# UK Photonics: The Hidden Economic Engine

PHOTONICS LEADERSHIP GROUP

The FUTURE PHOTONICS Hub
Advancing the manufacturing of next-generation light technologies

Innovate UK
Knowledge Transfer Network

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# Executive summary

## UK Photonics: The Hidden Economic Engine

**The UK photonics industry contributes £12.9bn to the economy per year and employs 65,000 people, with a manufacturing productivity of £62k per employee. In spite of this, UK photonics remains a largely hidden economy.**

Photonics manufacturing is distributed throughout the UK, from the far south west, to Scotland and Northern Ireland. Over 70% of photonics companies turn over less than £5m annually, with 170 mid- and large-sized firms employing 90% of the workforce, and generating 96% of the output.

Photonics manufacturing makes up around two thirds of the total reported output from the computing, electronics and optical products sectors. More people are employed in photonics manufacturing than in manufacturing pharmaceuticals, working in a larger number of companies and producing a similar total output.

Building on work by SPIE, the international society for optics and photonics, a robust methodology has been developed to estimate the size of the UK photonics industry. This has been designed to accurately estimate production from highly diversified companies engaged in photonics manufacturing, an industry for which there is no one single standard industrial classification (SIC) code.

Whilst Germany is the largest manufacturer of photonics in Europe, the UK, France and Netherlands all compete strongly for second place, each responsible for between 9-14% of EU output. 11.1% of all dedicated photonics funding made available under the European Commission's Horizon 2020 research and innovation programme (H2020) has been awarded to UK-based organisations. Furthermore, 65% of all H2020 consortia funded from photonics calls include UK partners.

The UK accounts for around 3-8% of global photonics production and, according to independent estimates from SPIE, is the eighth largest manufacturer of photonics components in the world.

**Photonics defined**

All science and technology related to the generation, transmission, detection and manipulation of light is know as 'photonics'. Photonics technologies range from basic optical lenses and optical fibre, to lasers, displays and cameras of all types, incorporated in products and high productivity manufacturing processes worldwide.

The UK has been innovating in photonics for over four centuries and it will continue to deliver critical functionality to society. Photonics will enable Internet 5.0, accurate sensing for autonomous vehicles, digital lasers for high-productivity manufacturing and non-invasive healthcare tools. Photonics innovations in these areas are vital to delivering the four Grand Challenges identified in the UK's Industrial Strategy (2017).

**Figure 1: Distribution of UK photonics industry activity**

# Introduction

**The UK photonics industry comprises all organisations involved in manufacturing, servicing and supporting products which use light-based technologies, known as *photonics*.**

Photonics technologies are vital to most of the products and services used by virtually everyone in the UK on a daily basis. Laser light and optical fibre form the basis of the communication networks underpinning the internet. Displays are the heart of all digital entertainment, from televisions to smart phones and tablets. We capture, record and view the world through optical lenses. Manufacturing processes, from automotive to food, rely on lasers to cut, mark and measure. Combined optics lasers and cameras are operating in the defence systems of today and will be the eyes of tomorrow's driverless cars.

Society depends on photonics. We rely on this technology daily yet the seamless functionality photonics provides means it often works unseen inside these everyday products.

The same is true for the UK photonics industry, ubiquitous in enabling wide parts of the economy. Photonics is a major manufacturing and exporting sector built on four centuries of UK leadership but few are aware of the scale of activity, or its impact. With companies distributed across the country, often of a small or medium-size, serving a huge range of very different applications and lacking in household names, it is easy to see how many people can remain unaware of the world-leading photonics manufacturer based just around the corner.

This report quantifies the size of the UK photonics industry. It is based on a robust methodology which has been developed using internationally-recognised data sources, designed to take into account the dispersed and concealed nature of the industry. Establishing this model also provides a framework for future quantitative reporting on the UK photonics industry - the merits and assumptions of which are detailed.

The report illustrates the UK photonics industry's regional distribution and compares photonics to other major UK industry sectors, as well as showing the position of the UK relative to other global photonics markets. Scope for future growth and impact on the UK Industrial Strategy Grand Challenge areas are also identified.

An in-depth analysis of the full range of applications (in e.g. transport, lighting, healthcare etc.) enabled by photonics technologies, and in turn their leverage on the UK economy as a whole, is beyond the scope of this report. This report focuses specifically on the size and key characteristics of the UK photonics industry. However, information on photonics-enabled technologies and markets is available in previous reports: Photonics Revolutionising our World[i], The Leverage effect of Photonics Technologies: the European Perspective[ii] and the IOP's Health of Photonics report (2018)[ix].

***Acknowledgements:***

*Full acknowledgement is made to the many industry leaders who, through the Photonics Leadership Group (PLG), contributed their insights to this report, the Knowledge Transfer Network (KTN) and its help in delivering a focused analysis, and the support of The Future Photonics Hub.*

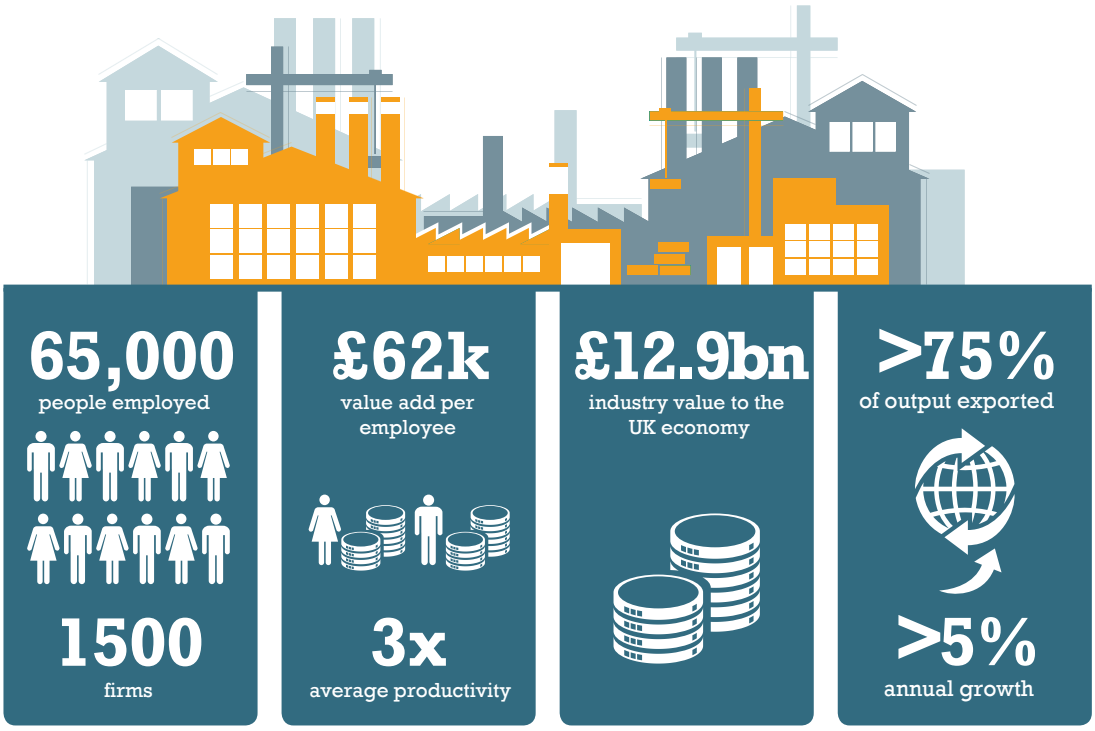
# The UK Photonics industry

**The UK photonics industry is estimated to have produced goods and services worth £12.9bn in 2016.**

Behind this impressive output lies at least 650 companies based across the UK, from Cornwall to Scotland, collectively employing 65,000 people. Each of those employees contributed, on average, £62,000 gross value to the UK economy in that year.

In addition to these 650 photonics companies, a further 850 UK companies engaged in photonics were also identified. However, these were not included in the present output, employment and GVA analysis due to lack of turnover data and/or, the company being identified as a "user" *deploying photonics* in its broader product portfolio and/or manufacturing process. For more details see Appendix 1: Methodology.

According to previous reports, over 10% of the entire European economy relies on photonics to maintain its competitive edge[ii]. Applied to the UK economy, this indicates that some £200bn of its total value depends on photonics, around a ten-fold leverage relative to the value of photonics goods produced in the UK.




*Source: The Knowledge Transfer Network (KTN) and Photonics Leadership Group (PLG), June 2017*

# Methodology

**Building on work by SPIE (2016), the international society for optics and photonics, a methodology has been developed to estimate the size of the UK photonics industry, accounting for its highly diverse nature.**

The photonics industry does not have a dedicated standard industrial classification (SIC) code. This is a challenge that has long hindered efforts to accurately quantify the size of the industry around the globe. Several other factors add to the complexity of analysis: many companies involved in manufacturing photonics products do so alongside producing non-light based products and a high number of photonics companies are SMEs and therefore report only abbreviated UK accounts to Companies House.

The methodology for this report was developed to meet these challenges and provides a valid, representative estimate of the UK photonics industry size, without the need to resort to confidential data. It also provides a framework to facilitate future reporting.

The methodology is outlined below and in Figure 2 (for details see Appendix 1):

**Step 1:** Compile a comprehensive list of companies engaged with photonics:

Data was gathered from sources including attendance records from UK photonics-focused events and regional photonics networks memberships.

**Step 2:** Estimate output, profit and employment figures:

a) Companies engaged in photonics manufacturing: output, profit and employment data was obtained from Dunn and Bradstreet, based on matching the company name and number and postcode.

b) Diversified companies producing both photonics and other products: the proportion of total company output categorised as specifically photonics was estimated by expert panel (companies deemed by the panel to be photonics users but not explicitly photonics manufacturers were excluded from the analysis).

The company's reported total output, profit and employment figures were then adjusted according to the proportion of photonics-specific activity, as estimated by the panel.

**Step 3:** Estimate Gross value added (GVA):

GVA was taken as the sum of apportioned profits plus the apportioned salary expenditure for all companies. The salary expenditure per company was estimated based on the industry average wages, as published in the 2016 edition of the annual Optics and Photonics Global Salary Survey (SPIE)[iii], and multiplied by the company's reported number of employees.

This methodology was designed to enable the inclusion of highly-diversified companies, without over-attributing the value of their output to photonics. In contrast, previous analyses of industry size carried out in other sectors have often been conducted using selected SIC codes alone, therefore reporting data based on the total company output. Such methodologies risk over-estimating the industry size by failing to account for any output value that may have been generated by a diversified company's activities outside the sector of interest.

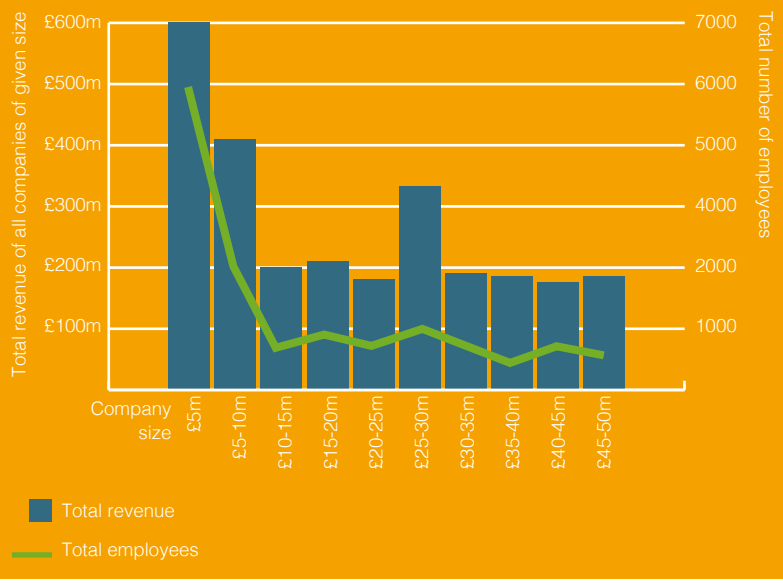
The present method yields a more reliable, representative assessment of the UK photonics industry size and is especially suited to industries for which no one single applicable SIC code exists. It is also closely aligned to the method used by SPIE (2016) in estimating the global photonics size, facilitating international comparisons.

**Figure 2: Methodology for estimating UK photonics industry size**

# Analysis: Company size

**The UK photonics industry comprises a high number of SMEs. Of the 650 companies included in this analysis, 73% reported that their annual output was less than £5m. These SMEs account for just 4% of the total UK photonics output but yet are responsible for employing 10% of the UK photonics workforce.**

**Figure 3: UK distribution of photonics revenues and employment by company size**




120 mid-sized companies, reporting revenues of up to £50m, generate around 20% of the total UK photonics industry output and employ 20% of the workforce (see Figure 3: UK distribution of photonics revenues and employment by company size).

80% of overall UK photonics revenue is generated by less than 8% of the total number of UK photonics companies. These 50 large companies employ some 70% of the UK photonics workforce. The UK photonics landscape mirrors the shape of the global photonics components industry, where SMEs producing output of less than $10m employ 75% of the global workforce, and the largest companies generate 73% of the overall revenue (SPIE, 2018)[iii].

# Analysis: Regional distribution

**The photonics industry shows significant economic activity across the UK, including in Northern Ireland, Scotland and the English regions from the Midlands to the South East and South West.**

Figure 4 illustrates the regional distribution of the UK photonics industry. The map should be interpreted with some caution since its accuracy depends on pinpointing the geographical location of a company's photonics activities. For example, a company may typically attribute its accounting figures to a central London headquarters but yet conduct its manufacturing activities at multiple regional locations. The regional data reported here factors in a preliminary correction of this London-centric location bias and recognises future scope for increasing the accuracy of regional analyses, including regional GVA contribution, by requesting confidential pay role return data from the government.

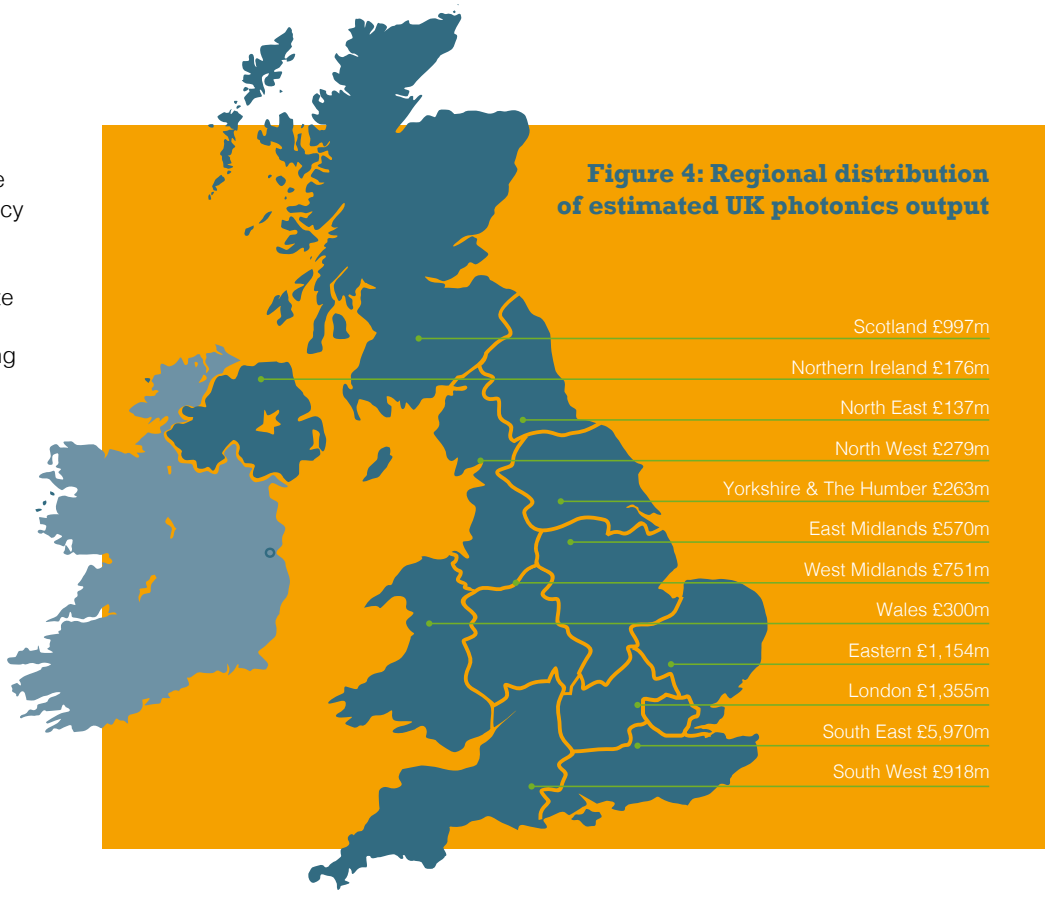
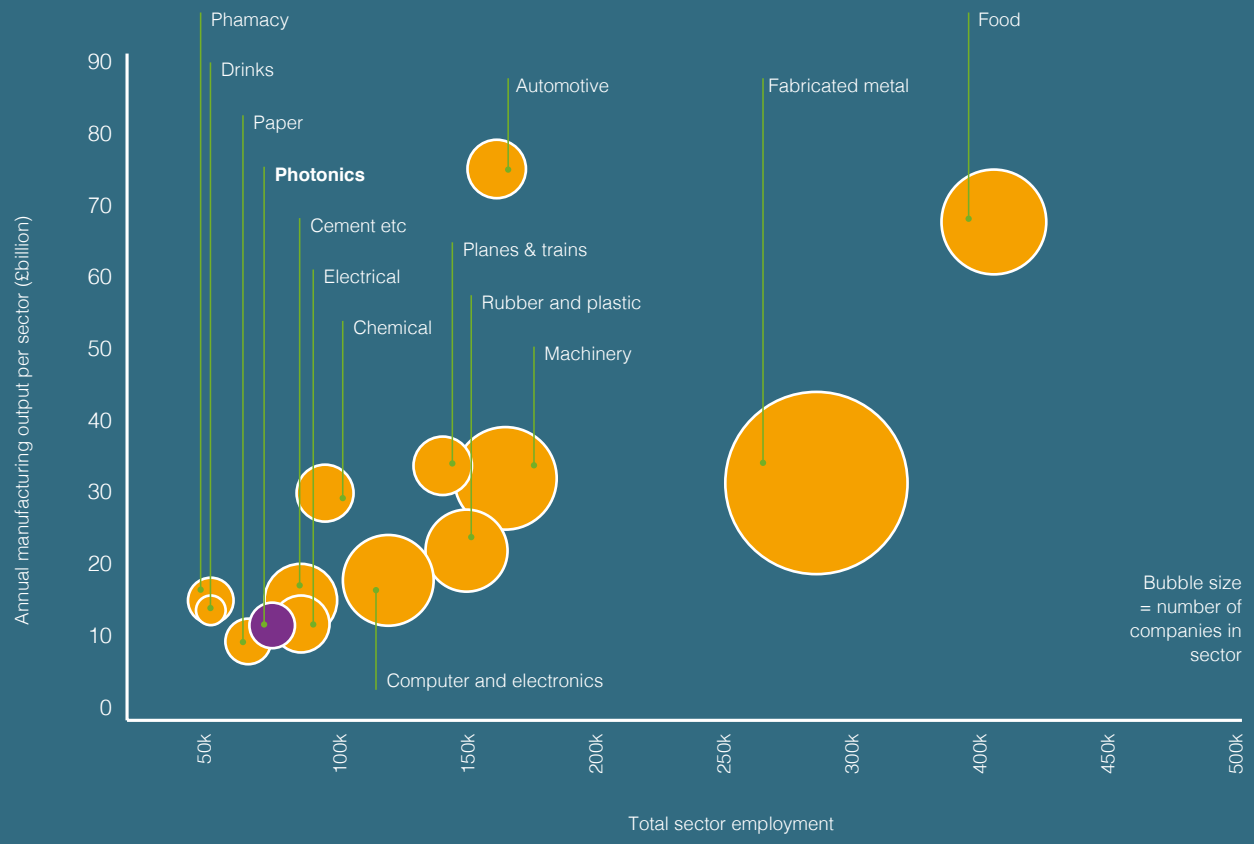



**Figure 4: Regional distribution of estimated UK photonics output**

**Figure 5: Output and employment in UK photonics as compared to other UK manufacturing sectors**




*Source (for manufacturing sectors other than photonics): Office for National Statistics (ONS), 2017[v]*

# Analysis: National performance

## The photonics sector accounts for some 7% of all UK manufacturing output[iv].

Figure 5 illustrates the size of the UK photonics industry relative to other key manufacturing sectors. Manufacturing sectors are positioned relative to their total employment and output as reported by the Office for National Statistics (ONS)[v]. The size of the bubble represents the number of companies operating in that sector.

### Scale

At £12.9bn, UK photonics produces an annual output comparable to the pharmaceutical manufacturing sector, whilst employing more people, in more companies. Annual UK photonics manufacturing output is also similar in value to that of the electrical equipment, non-metallic minerals e.g. cement, and paper goods sectors. Furthermore, photonics manufacturing is estimated to contribute to approximately two thirds of the total reported manufacturing output from the computer, electronic and optical products sectors (this is a tentative estimate as not all UK photonics companies report data to the computer, electronic and optical products SIC codes on which the ONS analysis is based).

### Productivity and added value

The productivity of a manufacturing sector can be broadly estimated from the ratio of output to employment in that sector.

Figure 5 shows that the majority of UK industry sectors, including photonics, share a similar baseline rate of productivity. Notable exceptions include the automotive sector, which has a significantly higher manufacturing output per employee, and the fabricated metal sector, where productivity is markedly below average.

However, estimating productivity from the output per employee fails to account for the value of manufacturing inputs, added lower in the supply chain, e.g. bought in sub-assemblies and components. This acts to boost the output per employee in assembly-orientated industries, e.g. automotive and aerospace, relative to enabling component industries, such as photonics, which are engaged in manufacturing vital value-adding components, then integrated by others further up the supply chain.

The Gross value added (GVA) per employee is an alternative method of assessing a sector's contribution to the overall economy. The GVA per employee for UK photonics is estimated at £62k, which is around the overall UK manufacturing average.

# Analysis: European performance

**For 2015/16, Photonics21 estimated the value of European photonics output at €69Bn (£60Bn)[vii]. Its value has grown by more than 62% in the last decade, at a rate of 5% (CAGR), twice as fast as the overall economy.**

In Europe, some 300,000 people are directly employed in photonics. Germany is the leading European photonics manufacturer, responsible for around 40% of all European output.

The photonics industries of the UK, France and the Netherlands are all similar in size, each with outputs estimated at 9-14% of total European output in independent EU studies.

**Figure 6: 2015 European photonics production**
**Total: EUR 69.2 billion**


*Source: Photonics 21 and Optech Consulting, 2017[vii]*

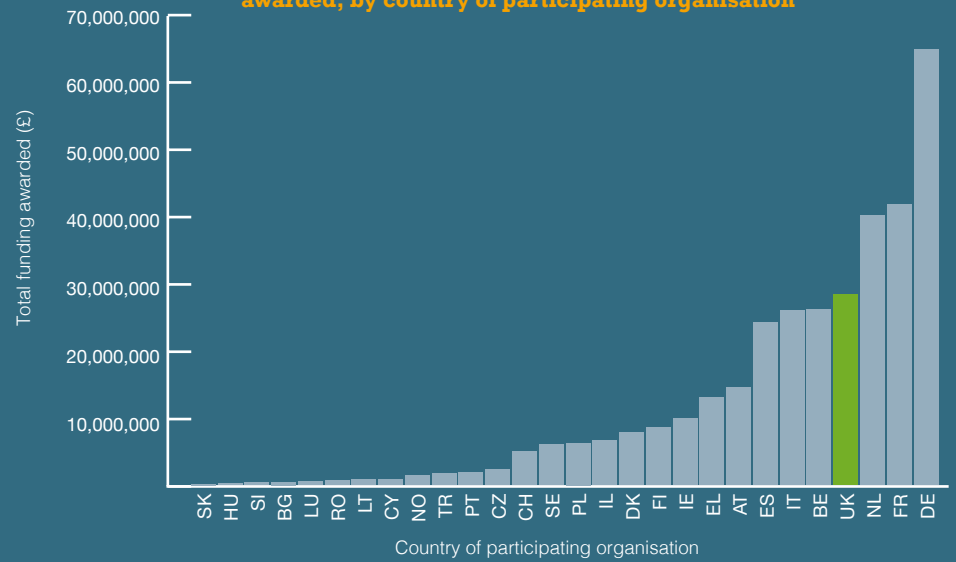
# Analysis: European innovation

**UK organisations have participated in 65% of all projects funded specifically in the area of photonics under the European Commission's Horizon 2020 research and innovation programme (H2020).**

Of the 605 organisations participating in winning projects across Europe, 67 were based in the UK.

To date, within the H2020 photonics call, grants to a total value of €250m (£219m) have been awarded. UK-based organisations have received some €25m (£22m) in total, equivalent to 11.1% (see Figure 7).

**Figure 7: Total value of Horizon 2020 photonics-specific grants awarded, by country of participating organisation**




*Source (data): CORDIS*[viii]

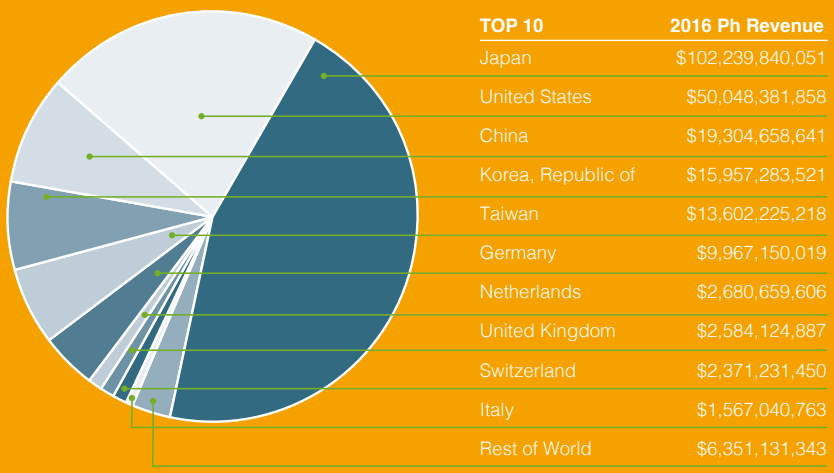
# Analysis: Global performance

**Multiple estimates of the size of the global photonics industry have been made in recent years. These vary from €447bn (£388bn) in 2015, as reported by Photonics21[vi], to $226bn (£161bn) in 2016, according to SPIE's analysis of the global photonics components market[iii].**

A comparison between these estimates and the UK photonics industry data reported here, suggests that the UK is responsible for between 3% and 8% of photonics production globally.

The variation in reported estimates of the global photonics market size arises from the differing definitions of 'photonics products'. The methodology underlying the 2016 SPIE estimate is largely similar to the method used in the present report, based on suitably apportioned output data sourced from Dunn and Bradstreet. However, unlike the present report, SPIE included only core photonics components e.g. lasers, lenses and optical fibre etc., to formulate the estimate, and excluded photonics-based products such as cameras, displays and inspection systems etc. Applying the narrower SPIE definition of 'photonics product' ranks the UK as the eighth largest manufacturer of photonics components in the world.

**Figure 8: Photonics components total global market ($226bn) share by country**



| TOP 10 | 2016 Ph Revenue |
|---|---|
| Japan | $102,239,840,051 |
| United States | $50,048,381,858 |
| China | $19,304,658,641 |
| Korea, Republic of | $15,957,283,521 |
| Taiwan | $13,602,225,218 |
| Germany | $9,967,150,019 |
| Netherlands | $2,680,659,606 |
| United Kingdom | $2,584,124,887 |
| Switzerland | $2,371,231,450 |
| Italy | $1,567,040,763 |
| Rest of World | $6,351,131,343 |

*Source: SPIE, 2018[iii]*

International comparisons are complicated further by the large number of UK companies which are subsidiaries of global corporations. Many estimates use the address of the company's global headquarters (HQ) as the basis for their analysis, rather than the country in which the company's manufacturing division is based. As a result, an international company with a substantial UK-based manufacturing arm would not be identified as a UK photonics producer in many global market reports.

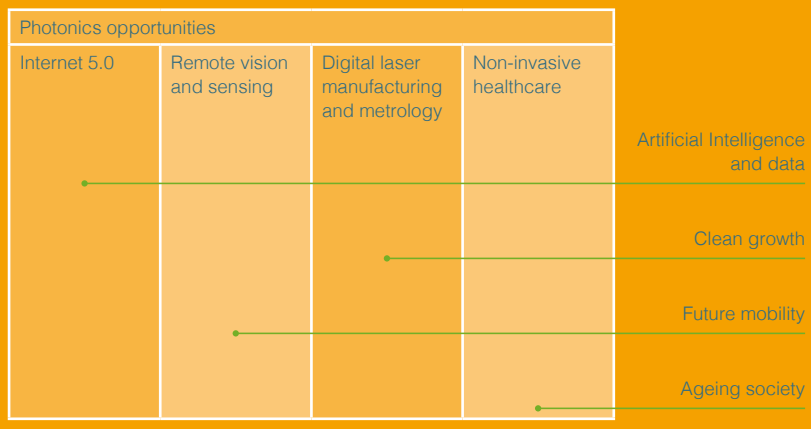
The methodology used in this report factors in measures to avoid this kind of data artefact and ensure that the geographical location of manufacturing activities is more accurately distinguished. Given the high levels of foreign direct investment (FDI) in UK photonics companies, it may be assumed that global photonics market reports founded on output data linked to the location of the company HQ, typically undervalue the contribution from UK industry.

# Future growth: Grand challenges

**The 2017 Industrial Strategy identified four Grand Challenges to put the UK at the forefront of future industry:**

- **Growing the Artificial Intelligence (AI) and data driven economy**
- **Clean growth**
- **Future of mobility**
- **Ageing Society**

**Figure 9: The 2017 Industrial Strategy Grand Challenges and opportunities for UK photonics**




Photonics is critical to delivering all four Grand Challenges.

The UK photonics community has come together to identify the major opportunities where photonics will have most impact and enable significant industrial growth over the next five to ten years.

These opportunities require overcoming major challenges in photonics. New approaches and innovations will be required which stretch beyond incremental improvements to existing technologies. Each opportunity corresponds to an area in which the UK has an established history of innovation. This ensures a critical knowledge base capable of generating solutions and a thriving industrial landscape in which they can be deployed. If overcome, either fully or in part, the technologies arising in response to these challenges will have a major impact on society, in the UK and across the world.

## Photonics opportunities

### Internet 5.0

Photonics is critical to delivering Internet 5.0 and future data, where data delivery is ubiquitous, invisible and instantaneous for all. Internet 5.0 will break the tie between rising digital demand and costs, including energy consumption and security issues, which constrain productivity and stand to limit the potential of the digital economy.

### Remote vision

Photonics is key to enabling autonomous and semi-autonomous vehicles by instantaneously providing cars, trains, planes and boats with a complete three-dimensional picture of their surroundings.

Light has long been used to capture information remotely. The challenge is to make detection adaptable, flexible, infallible and compatible with all situations, and budgets. This is essential to provide accurate, real-time information to the algorithms underpinning autonomous actions in all forms of future mobility.

### Digital laser manufacturing

Advanced digital manufacturing is required to produce all manner of things, ranging from cars and planes to food. It relies on photonics technologies to process, monitor and control cutting, joining, marking and assembly, enabling the next generation of more lightweight and efficient products. Digital lasers are already deployed at major stages of the industrial process. However, increasing productivity in all industries depends on their extension to new materials manufacturing techniques.

### Non-invasive healthcare

Photonics healthcare innovations can be deployed in non-sterile modalities that are both user-friendly and improve healthcare productivity for diagnostics, monitoring and treatment. For example, photonics provides simple, non-invasive technologies which enable pre-clinical health screening to take place in the home and pharmacy, thereby decreasing the load on primary care services and hospitals.

# Summary

**UK photonics is a significant industry with an output of £12.9bn, similar to that of UK pharmaceutical manufacturing. The photonics industry is distributed throughout the UK, with the workforce predominantly employed in SMEs and a small number of large firms responsible for producing the vast majority of revenue.**

The UK produces around 10% of total European photonics output and accounts for between 3-8% of global photonics production. UK manufacturers export over 75% of their output, with many companies shipping 100% overseas, indicating a high regard, and demand, for UK photonics products internationally.

To date, UK organisations have received 11% (€25m) of all European funding awarded in dedicated photonics programmes, demonstrating its strength in innovation at an international level.

The data presented here is based on a robust methodology that has been developed to accurately size an embedded, enabling industry. This method takes into account the contribution from SMEs and attributes to photonics an appropriate portion of the output from diversified manufacturers.

UK photonics is a burgeoning industry, with annual growth rates of 5-9%, and is set to expand further through its vital role in enabling critical innovations across all vertical sectors. Future light-based technologies for sensing, data, communications, laser manufacturing and metrology and non-invasive healthcare will be vital to the UK's ability to successfully realise solutions to all four of the Industrial Strategy Grand Challenges.

# Appendix

## Full methodology

**Step 1:** Compile a comprehensive list of companies engaged with photonics

A master list of companies was compiled from various sources: lists of companies attending and exhibiting at photonics events, and input from a number of professional associates. The master list was revised as follows:

Duplicate and non-trading organisations were removed, updates to company details were made as required by organisational changes e.g. company name changes, mergers with other companies. Considerable attention was made to ensure the integrity of this master list so as to make it valid as a basis for the analysis and to facilitate future updates.

**Step 2:** Estimate output, profit and employment figures

Output, profit and employment data for the master list of companies was obtained from Dunn and Bradstreet, based on matching company name and number and postcode.

Dunn and Bradstreet are independent providers of financial and employment figures, based on data from Companies House. The analysis presented here refers to the latest available financial data at the time of reporting: data for the period 2015-16.

Where company data was not available, e.g. for smaller companies, the Dunn and Bradstreet estimate was used. This calculation is based on factors such as typical company performance.

**Step 3:** Diversification

For diversified companies producing both photonics and other products, the proportion of total company output categorised specifically as photonics was estimated by expert panel. The expert panel comprised 30 members of the Photonics Leadership Group, a representative body for the UK photonics industry.

Panel members were asked: 'What portion of this company's output is photonics products / services made in the UK', with the answer provided as one of the following percentage range categories: <5%,<5-20%, 20-50%, 50-75%, 75-100%. Output and employment apportionment was then based on the median panel response for diversified companies. Where there were multiple very similar diversified companies, a common apportionment was applied to all.

**Step 4:** Manufacturer or user

Any companies deemed by the same expert panel to be 'enabled by' or 'users of' photonics, but not manufacturers or suppliers of photonics services, were removed from the master list. Such companies, e.g Rolls Royce, were not included in the present photonics industry size analysis but the scale of UK industries underpinned by photonics manufacturing was identified as an avenue worthy of future investigation.

**Step 5:** Apportionment

The company's reported total output, profit and employment figures were adjusted according to the average proportion of photonics-specific activity, as estimated by the expert panel in Step 3. For example, for companies with an estimated 5% of products deemed to be specifically photonics, 5% of their output and employment was included in the analysis, etc. These measures were taken so as to avoid over-estimating the UK photonics industry's size and scale.

Straight linear scaling was used with no difference in profitability or staffing ratios between photonics and non-photonic product lines assumed.

Particular attention was paid to checking the apportionment of the companies making the most significant contributions to the total figures for output and employment based on the assumption that the largest organisations are typically also the most diversified.

**Step 6:** Estimate Gross value added (GVA)

To evaluate photonics Gross value added (GVA), rather than use a broad assessment based on a ratio of GVA to output, we estimated GVA from the profit figure for each company added to the number of employees multiplied by the average photonics salary - suitably apportioned via the above rules. The average photonics salary was estimated based on industry average wages published in the 2016 edition of the annual Optics and Photonics Global Salary Survey (SPIE)[iii]. GVA per employee was taken from the total industry GVA divided by the total number of employees.

This method was developed to ensure that the GVA per employee better represented the

economic impact of each employee, using independently-provided data on wages and profit within the sector.

## Methodology comment

The present method yields a more reliable, representative assessment of the UK photonics industry size and is especially suited to industries for which no one single applicable SIC code exists. However, there remain some constraints with this approach:

## Age of data

In the main, this analysis relies on data sourced from published accounts submitted to Companies House and processed by Dunn and Bradstreet. Due to varying dates used by companies for the end of their financial year, such data is typically one or two years old. This creates an inherent delay between the reported figures and any additional growth that is likely to have occurred since. Due to typically high growth rates in the photonics industry, the analysis presented here may therefore underestimate the size of the UK photonics industry as it stands today.

## Regional analysis

Mapping the regional distribution of photonics manufacturing activities is non-trivial since many larger companies report their accounting information through a single registered address, relating to their London headquarters, rather than their manufacturing locations, which may be elsewhere in the UK. Furthermore, companies with multiple UK sites typically only publicly report a single UK output total.

Nevertheless, regional analyses of the UK photonics industry is of vital importance to those making the case for investment, including Local Enterprise Partnerships, devolved Administrations and government. The present report therefore undertook a case-by-case review of the data on company region, supplementing the location data from Companies House with input from the photonics industry expert panel and manual data verification.

## Missing/incorrect data

Every effort has been made to maintain an accurate, up-to-date list of photonics manufacturing companies. However, it is recognised that there will always be a degree of anomaly in the list as an inevitable consequence of the constantly evolving nature of business; new enterprises are founded and companies merge. In some existing companies, activities in photonics may yet to be identified and some businesses known to be currently engaged in photonics may opt to move out of the sector over time. The present analysis took steps to mitigate the margin for error through a manual review of the individual companies on which it is based, in addition to carrying out periodic updates to the master list.

## Data sources:

[i] *Photonics Revolutionising our World, Knowledge Transfer Network (2014): https://photonicsuk.org/wp-content/uploads/2014/02/photonics-revolutionising-our-world-1.pdf*

[ii] *The Leverage effect of Photonics Technologies: the European Perspective Study prepared for the European Commission, DG Information Society and Media under reference SMART 2009/0066, Final Report (March 2011): https://eeca-ict.eu/images/uploads/pdf/ICT_Communities/Photonics/The_Leverage_efect_of_Photonics_Technologies_Mar2011.pdf*

[iii] *2016 Optics and Photonics Global Salary Survey, SPIE (2016): https://spiecareercenter.org/survey/SPIESalarySurveyReport2016.pdf*

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[vii] *Market Research Study Photonics 2017, Photonics21 and Optech Consulting (2017): http://www.photonics.fi/wp-content/uploads/2018/01/Market-Research-Report_Photonics21_Internet.pdf.*

[viii] *CORDIS datasets: H2020 calls ICT-06-2014, ICT-26-2014, ICT-27-2015, ICT-29-1016, ICT-20,2017 (accessed on 27 April 2018)*

[ix] *Institute of Physics Report (May 2018): The health of photonics - How light-based technologies are solving industry challenges, and how they can be harnessed to impact future economic growth:http://www.iop.org/publications/iop/2018/file_71498.pdf*

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