Market Research Study Photonics 2017

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Summary

The global market for Photonics products in 2015 accounted for EUR 447 billion. The market grew at a compound annual growth rate (CAGR) of 6.2% during the last four years (2011 – 2015). That growth rate is calculated on a euro basis. Currency effects had a strong impact on growth rates. On a US dollar basis the CAGR was only 0.3%. Expressed versus a basket of relevant currencies, such as the SDR (IMF special drawing rights), the market grew at a CAGR of 3.4%[1].

Exchange rate shifts also had an impact on market shares. Following the so called J-curve effect for market shares after the devaluation of a currency, the share of the European production in the world market was worth less immediately after the devaluation of the euro. Market share gains are expected to occur with a time delay when increased competitiveness translates into increased sales.

The production volume of the European Photonics industry accounted for EUR 69.2 billion in 2015, corresponding to a global market share of 15.5%[2]. Since 2011 the production volume of the European Photonics industry has grown from EUR 65.6 billion to EUR 69.2 billion, corresponding to a CAGR of 1.3%. These figures include the European photovoltaic industry which shrank by two third during the here assessed 2011 to 2015 period due to harsh price competition from China. Excluding photovoltaics, the 2015 European Photonics production volume accounted for EUR 66.6 billion, corresponding to a 17.0% share in the world market (EUR 391 billion). The production volume of the European Photonics industry without photovoltaics grew from EUR 57.1 billion in 2011 to EUR 66.6 billion in 2015, corresponding to a CAGR of 3.9%.

The European Photonics industry grew much stronger than industrial production in Europe in general. For the EU28 the overall industrial production nearly stagnated with a CAGR of only 0.1% from 2011 to 2015. The growth of the European Photonics production from 2011 to 2015 (CAGR of 3.9%) was less than the growth of the world market which grew at a CAGR of 6.7% on a euro basis (excluding photovoltaics). The lower growth rate can be attributed mainly to two reasons. Firstly, to the J-curve effect after the devaluation of the euro vs. a basket of relevant currencies. Secondly, China takes an increasing share of the global Photonics production, leading to market share losses for all other major producing countries. Another issue which weighed on the European market share is the less favourable overall economic trend in Europe as compared to many other regions. In spite of strong exports to outside Europe, the major part of the sales of the European Photonics industry is within Europe.

The European industry was exposed to the advance of Chinese Photonics activities in several segments of Photonics. The largest quantitative impact was in photovoltaics, where competition from China erased most of the European market share within a few years. Other areas with fierce competition and market share losses for the European Photonics industry are solid state lighting and optical communication. Also other segments such as laser materials processing are increasingly affected by market share gains of the Chinese Photonics industry.

[1] During the 2011 to 2015 period the euro depreciated by -20% versus the US dollar and by -10% versus the SDR.
[2] Share of Europe based production in the global market.

Summary

Photonics products are used in a wide range of sectors, similar to electronics products. The applications and products can be summarized in **ten segments**. In the first segment, **production technology**, which includes equipment for laser materials processing as well as lithographic manufacturing processes, Europe has an especially large footprint with 50% of all products worldwide originating from Europe. The products of that segment are used for industrial manufacturing. Also the products of the second segment, **optical measurement & image processing**, are mainly used in industrial manufacturing. In this segment Europe makes 35% of all products, worldwide. The two segments together account for a 2015 production volume in Europe of about EUR 25 billion corresponding to 36% of the European Photonics production. The third segment, Photonics based **medical technology & life science**, accounts for a European production volume of EUR 9.6 billion or 14% of the total European Photonics production. 28% of all products worldwide originate from Europe.

The products in the next three segments deal with, data transmission, input, output, storage, and display. The segment of optical **communication** or optical networking comprises a European production volume of EUR 4.1 billion or 6% of European Photonics. The global market share of the European production is 18%. The segment of Photonics based i**nformation technology**, mainly comprising consumer electronics and office automation products, accounts for a European production volume of EUR 2.4 billion, corresponding to about 3.5% of European Photonics and 3% of the global market. The segment of flat panel displays and **display** materials accounts for a European production volume of EUR 1.7 billion or about 2.5% of European Photonics. The share in the global market is about 1.5%. All together the three segments account for about 12% of the European Photonics production.

Lighting accounts for an European production volume of EUR 8.3 billion or 12% of European Photonics. The share of the European production in the global market is 25%. **Defence & security** Photonics makes up for a European production volume of EUR 7.9 billion or 11% of European Photonics, and for a share in the global market of 26%. Optical **components & systems** account for a production volume in Europe of EUR 7.8 billion or 11% of European Photonics and for a share of 32% in the global market. Finally, **Photovoltaics** makes up for 4% of European Photonics, after shrinking from revenues of EUR 8.5 billion in 2011 to only EUR 2.6 billion in 2015. Now, it only represents 5% of the global production versus 17% in 2011.

European companies are well represented in the global market, with market shares mostly between 25% and 50%. The only exception are the data-related segments (information, communication, display) where the European Photonics industry only holds a 4% share in the world market. The small share is due to a very small European footprint in the large segments of flat panel displays, consumer electronics and office automation products. Optical communication is the only data-related segment where the European industry with a global share of 18% has a major presence.

The small footprint of the European Photonics industry in the data-related segments also means that its focus is strongly different from the focus of the global Photonics industry. While in the world market data-related Photonics

(information, communication, display) dominates with a 47% share, that area of photonics only accounts for a 12% share of the European Photonics production. In Europe, manufacturing oriented Photonics products are the most important ones. They make up for a 36% share of total Photonics production. The European industry holds substantial market shares in laser materials processing and lithography (50% share of the world market) as well as in measurement and image processing (35%). Other important sectors of European Photonics comprise medical technology & life science (28% share of the world market), optical components and systems (32%), lighting (25%), and defence & security (26%). In photovoltaics the European market share was down to less than 5% in 2015, from 17% in 2011 and from 35% in 2005.

Since 2011 the European Photonics industry grew especially strong in its already large segments, where it also holds a large share in the global market. Strong growth was observed in the manufacturing oriented sectors of production technology (2011 to 2015 CAGR 4.9%) and measurement & image processing (5.7%). The growth in production technology is due to laser materials processing (10.8%) while the production volume in lithography sub-segment only grew slightly due to the delay of the EUV technology[3]. Also the production in medical technology & life science grew strongly (5.3%). The European production volume in lighting grew at a CAGR of 3.7%. European manufacturers increased their sales amidst the transition of the sector to solid state lighting. The weakening euro helped to achieve growth for the European lighting industry, while at the same time it also lead to market share losses. Defence & security (CAGR 3.0%) suffered from the stagnating defence spending of European governments. Growth in the segment of optical components & systems was only 1.2% (CAGR), down from 7.0% for the years 2005 to 2011. The decrease is due to slowing growth in major user segments, besides a partial production shift from Europe to Asia. In the remaining segments the European Photonics industry was successful in niches, such as for flat panel display materials and high end digital cameras. Here, the success is due to good positioning of single companies. In photovoltaics the European production volume shrank dramatically from 2011 to 2015 (CAGR of -26%).

By country, Germany is the largest producer of Photonics in Europe with a share of 41.3%. Germany is the major European producer in all Photonics segments except production technology, where the Netherlands lead, and defence & security, where the United Kingdom and France lead. The Netherlands with a share of 12.5% is the second largest Photonics producer in Europe. The country is home to the European company with the largest production volume, ASML. France follows in third place with a share of 11.6%, ahead of the United Kingdom with a share of 9.9% and Italy with a 8.3% share. The other EU28 countries account for a combined share of 12.8%. Switzerland accounts for a 3.6% share, while other non-EU countries in Europe combined only have a very small share.

During the last four years the market shares of the countries in Europe did not change markedly. While the German share suffered from its large exposure to photovoltaics, the losses in that segment were balanced by growth in other segments. Germany has a large footprint in the growing Photonics segments of production technology, measurement & image processing and medical technology & life science. Also, the comparably

[3] EUV (Extreme Ultra-Violet) is a technology for producing advanced integrated circuits.

favourable economic environment in Germany helped. In contrast to other major European economies, the overall industrial production increased in Germany during the last four years.

By the end of 2015 the European Photonics industry employed 301 000 people. The number represents the employees in the Photonics core sector within Europe[4]. The number of employees has increased from 248 000 in 2005 to 308 000 in 2011, and subsequently decreased to 301 000 due to the downturn in the European photovoltaics industry. The number of employees in the photovoltaics sector decreased by 26,000 from 2011 to 2015 due to the harsh competition by solar cell and module suppliers from Asia, mainly from China.

Excluding photovoltaics, the number of employees in European Photonics increased from 235,000 in 2005 to 272,000 in 2011 and to 290,000 in 2015. For the 2011 to 2015 period, this corresponds to a CAGR of 1.6%. For the same period, the revenues of European Photonics grew at a CAGR of 3.9%. The difference is due to two issues. First, productivity in the industry increased leading to larger revenues per employee. Second, companies increasingly employ people outside Europe in order to support sales and service overseas.

The European Photonics industry excluding photovoltaics added 18,000 new employees between 2011 and 1015. If the growth of employment proceeds until 2020 at the same annual rate another 24,000 employees will be added, and the total increase of the number of employees between 2011 and 2020 will reach 42,000.

The European Photonics industry comprises about 5,000 manufacturing companies. Most of these companies are SME. Less than 200 companies employ more than 250 people.

R&D spending by companies is substantial in Photonics in order to compete in the highly innovative industry sector. In average, European Photonics companies spend 9.8% of their revenues for R&D. In addition, they invest in average 4.7% of their revenues bringing the total R&D and investment quota to 14.5%.

The following product segments had an especially strong impact on the growth of the global Photonics market since 2011. Flat panel displays added the largest volume. Starting at a global 2011 market volume of EUR 82 billion it added EUR 36 billion to EUR 118 billion in 2015, growing at a CAGR of 9.6% on a euro basis. Production technology also contributed substantially to the growth of Photonics (6.4% CAGR), with strongly increased demand for laser materials processing systems (12.0% CAGR), while growth in the lithography segment was slowed by the delay of the EUV technology. The demand for laser materials processing systems is driven by the mainstream trend of industrial manufacturing to automation, flexible production, controllable quality, and miniaturization. Other product categories contributing substantially to global market growth were measurement & image processing (5.8% CAGR), medical technology and life science (7.2%), lighting (8.7%), and defence and security (7.8%). In the information technology segment, market growth for consumer products was slowed

[4] Only employees are counted who work in the area of Photonics in Europe (core industry). Not included are: persons working in Photonics companies but not in the area of Photonics, persons working for subcontractors, persons working for sales and service subsidiaries of companies without Photonics production in Europe, persons working for research institutes and consulting companies.

by decreasing demand for digital cameras, while the increasing demand for camera modules for smartphones helped to avoid a contraction of the market segment. Market growth for photovoltaics was slowed by the continued price decrease for solar cells and modules.

By the origin of products China now is the clear leader in Photonics, substantially ahead of Japan, Europe, North America, Korea, and Taiwan. By country of manufacturer headquarters Japan is still the global market leader.

China continued to be the winner of market shares in Photonics during the last four years. Its production share in the global market increased from 10% in 2005 to 21% in 2011 and to 27% in 2015. The success of the Chinese Photonics industry is based on five segments: photovoltaics, information technology, lighting, displays, and communication. The Chinese industry has captured market leadership in a short period of time. In photovoltaics it took only a few years for the Chinese industry from holding a minor market share to dominate the global market with a production share of more than 50%. In lighting the transition to solid state technology is used by the Chinese industry to substantially increase its market share. In the display segment locally owned companies increasingly build factories for state of the art products. One major driver is the large local customer base making information technology devices such as TV sets and smartphones. Today, still nearly half of the Photonics production in China can be attributed to companies headquartered outside China, but the market share of locally owned companies increases rapidly. While in information technology the large Chinese market share is mainly based on foreign companies producing in China, locally headquartered companies dominate in photovoltaics, communication, lighting, and this is also expected for displays in the near future.

The market shares taken by the Chinese industry have been lost mainly by Japan, but to a lesser extent also by all other major Photonics producing countries. For the European industry market share losses are severe in photovoltaics, communication and increasingly in lighting.

The Japanese industry has played a pioneering role in many segments of Photonics, especially for information technology and displays. Nearly half of the Photonics production of Japan headquartered companies is located outside Japan, mainly in China. The share of overseas production for the Japanese Photonics industry has been about the same during the last four years as production shifts were implemented earlier.

Ten years ago Japan was the major producer of Photonics, with a global market share of 34%, not including overseas production of the Japanese industry. In 2011 that share had sunk to 21%, with production shifts in information technology to neighbouring countries being a major reason for the decrease. In 2015 the market share of Japanese domestic production was only about 15%. Including overseas production the 2011 market share of the Japanese industry in Photonics was about 40%. In 2015 that share was only about 30%.

1. Global Photonics Market and Production

1.1 Overview – Market Size and Market Growth

The global market for Photonics products accounted for a volume of EUR 445 billion in 2015. The market has grown substantially during the last ten years, at an average annual growth rate (CAGR) of 6.9%. Since 2011, the market has grown at a CAGR of 6.2% in euros.

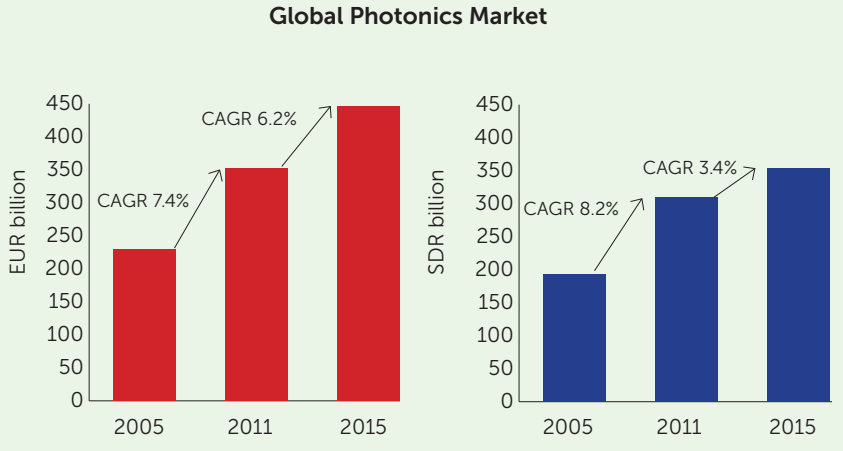


Diagram 1: Global Photonics Market

Source: Optech Consulting

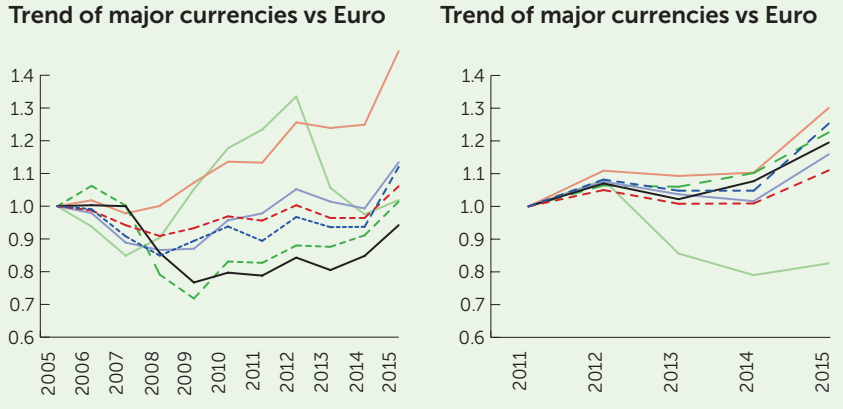


Diagram 2: Trend of Exchange Rates of Currencies of Major Photonics Producing Countries

Source: Optech Consulting

Due to a vigorous currency shift the 2011 to 2015 CAGR was only 0.3% in US-dollars. In order to eliminate currency effects as far as possible we have calculated the market growth in an appropriate basket currency. The special drawing rights (SDR) of the IMF serves as such a basket currency as it combines a weighted selection of major currencies. On an SDR basis, the global Photonics market has grown at a CAGR of 3.4% from 2011 to 2015.

1.2 Market by Product Segment

1.2.1 Overview

The global market for Photonics, totalling EUR 447 billion in 2015, breaks out into its segments as follows. Photonics products used in industrial manufacturing account for EUR 59.3 billion or 13% of the total Photonics market. This includes **production technology** products (laser systems and lasers for materials processing and lithography) valued at EUR 26.1 billion and optical **measurement & image processing** products valued at EUR 33.2 billion.

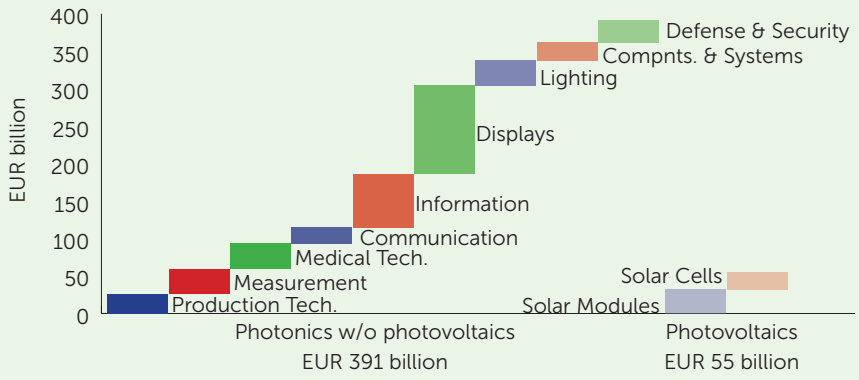


Diagram 3: Global Photonics Market by Segment, 2015

Source: Optech Consulting

Data Sources on Global and European Photonics Production

The Optoelectronics Industry and Technology Development Association (OITDA) of Japan publishes an annual production survey [1].

The Photonics Industry & Technology Development Association (PIDA) of Taiwan publishes an annual production survey [2].

Optech Consulting has covered European and global Photonics production in a series of reports:

– 2007, German production, global production [3]. Report for the German Bundesministerium für Bildung und Forschung (BMBF).

– 2007, European production [4]. Report published by Photonics21.

– 2010, German production, global production [5]. Report for BMBF.

– 2013, German production, European production, global production [6]. Report for VDMA, Spectaris, ZVEI, BMBF.

– 2008, 2009, 2011, 2012, 2013, 2014, 2016, Swiss production [7]. Reports for Swissphotonics.

Other reports consulted for the analysis on Europe include:

– 2014, French production, Tematys [10]

– 2013, European production, EPIC and Tematys [12]

Regarding North America only production data on components is available, for the USA by the Optical Society of America (OSA, OIDA) [8] and for Canada by Photonscanada – the Canadian Photonic Industry Consortium (CPIC) [9].

Photonics products used to transmit, store, acquire, and display information account for EUR 210.6 or 47% of the total Photonics market. This includes flat **panel displays** (EUR 117.6 billion), information technology products such as consumer electronics and office automation devices (EUR 71.0 billion), as well as products for optical **communication** (EUR 22.0 billion).

Another EUR 55.1 billion (12%) is due to **photovoltaics**. The balance of 28% of the Photonics market is accounted for by products for **medical technology & life science** (8%), **lighting** (8%), **defence & security** (7%), as well as **optical components** & systems (5%).

The table below provides an overview of the major products for each of the ten Photonics segments. Products include systems and components. In addition, selected materials for Photonic products have been included (optical glass, display glass, liquid crystals and OLED materials) as well as important subassemblies such as camera modules.

From 2011 to 2015 the market grew at a CAGR of 6.2%. The market for Photonic products used in industrial manufacturing increased at a CAGR of 6.1%, comprising **production technology** (CAGR 6.4%) and **measurement & image processing** (5.8%). Growth in production technology was especially driven by lasers and systems for materials processing (12.0%) while the lithography sub-segment only grew at a CAGR of 1.3%.

Table 1: Segments and Products of Photonics

Production Technology
Laser Materials Processing Systems
Lithography Systems (IC, FPD, Mask)
Laser for Production Technology
Objective Lenses for Wafer Steppers

Open Measurement & Machine Vision
Machine Vision Systems and Components
Spectrometers and Spectrometer Modules
Binary Sensors
Meas. Systems for Semiconductor Industry
Meas. Systems for Optical Communications
Meas. Systems for Other Applications

Medical Technology & Life Science
Lens for Eyeglasses and Contact Lenses
Laser Systems for Medical Therapy and Aesthetics
Endoscope Systems
Microscopes
Medical Imaging Systems (Photonics-Based)
Ophthalmic and other in Vivo-Diagnostic Systems
Systems for In-Vitro-Diagnostics, Pharmac & Biotech R&D

Information Technology
Consumer Electronics, Office Automation, Printing
Digital Cameras, Scanners
Optical Disk Drives
Optical Printers & Copiers, MFPs, PODs
Barcode Scanners
Systems for Commercial Printing
Lasers for IT Systems
Camera Modules
Image Sensors

Optical Communications
Optical Networking Systems
Components for Optical Networking Systems

Flat Panel Displays
LCD Displays
Plasma Displays
OLEDs and other Displays
Display Glass and Liquid Crystals

Lighting
Lamps
LED Lamps
OLEDs
Drivers, integrated lamps, light engines

Defence Photonics
Vision and Imaging Systems
Infrared and Night Vision Systems
Military Surveillance Systems
Ranging Systems
Guiding Systems
Avionics Displays
Image Sensors
Laser for Defence Systems

Optical Systems and Components
Optical Components and Optical Glass
Optical Systems
Optical & OE Systems & Components not elsewhere classified

Photovoltaics
Solar Cells
Solar Modules

Source: Optech Consulting

Changes of the Range of Products Included Versus Previous Reports

Compared to previous reports edited by Optech Consulting [3, 4, 5, 6] we have slightly modified the range of products included in the present report. The impact of the changes on previous data years is in the range of only 1% of the total. We would like to specifically note two changes: (i) In the information technology segment camera modules were introduced as a new product in order to account for the market shift from digital cameras to smartphones. (ii) In the communication segment optical fibres were included on a request from industry. In order to keep growth rates consistent the changes were also made for the data for the years 2005 and 2011.

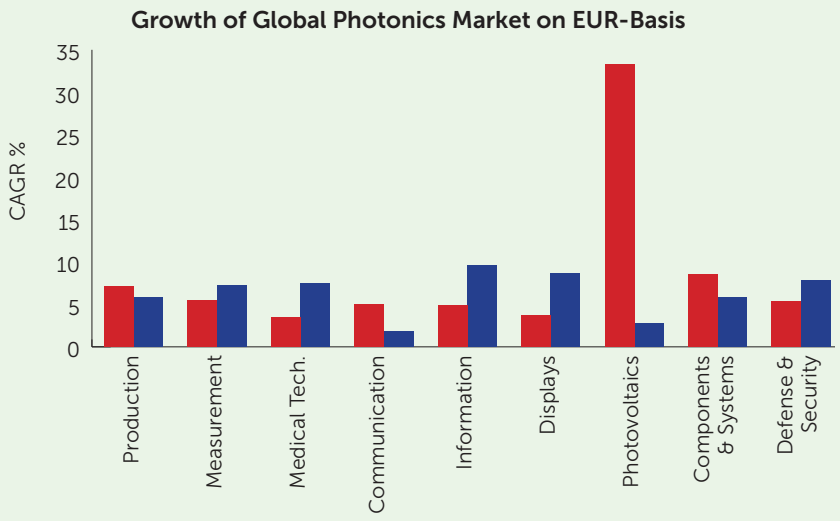


Diagram 4: Growth of Global Photonics Market on EUR-Basis

Source: Optech Consulting

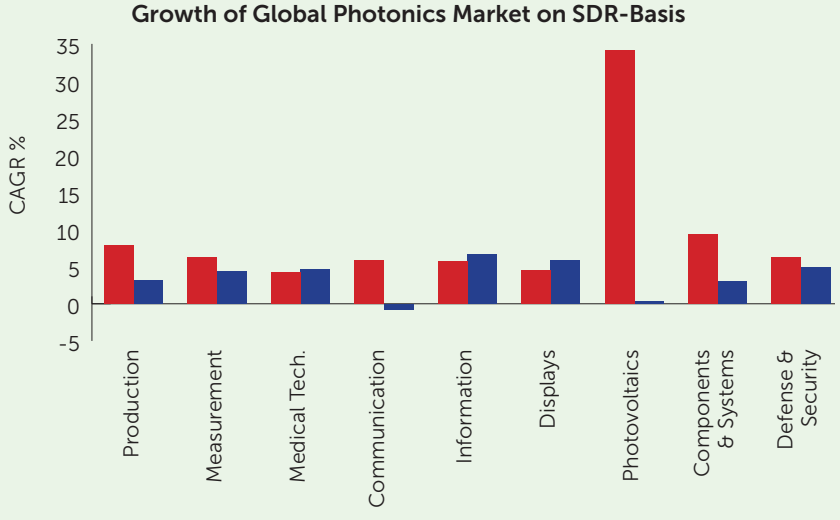


Diagram 5: Growth of Global Photonics Market on SDR-Basis

Source: Optech Consulting

The market for data-related Photonics products (information, communication, display) has increased at a CAGR of 6.4% from 2011 to 2015, especially driven by strong demand in the flat **panel displays** segment (9.6%), followed by optical **communication** products (7.5%) and **information technology** products (1.8%).

The **photovoltaics** market has increased from 2011 to 2015 at a CAGR of 3.0%. The market for Photonics products in all other segments combined has increased as follows: lighting (8.7%), components & systems (5.8), defence & security (7.8%). For details please see the following paragraphs.

It is important to note that these growth rates are for the market in euros. Especially for markets where the demand and the supply market both are to a large extent located outside Europe, such as e.g. for displays, the euro measured growth rates tend to overestimate the increase of the market for the 2011 to 2015 period.

1.2.2 Production Technology

Photonics based production technology comprises equipment used in industrial manufacturing. This includes on the one hand lasers and laser systems for materials processing. On the other hand it comprises systems for lithography, a major manufacturing process for semiconductors, printed circuit boards, and flat panel displays. On the component side we also include lasers (for laser based lithography systems) and the projection optics for microlithography.

The total size of the market in 2015 is EUR 26.1 billion, where the laser materials processing sub-segment is slightly larger than the lithography sub-segment. That ratio has reversed since 2011, when lithography accounted for a larger share. While laser materials processing grew at a CAGR of 12.0%, lithography only grew at a CAGR of 1.3%. The small growth rate for lithography is caused by the delay of EUV technology for the production of advanced integrated circuits.

In laser materials processing Europe is the major producer of lasers and systems. The laser system manufacturers in Europe are to a very large extent locally owned companies. For lasers for materials processing North America headquartered have continued to buy European laser manufacturers. This has lead to a meanwhile substantial share of the European industrial laser production being owned by North American companies.

Another trend in laser materials processing is the increasing market share of Chinese manufacturers of laser systems and increasingly also of lasers. The end markets for laser materials processing systems, such as the consumer electronics and the automotive industry, are shifting to China, and so does with time delay the manufacturing of laser systems used in these industries. Chinese suppliers of lasers and laser systems for materials processing so far mainly serve the local market. This may change quickly as we have seen in several other sectors of Photonics.

In lithography, ASML from the Netherlands is the major producer, worldwide. Its revenue of EUR 6.3 billion corresponds to nearly 10% of the European

production volume in Photonics. The company is the clear market leader in microlithography, while Japanese companies dominate the market for lithography systems for displays manufacturing.

1.2.3 Measurement & Image Processing

The total market volume of Photonics based measurement & image processing in 2015 was EUR 33.2 billion, up from EUR 26.5 billion in 2011, corresponding to a CAGR of 6.0%.

The sub-segment of optical measurement includes a large variety of systems and components, mainly for industrial applications. The global market volume in 2015 accounts for EUR 23.3 billion. The major products in terms of market volume are photonic sensors (binary sensors), spectrometers, semiconductor measurement systems, and geometrical measuring systems. Other optical measurement systems are used in the fibre optic industry, for geospatial and construction applications, for oil and gas exploration, the measurement of dynamic parameters, characterization of particles, environmental parameters, and many more applications. Market growth during the last four years was supported by many sub-segments, including binary sensors, spectrometers, fibre-optic measurement systems, while market growth for measurement systems for the semiconductor industry lagged behind.

The sub-segment of image processing, with a global market volume of EUR 9.9 billion in 2015, comprises systems and the associated components (including software). The majority of image processing systems is used in industrial production versus non-industrial applications. Today, the most important user industries are the semiconductor industry, the electronics industry and the flat panel display industry. The most important tasks of image processing systems in industrial manufacturing are production monitoring and control as well as quality assurance. An increasing market share is expected in the future for non-industrial applications, especially for security, medical technology and consumer-related applications.

1.2.4 Medical Technology & Life Science

Medical technology 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 lenses 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 systems, microscopes and surgical microscopes, capillary electrophoresis systems, DNA sequencers, cell sorters, plate and array readers. Further we include monitors for diagnostic purposes and for the surgery room.

Not included are non-photonic medical imaging systems such as analog X-ray, NMR and ultrasound systems. Also pulse oximetry systems are not included as their photonic content is small.

The total market volume of the segment in 2015 was EUR 33.8 billion, up from EUR 25.6 billion in 2011, corresponding to a CAGR of 7.2%. Product segments with strong growth (10% and more on a euro basis) are endoscope systems, therapeutic laser systems, and analytical systems for the pharmaceutical and biotechnology industry. Moderate growth was observed for vision correction products and microscopes.

Production in Europe accounts for EUR 9.6 billion, corresponding to 28% of the global market, ahead of North America with a 27% share, and Japan with a 22% share. Segments with strong European market shares include microscopes, endoscopes, and ophthalmic products.

1.2.5 Communication

Optical networking employs light for the transmission of data in the long range (wide area networks) and in 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 increasingly Ethernet is used vs. SDH/SONET. Industrial networks (wide area and local area networks, including data centre networks) increasingly use optical ethernet. In the short range also application specific networks are used. Data centre networks account for an increasing share and are considered to offer substantial growth potential.

Systems and components include multiplexer/de-multiplexers, switches, optical amplifiers, transceivers, lasers, LEDs, detectors, splitters, connectors, as well as other passive optical components. Also optical fibres are included as optical components. We do not include fibre cables as Photonic products.

Optical networking systems and components account for a 5% share in Photonics. The market has trended marginally positive during the last four years on a US dollar basis, which corresponds to a 2011 to 2015 CAGR of 7.5% on a euro basis. Growth drivers were components for local area networks and data centre applications. In China, the telecommunication segment grows. While bandwidth demand increases continuously in the telecommunication segment this is not enough to increase the market as technological progress often allows increasing bandwidth at stagnating cost. However, new applications in local area networks and especially data centres presently drive the market.

On the supply side, China is the largest supplier, followed by North America Europe, Japan, Korea and Taiwan. The market is subject to fierce competition. Companies headquartered in China have carved out an increasing share of the market. The competition is also a driver of the restructuring in the industry, which has lead to mergers and divestments in Europe.

1.2.6 Information Technology

Information technology products, including consumer electronics and office automation, account for a market volume of EUR 71.0 billion in 2015, corresponding to a share of 16% of Photonics. Market growth for the last four years was negative in US dollars, translating into a slightly positive trend in euros (2011 – 2015 CAGR of 1.8%).

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 such as in cars[5].

The market has been decreasing during the last four years, dragged down by strongly decreasing demand for digital cameras and nearly saturated markets for office automation products. In contrast, the market for camera modules and their components increased due to surging demand for smartphones, tablet PCs and automotive applications.

For this report we had to decide whether to include smartphones as Photonics devices. Displays and camera modules are key enabling components for smartphones and also make up for a substantial part of their value. The smartphone market accounts for a volume of about USD 400 million in 2015, i.e. it has the same order of magnitude as the Photonics market. However, including smartphones as Photonics products would change the definition of Photonics and its limits substantially. Therefore, we only include the displays and the camera modules as Photonics devices.

1.2.7 Displays

Displays, or more precisely flat panel displays[6], 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. We also do not include projectors for typical monitor and TV applications. However, we do include cinema projectors and monitors for medical purposes, these, however, in the segments of optical components & systems (projectors) and medical technology & life science (monitors). In the display segment we also include display materials (display glass, liquid crystals and OLED materials). In contrast to some statistics in Asia we do not include components such as colour filters, and we do not include display manufacturing equipment (unless the equipment is optics based such as systems for lithography and annealing).

Flat panel displays and display materials account for a 2015 market volume of EUR 117.6 billion or 26% of Photonics. During the last four years the market has grown by a CAGR of 3.6% on a US dollar basis, translating into a CAGR of 9.6% on a euro basis.

Market growth in the last four years was driven by high resolution displays and touch-panel displays for portable devices, including LCD and OLED based products. In contrast, large size TFT-LCD panel shipments for TV sets, PC monitors and notebooks decreased.

[5] For simplification reasons we include all image sensors and camera modules in the information technology segment, which is the major application segment. However, infrared sensors and infrared cameras are included in the defence & security segment.

[6] Cathode ray tubes are not included in this report.

Between 2011 to 2015 flat panel display production of Korean manufacturers grew slightly on a USD basis, while the production by Taiwanese manufacturers decreased. The display production of Japanese manufacturers increased strongly on a local currency basis, with most of the increase taking place outside Japan. On a US dollar basis, the production growth for Japanese manufacturers was negative. Display production in China grew substantially due to new factories becoming operational. Besides new production plants built by Japanese, Taiwanese and Korean manufacturers this includes an increasing number of locally owned factories. These are now setting up factories using current generation technology for producing high-end displays. Please see the paragraphs on the single Counties for more information.

As most of the end-products such as consumer electronics products are made in Asia, the lion's share of the market for flat display panels is in Asia. The market in Europe is due to manufacturing of specialized displays (industrial, medical, automotive, etc.) as well as due assembly plants of Asian consumer electronics manufacturers.

1.2.8 Lighting

The global market in the lighting segment accounted for a 2015 volume of EUR 33.4 billion, corresponding to 5.5% of the Photonics market. For the last four years the global lighting market has grown at a US dollar based CAGR of 2.7%, translating into a euro based growth rate of 8.7%.

In the lighting segment we include all types of lamps (incandescent, halogen, fluorescent, discharge, LED) for all applications (general lighting, automotive lighting, LCD backlighting, signalling applications[7]). We also include ballasts (drivers). LED chips are included as separate products. We do not include light control units and luminaires.

The global market (EUR 33.4 billion; USD 37 billion) breaks out as follows:
– LED chips: USD 4 billion
– LED packaging: USD 15 billion
– Other lamps: USD 13 billion
– Ballasts/drivers: USD 5 billion

The total lighting market, including the above mentioned products as well as luminaires and light control units is estimated at EUR 115 billion. It should be noted that this includes all types of luminaires for consumer lighting and professional lighting. Consumer luminaires include chandeliers, wall, ceiling, floor, and table standing lamps. Professional light control units and luminaires comprise a wide range of products used for such different application as for example office lighting and airport lighting.

The lighting market is presently characterized by the transition from incandescent and fluorescent lamps to LED based "solid state" lamps. Years ago, LED lamps first penetrated the market for mobile devices and display backlighting, followed by a range of applications from automotive to general lighting. At present, market growth for LEDs is mainly driven by general lighting applications.

[7] For simplification reasons we also include infrared LEDs such as for remote control.

The lighting market has a long history of continued growth (only interrupted during economic recession periods). During the last four years, besides the LED lamp market also the market for fluorescent lamps (energy saving lamps) and halogen lamps (automotive applications) increased. Many experts expect a shrinking lamp market (all types combined) in a few years due to the increased lifetime of LED lamps versus conventional lamps which is expected to result in a decreased replacement market. However, it has to be seen if the new lighting technologies create enough of an additional market in order to compensate for the shrinking replacement demand.

On the supply side, Asian manufacturers employ the transition to solid state lighting for gaining market shares. This is especially true for manufacturers in China, where massive government programs help companies to set up factories. In spite of these developments European manufacturers succeeded to grow their production during the last four years, although at somewhat lower growth rates than observed for the global market.

1.2.9 Defence & Security

According to SIPRI (Stockholm International Peace Research Institute) defence expenditures for many countries decreased since 2011 on a US dollar basis. For the USA, which accounts for roughly half of the global defence spending, expenditures decreased from USD 711 billion to USD 596 billion, for Japan from USD 61 billion to USD 41 billion, and for Western Europe from USD 393 billion to USD 328 billion. When translated into euros, expenditures in the USA and in Europe roughly stagnated, and expenditures in Japan fell by nearly 20%. In contrast, expenditures in China increased from USD 138 billion to USD 215 billion, translating into a nearly 90% increase in euros.

We estimate the market for Photonics based defence & security components and systems for 2015 at EUR 30.2 billion, up from EUR 22.4 billion for 2011. This corresponds to a CAGR of 7.8% on euro basis, and of 1.8% on a US dollar basis. The estimate is based on information retrieved financial reports of major producers. The market continued to increase in spite of the stagnating defence spending. This is due to the increased role of Photonics products in the sector.

Components and systems for vision and infrared vision account for about 40% of the of the total spending in 2015. This includes optical and optoelectronic systems as well as components (sensors, image sensors, infrared optics and components, lasers for illumination, etc.). Defence is by far the largest end market, but also the homeland and civil security market contribute 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 for security applications. Other products comprise range finding and lidar systems, missile and munition guidance systems, countermeasure systems, and fibre-optic communication systems for aircraft and military vehicles.

1.2.8 Optical Components & Systems

Optical components & systems account for a global market of EUR 24.1 billion. Of these EUR 12.1 billion are for components, and EUR 12.0 billion are for systems. The 2011 to 2015 CAGR on a euro basis is 5.8%, while on a US dollar basis the CAGR is slightly negative at -0.1%. In recent years a major driver of the market was the demand for optical components for consumer electronics which are mainly manufactured in Asia. The market in North America also showed solid growth, while the European market only showed moderate growth at a CAGR of 1.2%.

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[8]. High performance optics is used in applications such as astronomy and inertial fusion experiments.

In addition, we include in the present segment all optoelectronic components not elsewhere classified. For example, while lasers for materials processing are included in the segment of production technology, we include small and fragmented laser markets such as for measurement and research in the present segment.

Many optical components and modules are being integrated into products of other segments of Photonics and thus benefit from growth there. The largest end market for optical components is consumer electronics with mass products such as digital cameras and devices using camera modules. Increasingly also cars are equipped with cameras for driver assistance and safety.

Optical systems include objectives as well as classical optical systems such as telescopes, binoculars, and professional photo and video equipment. In addition, we include in the segment optoelectronic systems not elsewhere classified such as equipment for research laboratories.

1.2.8 Photovoltaics

The photovoltaics market reached an all time high in 2015 regarding the amount of solar cells and modules produced. The total power of the modules produced reached 55 GW[9]. From that number we calculate a total value of the modules of EUR 32 billion and a total value of the cells of EUR 23 billion.

Market for solar cells and modules

In previous assessments of the photovoltaics market we have added the market of solar cells (component) to the value of the market for the modules. This reflected the structure of the industry, with a large share of solar cells being sold in the open market to module manufacturers, as well as the employment in both sub-segments. For reasons of continuity we use the same methodology for 2015. Note, however, that adding the values of cells and modules leads to a total photovoltaics market that is considerably larger than the module market alone.

[8] Optical components for vision correction are included in the medical technology & life science segment.

[9] Estimates range from 45 GW to nearly 60 GW, with more recent estimates being on the upper limit of the range.

The reference year 2011 was characterized by an intermediate peak of the photovoltaics market in terms of value. While the module production only accounted for about 28 GW the average price was as high as EUR 1.0/ Watt (USD 1.4/Watt). This leads to an added cell and module market of EUR 49 billion.

From 2011 to 2015 the market for cells and modules grew at a CAGR of 3.0% on a euro basis, corresponding to a negative CAGR of -2.7% on a US dollar basis. The market development since 2011 was characterized by drastic price cuts for solar cells and modules driven by manufacturers in China. The harsh price decrease drove most of the manufacturers in Europe out of business. In the meantime, also major Chinese manufacturers, including some with multibillion US dollars of annual revenues, had to file for bankruptcy. At present some of the major manufacturers work profitably, while others still report heavy losses in their financial reports.

The demand market has shifted from Europe to Asia. In 2011, Europe absorbed more than 60% of the new solar module installations, with Germany accounting for about half of these installations. In 2015, Europe absorbed only about 13% of the new installations, while China alone absorbed about 29%, Japan 22%, and North America 14%.

By technology, poly-silicon based modules clearly dominate with a 70% share, while mono-crystalline based modules account for a good 20%. Estimates for the share of thin film modules are in the range of 5% to 8%.

1.3 Production by Country

1.3.1 Overview

Photonics production is mainly located in Asia. Nearly 70% are accounted for by China, Japan, Korea, Taiwan, and a few other Asian countries including the Philippines, Malaysia, Singapore, Thailand and India. Europe and North America account for 15.5% and 13.6%, respectively. Other Photonics producing countries include Israel, Turkey, Australia, South Africa, and Brazil.

China is the leading producer with a share of 26.5%, far ahead of Japan (15.4%), Europe (15.4%), North America (13.6%), Korea (12.5%), and Taiwan (10.6%). At present, Europe is the second largest producer in Photonics, about level with Japan. These production shares are valid for the market by origin of product. The production shares are very different when the country of company headquarter is used to allocate revenues. Then, Japan clearly is the leading producer with a share of nearly 30%. Nearly half of the Photonics production of Japan headquartered companies is located outside Japan, mainly in China.

By country of company headquarters, Chinese companies account for a global market share in the range of 14%, about level with Europe and North America. Nearly half of the Photonics production in China can be attributed to companies headquartered outside China, mainly to companies headquartered in Japan.

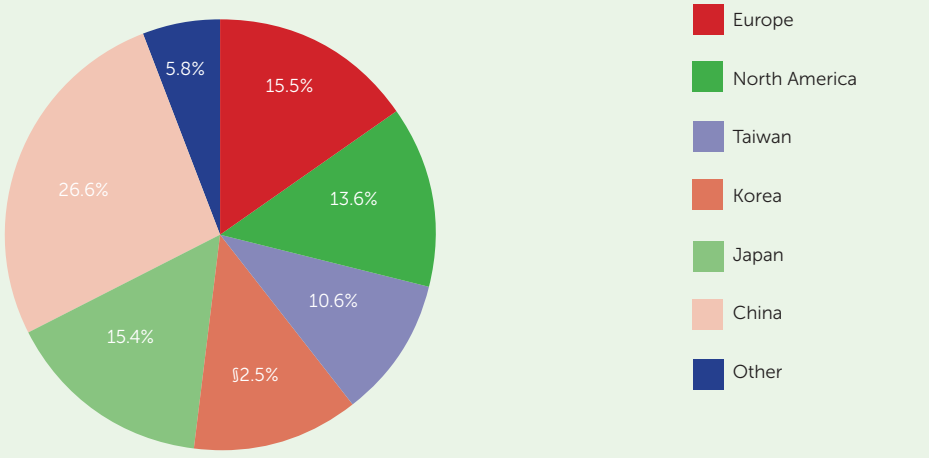


Diagram 6: Global Photonics Market by County, 2015

Source: Optech Consulting

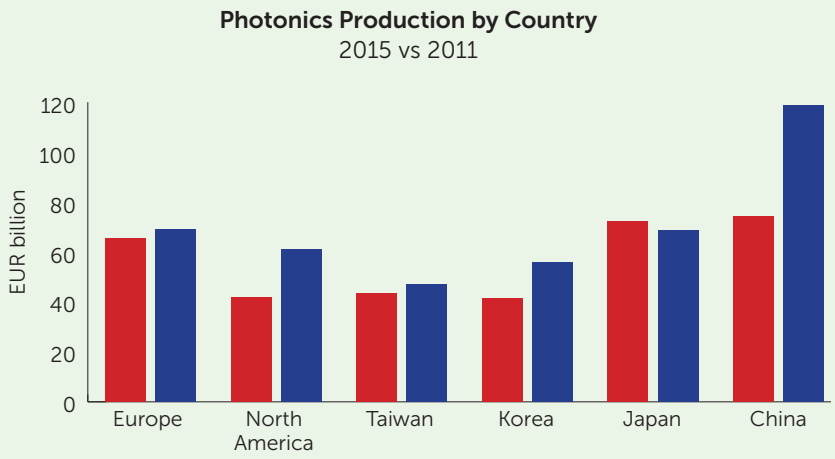


Diagram 7: Photonics Production by Country, 2015 vs. 2011

Source: Optech Consulting

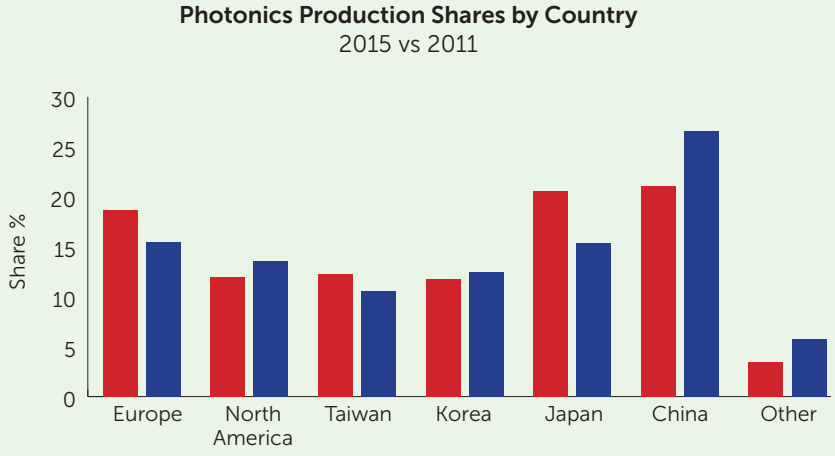


Diagram 8: Photonics Production Market Shares by Country, 2015 vs. 2011

Source: Optech Consulting

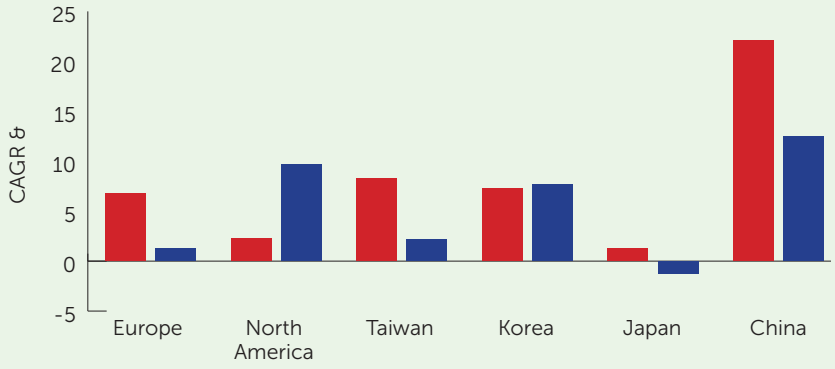


Diagram 9: Growth Rates for Photonics Production by Country

Source: Optech Consulting

The market shares of the Photonics producing countries have changed substantially during the last four years. While China gained market share, Japan, Europe, and Taiwan lost share. Europe lost market share during the last four years mainly due to three reasons; (i) the increased competition from China, (ii) the decrease of the value of the euro versus the currencies of most of the other Photonics producing countries (except Japan), (iii) the comparably low economic growth rate in Europe versus other regions. market share losses of Europe to China mainly concern photovoltaics, but also communication and lighting. Minor market share losses to China are also observed in production technology and for optical components.

Growth rates for production were strongly different for the regions and countries. The European Photonics production grew from 2011 to 2015 at a CAGR of 1.3%. Excluding photovoltaics the Photonics production grew from 2011 to 2015 at a CAGR of 3.9%. For details please see the further discussion in the paragraph on European Photonics.

Photonics production in China showed continued double-digit growth with a 2005 to 2011 CAGR of 22.1% and a 2011 to 2015 CAGR of 12.5%. The growth rate decreased in recent years due the moderate growth in the photovoltaics segment which has considerable weight in the overall Chinese Photonics production. Without photovoltaics, the CAGR for the Chinese photonics production was 14.3% for the 2005 to 2011 period, and 16.0% for the 2011 to 2015 period.

North America showed the second largest CAGR of 9.7% on a euro basis for the 2011 to 2015 period. It should be noted that on a US dollar basis the CAGR for North America was only 3.7%, somewhat less than for the 2005 to 2011 period (4.2%).

The euro based 2011 to 2015 CAGR of 7.7% for the Korean Photonics production corresponds to 1.5% in Korean won. The value of the Korean won increased by 27% vs. the euro from 2011 to 2015. The only moderate growth

rate in local currency is mainly due to modest production growth in the display segment, which dominates Korea production.

The 2.2% CAGR in euros for 2011 to 2015 for the Photonics production in Taiwan corresponds to a negative -1.1% CAGR in Taiwan dollars. The value of the Taiwanese currency increased by 14% vs. the euro from 2011 to 2015. The negative growth rate in local currency is mainly due to a decrease of production in the display segment.

The Japanese production volume decreased in euros at a 2011 to 2015 CAGR of -1.3%. Currency effects also played a major role, as the value of the Japanese yen decreased vs. the euro by a total 17% from 2011 to 2015. In local currency the domestic photonics production in Japan increased at a CAGR of 3.2% from 2011 to 2015.

1.3.3 China

Photonics production in China accounted for EUR 118 billion (USD 130 billion) in 2015. In US dollars the production volume increased from 2005 to 2011 at a CAGR of 24.5%, and from 2011 to 2015 at a CAGR of 6.3%. In euros the production volume increased from 2005 to 2011 at a CAGR of 22.1%, and from 2011 to 2015 at a CAGR of 12.4%.

Exchange rates

Market data for China is often reported in US dollars. From 2011 to 2015 the Chinese yuan (CNY) appreciated moderately by an accumulated 3.8% vs. the US dollar. Between 2005 and 2011 the Chinese yuan appreciated by an accumulated 26.7% vs. the US dollar.

Vs the euro the Chinese currency appreciated by 30.4% from 2011 to 2015, after appreciating by 11.0% from 2005 to 2011. The EUR/CNY exchange rate was 6.9 in 2015 vs. 9.0 in 2011.

Interestingly, the growth rate decreased in the last four years mainly due the photovoltaics segment. The harsh price decrease initiated by producers in China fell back on those as market expansion was limited and market shares were already high. While the photovoltaics segment had strongly supported growth of Photonics production in China from 2005 to 2011 period, it dragged down the growth rate between 2011 and 2015. Without photovoltaics the CAGR for the Chinese Photonics production was 14.3% for the 2005 to 2011 period, and 15.3% for the 2011 to 2015 period.

China continued to gain market share in Photonics during 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 to nearly 27% in 2015. Based on the actual production location China now is the clear leader in the Photonics industry, substantially ahead of Japan, Europe, North America, Korea, and Taiwan.

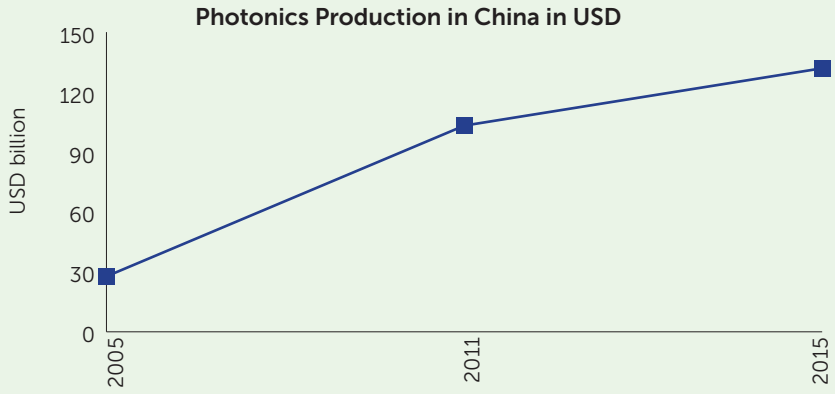


Diagram 10: Photonics Production in China in US Dollar

Source: Optech Consulting

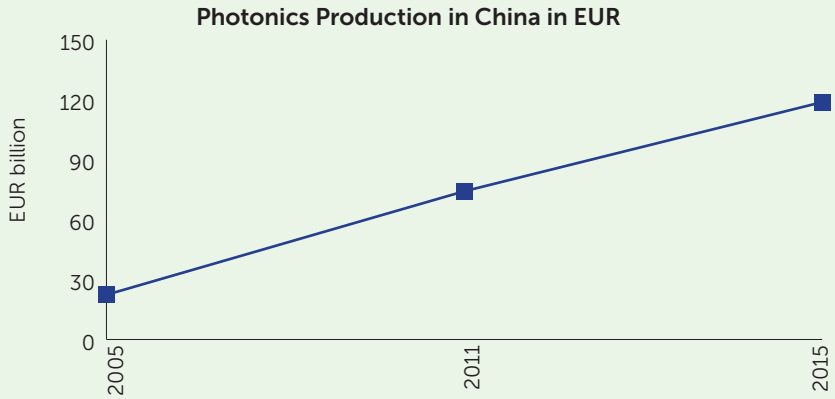


Diagram 11: Photonics Production in China in EUR

Source: Optech Consulting

Photonics production in China comprises three major segments with an annual production volume of more than EUR 20 billion: photovoltaics, displays, and information technology. In photovoltaics the Chinese share in the global market exceeds 50%, in information technology it exceeds 40%. In photovoltaics the large majority of the production plants are locally owned. The Chinese photovoltaics companies have dramatically gained market share since 2011 due to very aggressive product pricing. For displays the share of the production in China in the global market exceeds 20% and is growing rapidly due to new factories being built. This is partly due to locally owned new production plants (BOE, China Star), and partly due to factories being built by display manufacturers headquartered in Japan, Taiwan, and Korea. In information technology the Chinese industry is mostly foreign owned. Note that for Photonics based information technology the global market as well as the production in China decreased from 2011 to 2015 on a US dollar basis. The decrease is due to the decreasing market for digital cameras and optical disk drives as well as the nearly saturated optical printer market.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0				*Information	*Photovoltaics (share >50%)
30.0 ... 39.9		*Communication	*Lighting		
20.0 ... 29.9				*Displays	
10.0 ... 19.9	*Medical Tech *Compon. & Systs				
5.0 ... 9.9	*Production Tech *Measurement *Defence				
0.0 ... 4.9					
	2015 Production in EUR billion				

Diagram 12: Photonics Production in China and Global Market Share Source: Optech Consulting

Note: The production volume in photovoltaics is calculated as the sum of solar cell (components) and solar module production (see paragraph 1.2.8).

Nearly half of the Photonics production in China can be attributed to production plants of companies headquartered outside China, mainly in Japan, but also in Taiwan, Korea, North America, and Europe. However, the production share of locally owned companies has increased steadily. Locally owned manufacturing is especially important in photovoltaics, optical communication, solid state lighting, and flat panel displays, besides security & defence. Locally owned manufacturing also accounts for a rapidly increasing share in laser materials processing.

In the lighting segment Chinese companies are rapidly gaining market shares. Investments in production facilities are heavily supported by the government. In optical communication, a segment with a smaller overall size, Chinese companies have steadily increased their market share during the last ten years. In the production technology segment Chinese companies have gained market share in the area of laser materials processing systems, where they benefit from the rapidly increasing base of industrial manufacturing in China, and especially from manufacturing in the consumer electronics and automotive industry.

1.3.4 Japan

The domestic production volume reported by the Japanese Optoelectronics Industry and Technology Development Association (OITDA) accounts for JPY 8.6 trillion for 2015 (see text box). The production figures reported by OITDA are based on a product range which is different from the product range used in the present report. In the present report the product range has been chosen to represent Photonics in different countries and especially in Europe. Based on the product range used in the present report we estimate the domestic Japanese production volume at JPY 9.1 trillion for 2015.

Industry association data

The Japanese Optoelectronics Industry and Technology Development Association (OITDA) reports for the Japanese industry for 2015 a total Photonics production volume of JPY 16.9 trillion (EUR 126 billion) [1]. Of that volume a good half (JPY 8.6 trillion, EUR 66 billion) is domestic Japanese production, while the balance is due to the overseas production of Japanese companies.

OITDA has been reporting domestic production figures for more than 20 years and production figures for the Japanese Optoelectronics industry (including overseas production) since 2009. Since 2009 the share of the overseas production is roughly half of the total production.

Exchange rates

During the last four years the Japanese yen (JPY) has trended weak against the currencies of all other major Photonics producing countries. From 2011 to 2015 it depreciated by 17.4% vs. the euro and by 34.1% against the US dollar. The EUR/JPY exchange rate was 134 in 2015 vs. 111 in 2011.

Note that during the 2005 to 2011 period the Japanese currency had appreciated by 23.3% vs. the euro.

Major products included in the OITDA figures, but not in the present report, are smartphones (we include displays, camera modules, image sensors, optical components), display devices (we include the displays only) and photovoltaic systems (we include photovoltaic modules and cells separately, but not systems). On the other hand, we include products which are not included in OITDA's figures such as microscopes, optical components, and classical optical systems.

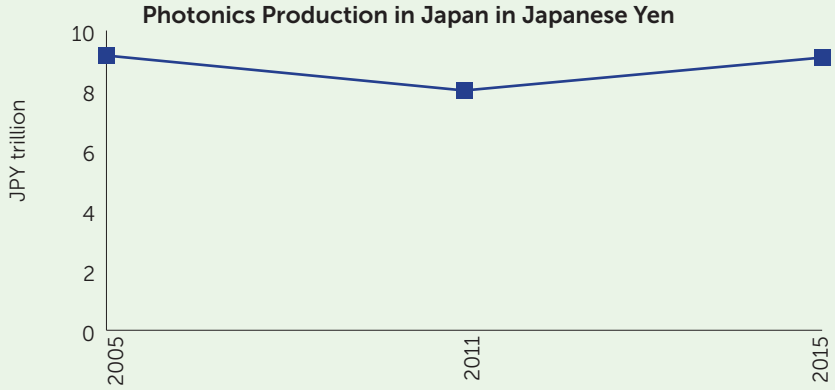


Diagram 13: Photonics Production in Japan in Japanese Yen

Source: Optech Consulting

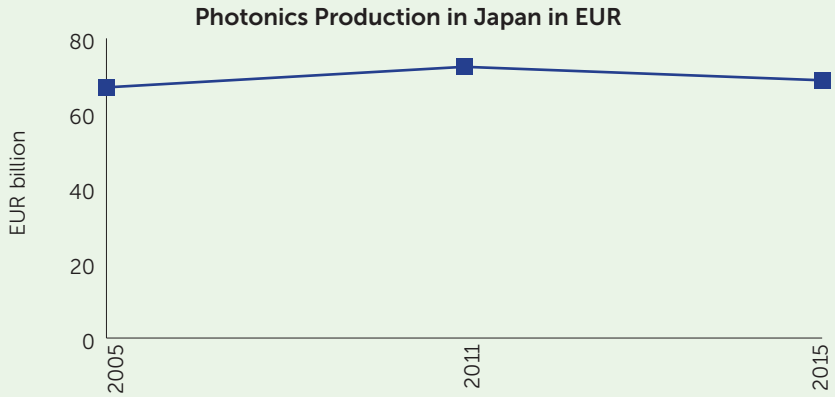


Diagram 14: Photonics Production in Japan in Japanese in EUR

Source: Optech Consulting

During the last four years the Japanese Photonics production increased (euro based data) in the segments of production technology, measurement & image processing and medical technology & life science. In these segments Japan took part in the global growth. Also during the last four years the Japanese Photonics production decreased (euro based data) in the segments of information technology, communication and displays. In the display segment the decrease is mainly due to a loss of market share in a growing market, besides the transfer of production capacity from Japan to China. The production decrease in the communication segment is mainly due to increased competition by companies headquartered in China.

Overseas production accounts for an especially large percentage of the total production for the following segments:
– Digital cameras: more than 75%
– Photovoltaic cells and modules: 65%
– Optical disk drives: about 65%
– Flat panel displays: more than 25%

Offshore production locations comprise China, but also other countries including Taiwan, the ASEAN countries, Western Europe, and North America.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0					
30.0 ... 39.9					
20.0 ... 29.9		*Production Tech *Measurement *Medical Tech *Compon. & Systs			
10.0 ... 19.9	*Communication	*Lighting	*Displays		
5.0 ... 9.9					
0.0 ... 4.9	*Photovoltaics *Defence				
	2015 Production in EUR billion				

Diagram 15: Photonics Production in Japan and Global Market Share

Source: Optech Consulting

In 2015 the domestic Photonics production in Japan had about the same volume as ten years ago (JPY 9.1 trillion), while dipping to JPY 8.0 trillion in 2011. In euros the production was also virtually unchanged in 2015 (EUR 67.7 billion) vs. 2005 (EUR 66.7 billion), but showed a peak volume of EUR 74.4 billion in 2011 due to the temporary increase of the value of the Japanese yen vs. the euro.

The stagnation of domestic production in Japan as well as of the Japanese production including overseas plants versus a growing global market indicates market share losses for the Japanese industry. During the last ten years market shares were lost especially in the following segments: information technology, production technology, optical components & systems, photovoltaics. In all these segments the Japanese industry held a more than 40% market share in 2005. In absolute figures losses were especially large in the information technology segment of the Japanese Photonics industry.

Today, the segments of information technology and displays still contribute the largest parts to the production volume in Japan. Five medium size segments contribute between EUR 5 billion and EUR 10 billion per year: production technology, measurement & displays, medical technology & life science, components & systems, lighting. Market shares of the Japanese domestic production in the global market range between 10% and 30% for the above mentioned segments as well as for communication. Only two segments hold a smaller market share: photovoltaics and defence & security. The Japanese industry has an impressive footprint in most Photonics segment. Including its overseas production it is still the clear leader of global Photonics, although the position has been eroded by its Asian neighbours, and especially by China.

1.3.5 North America

The Optical Society of America (OSA) estimates an optoelectronics component production by North America headquartered companies of USD 24.2 billion (EUR 22 billion) for 2013. Photonscanada estimates the Photonics component manufacturing in Canada for 2015 at CDN 4.6 billion (EUR 3.2 billion).

Industry association data

The Optical Society of America (OSA) has published data on optoelectronics components manufacturing by companies headquartered in the North America [8]. For 2013 the total is USD 22 billion. OSA says that these companies represent 90% of the total production leading to an estimate for the total to be USD 24.2 billion.

The association Photonscanada estimates the 2014 sales volume of Canadian Photonics companies at CDN 4.6 billion (EUR 3.2 billion) [9]. The estimated production volume is based on company revenues. 400 companies employ in total 25 000 people.

Exchange rates

During the last four years the US dollar has appreciated against all other currencies of the major Photonics producing countries, except the Chinese yuan. Against the euro the US dollar appreciated from 2011 to 2015 by 25.5%, after devaluating by 11% from 2005 to 2011.

The EUR/USD exchange rate was 1.11 in 2015 vs. 1.39 in 2011.

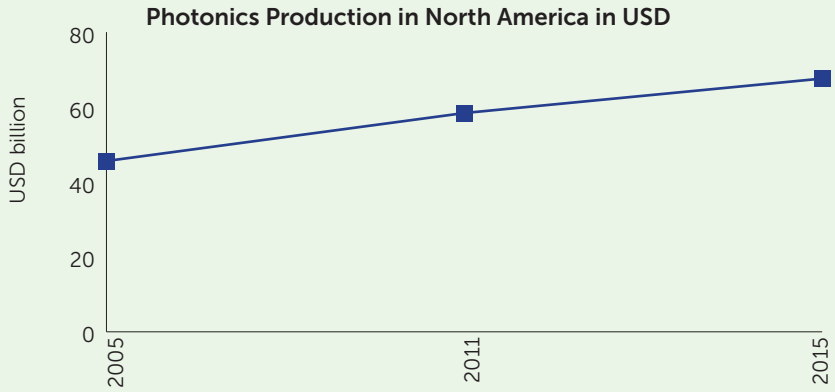


Diagram 16: Photonics Production in North America in US Dollars

Source: Optech Consulting

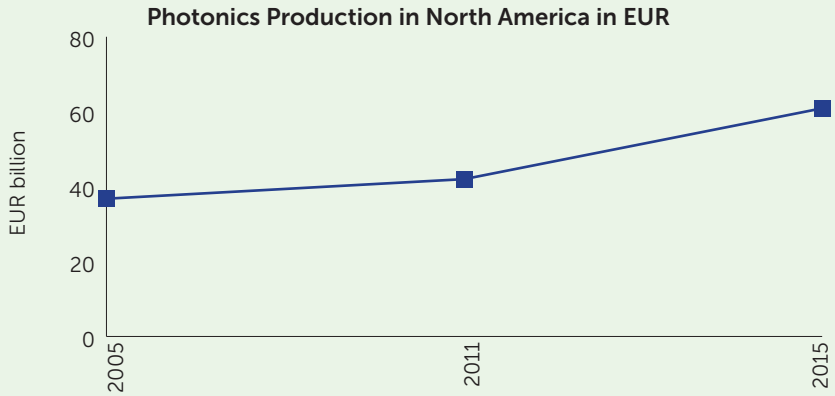


Diagram 17: Photonics Production in North America in EUR

Source: Optech Consulting

The range of products underlying these estimates is different from the product range applied in the present report. The two organizations include a few products which we do not include such as fibre cables and optical media (Canada). Also, the data apparently includes overseas production of North America based companies, which we do not include as North American production. On the other hand we include products which are not included in the data of the two organizations, especially Photonics systems.

For the product range included in the present report we estimate the Photonics production in North America for 2015 at USD 67.6 billion (EUR 60.9 billion) vs. USD 58.4 billion (EUR 42.0 billion) for 2011. This corresponds to a 2011 to 2015 CAGR of 3.7% on a US dollar basis, and of 9.7% on a euro basis.

In the last four years production growth was especially strong in the segments of photovoltaics, displays and display materials and components & systems. Moderate growth on a US dollar basis was observed in the segments of communication, medical technology & life science and defence & security.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0			*Defence		
30.0 ... 39.9					
20.0 ... 29.9	*Communication	*Measurement *Medical Tech			
10.0 ... 19.9	*Compon. & Systs				
5.0 ... 9.9	*Production Tech *Information Tech *Lighting *Photovoltaics				
0.0 ... 4.9	*Displays				
	2015 Production in EUR billion				

Diagram 18: Photonics Production in North America and Global Market Share

Source: Optech Consulting

In information technology most systems produced by North America headquartered manufacturers are produced in Asia (high throughput laser printers are produced in the USA). In production technology North American companies have a strong position regarding lasers, with a substantial portion of these being produced overseas. In the display segment, the market leader for display glass is located in the USA. In photovoltaics North American headquartered manufacturers partly produce within North America. In solid state lighting North America is home to two major manufacturers.

1.3.6 Korea

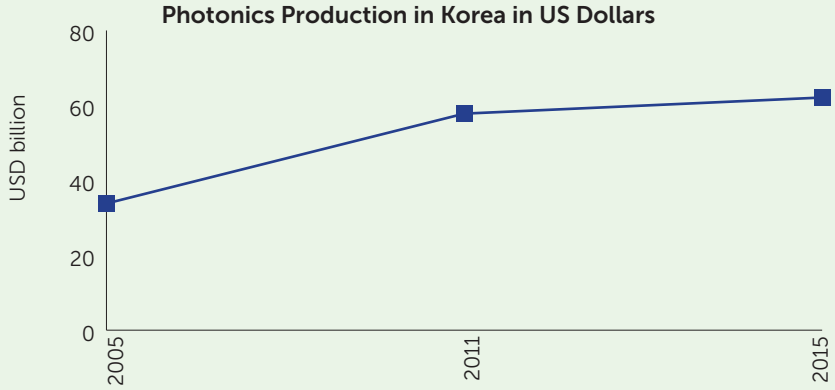


Diagram 19: Photonics Production in Korea in US Dollars

Source: Optech Consulting

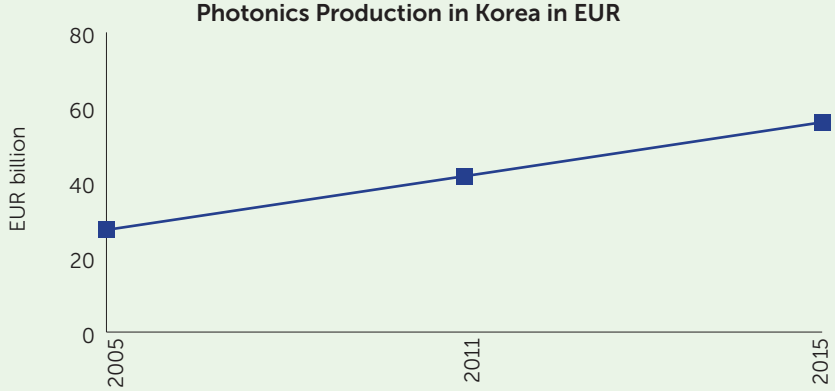


Diagram 20: Photonics Production in Korea in EUR

Source: Optech Consulting

Photonics production in Korea accounted for EUR 56.0 billion (USD 62.1 billion) in 2015. This compares to a volume of EUR 41.6 billion (USD 57.8 billion) in 2011. In US dollars the Korean Photonics production grew moderately from 2011 to 2015. On a US dollar basis the CAGR was 1.8%. Expressed in euros this translates into a CAGR of 7.7%.

The small growth rate in US dollars is mainly due to only modest production growth in the display segment. Flat panel display production in Korea grew only marginally on a US basis, which, however, still translates into a more than 20% accumulated increase from 2011 to 2015 on a euro basis.

Exchange rates

The Korean won (KRW) has trended mostly with the US dollar during the last four years. From 2011 to 2015 it depreciated by about 2% vs. the US currency and gained 22% of value against the euro.

The EUR/KRW exchange rate was 1260 in 2015 vs. 1540 in 2011.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0			*Defence		
30.0 ... 39.9					*Displays
20.0 ... 29.9					
10.0 ... 19.9	*Lighting				
5.0 ... 9.9	*Production Tech *Compon. & Systs	*Information Tech			
0.0 ... 4.9	*Measurement *Medical Tech *Communication *Photovoltaics				
	0.0 ... 4.9	**5.0 ... 9.9**	**10.0 ... 19.9**	**20.0 ... 29.9**	**30.0 ... 40.0**
	2015 Production in EUR billion				

Diagram 21: Photonics Production in Korea and Global Market Share

Source: Optech Consulting

The production of the Korean Photonics industry is strongly dominated by flat panel displays with a share of more than 70%. The two largest display manufacturers of the world, Samsung Display and LG Display are both located in Korea. They manufacture most of their displays within Korea, although both companies also produce in China. LG Display increased the sales from USD 24.3 billion in 2011 to USD 28.4 billion in 2015. The sales of Samsung Display fell from KRW 29.2 trillion (USD 26.2 billion) in fiscal year 2011 to KRW 27.5 trillion (USD 24.3 billion) in fiscal year 2015.

Besides flat panel displays the Korean Photonics industry produces information technology equipment such as digital cameras, optical printers and optical disk drives, image sensors, and camera modules. The information technology segment is the second largest of the Korean industry. Smaller contributions to the Korean Photonics production are provided by lighting, production technology, optical components & systems, and photovoltaics.

1.3.7 Taiwan

The Taiwanese Photonics Industry & Technology Development Association (PIDA) reports a production volume for the Taiwanese Photonics industry for 215 of EUR 54.3 billion. The product range underlying the amount is different from the one we use in the present report. Based on the product range used in the present report we estimate the domestic Taiwanese Photonics production at EUR 47.2 billion for 2015, compared to a production volume of EUR 43.3 billion for 2011.

Industry association data

According to the Photonics Industry & Technology Development Association (PIDA) the 2014 production volume of the Taiwanese Photonics industry accounts for NTD 1.91 trillion (USD 60.1 billion; EUR 54.3 billion). For 2011 PIDA had reported a production volume of NTD 2.3 trillion (USD 81.0 billion; EUR 73.0 billion).

PIDA further reports a production in the display segment for 2015 of USD 42.4 billion (NTD 1.35 trillion), vs. USD 55.0 billion in 2011.

Exchange rates

The Taiwan dollar (NTD) has trended more closely with the US dollar than with the euro during the last four years. From 2011 to 2015 it depreciated by 8.6% vs. the US currency and appreciated by 14.2% of value vs. the euro.

The EUR/TWD exchange rate was 35.2 in 2015 vs. 40.1 in 2011.

The growth rate for production in Taiwan when expressed in euros is affected by exchange rate effects, as the value of the Taiwanese currency increased by 14% vs. the euro from 2011 to 2015. The 2.2% CAGR in euros for the 2011 to 2015 period for Photonics production in Taiwan corresponds to a -1.2% CAGR in Taiwan dollars and to a -3.4% CAGR in US dollars. The negative growth rate is caused by a decrease of the production in the display segment.

The Taiwanese Photonics production is dominated by the display segment which accounts for about 60% of the total. The production volume decreased during the last four years on a US dollar basis. This is due to a loss of market share in a globally increasing market as well as production shifts from Taiwan to China by Taiwanese manufacturers

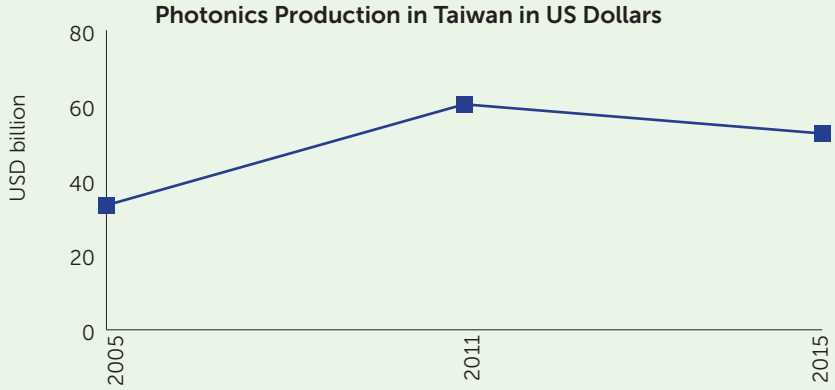


Diagram 22: Photonics Production in Taiwan in US Dollars

Source: Optech Consulting

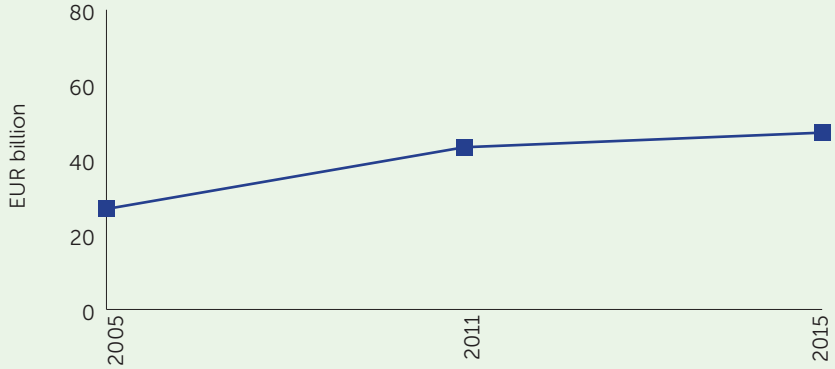


Diagram 23: Photonics Production in Taiwan in EUR

Source: Optech Consulting

Other major product segments include information technology with products such as camera modules, image sensors and optical disk drives. In addition, solid state lighting, photovoltaics and optical components contribute substantially to Photonics production in Taiwan.

During the last four years the production volume decreased on a USD basis. This is due to the above mentioned market share loss in the display segment. Growth in other segments, especially in lighting (solid state lighting), photovoltaics and optical components & systems, was not enough to fully make up for the decrease in the display segment. The Taiwanese Photonics industry has attained a good position in solid state lighting where it is among the top three suppliers, worldwide, and in photovoltaics, where the Taiwanese industry is positioned in second place behind its Chinese counterpart.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0					
30.0 ... 39.9					
20.0 ... 29.9				*Displays	
10.0 ... 19.9	*Lighting				
5.0 ... 9.9	*Photovoltaics *Compon. & Systs	*Information Tech			
0.0 ... 4.9	*Production Tech *Measurement *Medical Tech *Communication				
	0.0 ... 4.9	**5.0 ... 9.9**	**10.0 ... 19.9**	**20.0 ... 29.9**	**30.0 ... 40.0**
	2015 Production in EUR billion				

Diagram 24: Photonics Production in Taiwan and Global Market Share

Source: Optech Consulting

2. European Photonics Industry

2.1 Overview – Production Value, Growth and Global Market Share

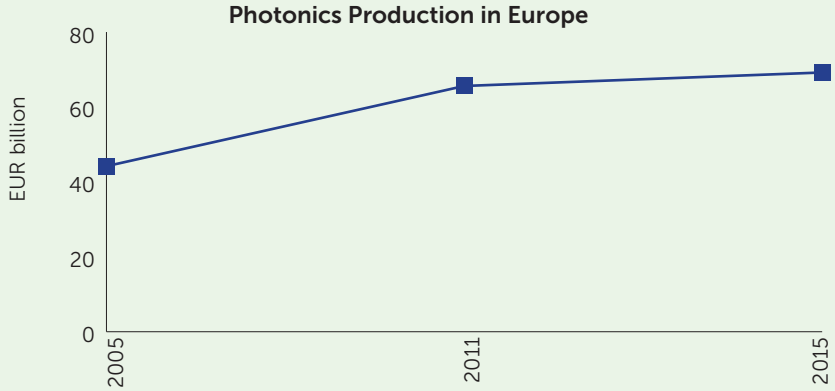


Diagram 25: Photonics Production in Europe, 2005 to 2015

Source: Optech Consulting

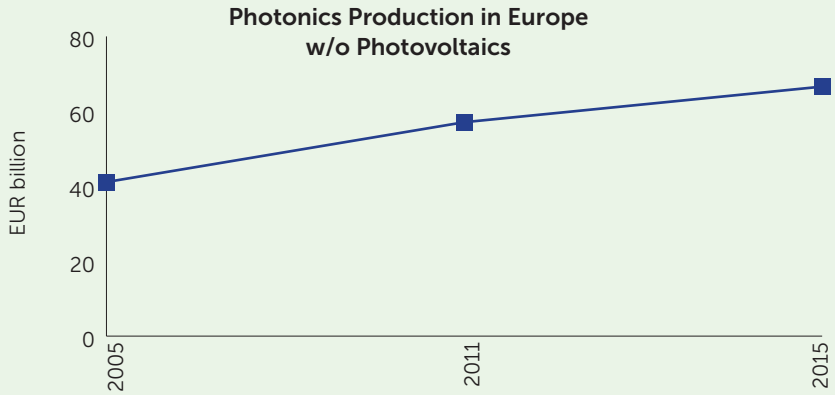


Diagram 26: Photonics Production in Europe, 2005 to 2015 Without Photovoltaics

Source: Optech Consulting

The production volume of the European Photonics industry accounted for EUR 69.2 billion in 2015, compared to a volume of EUR 65.6 billion in 2011. During the 2011 to 2015 period the production volume of the European Photonics industry grew at a CAGR of 1.3%, vs. a CAGR of 6.8% for the 2005 to 2011 period.

The growth rates in the periods were heavily impacted by the increase and subsequent decrease of the photovoltaics segment. Excluding photovoltaics, the European Photonics production grew at a CAGR of 5.7% between 2005 to 2011, and at a CAGR of 3.9% from 2011 to 2015.

In 2015 the European production (EUR 69.2 billion) accounted for a share of 15.5% in the global Photonics market (EUR 447 billion). Excluding photovoltaics, the European production volume accounted for EUR 66.6 billion in 2015, corresponding to a 17.0% share in the world market (EUR 391 billion), vs. 18.9% in 2011. The market share decreased by 1.9% percentage points, or by 10% compared to the initial share. At the same time the euro has lost 10% of its value against the SDR (special drawing rights of the International Monetary Fund) which represents a currency basket. This is in

accordance with the well-known J-curve effect for market shares after the devaluation of a currency. The immediate result is a loss of market share as the production volume is devaluated. Market share gains are expected to occur with a time delay when increased competitiveness translates into increased sales. Another reason for the market share losses of the European Photonics industry is increased competition by manufacturers in China.

Including photovoltaics the European share in the global market was 19.3% in 2005, 18.7% in 2011, and 15.5% in 2015. As discussed earlier the European photovoltaics production grew from EUR 3.1 billion to EUR 8.5 billion from 2005 to 2011, and then decreased to EUR 2.6 billion in 2015.

European Photonics Production

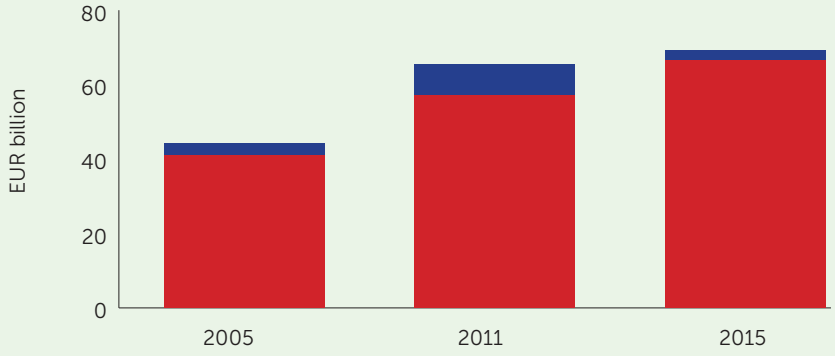


Diagram 27: Photonics Production in Europe 2005 to 2015, Impact of Photovoltaics

Source: Optech Consulting

Share of European Photonics Production in the World Market*

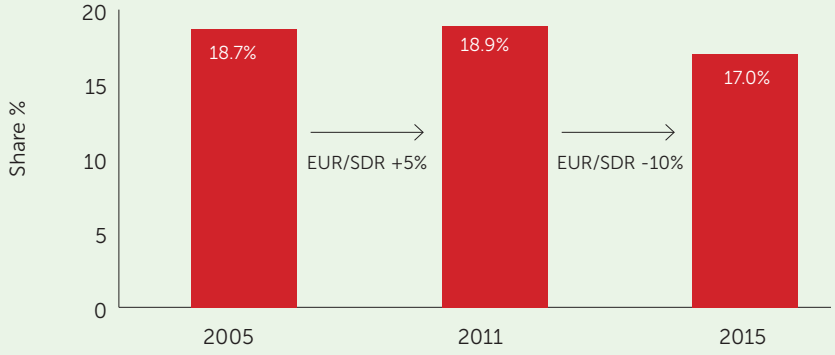


Diagram 28: Photonics Production in Europe, Global Market Share

* w/o photovoltaics

Source: Optech Consulting

2.2 Production by Product Segment

2.2.1 Overview

The two largest segments of European Photonics are **production technology** and **measurement & image processing**. The products of both segments are used for industrial manufacturing. The production technology segment, comprising laser materials processing and lithography equipment, accounts for a European production volume of EUR 13.1 billion. The measurement & image processing segment comprises a European production volume of EUR 11.7 billion. The two segments together account for a 2015 production volume in Europe of about EUR 25 billion corresponding to 36% of the European Photonics production.

The third segment, Photonics based **medical technology & life science**, accounts for a European production volume of EUR 9.6 billion or 14% of the European Photonics production.

2015 Global Photonics Production by Segment

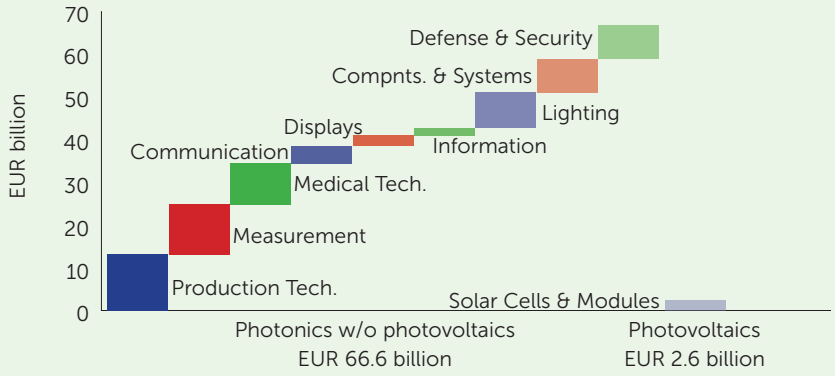


Diagram 29: Photonics Production in Europe 2015, by Segment

Source: Optech Consulting

Three of the ten Photonics segments are related to data in a wider sense: data transmission, acquisition, output, display, and storage. These are the segments of optical **communication, information technology** and **displays**. The segment of optical communication comprises a European production volume of EUR 4.1 billion or 6% of European Photonics. The segment of Photonics based information technology accounts for a European production volume of EUR 2.5 billion, corresponding to 3.5% of European Photonics. The segment of flat panel displays and display materials accounts for a European production volume of EUR 1.7 billion or about 2.5% of European Photonics. Together the data related Photonics segments account for 12% of the European Photonics production.

Lighting accounts for a European production volume of EUR 8.3 billion or 12% of European Photonics. **Defence & security** Photonics makes up for a production volume of EUR 7.9 billion or 11% of European Photonics. Optical **components & systems** account for a production volume of EUR 7.8 billion

or 11% of European Photonics. **Photovoltaics** accounts for a production volume of EUR 2.6 billion and makes up for 4% of European Photonics[10].

The two largest segments of European Photonics production, production technology and measurement & image processing, also account for the largest shares in the global markets (Diagram 30). Four further segments account for a substantial production volume and at the same time a substantial global market share: components & systems, medical technology & life science, lighting, defence & security.

2015 Share in Global Market in %	0.0 ... 4.9	5.0 ... 9.9	10.0 ... 19.9	20.0 ... 29.9	30.0 ... 40.0
40.0 ... 50.0			*Production Tech (share 50%)		
30.0 ... 39.9		*Compon. & Systs	*Measurement		
20.0 ... 29.9		*Medical Tech *Lighting *Defence			
10.0 ... 19.9	*Communication				
5.0 ... 9.9					
0.0 ... 4.9	*Information Tech *Displays *Photovoltaics				
	2015 Production in EUR billion				

Diagram 30: Photonics Production in Europe and Global Market Share, by Segment

Source: Optech Consulting

The communication segment accounts for 6% of European Photonics production corresponding to a 18% share of the global market. In the segments of information technology and displays the European industry has the role of a niche supplier with products such as display materials, high end digital cameras and high end optical printers. The photovoltaics segment accounts for 4% of European production and to a 5% share of the global market.

As discussed above, from 2011 to 2015 the European Photonics industry grew less than the world market, mainly due to currency effects and due to increased competition from China. Nonetheless, several segments of the European Photonics industry succeeded to grow at about the same level as the world market (Diagram 31). This includes the two segments with the largest European production volume, **production technology** and **measurement & image processing**. Also in medical technology & life science, another stronghold of European Photonics, growth in Europe nearly kept pace with global growth.

In optical **communication** the European Photonics production did not increase during the last four years, while the global market showed substantial growth on a euro basis. This is due to a European demand market

[10] Percentages may not add up to 100% due to rounding.

lagging behind in growth versus the world market, and also due to intense global competition. In **information technology** revenues of European suppliers developed in accordance with the global market. The global market grew moderately on a euro basis and shrank on a US dollar basis. In the **display** segment the European production profited from the growth of the global market. The major activity of the European industry here is the supply of materials to display manufacturers.

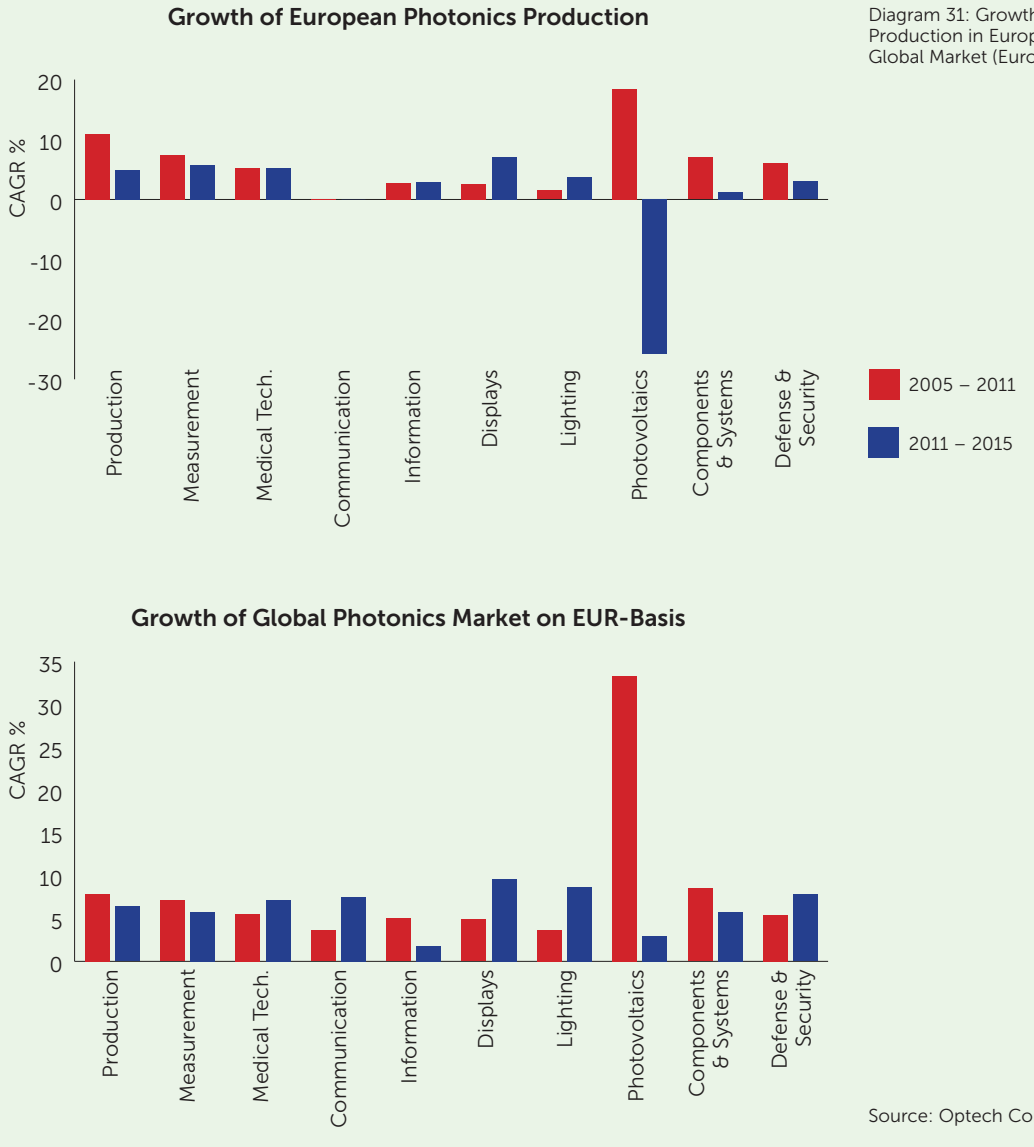


Diagram 31: Growth of Photonics Production in Europe vs. Growth of Global Market (Euro Basis)

Source: Optech Consulting

In the **lighting** segment the production volume in Europe grew by 3.7%, not keeping fully pace with the growth of the global market which was 8.7% on a euro basis. In the photovoltaics segment the European production volume sank drastically during the last four years. The global market trended positive on a US dollar basis, and increased substantially on a euro basis. In the segment of optical **components & systems** only moderate growth for the European production was observed, while the global market showed a substantial increase on a euro basis. Worldwide, growth was due to a positive trend in North American, as well as in parts of the Asian market (optics for camera modules). In the segment of **defence & security** the production of the European industry grew moderately, but growth rates fell short of the euro based growth rates in the global market.

Diagram 32 shows the 2011 to 2015 growth rate for European production in the single Photonics segments versus the size of the segments in 2011. During the last four years those segments of the European Photonics industry grew most which already had the largest production size in 2011: production technology, measurement & image processing, medical technology & life science.

The smaller segments in terms of European production volume in 2011, information technology and communication, also showed small growth rates (production for the communication segment stagnated). The only exception among the smaller segments is the display segment, where the European industry is represented mainly with the niche activity of supplying display materials.

Diagram 33 summarizes the findings regarding the 2015 production volume, the global market share and the growth rates for the segments of European Photonics. The diagram shows the data for nine segments. Production technology stands out in European Photonics regarding all three parameters: segment size, growth, and global market share. Also measurement & image has an outstanding role in terms of the economic indicators. Both segments comprise products which are mainly used in industrial manufacturing.

The segment of medical technology & life science has a somewhat smaller size and share in the global market, but it also grew substantially during the last four years. The European production in the segments of lighting and defence & security has a substantial size while showing global market shares in the range of 25% and growth rates of about 3.5%. Growth in the lighting segment was slowed by increased competition from Asia, while growth in the defence & security segment was slowed by stagnating defence budgets in Europe. The components & systems segment accounts for a substantial European production volume and share in the global market. After years of very strong growth (2005 to 2011) growth rates have slowed during the last four years. One reason is the shift of production to China by European manufacturers.

In the communication segment the European production holds a global share of 18%. European production did not increase in recent years due to strong competition especially from China, and due to comparably small growth rates of the European demand market. In the segments of information technology and displays the European industry holds small market shares.

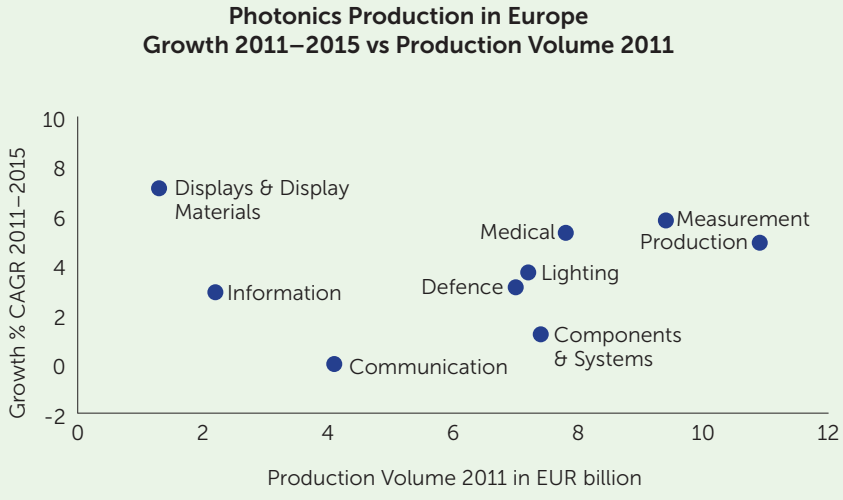


Diagram 32: Photonics Production Europe, Growth 2011 to 2015 vs. Production 2011

Source: Optech Consulting

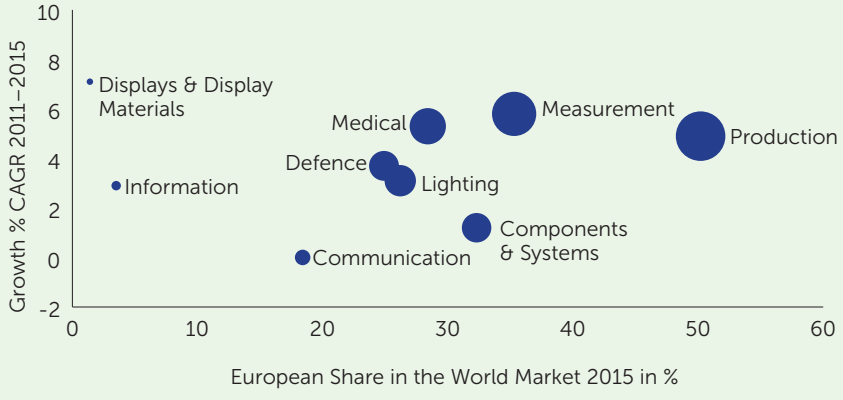


Diagram 33: Photonics Production Europe, Production, Growth and Global Market Share

Area of circle indicates production value

Source: Optech Consulting

2.2.2 Production Technology

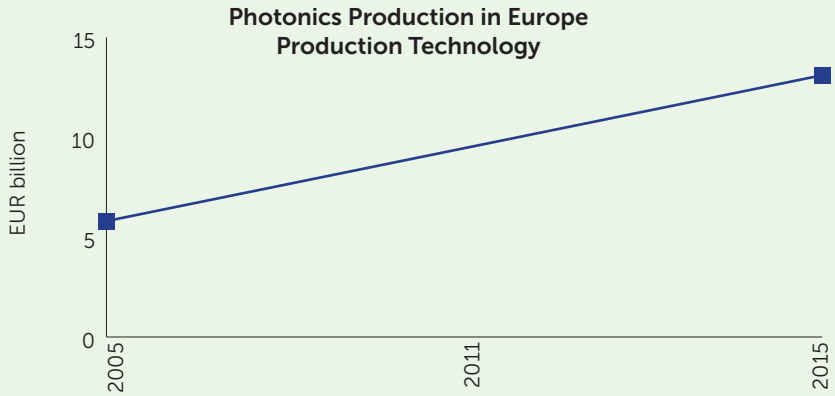


Diagram 34: Production Technology, European Production 2005 to 2015

Source: Optech Consulting

With a 2015 production volume of EUR 13.1 billion production technology accounts for 19.2% of European Photonics production. The segment breaks out into the sub-segment of laser materials processing (EUR 5.5 billion) and the sub-segment of lithography (EUR 7.6 billion). In the laser materials processing segment we count laser systems and lasers. In the lithography segment, systems for microlithography are included as well as systems used for lithography in flat panel display and printed circuit board manufacturing. We also include the lasers used in these systems and the objectives for microlithography.

Since 2011 the European production in the production technology segment grew at a CAGR of 4.9%. This is less than the 10.9% CAGR for the 2005 to 2011 period. From 2011 to 2015 the growth rates for the two sub-segments were strongly different. The laser materials processing sub-segment grew at a CAGR of 10.2%, while the lithography sub-segment only grew at a CAGR of 1.7%. The small growth rate for the European production in the lithography segment can be attributed to the delay of EUV technology for microlithography. The large growth rate in laser materials processing production is due to the adoption of laser technology in manufacturing, worldwide. Market drivers are the trend in industrial production for automated, flexible and quality-assured production, as well as the miniaturization of products.

The growth in the laser materials processing segment (10.2%) falls somewhat short of the growth of the global market in the segment (12.0%). The higher growth rate of the global market can be attributed to two issues. Firstly, the decrease of the value of the euro versus other major currencies, which devaluated the European production in the global context while there was not enough time for positive market share effects to unfold. Secondly, the large increase of the market in China, which is to an increasing extent served by local laser system manufacturers.

Production in EUR billion	
4.0 ... 7.9	*Germany *Netherlands
2.0 ... 3.9	
1.0 ... 1.9	
0.5 ... 0.9	*Italy *Switzerland *Other EU28 combined
0.0 ... 0.4	*France *United Kingdom

Diagram 35: Production Technology, European Production by Country
Source: Optech Consulting

Source: Optech Consulting

The major producers in the production technology segment in Europe are the Netherlands (microlithography systems) and Germany (lasers and laser systems for materials processing, lasers and objectives for lithography). Italy and Switzerland follow with substantial production volumes for laser materials processing systems. Many other European countries host laser and laser system manufacturing as well.

The European industry is the global market leader in Photonics based production technology as a whole (50% market share), as well as for many product sub-segments. Exceptions include laser micro-processing systems and lithography systems for flat panel displays where Asian manufacturers dominate. It is also important to note that the increasing relocation of industrial manufacturing to China leads to an increasing weight of the Chinese demand market for manufacturing equipment, which supports local laser system and laser production and is expected to lead to an increasing market share of local suppliers versus suppliers from Europe and other regions. Another note concerns the ownership of European manufacturers. While the large majority of laser system manufacturers in Europe is locally owned, European laser manufacturers are increasingly owned by North America headquartered companies.

2.2.3 Measurement & Image Processing

With a 2015 production volume of EUR 11.7 billion measurement & imaging accounts for 17.1% of European Photonics production. This corresponds to a global market share of 35.3%. The segment breaks out into the sub-segments of measurement (EUR 8.2 billion) and image processing (EUR 3.5 billion). In the measurement sub-segment we include components, modules and systems for measurement and analysis, while in the image processing sub-segment we include systems, components and software for image processing. Major European products in the segment include image processing systems, photonics sensors (binary sensors), spectrometers, analytical instruments, and geospatial measurement systems.

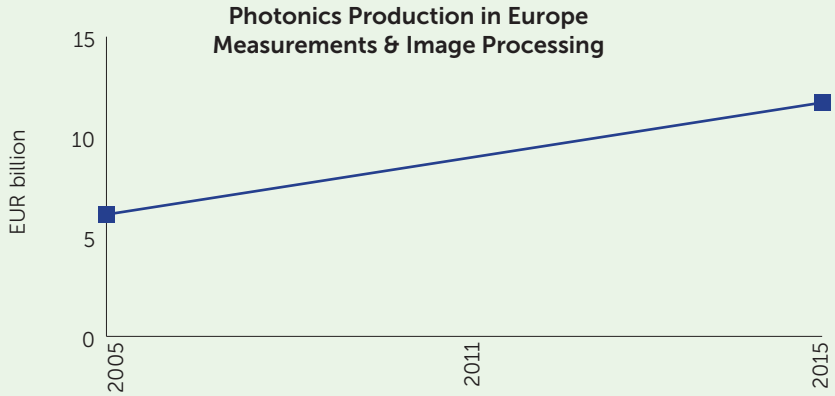


Diagram 36: Measurement & Image Processing, European Production 2005 to 2015

Source: Optech Consulting

From 20011 to 2015 European production in the segment grew at a CAGR of 5.7%, while the global market grew at a CAGR of 5.8%. The European production volume kept pace with the global market in spite of the devaluation of the euro versus major currencies. Market drivers in measurement & image processing are the trend in industrial production for automated, flexible and quality-assured production.

Germany holds a more than 50% share in the European production, due to a large share for several major products (image processing systems, photonic sensors, spectrometers). The United Kingdom, France, Italy, Switzerland, the Netherlands, and Sweden follow. Many other countries host manufacturing in the sector, including Belgium, Finland, Denmark, Spain, Austria, and Poland.

Production in EUR billion	
4.0 ... 7.9	*Germany
2.0 ... 3.9	*United Kingdom
1.0 ... 1.9	*France
0.5 ... 0.9	*Italy *Switzerland *Other EU28 combined
0.0 ... 0.4	*Netherlands

Diagram 37: Measurement & Image Processing, European Production by Country
Source: Optech Consulting

2.2.4 Medical technology & Life Science

With a 2015 production volume of EUR 9.6 billion medical technology & life science accounts for 14.0% of European Photonics production. This corresponds to a global market share of 28.4%. From 20011 to 2015 European production in the segment grew at a CAGR of 5.3%, while the global market grew at a CAGR of 7.2%. The European production volume nearly kept pace with the global market in spite of the devaluation of the euro versus major currencies.

Photonics based medical technology & life science showed substantial growth driven by the trend for minimally invasive surgeries, for Photonics based (in vitro) diagnostics, and for Photonics in drug development and biotechnology. The aging population also is a major market driver for Photonics, especially for ophthalmic products (diagnostic and therapeutic systems, eyeglasses).

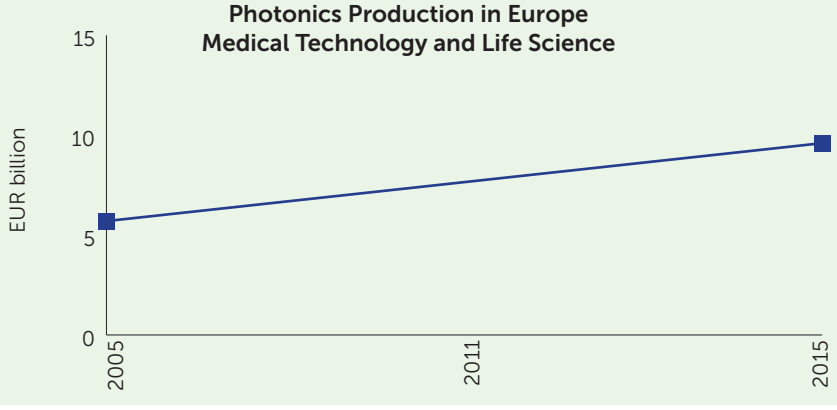


Diagram 38: Medical Technology & Life Science, European Production 2005 to 2015

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	*Germany
2.0 ... 3.9	
1.0 ... 1.9	*France
0.5 ... 0.9	*Italy *United Kingdom *Switzerland *Other EU28 combined
0.0 ... 0.4	*Netherlands

Diagram 39: Medical Technology & Life Science, European Production by Country
Source: Optech Consulting

Major products of the European industry include vision correction lenses and contact lenses, rigid endoscopes, microscopes, as well as optical systems for medical diagnostics and biomedical instrumentation. The European industry also is well represented in the areas of medical imaging systems (CR, DR) and therapeutic laser systems, especially ophthalmic systems. Its position is weaker in the areas of analytical equipment for biotechnology and pharmaceutical research and industry.

Germany holds a more than 50% share in the European production, mainly due to a large production share for microscopes, endoscopes, and medical imaging systems. France follows with an about 13% share, ahead of the United Kingdom (about 9%), Switzerland (about 6%), and Italy (about 5%). Many other countries host manufacturing in the sector (lenses for vision correction, contact lenses, ophthalmic instruments, endoscopes).

2.2.5 Communication

With a 2015 production volume of EUR 4.1 billion optical communication accounts for 6% of European Photonics production. It corresponds to 18% of the global market for optical communication products.

During the last four years production in Europe has stagnated, after also stagnating during the 2005 to 2011 period. While the production of optical fibres increased, according to Eurostat from EUR 449 million in 2011 to EUR 623 million in 2015, at the same time the production of networking systems and components decreased.

Diagram 40: Optical Communication, European Production 2005 to 2015

Source: Optech Consulting

The market share of the European industry in the world market has decreased from 31% in 2005 to 25% in 2011 and to 18% in 2015. At the same time the share of the Chinese industry increased from 15% in 2005 to 28% in 2011 and to 38% in 2015. Besides the European manufacturers also North American manufacturers lost market share. Besides fierce competition another issue weighing on the European production is the comparably weak trend of the European demand market.

The segment comprises systems and components for optical networking. Please see paragraph 1.2.5 for more details on the products included. The production values stated above include optical fibres, while cabled fibres are not included. Note that according to Eurostat the EU28 production of fibre cables amounts to EUR 1.42 billion, versus EUR 623 million for fibres.

During the last ten years the optical communication industry in Europe as well as in North America underwent continued restructuring, driven by increased competition in a market still plagued by overcapacities after the burst of "telecom bubble" in 2001. At the same time Chinese manufacturers gained market share while their home market grew rapidly. Also, the market (long haul, metro, local/data centres) changed continuously as well as the technologies used for increased transmission rates.

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	
1.0 ... 1.9	*France
0.5 ... 0.9	*Germany *United Kingdom
0.0 ... 0.4	*Italy *Netherlands *Switzerland *Other EU28 combined

Diagram 41: Communication, European Production by Country
Source: Optech Consulting

The global optical networking systems industry has become highly concentrated, with a few suppliers holding a large market share. Today, four to five manufacturers dominate in the market: Nokia (after takeover of Alcatel-Lucent), Huawei and ZTE (both China), and Ciena and Infinera (both USA). In Europe, other major manufacturers are Adva Optical and Coriant. Besides, USA headquartered component manufacturer Oclaro also produces in Europe. In the area of optical fibres Prysmian of Italy, which took over Draka from the Netherlands in 2011, is one of major global manufacturers. Optical fibre manufacturing (telecom fibres and specialty fibres) is hosted in several European countries including the Netherlands, Italy, Germany, United Kingdom, Poland, Italy, Spain, Finland, and Denmark. Fibre cables are produced in France, the Netherlands, the United Kingdom, Poland, Italy, Sweden, Romania, and Denmark.

2.2.6 Information Technology

Diagram 42: Information Technology, European Production 2005 to 2015

Source: Optech Consulting

Photonics based information technology accounts for EUR 2.5 billion or about 3.5% of European Photonics production. Europe holds a small market share of 3% in the global market for Photonics based information technology (EUR 71 billion). The European production is mainly due to a few companies and products. It includes high-end digital cameras, besides automated data acquisition equipment (barcode scanners and related devices), high-end office printers and photocopiers, as well as printing industry equipment. The European production in the segment continued to grow in the 2011 to 2015 period, as several major European manufacturers operated successfully in their product segments.

Germany is the major production location. 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.

2.2.7 Displays

The major European product in the display segment are flat panel display materials, besides a small number of specialty displays. In 2015 sales of display materials increased strongly due to exchange rate effects (products made in Europe and sold in Asia). The European production accounts for EUR 1.7 billion, corresponding to about 2.5% of European Photonics production. This compares to a global production volume of EUR 135 billion for flat panel displays and display materials.

Germany holds a more than 50% share in the European production in the segment, mainly due to the production of LCD and OLED materials.

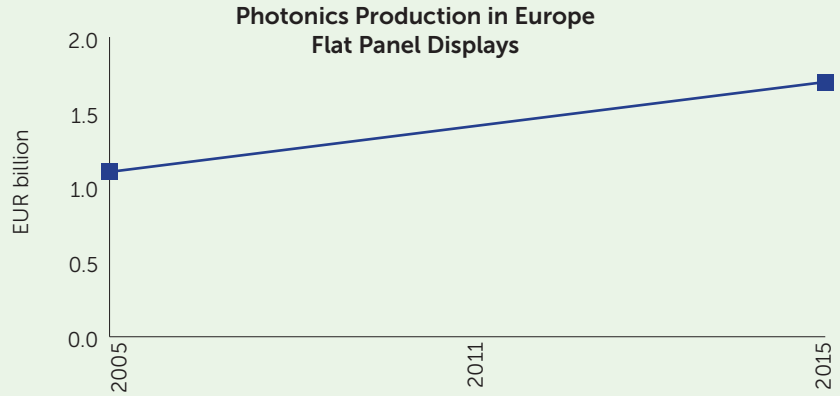


Diagram 43: Flat Panel Displays, European Production 2005 to 2015

Source: Optech Consulting

Please note that he following products are included in other segments:
- Monitors for medical applications are included in the medical technology & life science segment.
- Monitors and specialty display panels for military applications are included in the defence & security segment.
- Large projectors such as for cinemas are included in the optical components & systems segment.

The following products are not included in the present report (only the display panels are included):
- TV sets, notebooks, tablet PCs, smartphones
- Monitors for PC and presentation applications and projectors for TV and presentation applications

2.2.8 Lighting

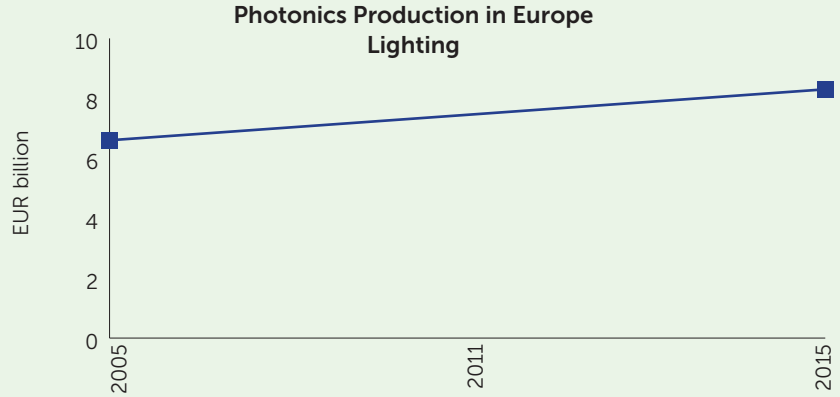


Diagram 44: Lighting, European Production 2005 to 2015

Source: Optech Consulting

With a 2015 production volume of EUR 8.3 billion lighting accounts for 12% of European Photonics production. The European production in the lighting segment corresponds to 25% of the global market (EUR 33.4 billion).

These figures include the production of the following products: all types of lamps (conventional and LED) for all applications such as general lighting, automotive lighting, display backlighting, signage, etc. LED chips are included as separate products. We also include closely related products such as ballasts. These Photonics products in lighting (global market EUR 33.4 billion) is part of the EUR 115 billion global lighting market. The latter comprises in addition luminaries and lighting control systems.

The lighting market is characterized by moderate long term growth, in many years outpacing GDP growth. During the 2011 to 2015 period the appreciation of major currencies versus the euro added extra percentage points to the global market growth measured in euros.

During the last four years the European production of Photonics products for lighting increased, but not at the pace of the global market. Market shares eroded due to the transition to LEDs, where new suppliers aggressively fight for market shares. The share of the production in Europe decreased from 34% in 2005 to 30% in 2011 and to 25% in 2015. The decrease has two reasons: (i) the transition to solid state lighting which attracts new competitors and (ii) (i) the decrease of the euro versus other major currencies.

The global lighting market presently transitions from incandescent and fluorescent lamps to LED based lamps. That technology transition has attracted new players to the lighting market, mainly in Asia. In China, the government strongly supports companies setting up LED factories.

Osram and Philips Lighting[11], 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. Osram also is among the global market leaders in LED lighting. However, in the LED part of the market companies like Nichia, Lumileds[12], Samsung, Seoul Semiconductor, and Cree have gained substantial market shares, besides a large number manufacturers from China.

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*Germany *Other EU28 combined
1.0 ... 1.9	
0.5 ... 0.9	*France *United Kingdom *Italy *Netherlands
0.0 ... 0.4	

Diagram 45: Lighting, European Production by Country
Source: Optech Consulting

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. These countries are estimated to account for a total of 30% of the European production volume. The remaining 35% of the production volume is shared by many countries, including Sweden, Spain, Belgium, Poland, Czech, Denmark, Finland, Romania, and Slovakia.

[11] Osram (several years ago) and Philips (2016) have become independent for their parent companies Siemens and Philips by IPO.
[12] The North America headquartered company was temporarily part of Philips.

2.2.9 Defence & Security

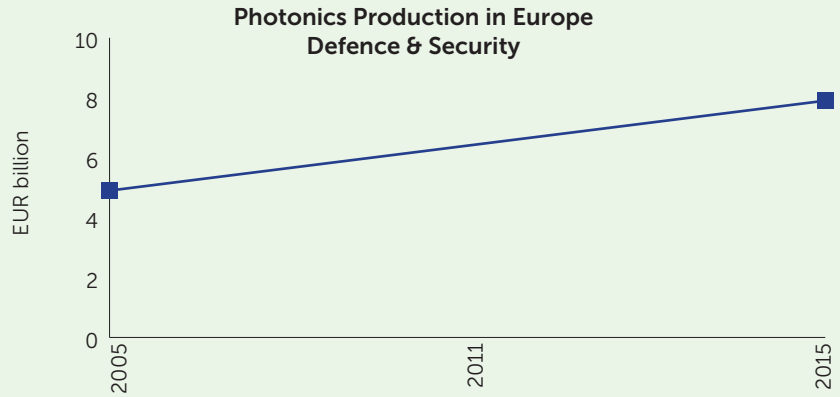


Diagram 46: Defence & Security, European Production 2005 to 2015

Source: Optech Consulting

With a 2015 production volume of EUR 7.9 billion defence & security accounts for 11.5% of European Photonics production. The market share of European production in the world market decreased from 31% in 2011 to 26% in 2015. The reason for the decrease is twofold. Firstly, the stagnating spending for defence in Europe weighed on the local market. Secondly, the market for defence based Photonics in the USA , which is about half of the global market, was lifted by 20% on a euro basis during the last four years only due to the exchange rate shift. While sales of Europe based manufacturers also benefitted from the currency effect, this is a minor issue because the US military mainly supplies at home.

The major producing countries in Europe are France and the United Kingdom (accounting for a combined share of 60% of the European production), followed by Italy, Germany, and Sweden. France headquartered Thales is the major producer of defence and security Photonics in Europe. Its production plants are mainly located in France and the United Kingdom, with smaller activities in other countries. Also Safran is an important producer in this sector in France. In the United Kingdom, Thales is the biggest defence and security Photonics producer. Other manufacturers in the United Kingdom include Italy headquartered Leonardo-Finmeccanica, BAE Systems, Qioptiq, and Qinetiq. Note that BAE Systems mainly produces its Photonics systems in the USA. In Italy, Leonardo-Finmeccanica combines major activities of the Photonic defence and security sector.

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*France *United Kingdom
1.0 ... 1.9	*Italy
0.5 ... 0.9	*Germany *Other EU28 combined
0.0 ... 0.4	*Netherlands *Switzerland

Diagram 47: Defence & Security, European Production by Country
Source: Optech Consulting

2.2.10 Optical Components & Systems

With a 2015 production volume of EUR 7.8 billion optical components & systems account for 11.4% of the European Photonics production. This corresponds to a share of 32% in the global market. The global market for optical components & systems increased substantially during the last ten years. While the European production even slightly outpaced the global market from 2005 to 2011, growth has been slower during the last four years. The share of European production in the world market decreased from 32% in 2011 to 26% in 2015. This is due to three major reasons. Firstly, recent growth was driven by the consumer electronics market, where European manufacturers are not strongly represented. Secondly, optical components production for other end markets (medical & life science, industrial) was partly shifted from Europe to Asia due to cost reasons. Also production of optical modules and systems (ranging from objectives to binoculars and projectors) was partly shifted to Asia. Thirdly, also in this segment, the exchange rate shift lead to a higher relative valuation of the production located in other regions (Asia, North America), while positive effects of the lower euro valuation were limited for the time being.

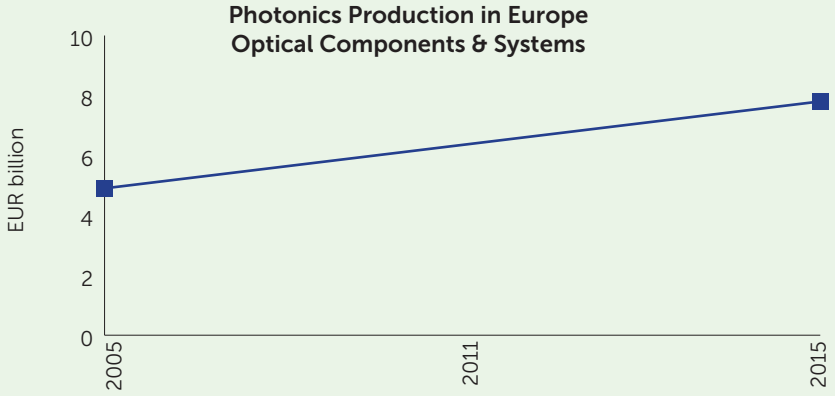


Diagram 48: Optical Components & Systems, European Production 2005 to 2015

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*Germany
1.0 ... 1.9	*Other EU28 combined
0.5 ... 0.9	*France *United Kingdom *Italy
0.0 ... 0.4	*Netherlands *Switzerland

Diagram 49: Optical Components & Systems, European Production by Country
Source: Optech Consulting

Germany holds a 50% share in the European production due to a strong manufacturing base for optical components as well as optical systems. Other major producing countries include the United Kingdom, Italy, France, Switzerland, the Netherlands, Sweden, and Belgium. Several other countries host a noteworthy production, including Spain, Portugal, Austria, Denmark, Finland, Poland, Bulgaria, Slovenia, Lithuania.

2.2.11 Photovoltaics

With a 2015 production volume of EUR 2.6 billion photovoltaics accounts for 4% of the European Photonics production. The amount adds up solar module and solar cell production. The EUR 2.6 billion correspond to a 5% share in the world market.

The European photovoltaics production grew from EUR 3.1 billion in 2005 to EUR 8.5 billion in 2011, and then decreased to EUR 2.6 billion in 2015. The production growth of the photovoltaics industry in Europe in the mid to late 2000s was due to government incentives which heavily boosted demand first in Germany and then in other European countries. The European market share in photovoltaics began to erode around the year 2007, when China became market leader for solar modules, surpassing Germany and Japan. While European production still grew until 2011, its share in the world market deceased from 35% in 2005 to 17% in 2011.

The government incentives in Europe had resulted in rapid growth of fragmented small volume production units in Europe, while cost issues were often neglected. That industry was then confronted with harsh price cuts driven by companies in China. The share of the European production decreased to only 5% in 2015. At present, many of the remaining European photovoltaics manufacturers struggle to survive.

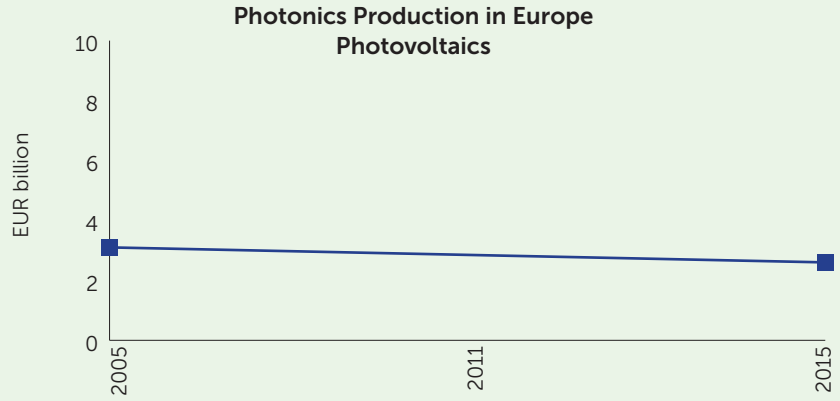


Diagram 50: Photovoltaics, European Production 2005 to 2015

Source: Optech Consulting

The major photovoltaics producing country in Europe is Germany with a share of nearly 60%, while Italy presently hosts the second largest production volume.

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	
1.0 ... 1.9	*Germany
0.5 ... 0.9	*Italy
0.0 ... 0.4	*All other

Diagram 51: Photovoltaics, European Production by Country
Source: Optech Consulting

2.3 Production by Country

2.3.1 Overview

The European Photonics production accounts for a 2015 volume of EUR 69.2 billion (diagram 52). Within Europe, Germany accounts for the largest production volume for Photonics with a share of 41.3%. The Netherlands, France, the United Kingdom, and Italy follow. The other EU28 countries combined hold a combined share of 12.8%. Switzerland holds a 3.6% share, while the share of the other non-EU countries in Europe is small.

Excluding photovoltaics the production volume is EUR 66.6 billion (diagram 53). The breakout by countries agrees within half a percentage point with the breakout including photovoltaics (the impact of photovoltaics is mainly on growth rates).

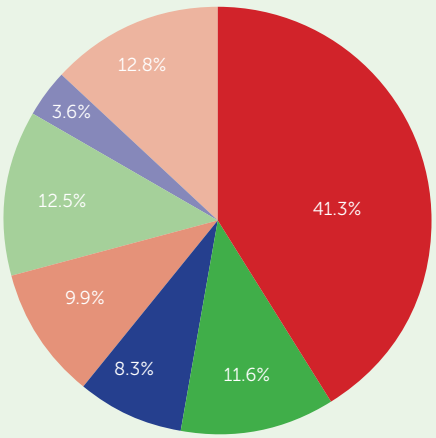
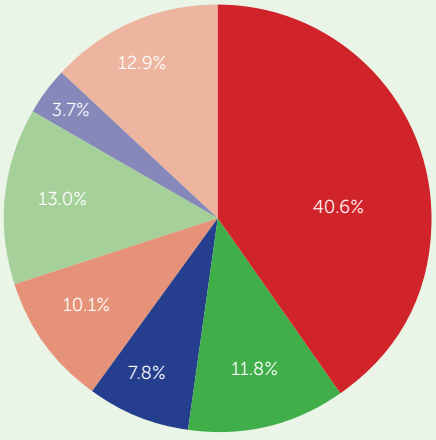


Diagram 52: European Production by Country, 2015

Source: Optech Consulting



* w/o photovoltaics

Diagram 53: European Production Excluding Photovoltaics, by Country, 2015

Source: Optech Consulting

Excluding photovoltaics the EU28 Photonics production grew at a CAGR of 3.9% from 2011 to 2015. This compares to a CAGR of 0.1% for the total industrial production of the EU28 countries (table 2). In other words, while the industrial production virtually stagnated during the last four years Photonics production grew in average at about 4%, annually (table 2).

Growth of European Photonics Industry vs Growth of Industrial Production

	Industry production CAGR % Data source: Eurostat	Photonics production CAGR % w/o photovoltaics	Photonics production CAGR % inc. photovoltaics
EU28	0.1	1.3	3.9
Germany	0.5		
France	0.5		
UK	0.2		
Italy	2.3		
Netherlands	1.6		

Table 2: Growth of European Photonics Industry Vs. Growth of Industrial Production

Source: Optech Consulting

Note that industrial production growth inflation adjusted while Photonics growth is in nominal euros.

2.3.2 Germany

With a 2015 production volume of EUR 28.5 billion Germany accounts for a 41.3% share of European production. The share has slightly increased since 2011 (40.7%). While Germany was hit especially hard by the contraction of the European photovoltaics industry due to its large exposure to the sector, substantial growth in the other segments of Photonics more than compensated for that. The German Photonics industry is well represented in strongly growing segments such as laser materials processing, measurement & image processing and medical technology & life science. Also, the German home market developed comparably well due to the, in the European context, good development since 2011 of the economy and especially of the industrial production. Photonics production including photovoltaics grew at a CAGR of 1.7% from 2011 to 2015, vs. a CAGR of 7.8% estimated for the 2005 to 2011 period. Production excluding photovoltaics grew at a CAGR of 5.4% since 2011 vs. 6.2% CAGR estimated for the 2005 to 2011 period.

Major sectors of Photonics production in Germany include:
- Measurement & image processing is the largest segment of Photonics in Germany. This comprises image processing systems and components as well as a large range of products for measurement including binary sensors, spectrometers as well as systems for measurement and analysis.
- Medical technology & life science is the second largest segment. Products include endoscope systems as well as microscopes and surgical microscopes, spectacle lenses and contact lenses, medical lasers & systems (especially for ophthalmology), diagnostic systems for ophthalmology, and medical imaging systems.
- Production technology is the third largest segment. The German industry produces lasers and laser systems for materials processing, as well as lasers and objectives for microlithography.

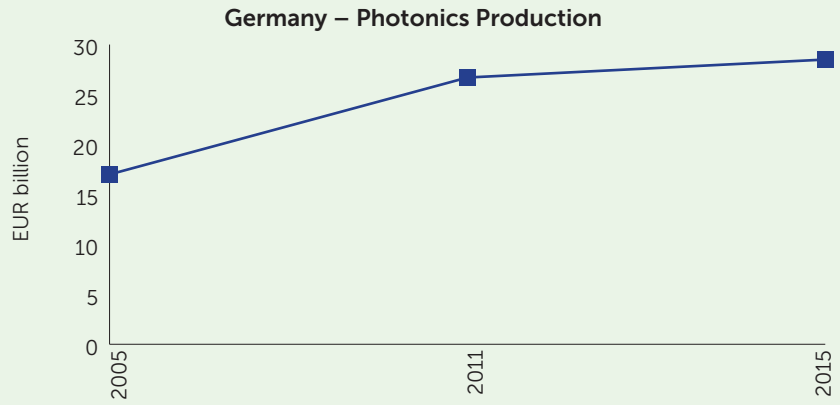


Diagram 54: Germany, Photonics Production 2005 to 2015

Source: Optech Consulting

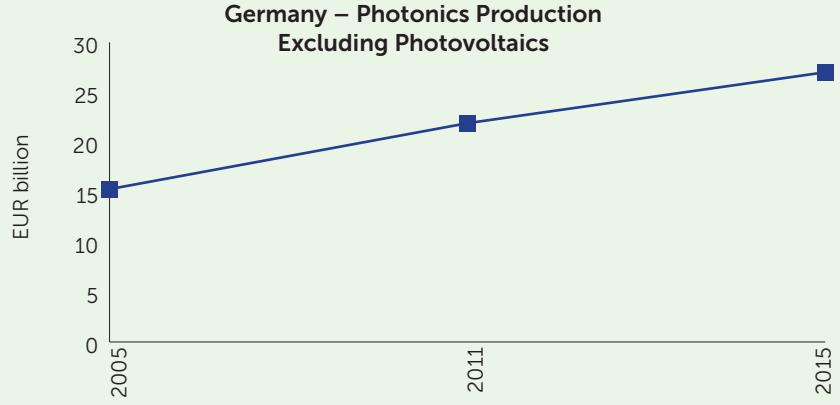


Diagram 55: Germany, Photonics Production Excluding Photovoltaics 2005 to 2015

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	*Production Tech. *Measurement *Medical Tech.
2.0 ... 3.9	*Lighting *Compom. & Systs.
1.0 ... 1.9	*Displays *Photovoltaics
0.5 ... 0.9	*Communication *Information Tech. *Defence
0.0 ... 0.4	

Diagram 56: Photonics Production in Germany, by Segment
Source: Optech Consulting

- Optical components & systems is the fourth largest segment. Products include optical glass, optical components as well as optical systems ranging from binoculars to equipment for the movie industry. Optical components are produced by system companies like Zeiss, but also by specialized companies such as Qioptiq (former Linos) and Sill Optics. Arri produces equipment for the movie industry. Several manufacturers of binoculars and telescopic sights are located in Germany. Schott produces optical glass.
- Lighting is the fifth largest segment. Germany hosts manufacturing plants of Osram and Philips Lighting as well as of producers of specialized lamps for technical use.
- Optical communications: The major producers in Germany are Coriant and Adva Optical. While Coriant emerged from former Nokia Siemens Networks, Adva Optical has grown from a small company to substantial size within a short time.
- Information technology: Germany hosts production of digital cameras, systems for the printing industry, and high end office printers.
- Photovoltaics: The German production of solar cells and modules shrunk during the last four years under the fierce competition from China. Major manufacturers have shut down or relocated manufacturing to Asia. The remaining production of for solar cells and modules accounts for about EUR 1.5 billion.
- Displays: A major manufacturer of display materials is located in Germany.
- Defence & security: Germany hosts several manufacturers of defence optronics and infrared and night vision equipment.

2.3.3 France

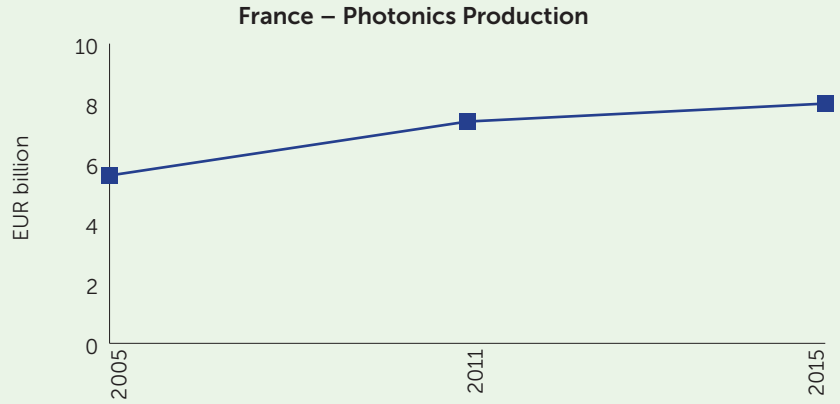


Diagram 57: France, Photonics Production 2005 to 2015

Source: Optech Consulting

With a 2015 production volume of EUR 8.1 billion France accounts for a 12.5% share of European production. Production grew at a CAGR of 2.2% since 2011 (excluding photovoltaics: 2.9%).

Major sectors of Photonics production in France are:
- Defence & security: France headquartered Thales is the major producer of defence & security Photonics in Europe. Its production plants are mainly located in France and the United Kingdom, with smaller activities in other countries. Also Safran is an important producer in this sector in France.
- Optical communications: Nokia, one of the global market leaders for optical networking systems, has substantial production operations in France. This is due to the takeover of Alcatel-Lucent. Note that we do not include fibre cables in this report. According to Eurostat the fibre cable production in France amounts to EUR 399 million in 2015, corresponding to 28% of the European production (EUR 1.42 billion).

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*Defence
1.0 ... 1.9	*Measurement *Medical Tech. *Communication
0.5 ... 0.9	*Lighting *Compom. & Systs.
0.0 ... 0.4	*Production Tech. *Information Tech. *Displays *Photovoltaics

Diagram 58: Photonics Production in France, by Segment

– Measurement & image processing: Products include binary and other photoelectric sensors, image processing systems and spectrometers. Major manufacturers include Schneider Electric, Japan headquartered Horiba Yobin Yvon. I2S, and E2V. More than 25 companies making image processing systems were identified in France.
– Medical technology & life science: Essilor is the world market leader for spectacle lenses & contact lenses and operates production in France and in many countries worldwide. Other companies of the medical technology & life science segment in France include Japan headquartered Horiba Medical and Mauna Kea Technologies.
– Optical components & systems: France hosts a substantial amount of optical components production for industrial, military, scientific applications. Other products of the sector include optoelectronic components and lasers. Manufacturers include Thales, Safran and Cilas. Radiall makes products for free space communications. Soitec produces semiconductor materials for optical devices.
– Lighting: France hosts production of conventional lamps. The decrease in the market has not been compensated by new products.
– Production technology: Products include laser systems for cutting, welding, marking, and additive manufacturing.

In 2014 Tematys has evaluated the French Photonics industry [10]. The estimate for the production volume was EUR 10.45 billion. The difference of EUR 2.35 billion vs. the EUR 8.1 billion estimated in the present report is mainly due to lighting where Tematys estimates a production volume of EUR 2.66 billion, while we estimate about EUR 0.5 billion. We assume that the difference is due to the fact that the analysis of Tematys includes luminaires.

2.3.4 United Kingdom

With a 2015 production volume of EUR 6.8 billion the United Kingdom accounts for a 9.9% share of European production. In local currency the production decreased from 2011 to 2015. This translates into a small increase on a euro basis, at a CAGR of 1.4% from 2011 to 2015 (excluding photovoltaics: 3.6%).

The decrease of the production volume from 2011 to 2015 in local currency is due to several segments. In photovoltaics, production in the United Kingdom decreased sharply as a Japanese manufacturer cut manufacturing in the country. In communication, production decreased in the course of the restructuring of the European industry. Only in a few Photonics segments production grew on a British pond basis. These include production technology (laser materials processing), measurement & image processing and optical components & systems.

Major sectors of Photonics production in the United Kingdom include:

- Defence & security: The major defence and security Photonics producers in the United Kingdom are France headquartered Thales, Italy headquartered Leonardo, BAE Systems[13], Qioptiq, Qinetiq, and E2V.
- Measurement & image processing: The United Kingdom produces spectrometers and spectrometer based analytical systems. Also image processing systems are produced in the United Kingdom, including for the security sector. Photonics based measurement systems for the oil and gas industry are of increasing importance.
- Medical technology & life science: Products include spectacle lenses and contact lenses, ophthalmic instruments and medical lasers.
- Optical components & systems: Products comprise optical glass, optical and optoelectronic components (lenses, mirrors, filters, fibre-based components), and optical and optoelectronic systems (objective lenses, binoculars and telescopic sights, television cameras, lasers).
- Communication: Ericsson has left the optical networking segment. The left behind activities in the United Kingdom partly continuing as smaller firms under new names. Oclaro is active in the optical networking components segment. Also smaller firms which have emerged from institutes produce components and modules.

[13] BAE Systems' Photonics systems production is mainly located in the USA.

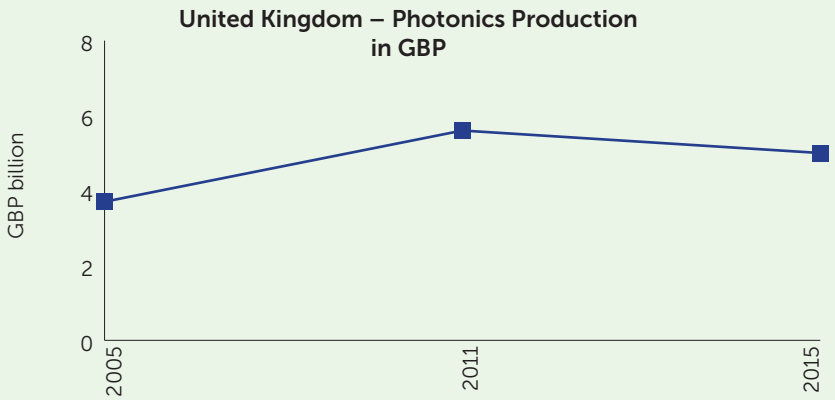


Diagram 59: United Kingdom, Photonics Production 2005 to 2015 in British Pound

Source: Optech Consulting

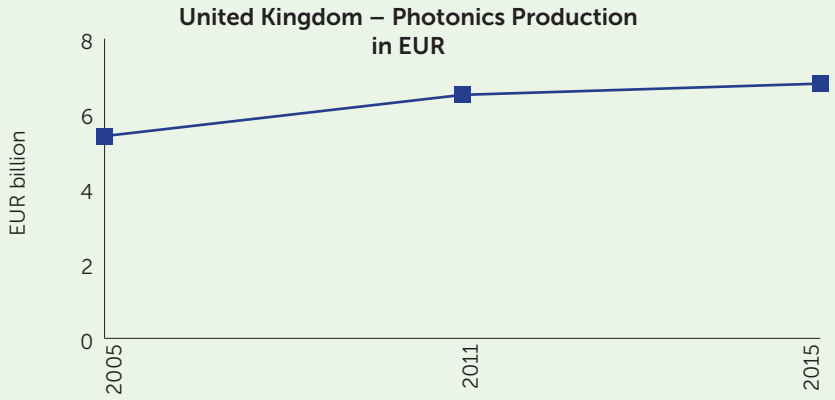


Diagram 60: United Kingdom, Photonics Production 2005 to 2015 in EUR

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*Defence
1.0 ... 1.9	*Measurement
0.5 ... 0.9	*Medical Tech. *Communication *Compom. & Systs.
0.0 ... 0.4	*Production Tech. *Information Tech. *Displays *Lighting *Photovoltaics

Diagram 61: Photonics Production in the United Kingdom, by Segment
Source: Optech Consulting

2.3.5 Italy

With a 2015 production volume of EUR 5.7 billion Italy accounts for a 8.3% share of European production. Production grew at a CAGR of 0.1% since 2011 (excluding photovoltaics: 1.6%), vs. a 7.0% CAGR for the 2005 to 2011 period.

Major sectors of Photonics production in Italy include:

- Defence & security: Since April 2016 Leonardo-Finmeccanica combines major activities of the Photonic defence & security sector such as the former Selex ES (Rome) and the former Galileo Avionica (Florence).
- Production technology: Laser machines and lasers are produced by Prima Industrie, BLM Adige, Salvagnini, and many other companies.
- Information technology: In its Automatic Data Capture (ADC) division Datalogic produces barcode scanners and related equipment. The company is the third largest manufacturer in that segment, worldwide. Olivetti (parent: Telecom Italia) produces laser printers and photocopiers.
- Measurement & image processing: The Italian industry produces systems for image processing and optical measurement systems. Eurostat data also indicates a small production volume of spectrometers.
- Lighting: Italy hosts a large size lighting industry which produces lamps as well as luminaires (note that we do not count luminaires as Photonics products in this survey).

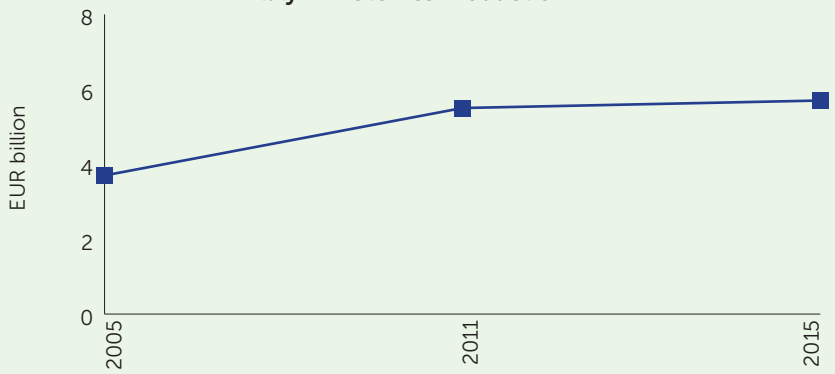


Diagram 62: Italy, Photonics Production 2005 to 2015

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	
1.0 ... 1.9	*Defence
0.5 ... 0.9	*Production Tech. *Measurement *Information Tech. *Lighting *Photovoltaics *Compom. & Systs.
0.0 ... 0.4	*All other

Diagram 63: Photonics Production in Italy, by Segment
Source: Optech Consulting

During the last four years the best performing segment was production technology with double-digit annual growth, followed by measurement & image processing. In the information technology segment Datalogic increased revenues. At the same time the segments of defence & security, optical components & systems, medical technology & life science, Optical communications, and photovoltaics showed decreased production.

2.3.6 Netherlands

With a 2015 production volume of EUR 8.7 billion the Netherlands account for a 12.5% share of European production. Production grew at a CAGR of 1.7% since 2011, down from the 13.2% CAGR for the 2005 to 2011 period. Photonics production in the Netherlands strongly depends on one company, ASML. Sales of ASML trended about sideward from 2011 to 2015, after growing strongly in the years before.

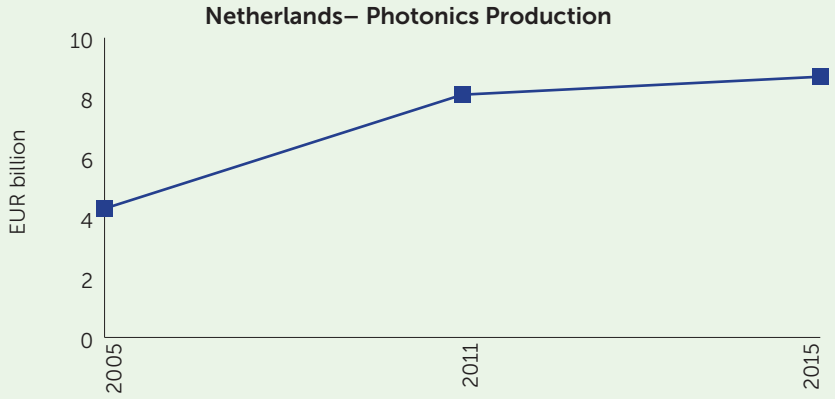


Diagram 64: Netherlands. Photonics Production 2005 to 2015

Source: Optech Consulting

Major sectors of Photonics production in the Netherlands include:

- Production technology: This comprises the production of lithography systems (ASML), besides laser materials processing systems.
- Lighting: Philips Lighting, after the IPO a stock exchange listed company, is headquartered in the Netherlands[14]. The large majority of the lamp production of Philips Lighting is located abroad.
- Information Technology: Oce (now part of the Japanese Canon group) produces optical printers and copiers (a major production location is in Germany). Barco produces projectors (which we include in the optical components & systems segment) and monitors for medical applications (which we include in the medical technology & life science segment). Note that we do not include monitors and projectors for PC, TV and conference room use as Photonics products.
- Communication: Manufacturers of optical fibres include Draka and Eurofiber. Note that we do not include fibre cables as Photonics products in this report.
- Optical components & systems: Companies active in this segment include Anterion and Nedinsco.
- Measurement & image processing: Products include sensors, spectrometers, measurement, analysis and image processing systems. Manufacturers include Adimec, Advantech, Avantes, Batenburg Mechatronics, Cosine. Isotron, Sumipro, Technobies, and 3D One

[14] Lumileds, formerly majority owned by Philips, is located in the USA.

Production in EUR billion	
4.0 ... 7.9	*Production Tech.
2.0 ... 3.9	
1.0 ... 1.9	
0.5 ... 0.9	*Lighting.
0.0 ... 0.4	*All other

Diagram 65: Photonics Production in the Netherlands, by Segment
Source: Optech Consulting

2.3.7 Switzerland

With a 2015 production volume of EUR 2.5 billion Switzerland accounts for a 3.6% share of European Photonics. In local currency production virtually stagnated between 2011 and 2015. This translates into an increase on a euro basis at a CAGR of 3.5% from 2011 to 2015. The appreciation of the Swiss franc versus the euro and other currencies had a strong impact on Photonics production n Switzerland. The appreciation occurred mainly in the years 2010 and 2011 and weighed on the sales of the Swiss Photonics industry for several years now. The industry exports 90% of its production, with the majority of products going to the euro area.

Association data

The data presented here originates from a series of analyses and reports which Optech Consulting carried out for Swissphotonics. When comparing the data it is important to note that the data published in the reports for Swissphotonics includes equipment for solar cell and module production which is not included in the data in the present report. The data shown for 2005 is an estimate as the series of reports started with data year 2007.

Exchange rate

The accumulated appreciation of the Swiss franc versus the euro from 2011 to 2015 was by 14.6%.

However, the stronger impact on Swiss Photonics is due to the preceding appreciation of the Swiss Franc in 2010 vs. 2009 (+13.2%) and in 2011 vs. 2010 (+15.7%), which had a long term effects on the sales of the Swiss Photonics industry. 90% of the Swiss Photonics production is exported, mainly into the EUR area.

Major products of the Swiss Photonics industry include:

- Production technology: Several manufacturers of lasers and laser systems for materials processing produce in Switzerland. Locally headquartered Bystronic and Germany headquartered Trumpf are the major producers. The segment accounts for a 2015 production volume of EUR 740 million, up from EUR 690 million in 2011. The moderate increase in euros corresponds to a decrease in local currency of accumulated -6.3%. Besides the long term effect of the currency shift another reason for the decrease is the shift of end markets to China. Manufacturers in Switzerland increasingly serve the Chinese market by machines manufactured in China, thus reducing exports from Switzerland as well as from other European locations.
- Measurement & image processing: The segment accounts for a 2015 production volume of about EUR 670 million, up from EUR 540 million in 2011. Also in this segment the production decreased in local currency. Major manufacturers in Switzerland include Leica Geosystems (parent: Hexagon of Sweden), Baumer and Cedes..
- Medical technology & life science: The segment accounts for a 2015 production volume of about EUR 530 million, up from 460 EUR million in 2011 volume. Major manufacturers in Switzerland include Haag-Streit, Leica Microsystems, and Tecan.
- Optical components & systems and security & defence: The two segments account for a combined 2015 production volume of about EUR 390 million vs. EUR 380 million in 2011. Manufacturers of optical components & systems in Switzerland include Fisba Optik, SwissOptic (parent: Berliner Glas of Germany), and Schott Suisse. Vectronix, part of Safran group in France), makes defence & security systems.
- Other sectors of Photonics in Switzerland include information technology and optical communication. Manufacturers in Switzerland include Huber+Suhner, II-VI Laser Enterprise and Daetwyler Graphics (part of Heliograph Holding, Germany).

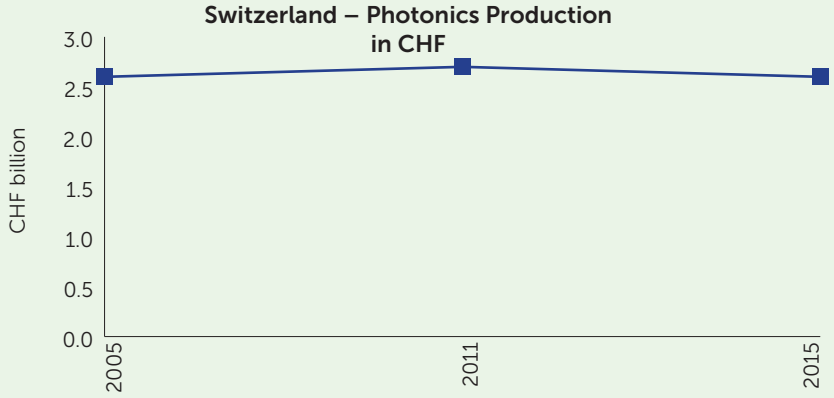


Diagram 66: Switzerland, Photonics Production 2005 to 2015 in Swiss Franc

Source: Optech Consulting

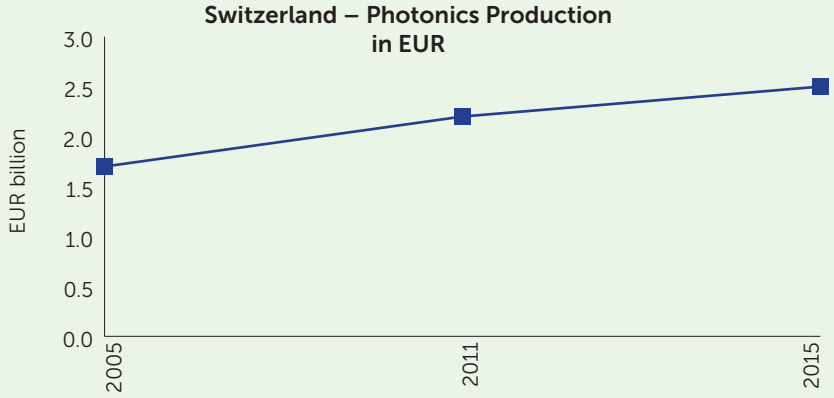


Diagram 67: Switzerland, Photonics Production 2005 to 2015 in EUR

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	
1.0 ... 1.9	
0.5 ... 0.9	*Production Tech. *Measurement *Medical Tech.
0.0 ... 0.4	*All other

Diagram 68: Photonics Production in Switzerland, by Segment
Source: Optech Consulting

2.3.8 Other Countries

With a 2015 production volume of EUR 8.9 billion the other EU28 states account for a 12.8% share of European production. The production decreased at CAGR of -1.1% since 2011. The decrease is due to photovoltaics, where these countries were substantially engaged. Excluding photovoltaics the Photonics production increased from 2011 to 2015 at a CAGR of 4.2%.

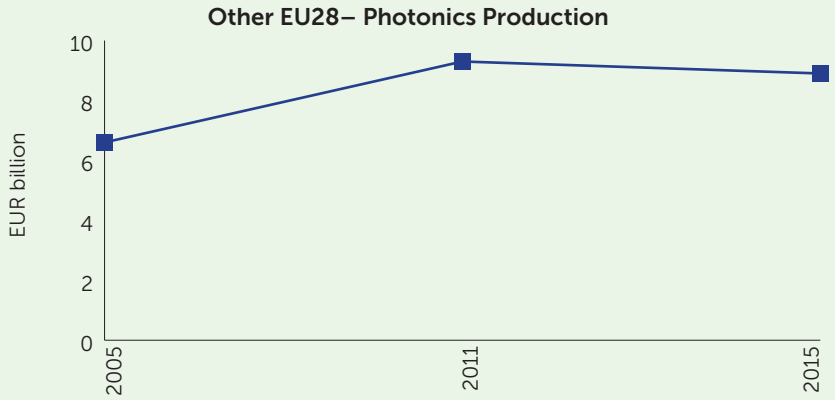


Diagram 69: Other EU28 Countries, Photonics Production 2005 to 2015

Source: Optech Consulting

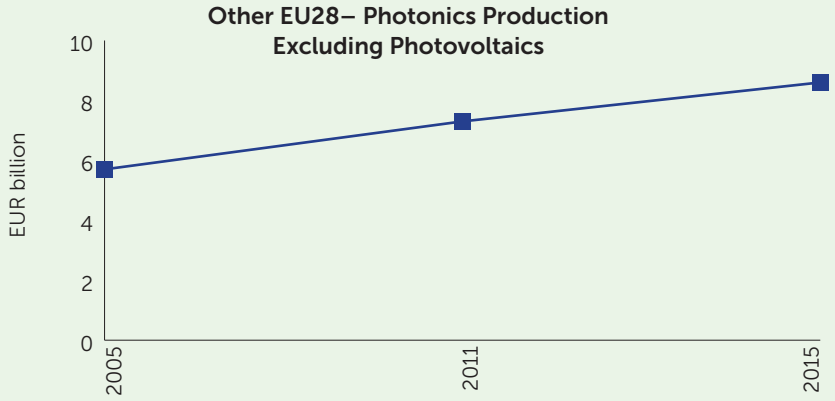


Diagram 70: Other EU28 Countries, Photonics Production Excluding Photovoltaics 2005 to 2015

Source: Optech Consulting

Production in EUR billion	
4.0 ... 7.9	
2.0 ... 3.9	*Lighting
1.0 ... 1.9	*Compom. & Systs.
0.5 ... 0.9	*Production Tech. *Measurement *Medical Tech. *Defence
0.0 ... 0.4	*All other

Diagram 71: Photonics Production in Other EU28 Countries, by Segment
Source: Optech Consulting

Major contributions to Photonics production come from Sweden, Spain, Finland, Belgium, Austria, and Denmark. **Sweden** accounts for a 2015 production volume of about EUR 1.8 billion.

Photonics in Sweden comprises:
- Production technology: Manufacturers include Mycronic, Esab, Elos Fixturlaser, and Permanova. Optoskand makes fibre-optic components for laser systems.
- Measurement & image processing: Manufacturers include Hexagon, Optronic Norden, Perten Instruments, and Senseair.
- Medical technology & life science: Manufacturers include Hemocue, Cellavision, and Masimo.
- Communication: Manufacturers include Transmode Systems, Finisar, and Flatfrog. Note that Ericsson quit optical networking in 2014 and its optical networking activities were outside Sweden.
- Defence & security: Manufacturers include Axis Communication, Trimble, and Image Systems.
- Optical components & systems: Manufacturers include FLIR Systems, Toby Technology, and Victor Hasselblad.

Spain: Products include spectacle lenses and contact lenses, laser materials processing systems, optical measurement and image processing systems, solar cells and modules, and optical components and systems.

Belgium: Major product areas are measurement and image processing, lighting (lamp production by Philips), production technology (laser materials processing systems), and spectacle lenses. Barco produces cinema projectors and monitors for the medical sector..

Finland: Production comprises nearly all segments of Photonics: Laser materials processing, optical measurement & image processing, optical components & systems, medical technology & life science, and defence & security.

Denmark: Major products include optical measurement systems, optical and fibre-optic components, lasers, and optical systems.

Austria: Major products include optical measurement systems, optical components and systems, laser systems for materials processing, lighting products, systems for medical technology & life science.
Poland: Products include optical components and systems, laser systems for materials processing, lighting products (lamps), spectacle lenses, endoscopes, and solar cells/modules.

Other countries: Major product segments comprise lamps (Bulgaria, Hungary, Czech, Slovakia), spectacle lenses and contact lenses (Bulgaria, Estonia. Ireland, Greece, Hungary, Portugal, Romania, Slovenia), optical components (Bulgaria, Czech, Latvia, Hungary, Portugal, Romania), optical systems (Bulgaria, Czech, Ireland, Lithuania, Hungary, Poland, Romania), endoscopes (Estonia, Bulgaria, Hungary), and solar cells and modules (Bulgaria, Czech, Ireland, Greece, Lithuania, Hungary, Slovenia, Slovakia, Croatia).

We mention the following products and manufacturing activities not included in the scope of the present report:
- Automotive lighting products (manufactured in Czech, Slovakia and other countries in East Europe)
- Assembly of LCD panels (Poland, Slovakia)
- Assembly of consumer electronics and office automation products in East Europe by Asian manufacturers and EMS companies (electronics contract manufacturers).

2.4 Employment in European Photonics

As of 2015 the European Photonics industry employed 301 000 people (table 3). This includes only employees working in Europe for companies manufacturing Photonics products in Europe (see text box for details).

	2005	2011	2015	Increase 2005–2011	Increase 2011–2015	Increase 2005–2015
Photonics w/o photovoltaics	**235,000**	**271,000**	**290,000**	**36,000**	**19,000**	**55,000**
Photovoltaics	13,000	37,000	11,000	24,000	- 26,000	- 2,000
Total	**248,000**	**308,000**	**301,000**	**59,000**	**- 9,000**	**51,000**

Table 3: Employment in the European Photonics Industry

Source: Optech Consulting

Employment in Europe – What is included

The number of employees includes people working in Europe for companies manufacturing Photonics products in Europe. For companies which are also active outside Photonics only the employees of the parts of the companies involved in Photonics are included. The number does not include employees of research institutes and consulting companies. Employees working in sales and service are included if the respective company also has at least some Photonics manufacturing activity in Europe. Employees of pure sales and service organizations of overseas companies are not included. Employees of suppliers (subcontractors) to the photonics industry are not included, unless the supplier also belongs to the Photonics industry such as for example a manufacturer of optical components.

The number of employees in the European Photonics industry has decreased from 2011 to 2015, after increasing from 2005 to 2015. The decrease during the last four years is due to the photovoltaics segment, where employment had sharply increased from 2005 to 2011 and then fell back to even slightly below its 2005 level (please see table 3 and diagram 72).

For Photonics excluding photovoltaics the number of employees in European Photonics increased steadily from 235,000 in 2005 to 271,000 in 2011 and to 290,000 in 2015. In the photovoltaics segment 24,000 jobs were created between 2005 and 20122, but 26,000 were lost between 2011 and 2015.

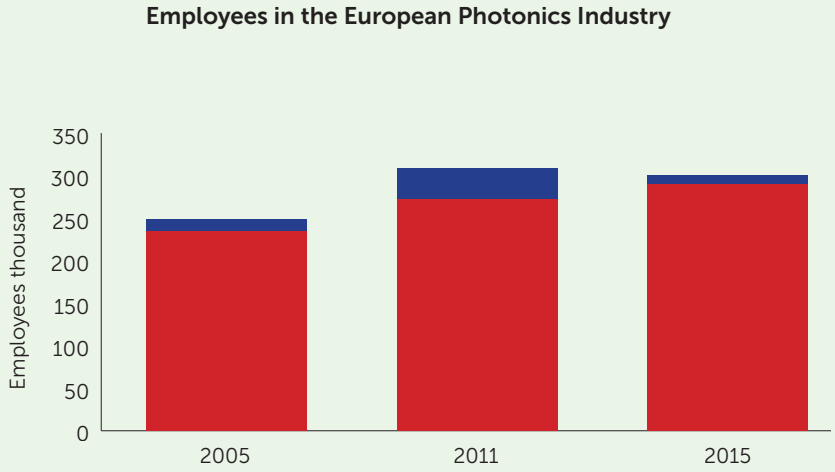


Diagram 72: Employees in the European Photonics Industry

Photonics w/o photovoltaics

Photovoltaics

Source: Optech Consulting

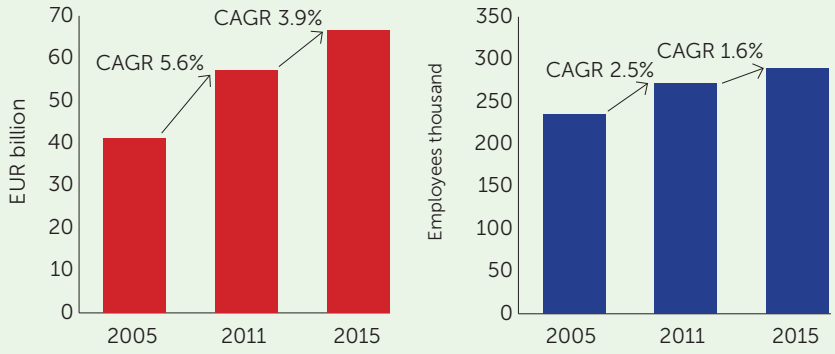


Diagram 73: Europe, Growth of Photonics Production and Employment

Production

Employment

Source: Optech Consulting

* w/o photovoltaics

Employment and Public Private Partnership

In this report, as in our previous reports on Photonics we include photovoltaics. The public private partnership (PPP) for Photonics does not include photovoltaics. The target of the PPP is to increase the number of employees from 2011 to 2020 by 30,000. For Photonics excluding photovoltaics the number of employees grew by 18,000 between 2011 and 2015. If the growth of employment proceeds until 2020 at the same rate as for the last four years another 24,000 employees will be added until 2020. I.e. the total increase of the number of employees between 2011 and 2020 will reach 42,000.

For Photonics including photovoltaics the target of 30,000 new jobs created between 2011 and 2020 is unlikely to be reached, after 26,000 jobs were lost between 2011 and 2015. The larger than expected increase of employment in the other segments of Photonics cannot compensate for the massive job loss in photovoltaics.

For Photonics excluding photovoltaics the number of employees increased at a CAGR of 1.6% from 2011 to 2015. At the same time the production volume of the European Photonics industry at a CAGR of 3.9%. The difference is due to two issues. Firstly, productivity in the industry increases, leading to larger revenues per employee. Secondly, overseas employment for the support sales and service increases for many companies somewhat faster than employment in Europe.

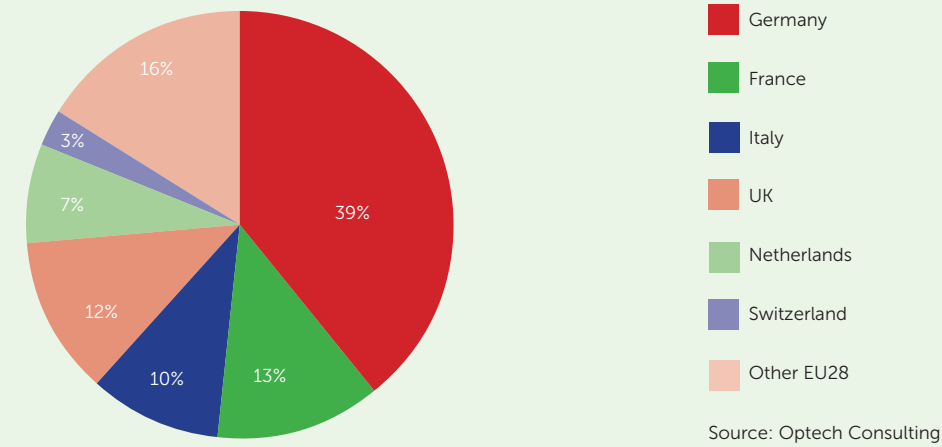


Diagram 74: Employees in the European Photonics Industry, by Country

Source: Optech Consulting

The breakout of the number of employees by country follows the breakout of the production volume with some exceptions. The Netherlands, accounting for 12.5% of the revenues, only accounts for about 7% of the number of employees. Germany, accounting for 41.3% of the revenues, accounts for about 39% of the number of employees. The revenue per employee figure is especially high for the Netherlands, Germany, and Switzerland. It is lower for France, Italy, United Kingdom, and for the average of the other EU28 countries.

2.5 R&D and Capex

R&D spending is substantial in Photonics in order to compete in the highly innovative industry sector. In average European Photonics companies spend 9.1% of their revenues for R&D. In addition, they invest in average 4.7% of their revenues, bringing the total R&D and investment quota to 13.8%.

These figures were calculated based on financial reports of 27 companies. The selected companies are headquartered in five different countries of the EU and are active in various segments of Photonics. In order to make sure the figures are characteristic for Photonics activities only companies were chosen with Photonics revenues constituting more than 65% of their total revenues. The selected 27 companies represent more than 30% of European Photonics by revenue.

In detail the results were as follows:
– R&D quota, average: 9.3%
– R&D quota, weighted average: 10.1%
– Capex/sales, average: 4.7%
– Capex/sales, weighted average: 4.9%

For capex/sales the average and the weighted average are nearly the same. For the R&D quota both figures differ by 0.8 percentage points indicating that the weighted average may be somewhat too high due to an overrepresentation of large companies (smaller companies report a somewhat smaller R&D ration in average). Therefore, we conclude that the R&D quota for European Photonics is in the range of 9.7%.

The R&D quota of the companies analyzed varies from 3% to 18%, while the capex/sales ratio ranges from 2% to 11%. The R&D ratio depends on the Photonics segment and on single companies. For example, it was found to be high (17.7%) for ASML, the largest Photonics producing company in Europe. It is comparably high for the communication segment: 17.7% for Adva Optical and 16.6% for Alcatel Lucent (now part of Nokia)[15]. The R&D quota in optical communication is also high for companies worldwide, e.g. currently in the range of 20% to 21% for Ciena and Infinera of the USA[16].

The capex/sales ratio is high for companies operating in product segments requiring costly manufacturing equipment and facilities. It may vary considerably for companies in the same segment, depending on their present investment activities.

[15] The figure is not included in the average of the 27 companies because it refers to the company's USD 15 billion total revenue and is not indicative for its optical networking activity.
[16] These are system manufacturers. The R&D quota is lower for component manufacturers for optical communication.

2.6 Number of Photonics SME in Europe

For 2015, we estimate the number of manufacturing companies in Photonics in Europe at 5,000, with an error bar of +/- 1,000. The number refers to companies with a minimum size of ten employees working in Photonics. The estimate is based on the extrapolation of data available on single countries and regions.

Estimates for the number of Photonics companies in Europe

In the report "Photonics in Europe – Economic Impact" [5], published in 2007, we estimated the number of European Photonics manufacturing companies at 5,000 for the year 2005. The estimate was based on an extrapolation of information on Germany collected during the evaluation for the report "Optische Technologien – Wirtschaftliche Bedeutung in Deutschland" [3] published in June 2007. Another source of information were member lists of the local Photonics networks (Optische Netzwerke) in Germany.

By the mid 2000s AFOP had estimated 1,000 companies for Photonics in France, including non-manufacturing companies [11]. In an analysis published 2014 Tematys [10] counted 657 companies in France for a Photonics sector defined somewhat larger than in the present report.

In 2012, EPIC estimated a number of 3,500 companies for Photonics in Europe [12].

In the 2015 edition of the report "Photonik in der Schweiz" [7] we list more than 100 companies manufacturing Photonics products in Switzerland by name and product segment.. The Swiss Photonics association Swissphotonics has identified about 100 additional Photonics manufacturing companies in Switzerland, bringing the total to more than 200. Switzerland accounts for 3.6% of the European Photonics production. A linear extrapolation leads to 5,500 companies in Europe.

For 2015 we identified less than 200 companies having more than 250 employees in the area of Photonics. This means that most of the 5,000 companies are SME. Small companies with less than 50 employees[17] make up for the large majority of companies. The combined revenue of the companies with less than 50 employees is only a minor part of the total revenue of the industry. The total revenue of the industry is mainly due to the companies with more than 250 employees. Therefore, revenue estimates do not provide information on the number of SME.

The accuracy of the estimate of the number of companies is limited by the difficulty to identify thousands of small companies and knowing their revenue in Photonics (or number of employees). Without that information a limit for the minimum company size cannot be applied.

The estimate of 5,000 +/- 1,000 manufacturing companies in European Photonics is the same for 2005 and 2015. Since 2005 the production volume of European Photonics has increased by 56%. However, the revenue of major manufacturers has increased by an even higher percentage. Due to the large share of the big companies in Photonics production revenue considerations do not provide substantial evidence for an increase or decrease of the number of SME. Also the accuracy of the SME count does not allow to identify an increase or decrease of their number within the last ten years or even within the 2011 to 2015 period which is the focus of the present report.

[17] The employee numbers refer to the Photonics activities of the companies, not to their total size.

Methodology, Data Sources, Definitions

The present report contains an analysis of the global and European Photonics industry. The information sources on the **global market and production** volume comprises association statistics (data mainly available for Japan and Taiwan), publications of market research companies specialized on the single product areas, financial reports of Photonics manufacturers, and customs statistics. For the single product segments, major products and countries information from these data sources is used upon availability and quality of data.

The **European** production has been assessed based on financial reports of Photonics manufacturers, public statistics on industrial production and customs statistics. On some of the European countries local Photonics associations and experts have provided valuable information on the local Photonics industry.

The multi-source based analysis for the global market as well as the European production is needed because production volumes of more than half of the Photonics production volume (by value) cannot be retrieved from public statistics.

The data of the various sources use different definitions and needs to be adapted to a common base, regarding the range of products included, whether data includes products only or also parts & service, different data years, and different currencies.

Growth rates for the global market as well as for the European production can only be calculated with sufficient accuracy when the data source provides a consistent time series, such as financial reports of companies. Association statistics and market research reports have varying quality, with especially growth rates being often revised. Public statistics and trade statistics, where available, provide mostly reliable data (except for artefacts).

Photonics comprises systems, modules, components, and materials. Often products along the value chain are manufactured by different companies. For calculating the total revenue of the industry we add up the revenues along the value chain, rather than adding the added value. Thus, the employees at each level of the value chain are correlated with the revenue per employee ratio for that level. The selection of the pre-products along the value chain impacts the total revenue determined for the segment. For example, we needed to make a decision whether to include solar cells as a separate product, or only to include solar modules as the final product. Adding both increases the revenues for the photovoltaic segment and its weigh in Photonics. A particular problem is that industry structure may change over time (backward or forward integration of companies) requiring to decide between continued reporting or adaptation of the data to a changing industry structure.

While the data on the world market, which is mainly based on association data, market reports and customs data, excludes the value of parts and service, parts and service are included for the European production volume,

which is mainly based on financial reports of companies. This tends to overestimate the European production volume versus the global market. However, there is also an effect underestimating the European production versus the world market: By adding company revenues some of the double counting along the value chain, which adheres to the global figures, is eliminated for the European production. The two effects are estimated to be in the range of less than 10%, each, and tend to balance each other.

Employment figures for the European Photonics industry were determined by evaluating financial reports of companies. This allows to determine characteristic revenues per employee for single product segments, company sizes and countries.

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