industrial machine vision cameras, are, however, growing very rapidly in Asia.

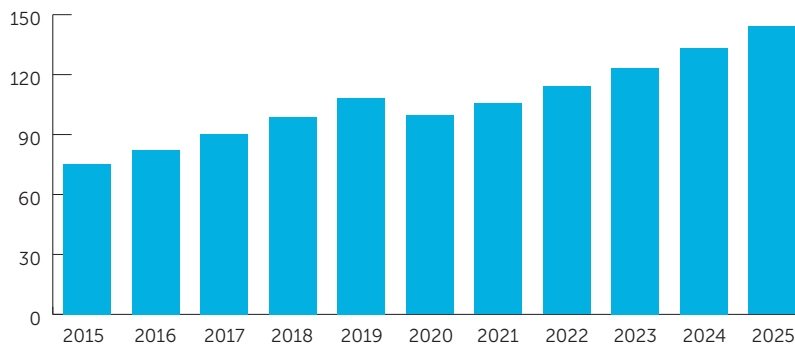
4.6 Environment, lighting & energy

World Market (2019)	\$108.2 billion
	€96.6 billion
CAGR 2015–2019 (\$)	9%
European production (2019)	\$18.7 billion
	€16.7 billion
% of Global Market (\$)	19%
Main sub-segments	
Measurement of pollution and GHG	
LED-based lighting modules & systems	
Photovoltaic modules	
Solar thermal energy (STE) systems	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- The segment of photonic systems for environment, lighting and energy is the second largest segment in value behind the consumer and professional segment, with \$108 billion. These systems are directly related to sustainable development because they can probe the environment, produce 'clean' energy or save energy by using energy-saving sources (LEDs).
- The most important sub-segment is lighting with approximately \$54 billion and growing with a CAGR of more than 10%.
- The second segment consists of photovoltaic modules and accounted for \$46 billion. The growth of this market is 7% since 2015. The installed power has increased from 50 GW in 2015 to almost 120 GW in 2019. At the same time, however, the price of the modules has fallen sharply from \$0.7 per installed watt to around \$0.4.
- The last 2 sub-segments are solar thermal (\$4.2 billion) and environmental instruments (\$3.8 billion).

European production summary

In the global market of Photonics systems for environment, lighting and energy worth €96.6 billion in 2019, European production accounted for €16.6 billion, i.e. a global market share of 19%.

This represents 16% of total production in Europe. Europe has a significant market share in the field of Lighting (25%) and Environment monitoring (about 30%). On the other hand, the European market share in Photovoltaic modules is less than 5%. The industry was confronted for more than 10 years with harsh price cuts driven by companies in China.

Germany is the largest manufacturer of lighting products in Europe, with a share of more than 35%. Several other countries hold a share of 5% to 10%, including Italy, France, the United Kingdom, and the Netherlands. Osram and Signify, the two major European manufacturers of lighting products, held for a long time and still hold the leading two positions in the global lighting market. The technology transition to LED-based lamps has attracted new players to the lighting market, mainly in Asia. In China, the government strongly supports companies setting up LED factories which will represent a major competition for European manufacturers.

Sub-segments and main products

The main sub-segments and products are summarized in the following table.

Table 9: Sub-segments of the segment "Environment, lighting and energy" and product typology.
(Source: Photonics21 / TEMATYS).

Sub segments	Product typology
Lighting ²¹	OLED and LED Lighting (Inside and outside) – Car lighting is included in the Mobility segment (as well as lighting for other mobility means)
Energy	Photovoltaic modules (do not include panels)
	Thermal solar
Control and Measurement (urban & domestic level)	Photoelectric sensors for luminous flux
	NDIR and mobile IR for gas and particle sensing
	IR thermography
	Ambient and proximity light sensor
	UV-C robots (mostly for surfaces)
	UV-C disinfection systems (mostly water decontamination)

Market evolution

Concerning the photovoltaic module market: this had strong growth from 2015 to 2017 and then suffered a sharp slowdown due to the combination of two factors: on one hand, the installed power per year is growing much less quickly (<10% per year); on the other hand, the price of modules has continued to fall even if this drop is much less rapid than it was a few years ago. For the year 2020, the market will probably be below the 2019 level due to delays in the installation of photovoltaic power plants following the Covid-19 epidemic.

²¹ Note that this sub-segment does not include all luminaires. A spotlight or a desk lamp are not included in this sub-segment at all. These are "solid-state" lighting subsystems such as LED modules, devices including LEDs, drivers and lenses for home lighting (bulbs), street lighting or professional lighting such as LED-based ceiling tiles or power modules for show or sports lighting.

The general lighting market transformation has radically changed the landscape. The conversion to LED lighting is well underway. The transition to Connected Lighting has started. In this global transition, the main European players, including Osram and Signify, will have to innovate both in terms of products and business model to keep their market share in the face of new entrants, particularly Chinese: strategic repositioning from light sources to luminaires with high quality and sustainability lighting products, systems and services and too high-value segments like Agri-Lighting, Solar and Connected Lighting.

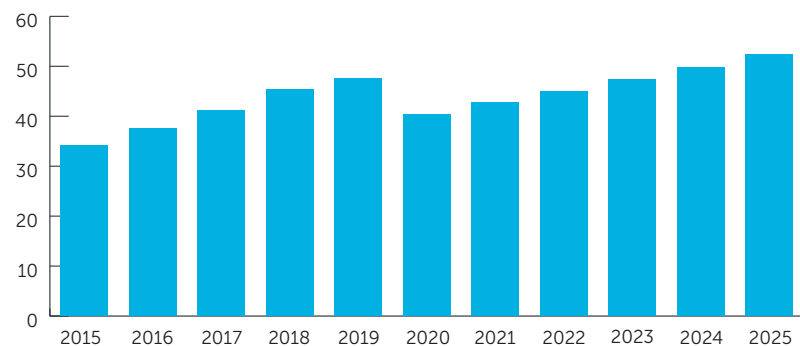
4.7 Mobility: automotive, maritime, railway, aeronautics

World Market (2019)	\$47.5 billion
	€42.4 billion
CAGR 2015–2019 (\$)	8%
European production (2019)	\$8.3 billion
	€7.4 billion
% of Global Market (\$)	17%
Main sub-segments	
Lighting systems	
Displays	
Cameras and LIDARs	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

All photonic systems for the mobility sector (automotive, railways, aeronautics, etc.) accounted for a \$47.5 billion market in 2019. This market has increased with a CAGR of 8.6% since 2015.

The most important part is made up of lighting systems (around \$25 billion showing a decline of 8% YoY in 2019), with car headlights being the most important. Following this is Displays for a total market of 17.8 billion. This last sub-segment has increased by more than 10% per year in recent years, especially in the automotive field.

However, the sub-segment with the strongest growth is that related to LIDARs with an increase of more than 20% since 2015. The market is still small with a value of little less than \$0.5 billion but is expected to develop very strongly over the next few years with the growth of ADAS systems and the emergence of autonomous vehicles.

European production summary

In the global market of photonic systems for the mobility sector worth €42.4 billion in 2019, European production accounts for €7.4 billion, i.e. a global market share of 17%.

Germany is the largest manufacturer of photonic systems for the mobility sector in Europe, with a share of almost 40%. The UK follows with a 17% share. Several other countries hold a share of 5% to 10%, including Italy, France, Austria, and Sweden.

Of the top five international car headlights manufacturers (Koito, Valeo, Marelli Automotive Lighting, Hella and Stanley), three are European. The innovation in this field in Europe is very high. Car headlights made in Europe are real photonic systems with freeform optics, light guides and cameras for adaptive front lighting.

In the LIDAR segment, Valeo is the leader in Europe and is the only company to manufacture Lidar for the automotive industry in large quantities. Currently, no company in Europe would be in a position to challenge his leadership. On the other hand, there are many SMEs and start-ups in Europe in this field.

Sub segments	Product typology
Imaging & sensors	Cameras for automotive
	Night vision imaging
	LIDARs, Speed optical sensors
Lighting	Automotive LED lighting, Maritime, Railway and aeronautic lighting
	Laser Headlights
Displays	Automotive Displays systems and panels
	Maritime, Railway and aeronautic displays
Connecting and Datacom	MOST components and systems
Projectors, HUD & AR/VR	HUD in automotive and aeronautics, AR/VR in aeronautics and other mobility means

Table 10: Sub-segments of the segment "Mobility: automotive, maritime, railway, aeronautics" and product typology. (Source: Photonics21 / TEMATYS).

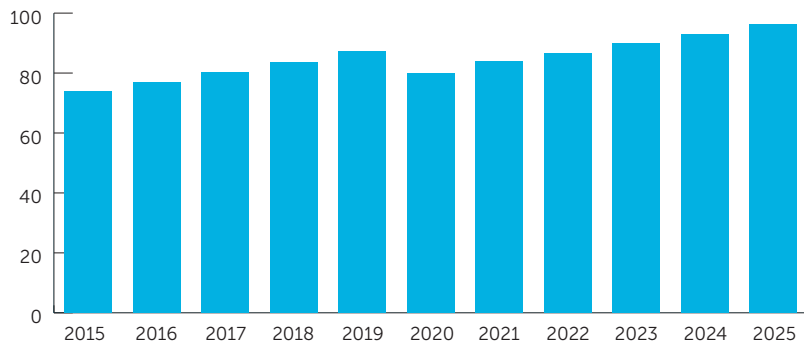
4.8 Healthcare and wellness

World Market (2019)	\$87.2 billion
	€77.8 billion
CAGR 2015–2019 (\$)	4.5 %
European production (2019)	\$17.8 billion
	€15.9 billion
% of Global Market (\$)	21%
Main sub-segments	
Life science	
Medical Diagnosis	
Medical treatment	
Lens-based ophthalmic correction	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

- The segment of photonic devices and systems for healthcare and wellness was worth a total of \$87.2 billion in 2019.
- The largest sub-segment is spectacle and contact lenses, which accounted for a total of \$43 billion with a growth of less than 3% per year. The remaining \$44.1 billion consists of Biophotonics devices and systems. The diagnostic systems are as follows:
 - X-ray based devices: radiography, mammography, 3D tomography for \$17.2 billion.
 - Other diagnostic equipment \$14.5 billion: endoscopes, OCT, photo-acoustics ...
 - in-vitro diagnostic systems and for Life Sciences: DNA sequencers, cytometers, microscopes ...
- The final sub-segment consists of laser-based systems and was worth approximately \$5 billion in 2019.

European production summary

With a 2019 production volume of €15.9 billion, photonic devices and systems for healthcare and wellness accounted for 15% of European Photonics production. This corresponds to a global market share of 21% (26% on instruments & devices and 14% on lenses for vision correction). Major products of the European industry include spectacle and contact lenses, endoscopes, microscopes, as well as optical systems for medical diagnostics and biomedical instrumentation. The European industry also is well represented in the areas of X-rays based medical imaging, OCT and therapeutic laser systems. Its position is weaker in the areas of analytical equipment for biotechnology and pharmaceutical research and industry.

Germany holds almost 40% share in European production, mainly due to a large production share for microscopes, endoscopes, and medical imaging systems. France follows with an about 20% share, ahead of the United Kingdom (about 12%), Switzerland (about 5%), and Italy (about 5%). Many other countries host manufacturing in the sector (spectacle and contact lenses, endoscopes ...).

Sub-segments and main products

The Healthcare and Wellness segment comprises therapeutic medical systems as well as systems for in-vivo and in-vitro diagnostics. Life science includes analytical systems used in R&D, in the pharmaceutical and biotechnology industry. Major products include endoscope systems and accessories, spectacle and contact lenses, therapeutic lasers and laser systems (including for cosmetic purposes), medical imaging systems (CR – computed radiography and DR – digital radiography), fluorescence diagnostics and analytical systems, diagnostic systems for ophthalmology, optical coherence tomography (OCT) systems, microscopes and surgical microscopes, capillary electrophoresis systems, DNA sequencers, cell sorters, plate and array readers.

Not included are non-photonic medical imaging systems such as MRI and ultrasound systems.

4 European photonics industry by application segment

Table 11: Sub-segments of the segment "Healthcare and wellness" and product typology.
(Source: Photonics21 / TEMATYS).

Sub segments	Product typology
Medical Diagnosis	X-rays based (medical imaging) Mammography CT Scanner
	VIS-NIR based (dermatoscope, slit lamp, aberrometer ...)
	OCT
	Photoacoustic
	Other Laser-based (Raman, 2 photons, PDD)
	Surgery Microscopes
	Endoscopes
	Digital Pathology Scanners
Projectors, HUD & AR/VR	Haematology screeners
	Oximetry
	Sequencing
	Cytometry
	Biosensors
	Microscopy
Medical treatment	Laser based (dermato, uro, ophtalmo, gyneco ...) Aesthetic laser-based Ophthalmic correction laser-based Dental laser-based Urology and gynaecology laser-based cardiovascular laser-based
	Other (dermatology / veterinary laser-based)
	Photodynamic therapy
	UV based
Lens-based ophthalmic correction	Spectacle and contact lenses

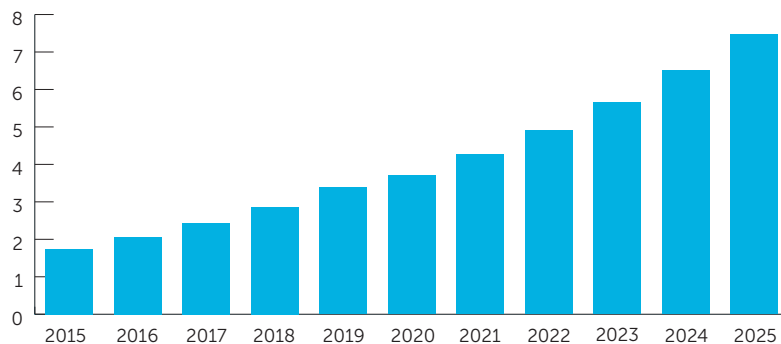
4.9 Agriculture and food

World Market (2019)	\$3.4 billion
	€3 billion
CAGR 2015–2019 (\$)	18%
European production (2019)	\$0.71 billion
	€0.64 billion
% of Global Market (\$)	21%
Main sub-segments	
Imaging & Measurement	
Lighting in agricultural greenhouses	
UV disinfection	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

The segment of photonics for agriculture and food processing remains for the moment an emerging market but it is the one that is experiencing the strongest growth.

This segment accounted for approximately \$3.4 billion in 2019 with a CAGR of 18%. In this segment, we have included only systems dedicated to this market: imaging and sensing systems and LED-based devices for lighting in agricultural greenhouses.

It should be noted that general vision systems are included in the Industry segment, while a significant part is used by the food industry.

Also, optical measuring instruments are used in this segment, such as reflectometers, particle measuring systems, FTIR systems, cytometers, etc.

European production summary

A rapidly growing global population will dramatically increase the demand for food production. Therefore, new practices, technologies and methods are required to implement sustainable management of natural resources, manage climate exchange, and ensure viable food production.

Europe is playing a central role in meeting these challenges, due to its technological leadership in the Agriculture sector and, in particular, in the vanguard of high-tech precision farming. Relevant photonics devices and techniques include LIDARs, sensors, energy-efficient LEDs, spectroscopy, laser scanning, multi and hyperspectral imaging.

In the market of agronomic and on-line sensors, mainly generated by tools for measuring sugars and proteins, major players in Europe include FOSS, Zeiss and Chauvin-Arnoux.

There are also a lot of European SMEs and start-ups in the segment including Avantes, AVL Motion, BoMill, Cascade, Deka, Fritzmeier, Heliospectra, Lumichip, Spectral Engines ...

Table 12: Sub-segments of the segment "Agriculture and Food" and product typology. (Source: Photonics21 / TEMATYS).

Sub segments	Product typology
Imaging & Measurement	VIS Camera, RGB-NIR, Spectrometers, Cytometers, X-rays devices, THz devices
	Process Spectroscopy in the food industry
Photonics based treatment	UV based devices online and on field
	UV disinfection
Lighting	Horticulture illumination

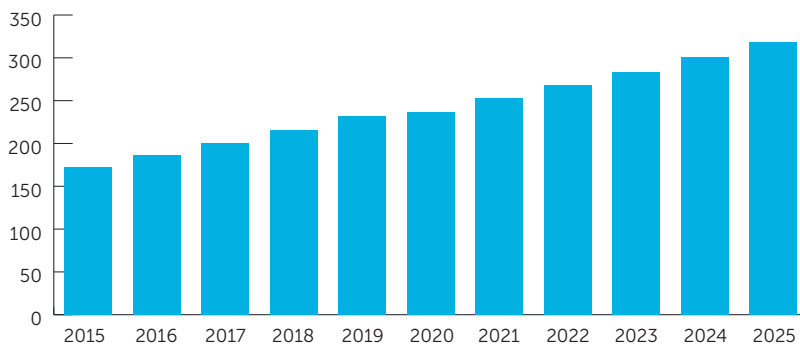
4.10 Consumers and professionals

World Market (2019)	\$231.7 billion
	€206.9 billion
CAGR 2015–2019 (\$)	7.7 %
European production (2019)	\$6.3 billion
	€5.6 billion
% of Global Market (\$)	3%
Main sub-segments	
Homes and Offices	
Mobile phones and devices	
Education	
Professionals	
Entertainment & Leisure	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

The segment of photonic systems for consumers and professionals was by far the largest: \$231.7 billion in 2019 with a growth of 7.7% per year, which is fairly close to the growth of the global market.

The largest sub-segment was that of displays: \$172.3 billion, of which \$117.1 billion is for TV and computer screens and \$55.2 billion for smartphone screens.

Other sub-segments with a high global market were camera modules for smartphones (\$23.2 billion), CCTV systems (\$14.9' billion) and computer peripherals (optical disk drives, optical mice, laser printers) for a total of \$7.4 billion.

Finally, systems for leisure and entertainment accounted for a total market of \$8.4 billion

European production summary

In the global market of photonic systems for consumers and professionals, European production accounted for €5.6 billion in 2019, i.e. a market share of 3%. Asia is leading the game in this segment and Europe has a very small market share. This is due to a combination of factors: historical first, the emergence of consumer products in Japan and Korea such as flat panel displays; economic also, the cheap labour combined with greater investment capacity in Asia (and especially in China).

Germany is the major production location for IT in Europe with a 30% share. Products include digital cameras, printing industry equipment optical printers. Italy follows, hosting producers of automated data acquisition equipment as well as optical printers and copiers. The Netherlands host the European headquarters of a Japanese manufacturer of optical printers and copiers. AMS in Austria and ST Microelectronics in France are also major players.

Germany also holds a major share in the European production for displays, mainly due to the production of LCD and OLED display materials.

Sub-segments and main products

Major products include digital cameras, optical printers and copiers, scanners, barcode readers, and optical disk drives. Also included are image sensors and camera modules. Camera modules are mainly used in smartphones, but also for other applications. Displays, or more precisely flat panel displays, comprise a wide range of products. These are characterized by technology: LCD, LED-backlit, LED, OLED, and e-Ink. For projectors, the technologies are LCD, DLP and LCoS. In this report, we include the displays only. We do not include display-based products such as monitors, notebooks, and TV sets. However, we include cinema projectors and cameras.

The details of the sub-segments and products are given in the following table.

4 European photonics industry by application segment

Sub segments	Product typology
Homes and Offices	Scanners
	Optical disk drives
	Optical mouse
	Laser Printers and copiers
	3D printers
	Displays (FPD) for TV & laptop
	Fingerprint ID
Mobile phones and devices	Cameras module for smart Phones
	Spectroscopic module for smart Phones
	Displays for Smartphones
	3D modules for Smartphones
	Illumination sub modules(LED / VCSEL) for 3D sensing
Professionals	Zoom for professional camera
	Sport/passion optics (Telescopes, Binoculars, Rangefinders, And Riflescopes) for various Hobbies and sports (Shooting Sports, Golf, Water Sports, Wheel Sports, Snow Sports, Horse Racing)
	CCTV systems (design and manufacturing; the assemblers of purchase equipment are integrators)
Education	Photonic equipment for education
Entertainment & Leisure	Projection and Lighting
	Laser phosphor projector for office home theatre & digital cinema
	Laser-based projection TV & projector
	Laser Light show
	AR/VR Headsets
	Cinema projector
	Video Walls
	Urban Projection and urban large displays / Projection mapping

Table 13: Sub-segments of the segment "Consumers and professionals" and product typology.
(Source: Photonics21 / TEMATYS).

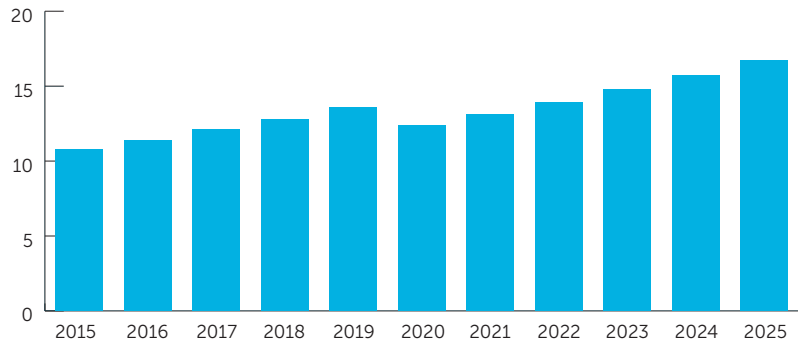
4.11 Instrumentation and optical measurements

World Market (2019)	\$13.6 billion
	€12.1 billion
CAGR 2015–2019 (\$)	6%
European production (2019)	\$5.2 billion
	€4.6 billion
% of Global Market (\$)	38%
Main sub-segments	
Distance measurement	
Spectral measurement	
Distributed measurement (fibre sensors)	
Others	

(Source: TEMATYS market estimates 2020).

World market evolution

Global market (\$ billion)



World market summary

Optical instrumentation and measurement systems were worth a total of \$13.6 billion in 2019 with an annual growth rate of 6%.

They are made up of:

- 3D measurement systems (stereo vision, triangulation, photogrammetry, LIDAR, etc.)
- Spectrometers and spectral cameras,
- Fibre optic sensors,
- Microscopes (other than those used for healthcare or life sciences),
- Optical instruments such as reflectometers, interferometers, ellipsometers, etc.
- Optical systems not elsewhere classified, such as custom optical benches.

European production summary

In the global market of Optical instrumentation and measurement systems worth €12 billion in 2019, European production accounted for €4.6 billion, i.e. a market share of 38%.

It represents 4.5% of the total production in Europe. Europe has a significant market share in the field of microscopes, Fibre optic sensors, Spectrometers and spectral cameras.

Germany and the UK hold together more than 70% share in European production due to a strong manufacturing base and history. Other major producing countries include France, Italy, the Netherlands, and Sweden.

The main producing companies include (>€100 million revenue): Zeiss, Leica Microsystems, Bruker Optik, Spectro Analytical Instruments, Analytik Jena AG, Horiba Jobin Yvon, Malvern Panalytical ... These big companies are mainly active in the segment with standard products, such as e.g. microscopes and spectrometers.

Sub-segments and main products

The sub-segment of Instrumentation and Optical Measurements includes a large diversity of systems for various applications. The major products in terms of market volume are fibre optic sensors, 3D measurements, spectrometers, and geometrical and distance measuring systems. These systems are used for geospatial and construction applications, oil and gas exploration, the measurement of materials and constituents, characterization of particles, R&D, and many more applications.

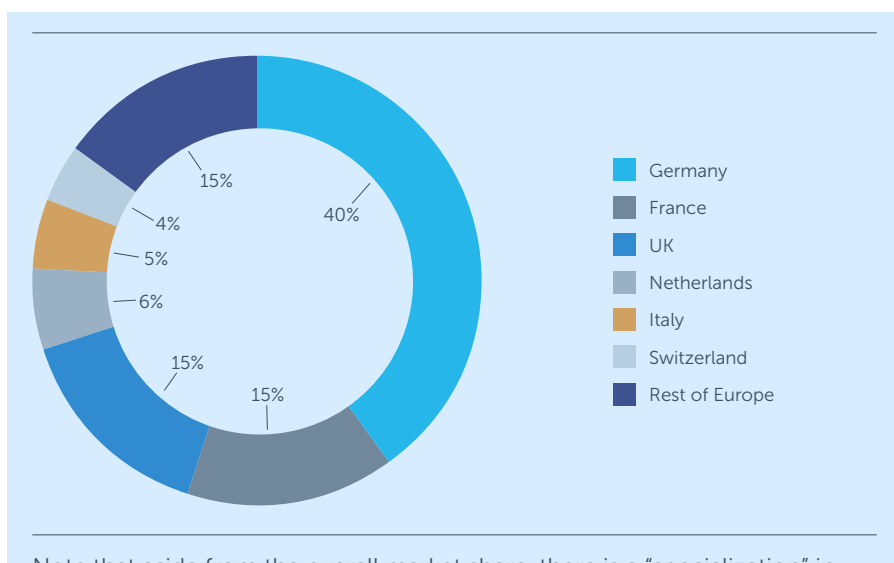
Sub segments	Product typology
Distance measurement	3D stereovision ...
	Airborne and drone LIDAR (corridor mapping, altimetry ...)
Spectral measurement	Colorimetry, RGB NIR imaging
	Hyperspectral imaging
	Optical Emission Spectroscopy
	Vibrational spectroscopy (FTIR + Raman + NIR + MIR)
	THz spectroscopy & imaging
Distributed Measurements	Narrowband laser used in measurements
	Fibre sensors (Bragg)
	Fibre sensors (Raman Scattering DTS)
	Fibre sensors (Rayleigh scattering DAS)
	Interferometric and others
Other	Microscopy (not life science)
	Optical instruments such as reflectometers, interferometers, ellipsometers, etc. and systems not elsewhere classified

Table 14: Sub-segments of the segment "Instrumentation and Optical Measurements" and product typology. (Source: Photonics21 / TEMATYS).

5 European production by country

The total European Photonics Production in 2019 was €103 billion with a CAGR of 7% from 2015 to 2019. The breakdown by country is depicted in Figure 25. Within Europe, Germany accounts for the largest production volume for Photonics with a share of 40%. France and the United Kingdom hold a similar share of 15%. The Netherlands (6%) and Italy (5%) follow. Switzerland holds a 4% share. The other European countries hold a combined share of 15%.

Figure 25 – European Photonics Industry – Breakdown by country.
(Source: Photonics21 / TEMATYS).



Note that aside from the overall market share, there is a “specialization” in some segments for the countries and they often have a greater share in their speciality.

With a 2019 production volume of €40.8 billion, Germany accounted for a 40% share of European production. The share is almost stable since 2011 (40.7%). The German Photonics industry is well represented in strongly growing segments such as Photonics for Industry (laser materials processing, measurement & machine vision) and Healthcare. Photonics for Industry is the largest segment in Germany and accounted for more than half of the European production. In Environment, energy and Lighting and Components and Materials, the share of the German Photonics industry is above 40%.

France accounted for 15% of European production with a 2019 production volume of €15.3 billion. French Photonics industry developed very well in the last years building on historical sectors such as Defence & Security and Telecommunications in which the share of France is more than 30%. Photonics for Healthcare is also a large segment in France. It is second behind Germany and accounted for around 22% of European production.

With a 2019 production volume of €15.6 billion, the United Kingdom accounted for 15% of European production. Components and Materials is the largest segment and accounted for about 20% of the European Production. Photonics for Defence and Security is the second largest segment in the UK with 25% of European production.

With a 2019 production volume of €6.2 billion, the Netherlands accounted for 6% of European production. Photonics for Industry is by far the largest segment and accounted for about 17% of the European Production. This comprises the production of lithography systems where ASML is the world leader. ASML is responsible for about 45% of the total photonics production in the Netherlands.

Italy accounted for about 5% of European production with a 2019 production volume of €5.2 billion. The largest segment is Photonics for Defence & Security. Other major segments are Photonics for Industry and Environment, energy and lighting.

With a 2019 production volume of €4.4 billion, Switzerland accounted for about 4% of European production. The major segments of Photonics production in Switzerland include Optical components & materials and Photonics for Industry.

Other major contributions to European Photonics production came from Sweden, Spain, Finland, Belgium, Austria, and Denmark. Spain accounted for a 2019 production volume of about €2.4 billion and Sweden of around €2 billion. The photonics industry in Finland has been evaluated at €1.2 billion²².

The following subchapters focus on the 6 countries with the highest share in European Photonics and give details on the main segments and the main companies contributing to the production in each country.

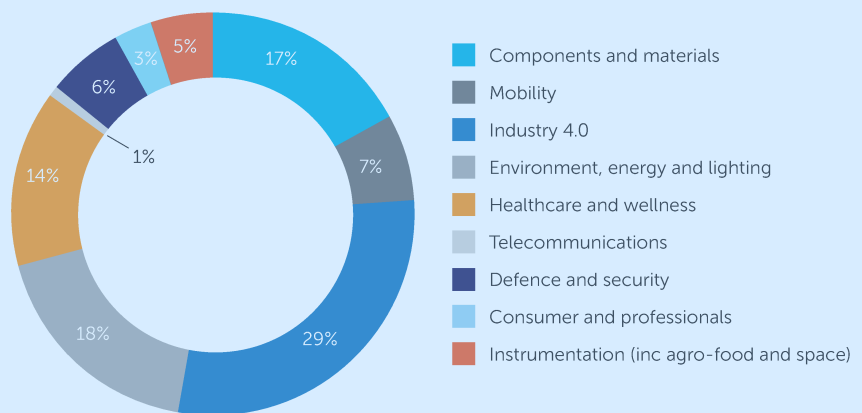
²² <https://www.photonics.fi>

5 European production by country

5.1 Germany

Area (km ²)	357 114
Population (2019)	83 132 800
GDP (2019)*	3 944
GDP growth*	6.8%
Industry (%GDP)	26.7%
Currency	EUR
Photonics production	
Europe (€ billion)	103
Germany (€ billion)	40.8
Share / Europe	40 %
Employees	160 350

Breakdown per segment



* in constant 2010 US\$ billion (growth from 2015 to 2019)

Germany production summary

- With a 2019 production volume of €40.6 billion, Germany accounted for about 40% of European production²³. The share is almost stable since 2011 and 2015 (41%). German Photonics industry developed very well due to the European good development of the economy and strong exports.

The major segments for Photonics in Germany are the following:

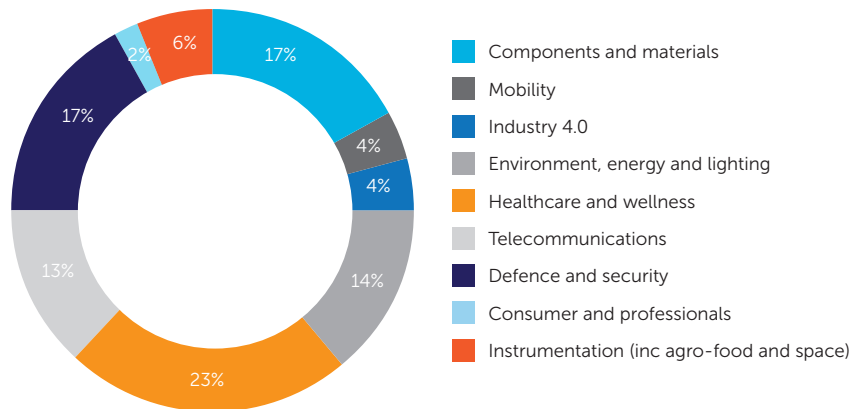
- Photonics for Industry is the largest segment in Germany and accounted for more than half of the European production. This comprises Machine vision and sensors as well as systems for laser materials processing and microlithography. The leading companies include Trumpf, Zeiss, Sick ...
- Environment, energy and Lighting is the second largest segment and accounted for about 45% of the European production. The main companies include Osram, Signify, Lumileds Germany, IBC Solar, Meyer Burger ...
- Components and Materials is the third-largest segment accounting for about 40% of the European Production. The main company producing optical glass is Schott. Optical components are produced by system companies like Zeiss or Jenoptik, but also by specialized companies such as Qioptiq, Sill Optics, Laser Components ...
- Healthcare is also an important segment accounting for almost 40% of the European Production. Products include endoscope systems (ex. Karl Storz), microscopes and surgical microscopes (ex. Leica), spectacle lenses (ex. Zeiss), medical lasers & systems (ex. Lisa Laser), diagnostic systems for ophthalmology (ex. Zeiss), and medical imaging systems (ex. Siemens Healthcare).
- On the other segments, Germany hosts a production of digital cameras, systems for the printing industry, car headlights and defence Optronics and infrared & night vision equipment.

²³ Note that these figures are in line with the former reports published by Photonics21 (2017), BMBF, Spectaris and VDMA (2013).

5.2 France

Area (km ²)	543 940
Population (2019)	67 059 890
GDP (2019)*	2 972
GDP growth*	6.9%
Industry (%GDP)	17.1%
Currency	EUR
Photonics production	
Europe (€ billion)	103
France (€ billion)	15.3
Share / Europe	15%
Employees	60 680

Breakdown per segment



* in constant 2010 US\$ billion (growth from 2015 to 2019)

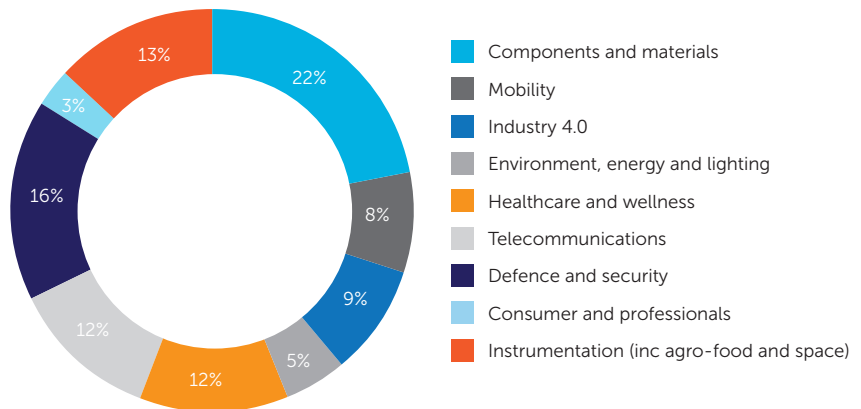
France production summary

- ▶ With a 2019 production volume of €15.3 billion (almost 2% of French industry), France accounted for 15% of European production. The increase is 5.15% in revenues and 1.7% in employment since 2018 when the study was carried out for Photonics France. French Photonics industry developed very well in the last years building on historical sectors such as defence and telecommunications.
- ▶ Photonics for Healthcare is the largest segment in France. It is second behind Germany and accounted for around 22% of European production. The leaders are GE Medical Systems (medical imaging), Essilor (spectacle lenses and contact lenses), Trixell (Radiography and Fluoroscopy) and HORIBA ABX (Hematology).
- ▶ Photonics for Defence and Security is the second largest segment in France with almost 30% of European production. France is the second-largest producer of Photonics for Defence in the world behind the USA. The two leaders in this segment are Thales and Safran.
- ▶ Components and Materials is the third-largest segment and accounted for about 16% of the European Production in 2019. The main companies producing components and materials include Lumibird, Lynred, STMicroelectronics, Teledyne e2v, Soitec, Saint-Gobain, Radiall.
- ▶ Telecommunications is also an important segment and accounted for about one-third of the European production in 2019. Nokia, has substantial production operations in France, due to the takeover of Alcatel-Lucent. After a few years with flat sales, Optical network segment sales in Nokia bounce back by 9% in 2019. The advent of 5G is likely to boost sales in the coming years. Others companies in this segment include 3SP, Alcatel Submarine Networks, Draka, Ekinops, Prysmian.
- ▶ Environment, lighting & energy is also a major segment. France hosts the production of lighting components and modules (Signify, Schneider Electric, Hager, Osram, ZG Lighting ...). In the same segment, ENVEA is among leaders in measurement for the environment.

5.3 United Kingdom

Area (km ²)	242 495
Population (2019)	66 834 400
GDP (2019)*	2 921
GDP growth*	6.8%
Industry (%GDP)	17.4%
Currency	GBP
Photonics production	
Europe (€ billion)	103
UK (€ billion)	15.6
Share / Europe	15%
Employees	70 040

Breakdown per segment



* in constant 2010 US\$ billion (growth from 2015 to 2019)

UK production summary

- With a 2019 production volume of €15.6 billion, the United Kingdom accounted for 15% of European production according to our evaluation. Production volume and number of employees are completely in line with the study made by Photonics UK in 2018²⁴ (with 4.6% growth in revenues and 1.5% growth in employees). UK Photonics industry developed very well in the last years but during the period, growth in euros remained weak due to the depreciation of the British pound by around 20%.

Major segments of Photonics production in the United Kingdom are the following:

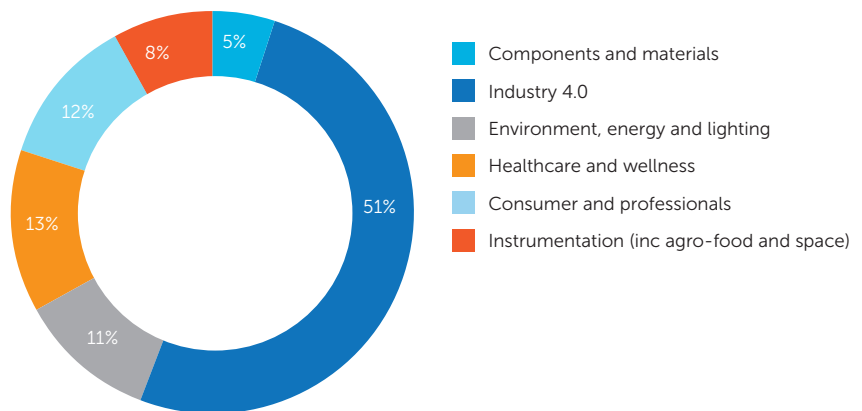
- Components and Materials is the largest segment and accounted for about 20% of the European Production in 2019. Products comprise optical glass as well as optical and optoelectronic components (lenses, mirrors, filters, fibre-based components).
- Photonics for Defence and Security is the second-largest segment in the UK with 25% of European production. The main UK producing companies are France headquartered Thales, Italy headquartered Leonardo, BAE Systems, Qioptiq, Qinetiq, and Teledyne e2v.
- Photonics for Healthcare is the third-largest segment. Products include spectacle lenses and contact lenses, ophthalmic instruments and medical lasers.
- Telecommunications is also an important segment. According to Photonics UK, the big conglomerate that combines Virgin Media and O2 has activities in the optical networks. Lumentum is producing optical networking components in the UK. Besides, there are also smaller companies which have emerged in the last years and that produce components and modules.

²⁴ https://photonicsuk.org/wp-content/uploads/2018/05/UK_Photonics_The_Hidden_Economy.pdf

5.4 Netherlands

Area (km ²)	41 850
Population (2019)	17 332 850
GDP (2019)*	962
GDP growth*	9.5%
Industry (%GDP)	17.7%
Currency	EUR
Photonics production	
Europe (€ billion)	103
Netherlands (€ billion)	6.2
Share / Europe	6%
Employees	15 500

Breakdown per segment



* in constant 2010 US\$ billion (growth from 2015 to 2019)

Netherlands production summary

- With a 2019 production volume of €6.2 billion, the Netherlands accounted for 6% of European production according to our evaluation. The production volume was larger in the previous report because the entire turnover of ASML (around €6 billion) was included. PhotonicsNL believed that one should include only 25% of ASML (National agenda – July 2018). Taking this into account, our assessment of the production volume is in line with the study made by PhotonicsNL (€4.2 billion in 2015 resulting in a 10% CAGR, mainly due to the doubling of ASML's turnover). In 2019, ASML was responsible for about 45% of the total photonics production in the Netherlands.

An estimate shows that almost 300 companies in the Netherlands are directly or indirectly related to photonics. The photonics value chain is characterized by major players from the Netherlands: Signify (Philips Lighting) in the lighting industry, Philips Medical in medical photonics and ASML in lithography machines. NXP and Canon Production Printing have important activities in the Netherlands. The landscape also consists of a large number of innovative SMEs.

Major segments of Photonics production in the Netherlands are the following:

- Photonics for Industry is by far the largest segment and accounted for about 17% of the European Production in 2019. This comprises the production of lithography systems where ASML is the world leader and laser materials processing systems. There are also many SMEs working on sensing for industry and Machine Vision.
- Photonics for Healthcare is the second largest segment. This is due to Philips Medical and Canon Medical Systems but also a lot of SMEs active in this segment.
- Many companies are active in the Agri-food segment. However, its share in the Netherlands Photonics industry is still limited (around 5% of the total production). This is because players specializing in photonics for Agri-food are small enterprises.

5.5 Italy

Area (km ²)	301 339
Population (2019)	60 297 400
GDP (2019)*	2 151
GDP growth (2015–2019)*	4.3%
Industry (%GDP)	21.4%
Currency	EUR
Photonics production	
Europe (€ billion)	103
Italy (€ billion)	5.2
Share / Europe	5%
Employees	15 000

Main segment

In Italy major Photonics production segments include the following:

- Mobility
- Industry 4.0
- Environment, energy and lighting
- Healthcare and Wellness
- Defence and Security

Italy production summary

- With a 2019 production volume of €5.2 billion, Italy accounted for about 5% of European production.

Major sectors of Photonics production in Italy are the following:

- The largest segment is Photonics for Defence & Security: Leonardo combines major activities of the segment such as the former Selex ES and the former Galileo Avionica.
- Photonics for Industry: Laser machines and systems for imaging and optical measurement are produced by various companies. Datalogic produces barcode scanners and related equipment. The company is the third-largest manufacturer in that segment.
- Environment, energy and lighting: Italy hosts a large size lighting industry that produces LED-based lamps and modules.
- Mobility: Several companies have car headlight production plants in Italy, including Hella and Marelli Automotive Lighting.
- In Healthcare: Hoya and Essilor have some factories in Italy for the production of spectacle lenses and contact lenses. Moreover, many SMEs are producing medical imaging equipment.

* in constant 2010 US\$ billion

5.6 Switzerland

Area (km ²)	41 284
Population (2019)	8 574 830
GDP (2019)*	681
GDP growth (2015–2019)*	7.4%
Industry (%GDP)	25.6%
Currency	CHF
Photonics production	
Europe (€ billion)	103
Switzerland (€ billion)	4.4
Share / Europe	4%
Employees	12 000

Main segment

In Switzerland, major Photonics production segments are the following:

- Components and materials
- Industry 4.0
- Environment, energy and lighting
- Healthcare and Wellness

Switzerland production summary

- With a 2019 production volume of €4.4 billion, Switzerland accounted for about 4% of European production.

Major sectors of Photonics production in Switzerland include:

- Photonics for Industry: Several manufacturers of lasers and laser systems for materials processing produce in Switzerland. Bystronic and Germany headquartered Trumpf are the major producers.
- Optical components & materials: Manufacturers of optical components in Switzerland include Spectros AG, Fisba Optik, SwissOptic, and Schott. There are also a lot of SMEs like SUSS MicroOptics, ESPROS Photonics AG and Exalos.
- Consumers and Professionals: Logitech manufactures optical mice and webcams for video conferencing, recording or gaming but most of the production is located in China. Daetwyler Graphics produces Laser engraving equipment for the structuring of rollers (for printing processes).
- Photonics for Healthcare: Major manufacturers in Switzerland include Haag-Streit and Meridian Medical.
- Other sectors of Photonics in Switzerland include Environment, energy and lighting and optical communication. Manufacturers in Switzerland include Huber+Suhner, II-VI Laser Enterprise and Meyer Burger.

* in constant 2010 US\$ billion

6 Main data sources

European and global data

- 2019, French photonics assessment for 2018, Tematys.
- 2017, German, European and global production report – VDMA, Spectaris, ZVEI, BMBF.
- 2015, European Photonics Industry and market study. Report published by Photonics21.
- 2013, European ecosystem, EPIC and Tematys.

North America

- For the USA: Optical Society of America (OSA/OIDA) publishes annual review of US Photonics.
- For Canada: Canadian Photonic Industry Consortium (CPIC).
- SPIE recently publishes the “2020 optics and photonics industry report”.

United Kingdom

PLG (Photonics UK) – <https://photonicsuk.org> – Photonics Leadership Group collects and disseminates input from the whole UK photonics industry to guide government, support agencies, users and developers of photonics.

Japan

The Optoelectronics Industry and Technology Development Association (OITDA) of Japan publishes an annual report based on a production survey.

Korea

The Korea Association for Photonics Industry Development (KAPID) publishes an annual report.

Taiwan

The Photonics Industry & Technology Development Association (PIDA) of Taiwan publishes an annual production survey.

Others

Australian and New Zealand Optical Society (<https://optics.org.au>) recently published a report: “Photonics in Australia and New Zealand – Lighting Economic Growth – An Industry Review 2020”.

7 Appendix: Segmentation of photonics applications

Categories	Sub-categories	Products typology
0. Photonics – Core components and materials		
	Materials, Thin Films and Generic Components	Optical glass, filters, prisms, coatings, lens, electrochromic glass
	Sources	LEDs, laser chip, laser module
	Image sensors (CCD, CMOS, InGaAs...), detectors	Image sensors (CCD, CMOS, InGaAs...), detectors
	Production equipment	MBE, MOCVD, 2PP, Laser writing
	Assembly equipment	Pick & place
1. Mobility: automotive, maritime, railway, aeronautics		
	Imaging & sensors	LIDAR, Cameras, speed and distance optical sensors
	Lighting	Automotive lighting, others...
	Projectors, HUD & AR/VR	Screens and displays for Aerospace, Automotive, Motorcycle
2. Industry 4.0		
	In-line control and measurement	Process Spectroscopy, Gas sensing
		In-line measurement (shape, colour, size, defects ...)
	Machine vision	Cameras & visible-light imaging systems
		Barcode Scanners
		Non-conventional imaging systems
	Material processing, laser cleaning	Laser sources for cutting, welding, cleaning ...
		Lithography tools (for semiconductors)
		LED and laser-based 3D printers
3. Environment and energy (including lighting/building)		
	Lighting	Lighting
	Energy	PV Material, cells et pannels
		Thermal solar
	Control and Measurement (urban & domestic level)	Presence sensors, aerosol measurement, luminous flux, Measurement of BTEX, VOC, CO2 ...
4. Agriculture and Food		
	Imaging & Measurement	VIS Camera, RGB-NIR, Spectrometers, Cytometers, X-rays, THz
	Photonics based treatment	UV based, online, on-field

7 Appendix: segmentation of photonics applications

Categories	Sub-categories	Products typology
5. Health and Wellness		
	Medical Diagnosis	X-rays based (Computed Tomography)
		VIS-NIR based (slit lamp, aberrometer ...)
		Laser-based (OCT, Photoacoustics, Raman, 2 photons)
		Surgery Microscopes
		Endoscopes
		Digital Pathology Scanners
	Life science	In-vitro Diagnostics and imaging
	Medical treatment	Laser based (dermatology, urology, ophthalmology, gynecology ...)
		LED and fibre-based (PDT)
		UV based
		Lens-based ophthalmic correction (eyeglasses and contact lenses)
6. Telecommunication and quantum information		
	Telecom equipment	Telecom Devices (QC, Tx/Rx, TOSA...)
	Fibres	Fibres
	FSO (space et ground)	FSO
	LiFi	LiFi
	Telecom instrumentation	DWDM testor, OTDR, optical spectra analyzer ...
	Quantum Optics	OPU, Magneto-optical Trap
7. Defence & security		
	Imaging, measurements, countermeasures	Periscope, night vision, telemetry, tachymetry, laser vibrometry, countermeasures, CBRN measurements...
	Weapons	Laser weapons, THz & Microwave weapons
	CCTV and security lighting	Camera for security & video surveillance
8. Large instruments and space		
	Ground (ELI, ELT...)	Components and Systems
	Space	Components and Systems
9. Professionals and consumers		
	Home	Scanners
		Optical disk drives

Categories	Sub-categories	Products typology
		Optical mice
		Laser Printers and copiers
		3D printers
		Displays for TV, Laptop
		Fingerprint ID
	Mobile phone and device	Spectral sensors, range meters, cameras
		Displays for Smartphones
	Professional	Video camera, professional camera
		Binoculars
		Telescopic sights
		CCTV systems (design and manufacturing; the assemblers of purchase equipment are integrators)
	Education	Photonics equipment for education
	Entertainment & Leisure	Lasers and Lighting
		Urban Projection and urban large displays
10. Instrumentation and Optical Measurements		
	Distance	3D stereovision, LIDAR, ...
	Spectral measurements	FTIR, Raman, Spectros, Colorimetry, RGB NIR imaging, Hyperspectral imaging
	Distributed measurements	Fibre sensors (Bragg, DTS, Raman, Brillouin)
	Other	Other sensors
11. Services		
	Services specifically dedicated to the photonics industry and community	Optical design
		Marketing, finance, Communication, Human resources, business development
		Industrialisation consulting
12. Distributors & Resellers		
	Distribution	All brand distribution
		Local selling offices of foreign companies
13. Software		
		Optical design and simulation software
		Other modelisation software

