

# UK physics research

Driving innovation and economic growth

UK physics  
has the highest  
scientific  
impact of top 10  
countries

Physics-based  
UK businesses  
contribute  
£77bn to the  
economy

Physics-based  
UK manufacturing  
contributes  
£20bn to the  
economy

GVA per  
worker in  
physics-based  
businesses is  
twice the national  
average

66% of UK  
physics research  
papers involve  
international  
collaboration



Physics has been at the heart of innovations from the light bulb to the Large Hadron Collider. Today physics powers industries across the UK. From oil exploration to aerospace and regenerative medicine to robotics, physics and physicists drive the success of the best and brightest companies.” (Institute of Physics Innovation Awards 2013)

Through the application of novel knowledge, instruments and the skills and abilities of physicists, physics research plays a pivotal role in the world economy.

Several studies have demonstrated the economic impacts of physics in the UK<sup>1</sup> and other European countries<sup>2</sup>. Others have provided evidence of the economic effects of specific technologies generated by physics research<sup>3</sup>. The contribution made by physicists to the UK economy has also been revealed in surveys showing the wide distribution of highly skilled people with an academic background in physics across economic sectors<sup>4</sup>.

The strength of UK physics is highlighted in a new report, *The UK's performance in physics research: National and international perspectives*, which examines patterns of performance in physics research in the UK. It was prepared by Science-Metrix for the Engineering and Physical Sciences Research Council (EPSRC), the Institute of Physics (IOP) and the Science and Technology Facilities Council (STFC).

### THE UK PHYSICS RESEARCH BASE IS CONTINUING TO PERFORM WELL

- The number of **UK physics papers published annually has been steadily increasing** from 10,000 in 2002 to 13,500 in 2011.
- However, the **UK's share of world papers in physics publications has fallen**, from 5.1% in 2002 to 4.0% in 2012, due mainly to the rapid rise in publications from countries such as China, India and the Republic of Korea.
- The **UK's scientific impact in physics has been increasing**, in terms of average citation rate and top highly cited papers, and the **UK has the highest scientific impact amongst the top 10 countries publishing in physics**.

### Impact of physics research

Physics research has led to many important industrial benefits, such as developing prototypes, creating new scientific instrumentation, the supply of skilled graduates and the creation of new companies, playing a crucial role in the world economy. The following examples highlight a range of applications where physics has significant impact.

#### Benefitting industry and medical research

Imaging techniques are widely used by international engineering and aerospace companies, e.g. BAE Systems,

### INTERNATIONAL COLLABORATION BY UK PHYSICISTS IS STRONG AND RISING

- Growing steadily over the last 10 years, **international collaborations occur in nearly two thirds of UK physics papers**, with the most important partnerships being with the US, Germany, France, Italy and China.
- These **collaborations have resulted in clear gains in scientific impact** for both the UK and its principal partners, including the new and fast-growing scientific players in the field such as China, India and the Republic of Korea.

Rolls-Royce and Airbus. The aerospace sector also benefits from research in defect analyses and advanced-materials conception because it facilitates stronger and lighter manufacturing.

Imaging techniques are also widely used by a suite of successful UK medical imaging businesses including award-winning company Coherent Scotland Ltd. The company has developed a range of table-top, ultra-fast lasers which have underpinned advances in the biological and medical research sectors.

### Practical applications from fundamental research

From attempts to solve unanswered questions in particle physics to mathematical descriptions of black holes, the primary research goals in the cosmology, quantum field theory and particle physics areas remain close to fundamental science. The recently confirmed existence of the Higgs Boson, postulated in 1964, resulted from experiments at CERN's Large Hadron Collider.

Examples of practical applications in this area include:

- the development of a commercial weather forecasting tool for the ionosphere;
- improved cooling and vapour technology used in a variety of industrial applications;
- precision detection equipment developed for space systems, but now used by large computing companies such as Dell and IBM; and
- new computer algorithms that have been used by software engineering companies.

### Underpinning energy technologies

**Applied superconductivity and materials science:** These include the development of novel materials or tools that enable new ways to store and convert energy for more

## UK PHYSICS DELIVERS SIGNIFICANT IMPACT FOR THE ECONOMY

Physics-based businesses account for more than **one million jobs in the UK and contribute £77 billion to the UK economy** directly (with high-value physics-based manufacturing accounting for **500,000 jobs and £20 billion**). These figures grow to nearly **four million jobs and £220 billion** when indirect effects such as supply chains are taken into account. The creation of products and devices enable growth in areas such as:

- **Aerospace and automotive:** Physics-based technologies, such as advanced materials, are driving development in the aerospace sector, for example, nanomaterials are used to coat aircraft helping to reduce friction and thereby reducing fuel consumption and costs. Physics-based transport industries directly contribute **60,000 jobs in the UK economy, £5 billion in GVA**.
- **Nuclear and offshore wind:** The UK physics-based electricity production and distribution industry **directly employs 50,000 people, £7 billion in GVA**.

Physics is at the heart of new nuclear power stations and wind-farms efficiently capturing and storing energy.

- **Life sciences and agri-tech:** Physics technologies are critical to advances in the life sciences – a sector **employing 160,000 people in the UK**. From playing a fundamental role in the discovery of DNA in the 1950s, physics has continued to underpin research in this area through technologies such as high-resolution cameras and optical tweezers – a laser system that is able to move biological systems on the micrometre scale.

efficient batteries that are urgently required for the smart grid; and light-emitting diode (LED) light bulbs, developed from condensed-matter physics, that are 10 times more efficient than an incandescent light bulb.

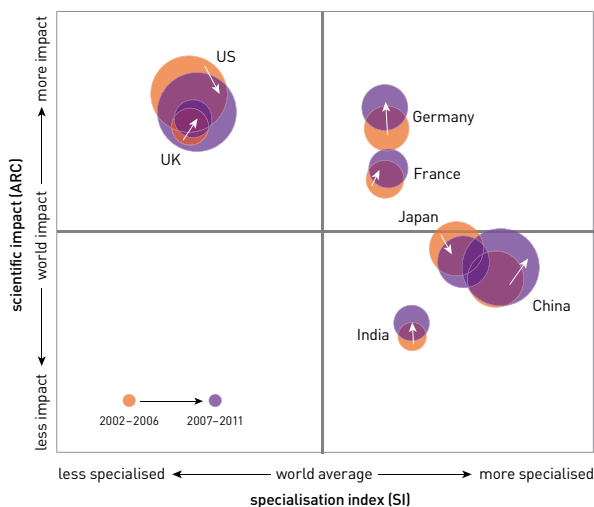
**High-temperature superconductors:** These could be a feasible alternative to copper wire in the future for more efficient transmission of electricity over long distances. Superconductivity had been thought to occur only at the very lowest of temperatures until the 1980s when Nobel-prize winning research led to the discovery of so-called 'high temperature superconductors'.

**Energy-efficient windows:** The application of coatings using magnetron sputtering to reduce heat loss was

developed in plasma physics research. In the UK, low emissivity, high solar gain windows are able to reduce heat loss by as much as 40 per cent compared to standard double glazing.

**Phase-change materials (PCMs):** These are helping to reduce the amount of energy needed to heat and cool buildings, which accounts for one third of all carbon-dioxide emissions globally. Advanced PCMs also have the potential to help make appliances such as dishwashers, washing machines and fridges even more efficient. In 2009 the world market for PCMs was already worth \$300 million. It is growing at a rapid pace and is set to reach \$1.5 billion per year by 2015.

### UK physics research - less specialisation, more impact



The specialisation index (SI) score uses fractional-paper counting, whereas the average of relative citations (ARC) score uses full-paper counting. The direction of the arrows and colour of the circles reflect the changing position of countries from 2002–2006 to 2007–2011. At the time of writing the report, the latest available year for the ARC scores was 2009. (The area of the circles is proportional to the number of publications.) **Source: Computed by Science-Matrix using the Web of Science (Thomson Reuters)**

### Contribution of GPS to economic growth

Extremely precise time measurement is crucial to satellite-navigation systems and requires the use of atomic clocks – the most accurate clocks available. The first one was built at the UK's National Physical Laboratory in 1955 by UK physicist Louis Essen. Today, not only does Global Positioning System (GPS) technology support and improve transport systems, but areas such as financial services, computer systems, mobile communication, security and energy supply are dependent on its precision time measurements.

The impact of satellite timing and navigation can be quantified on two levels: that generated by companies directly involved in the provision and manufacture of the satellite and receiving technology, and the much wider impact of the many industries that rely on its capabilities. The satellite-navigation industry itself made a value-added impact contribution to UK GDP of around £113 million in 2010 and is expected to generate a value-added contribution to the UK worth £1.45 billion between 2011 and 2020. More broadly, the technology is a critical component of 21st century telecommunications and transport systems, and the UK's economy is increasingly

## PHYSICS-BASED SOFTWARE LEADS TO SPIN-OUT COMPANY SUCCESS

The award-winning University of Exeter spin-out company Simpleware was set up to commercialise a physics-based computer simulation tool. The software is underpinned by patented techniques developed and improved, with the aid of EPSRC funding, to produce a previously unattainable level of realism in 3D computer models used for engineering design and simulation. Originally developed in the biomedical field with the company's first project in partnership with the National Health Service, focusing on improving the understanding of how loads are transmitted in healthy hips, the software has since been successfully adopted in a wide range of healthcare-related projects and across a host of disciplines and industries – from mobile phones to car engines, asphalt damage to back pain and contact lenses to hearing aids. Simpleware has achieved over a 40 per cent annual growth rate with exports contributing 81 per cent of total turnover. Its global markets include the US, EU, China and Canada.



Attention to detail: A finite element mesh of an open-cell foam.

Strong re-selling networks are also being established in India, Taiwan and Singapore. Company founder Professor Philippe Young states: "The ability to generate robust and accurate numerical models from various sources of image data has started a revolution in the world of multi-physics simulation."

dependent on satellite navigation, with the GPS-sensitive portion of UK GDP being around seven per cent, or £100 billion in 2010 prices.

Research in this area is also perceived as having a high relevance for industry through the increase of the capacity for scientific and technological problem-solving. For example, the detectors used today in household cameras and smartphones were the result of problem-solving by astronomers.

### The UK challenge for physics research

The combined pressure from emerging and traditional competitors presents the UK with a significant challenge if it is to maintain a leading position in physics research over the next 10 years.

To strengthen the economic benefits from physics research and expand the boundaries of physics knowledge, the UK must continue to secure a strong scientific and technological base in physics and ensure that there are efficient knowledge flows between the public and private sectors. This is particularly important as emerging scientific countries in physics – such as China, India and the Republic of Korea – are changing

### DESPITE THIS STRENGTH THE UK PLACES LESS EMPHASIS ON PHYSICS RELATIVE TO OTHER SUBJECTS

Compared to other leading countries such as France and Germany, as well as emerging countries such as China, India and the Republic of Korea, the UK has less emphasis in physics than in other fields of research. In 2011, out of the top 25 countries, the UK had one of the lowest proportions of physics publications relative to those in other subjects. The leading countries that have shown the biggest growth in world share, such as China and India, have achieved this whilst maintaining and in some cases improving their scientific impact.

the landscape of physics research activities. These are increasingly placing competitive pressure on countries with more established physics research, such as the UK, with their ability to employ highly qualified personnel who contribute to the development and production of high-tech, high-value-added goods.

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**The UK's performance in physics research: National and international perspectives is available to download from the EPSRC, IOP and STFC websites.**

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1 See, for instance, *The Importance of Physics to the UK Economy*, London: Institute of Physics, 2012.

2 *The Importance of Physics to the Economies of Europe*, Mulhouse, France: The European Physical Society, 2013.

3 See, for instance, *The Economic Impact of Physics Research in the UK: Magnetic Resonance Imaging (MRI) Scanners Case Study*, London: Oxford Economics, 2012; and *The Economic Impact of Physics Research in the UK: Satellite Navigation Case Study*, London: Oxford Economics, 2012.

4 *The Career Paths of Physics Graduates*, London: Institute of Physics, 2012.