



# UK PHOTONICS 2035



# THE VISION

Light is everywhere, touches everything, is the basis for life and how we understand our world. Society increasingly depends on the transformative power of **photonics**—the collective technologies of light. From rapid infection diagnosis and digital surgery, communications, advanced manufacturing and agriculture; photonics is critical to making products and services deliver value to consumers and industry across all vertical markets.

Solutions to the greatest challenges of the 21<sup>st</sup> century, from global warming to digital inclusivity, depend on photonics. Photonics systems, from lasers to sensors, are at the core of autonomous transport, quantum tech, real-time digital services, 3D printing, defence and security solutions.

To have leadership in photonics gives the UK control of the heart of future capability, security of supply and influence over this deep technology and how it is applied. To neglect domestic photonics capability, will condemn the UK to buying in essential photonic systems, making us dependent on others for innovation and supply.

Today, 76,000 people are employed in photonics in 1,200 firms across all UK regions generating £14.5 billion of annual output. With gross value added

By 2035 more than 60% of the UK economy will directly depend on photonics to keep it competitive.

By 2035 UK photonics will be a £50 billion industry, add an additional 150,000 direct jobs and be one of the top three most productive manufacturing sectors in the UK.

to the economy of £85,000 per employee, photonics is one of the UKs most productive manufacturing sectors. Our universities have been global leaders in the field for over 200 years since Maxwell published the theories of optics still in use today. Some 20% of global publications in the field originate in the UK. This has attracted global inward investment, with the biggest names in the business growing manufacturing and design facilities in the UK attracted by our talent and knowledge.

Building on this capability our dependence on photonics will grow substantially. Major developments will be key to delivering net zero, digital connectivity, autonomy, productivity, healthcare, defence, security and pushing the boundaries of human knowledge.

BY 2035

## Photonics Will Digitally Shrink the UK

Innovations in optical fibre will digitally shrink the UK, bringing London 100 miles digitally closer to Newcastle and Frankfurt and 1,000 miles closer to New York. Radically reducing latency in our core telecommunications network will half the time it takes data to get from the user to the data processing centre and back. This UK invention will benefit the entire digital economy bringing regions closer, reducing the number of data centres required to cover the country, dropping emissions and costs by a third and ensuring access to real time services from health to entertainment.

Providing the fastest connectivity to even the most remote regions of the UK, by 2035 lasers will be used for all inter-satellite communications for low earth orbit satellite constellations. To meet ever increasing demand for location independent bandwidth, optical links will also become standard for satellite to earth communications.

We already manufacture the base material for the lasers that power global communications. Now is the time to capture more value in the UK, moving higher in the supply chain, delivering trusted 5G network solutions and setting the groundwork for a UK quantum communications industry.

## Photonics will Increase Manufacturing & Agriculture Productivity by 20%

The UKs Made Smarter Review identified £455 billion worth of economic impact from industrial digitisation and the potential for a 4.5% reduction in CO<sub>2</sub> emissions. Photonics will be core to delivering this impact through the digital cutting, joining, marking, texturing 3D printing of materials especially metals and through machine vision inputs to robotic and automated systems.

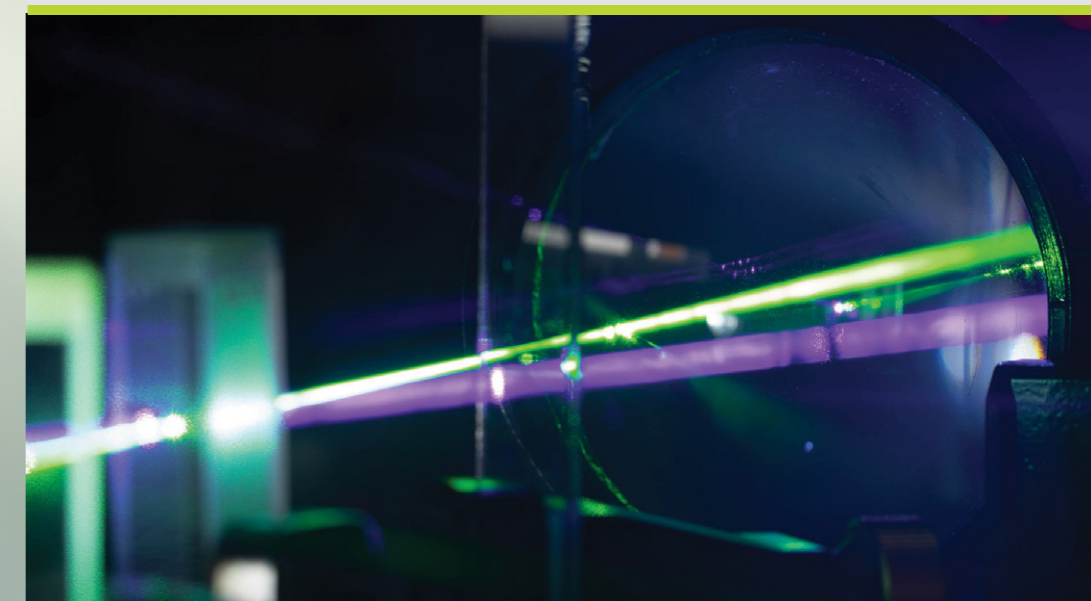
Industrial processing of materials uses one third of the ~£11 billion global market for lasers. Yet adoption by UK industry is pitifully low, especially outside our largest manufacturers. Remediating this would generate £8 billion in direct annual revenues by 2035 in laser manufacturing and extend application of this key productivity enabler to another 20,000 UK manufacturers. In particular laser processing and machine vision will be essential to support competitive electric motor and battery production in the UK, with innovation needed to adapt to the wide range of different materials.

Photonics is just beginning to drive productivity in agriculture, e.g. UK developed laser based milking machines are starting to penetrate the market, improving dairy yields and animal welfare. By 2035 photonics will also digitise agronomy end enabling a food farming revolution. Vertical farming, close to point of consumption and powered by photonics, can reduce water consumption 10-100 fold and eliminate pesticide use. With the UK leading the development of high efficiency agriculture, and its critical dependence on photonics innovations, capturing just 3% of these markets would generate £2.5 billion in revenues.

## Photonics Tools will Push the Boundaries of Scientific Understanding

From telescopes, to particle accelerators and Laser Interferometer Gravitational-wave Observatory (LIGO), large scale fundamental science uses photonics to push back the boundaries of human knowledge. Half of all Nobel Prizes in physics awarded in the last 25 years related to either photonics discoveries or directly depended on photonics as a discovery tool. The thrilling new world of quantum superposition applications from quantum computing to secure quantum communications, is either directly based on photonics or needs photonics to function.

Predicting what, where and when new discoveries will be made is impossible, but it is certain that the majority will be discovered with the use of photonics. From extreme high-power lasers to single photons, from telescopes, to super resolution microscopes, if the UK is to be a science superpower it must also be a photonics superpower.



## Photonics will be Essential to Delivering a Net Zero Economy

Photonics acts on three fronts to support sustainability and delivery of net zero.

Direct **power generation** with flexible high efficiency photovoltaics enabling seamless integration of solar power into buildings and infrastructure without compromising aesthetics and land use.

Indirect **power generation** where reduced downtime and improved wind mapping, photonics will provide a 1.5-2% increase in the efficiency of wind turbines in existing and new facilities. With little additional cost this will provide an additional 15 GW generating capacity globally by 2035, equivalent to five Hinkley Point C nuclear power stations saving over £100 billion and increase safety and resilience.

**Energy use** in the digital economy and manufacturing.

Datacentres, central to financial services, health and entertainment, already consume 4% of global energy, a share that will increase rapidly without action as the digital economy accelerates. Innovation in integrated photonics will reduce datacentre energy consumption by >50% by 2035 leveraging leading UK capability to enable growth of the digital economy without increasing emissions.

In parallel innovation and adopting of laser processing, including 3D printing of metals, will drive productivity and reduce waste across all manufacturing sectors.

**The circular economy** will depend on photonics sensors and tools. Rapid optical identification and labelling of materials and components will enable tracking through the supply chain providing the data to enable a functioning circular economy and efficient reuse of materials across all sectors.

Adaptability and reconfigurability in photonics components will improve manufacturing scale, reduce waste and enable redeployment without remanufacture.

## The UK must be a Manufacturing Hub for the “Digital Eyes” of the 21<sup>st</sup> Century

To grow without economic stagnation with an aging population and a shrinking workforce the 21<sup>st</sup> century will be the age of autonomy. Artificial Intelligence (AI) and machine learning systems have the potential to deliver autonomous decision making and a step change in productivity, but are only as good as the data they are fed.

Remote healthcare, autonomous vehicles, autonomous and virtual reality, digital security, i.e. almost all of the highest impact, multi-billion Pound opportunities of the next two decades need optical sensors – the ‘digital eyes’ of the future to enable them to function. Without control and production of this core technology all of these advanced systems will be dependent on external hardware and be vulnerable, no matter how good the software is.

The UK is the world leader in the compound semiconductors behind ‘digital eyes’, already manufacturing the base material for billions of lasers & sensors used in facial recognition in mobile phones. Scale and innovation speed is everything when delivering consumer focused solutions. The UK is at the turning point where it could be the volume compound semiconductor producer for the 21<sup>st</sup> century, making the ‘digital eyes’ for the world, or it could see investment follow that of silicon semiconductors out of the UK.

## SUMMARY

Photonics is now at a critical, grow or die turning point. An established £14.5 billion ‘niche’ industry, photonics will be behind some of the most dynamic and highest profile markets ever seen. Capturing the opportunity, value and security of supply in the UK requires supporting scale-up across the board to meet the demand from multiple £billion markets. Photonics is already the 5<sup>th</sup> most productive manufacturing sector in the UK, but to keep capacity in the UK, it is essential to scale-up to take volumes to the next stage, ensure a pipeline of 150,000 new employees and raise productivity even higher.

To address societies’ 21<sup>st</sup> century challenges we need to ensure that we are capturing the benefit of photonics in the UK. Most UK pho-

tonics companies currently export the majority, if not all, of their output. A fantastic global endorsement of our capability, but also an indication the UK is missing out on applying its domestic photonics base. The UK needs to confront outdated economic and capability assumptions, embed photonics into interventions across all markets, challenge traditional sectors to adopt the latest photonics innovations, and de-risk deployment so we are maximising competitive advantage and minimising supply chain vulnerability.

The recent vulnerability of car production to chip supply, and food to fertilizer production, has shown how even the largest production lines can be brought to a standstill by shortages in essential components. Photonics will

## Photonics will be Embedded in >20% Diagnostic Tests Delivering Healthcare Efficiency

Every one of the 700,000 daily PCR tests the UK has the capability to process are digitally read with lasers. Even before COVID-19, no one entered the healthcare system without test results facilitated with photonics. The NHS employs 25,000 people in pathology, all of them using photonics based instruments, costing the NHS £2.5 billion annually, ~4% of its budget.

To keep growing central testing is unsustainable and unaffordable, lengthening treatment and increasing costs. By 2035 advances in integrated photonics will enable the level of testing currently undertaken in laboratory sized instruments to be undertaken on miniature chips, bringing testing to the bedside, the operating theatre and GPs surgery. Photonics is the key to combining accuracy with the convenience of the lateral flow test that we are now so familiar with.

As soon as 2025, the global point-of-care testing market is forecast to reach £37 billion; hospital visits for tests could be reduced by a quarter. The UK has the capability to be at the centre of this global, optically driven, diagnostic revolution leveraging its skills in integrated photonics. The potential is illustrated by UK integrated photonics firm Rockley Photonics whose 2021 IPO values them at \$1.2 (£0.87) billion.

Light is also a vital treatment tool. For some procedures, laser surgery improves patient outcomes, raises efficiency and reduces waiting times. Implantable optogenetic devices will play a role in neurotechnology addressing diseases such as Parkinson’s and opening up the possibility of optical brain-computer interfaces with drastic reductions in ongoing care costs for a variety of chronic conditions.

## Defending a Secure Resilient Nation will not be possible without Photonics

Location, traceable time and secure communications are key pillars of resilience. Already all data is transported optically at some point during its journey; by 2035 transmitted data will spend >99.5% of its journey time as light. That makes photonics essential to our digital resilience. The Telecommunication Diversification Strategy makes clear the need to support UK capability in this critical infrastructure.

Optical fibre, optical amplifiers and atomic clock traceable time stamps are all UK inventions. Secure quantum communications is being pioneered in the UK. As the globe recognises the vulnerability and criticality of digital, mostly optical, infrastructure, the UK is uniquely positioned to be at the core of the next secure trusted telecoms revolution in 5G, 6G networks and beyond. By 2035 the UK will once again be a global provider of critical communications infrastructure. Capturing just 5% of a multibillion Pound market growing at 10% annual could generate £15 billion in UK revenues by 2035.

The Prime Minister set out in his statement on the Integrated Review that “Our warships and combat vehicles will carry directed energy weapons, destroying targets with inexhaustible lasers”. Extreme power lasers, tracking of objects by quantum Radar and LIDAR, including through and around solid objects and seeing the otherwise invisible in extreme environments will all be part of UK defence and security capability by 2035.

These capabilities are all coming, and are based on UK inventions. The question is how much we will invest in such capabilities of the future to ensure their commercial and capability value that will be captured in the UK?

provide the ‘digital eyes’ for autonomy, digital highways for remote working, the ‘electro-optic ears’ for rapid diagnostics, the brains for AI & quantum. The USA, China, Taiwan and Singapore have identified the strategic importance of photonics. Scale-up and adoption support is essential not just to deliver this £50 billion vision, but to ensure we are not dependent on importing billions of photonics components to keep our future economy operating.

**The 21<sup>st</sup> century will be the age of photonics, the question is only how much can we capture in the UK?** The Photonics Leadership Group call for a constructive partnership with government to develop a detailed plan and select interventions to deliver the 2035 photonics

vision. Only through partnership with industry, government and academia, will we scale to meet the insatiable demand whilst capturing maximum value in the UK. **Dedicated personnel assigned to the photonics portfolio are essential in both The Department for Business, Energy and Industrial Strategy (BEIS) and Innovate UK** and the all-pervasive nature of photonics necessitates a seat on the new Science and Technology Council. In return **the photonics industry will continue to invest, to expand, to train and employ and champion the UK** as a global powerhouse for science, technology and manufacturing, highlighting the benefits of investing in the UK in boardrooms across the world.

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