Microelectronics and Photonics in the Heart of the South West Region

Unrivalled experience in the design and manufacture of photonics and electronics for the most failure-intolerant applications

Enabling the future digital world

Built to survive

Hub of integrated photonics design

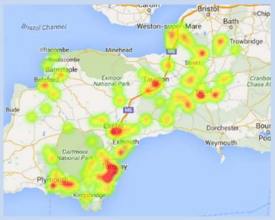
All communications solutions in one place

Pioneering next generation photonics enclosures

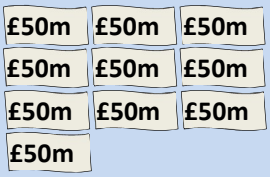
Experience

Photonics & Electronics in the Heart of South West

3,125 people employed



>174 companies



£516million output

Ver 2.0 August 2017

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Project: **Strengths and Capabilities of Microelectronics & Photonics in HotSW LEP Region**

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1 Executive Summary

The Heart of the South West region has u**nrivalled experience in the design and manufacture of photonics and electronics for the most failure-intolerant applications.** This unique position is built on a unique combination of four capability pillars:-

- **Manufacture, design and test of high reliability photonics and electronic components and systems.**
- **Strength and depth in all terrestrial communications technologies- radio frequency, integrated photonics and fibre optics.**
- **The most experienced harsh environment and high durability photonic and microelectronic design engineers.**
- **Pioneers in next generation integrated photonics design and packaging.**

These pillars, and the unique capability they offer when combined, are a direct result of the South West photonics and microelectronics industry supplying solutions to the defence, aerospace and communications markets over multiple decades.

The South West region is the **largest employer in the UK in 'instruments', 'lighting and electrical equipment' manufacturing** and in the top 20 regions by employment within these high value sectors in Europe. Across the whole of photonics, from lasers to lighting, the region is in the top four by employment and output in the UK for a sector which contributes over £12.9bn to the UK economy.

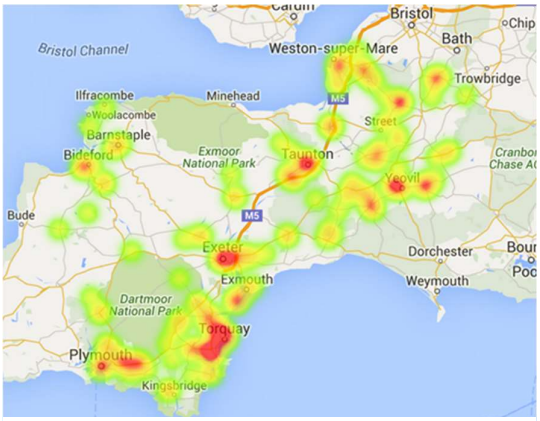


Figure 1 Distribution of electronics and photonics companies in the HotSW region

The combination of photonics and electronics expertise in the region means local firms are able to identify how photonics and microelectronics can digitise and improve the productivity of the most critical failure intolerant applications. Such applications are growing rapidly as society increasingly depends on electro-optical technology to address the greatest societal and industrial challenges of our time, from communications and security, to healthcare and autonomous vehicles. The regions experience is enabling local companies, to identify the major hurdles holding back development and focus on innovating new ways to combine these technologies together to give reliable, cost effective solutions for the most demanding applications.

The key messages capturing the regions capabilities are:-

Enabling the future digital world

Built to survive

Hub of integrated photonics design

All communications solutions in one place

Pioneering next generation photonics enclosures

Experience

These messages should form the backbone of a 7-point action plan to build inter- and intra-regional partnerships for sectorial growth and inward investment in the region consisting of:-

1. Targeted articles in marine, aerospace, nuclear publications.
2. Cross-sector events in the HotSW region with nuclear, aerospace and marine.
3. Hosting national / international focused meetings in the region.
4. Forging links & partnerships with national aerospace, compound semiconductor, satellite, and health-care photonics centres.
5. Inter-LEP collaborations with Midlands, North East, Scotland, Solent and South Wales.
6. Inter-regional training links to colleges focusing on hi-tech manufacturing.
7. Participation in European Coordination and Support actions.

Inter-regional collaborations should reach out to those UK regions with complimentary foci where photonics will have significant future impact; e.g.

- automotive & autonomous vehicles and digital manufacturing in the Midlands,
- the digital economy and datacentre developments around Slough,
- healthcare instrumentation innovation in the North East and
- space and satellite solutions clusters around Harwell.

They should also leverage collaborations with regions such as the Central Belt of Scotland and Southampton Solent area who have similar focus to the HotSW, making it easier to find collaborations with common cause and understanding.

Within the region, the greatest leverage will be in forging partnerships with other regional strengths in nuclear control, marine electronics and aerospace and photonics integration. However, as the photonics and micro-electronics industry is predominantly export focused, events to bring these sectors together need to focus on developing a common understanding of the problems challenges and opportunities in order to forge new partnerships.

As technologies that are imbedded in all applications and increasingly pivotal to providing added value, supporting photonics and microelectronics enables growth to be supported in all vertical markets without having to pick winners. Support for enabling technology reduces risk of down cycles in any single end application and increases efficiency of investment as solutions are applied to multiple problems. The region has some of the greatest experience in applying these technologies to societies most demanding problems, **when it comes to mission critical digital solutions, why risk going elsewhere**.

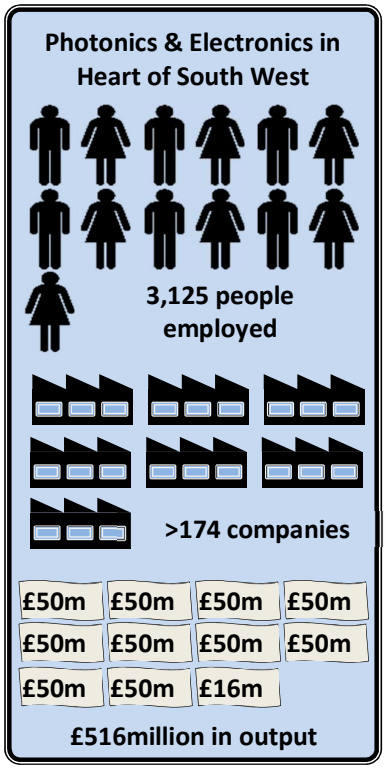


Figure 2: Key statistics on the photonics and electronics sectors in the HotSW region (2016 figures)

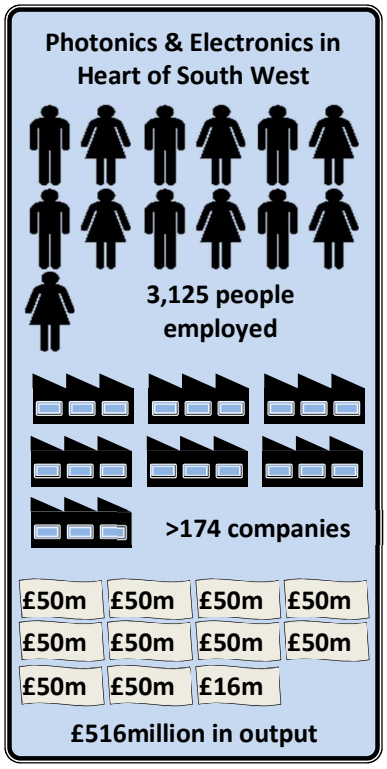
2 Introduction

The South West region has a strong and vibrant cluster in photonics and microelectronics. Although often low profile, the areas' companies are highly respected by their customers, and by virtue of their ongoing success, seen by their customers as delivering high value differentiated products. The photonics and microelectronics sector is an asset of the region, generating and maintaining high value manufacturing jobs that are vital to underpin the UK's industrial strategy, economic growth and productivity.

This report identifies what makes the areas' electronics and photonics sector unique, how it is distinguished from other regions in the UK (and Europe) and where it is similar. Clear links are made between the key strengths of the region, the UK's latest industrial strategy and how the region has a leading role delivering solutions to society challenges in digitising the economy, the rising cost of healthcare, autonomous transport and energy.

Actions are identified that will raise awareness of the capabilities of the region and foster further partnerships both within the region and between regions that leveraged the capabilities of the sector. The factors that have driven companies to locate and grow their operations in the region - the Unique Selling points of the regions photonics and microelectronics cluster are further highlighted as a basis for supporting inward investment to the region.

This report builds on a previous "Microelectronics and Photonics Cluster in the Heart of the South West Region" 2015 study that quantified the strength and depth of the region's photonics and



microelectronics cluster as employing over 3000 people (1 in 20 of those working in manufacturing in the region) in more than 174 firms generating over £500m in output per year at a productivity of £100k-£140k per employee.

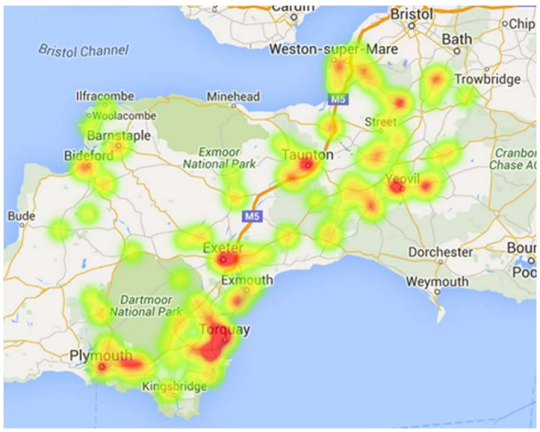


Figure 3: Heat map of the location of electronics and photonics companies in the HotSW region

Photonics & Electronics defined

Photonics *is the technology of light, including all design & products emitting, processing, manipulating and detecting light e.g. lighting, LEDs, cameras, lasers and fibre optics.*

Microelectronics*, includes all the technologies of designing, fabricating and integrating small (micro) electrical circuits, most commonly (but not exclusively) using digital signals.*

3 Underpinning Technology

The UK Government's January 2017 industrial strategy green paper identifies multiple horizontal activities to support industrial growth, identified within its 10 pillars[1]. Support for these 10 pillars is coupled with a plan for cultivating world leading sectors through sector deals, with eight sectors identified for the initial focus of the Industrial Strategy Challenge Fund. Photonics is a vital enabler for all of these vertical sectors, with organisations in the HotSW area making a significant contribution to all of these as illustrated with select examples in the table below.

Industry strategy challenge fund area (from industry strategy 2017)	Photonics and microelectronics enablers from SW region and surrounding area.
Smart, flexible and clean energy technologies	Optical and radio communications networks, smart metering and micropower generation management Low power LED lighting GaN capacitors from IQE and the compound semiconductor cluster in Cardiff, for electrical power regulation.
Robotics and artificial intelligence (including connected and autonomous vehicles and drones)	Multi-function remote sensors for autonomous vehicles. Packaging of photonics and microelectronics for harsh environments e.g. vehicles, aerospace, space and marine. Light-weight low-power electronics for drones Underwater and radiation tolerant cameras for monitoring marine and nuclear environments
Satellites and space technologies	Optical communications inside satellites Satellite to earth direct laser data links High resolution satellite based imaging systems
Leading-edge healthcare and medicine	Blood flow monitoring Optical coherence tomography for imaging through skin and ophthalmic diagnosis. Real time optical communication networks for remote healthcare & treatment
Manufacturing processes and materials of the future	Laser based cutting, welding and marking 3D printing of metals and composites
Bioscience and biotechnology	Multi-colour laser sources for confocal microscopy. Automated cell counting Process monitoring in drug manufacturing.
Quantum technologies	Single photon sources and counters for Qubits core elements in quantum cryptography and quantum computing .
Transformative digital technologies - super-computing, advanced modelling and 5G mobile network technology.	Optical fibre networks providing data links for the internet, modern datacentres, super-computers and mobile mast connectivity 5G mobile test and characterisation equipment.

Table 1 Link between key industry challenges identified in Government industry strategy green paper and photonics and microelectronics enables in the HotSW region

[1] Building our Industrial Strategy, Green Paper Jan 2017 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/611705/building-our-industrial-strategy-green-paper.pdf

The BEIS Committee 'First Review of the Industry Strategy[2] highlighted the risks of narrow sectorial based support and advocated a more horizontal approach defining UK wide and local missions that require addressing, e.g. "maximising opportunities from the fourth industrial revolution". As enabling technologies, photonics and microelectronics are just as critical for such sector cross-cutting missions.

Photonics and microelectronics provide a solution to the compromises between narrow vertical sector support and cross cutting horizontal support. Fostering such enabling technologies provides a foundation for advances in all of the vertical sectors identified in the 2017 UK industrial strategy and supports delivery of solutions to societal challenges by providing core functionality that can be deployed to a diverse range of societal problems or missions.

Fostering the local photonics and microelectronics industry is one of the most efficient ways to support industrial growth in and around the region, providing multiple efficiency gains including:-

- Supporting growth in many vertical sectors simultaneously without having to select a single end market for selective support.
- Reducing risk that any single end application or market fails, as the core competence in microelectronics and photonics can be re-deployed to multiple end markets
- Maximising leverage of public and private investment and local expertise by:-
    - leveraging expertise in fail-safe and highly durable photonics and microelectronic solutions from aerospace to nuclear and marine applications,
    - leveraging experience in integration and component encapsulation from communications to new solutions for autonomous vehicles and healthcare diagnostics,

Societal challenge / mission (from Industrial Strategy First Review).	Photonics and microelectronics relevance / impact
Decarbonising energy intensive industries	Laser based materials processing for greater energy efficiency in cutting and welding Low energy LED lighting in the workplace
Improving the affordability and effectiveness of health and social care in the context of an ageing population	Pre-clinical automated diagnostic and drug (e.g antibiotic effectiveness tests. Minimum invasive diagnosis and in operative tumour boundary detection with optical coherence tomography.
Maximising the country's opportunities arising from the fourth industrial revolution	Optical and radio networking to enable digital connectivity of machines and real-time process control. Robust remote sensors for industrial process monitoring
automating and electrifying our transport infrastructure	Low cost remote sensors optimised for the long life / durability leveraging experience of supplying aerospace.
Capturing as much value from a growing global population with rising disposable income	Ubiquitous High bandwidth connectivity combining satellite, radio and optical communications for entertainment and remote working

Table 2 Link between the societal challenges identified in First Review of 2017 UK Industrial Strategy and photonics and microelectronics

[2] Second Report - Industrial Strategy: First Review https://www.publications.parliament.uk/pa/cm201617/cmselect/cmbeis/616/616.pdf

- supporting cross fertilisation of innovation between photonics and microelectronics.

- Maximises leverage of training. A skilled photonics and microelectronics technician can work in multiple end sectors and have skills applicable to wide range of local employers.
- **Raises productivity** of:-
  - **Research and development**, as moving, e.g. telecom technology, into other high reliability sectors does not require starting development from scratch.
  - **Manufacturing** by increase local availability of the core technology underpinning digital manufacturing and manufacturing 4.0 processes.

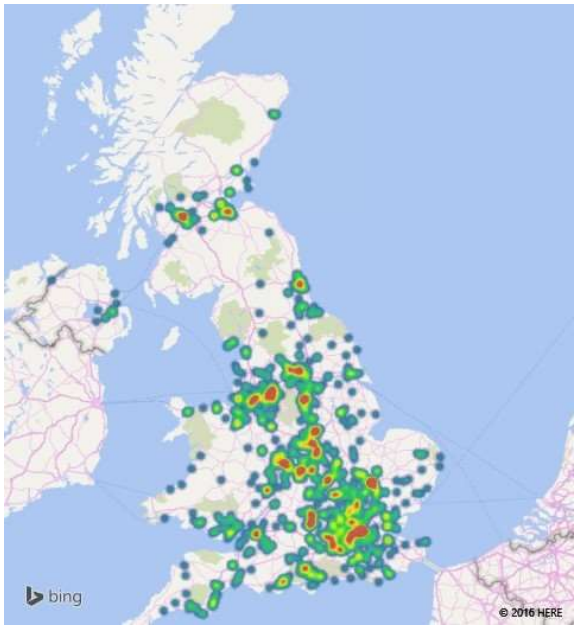


Figure 4: Location of all 1500 UK photonics companies (Source: Photonics Leadership Group)

4 Electronics and Photonics Clustering in UK

There are over 1500 organisations manufacturing, developing, researching and supporting photonics in the UK and at least the same again in microelectronics. These are distributed around the UK as shown, concentrating broadly along the industrial spine of the country from London to the North West. However, few of these organisations focus on all the possible applications for photonics and micro-electronics. Individual firms generally focus on sectors, where their products have particular application, differentiation and/or reputation.

Such clustering in photonics and microelectronics is not as strong as it is other sectors such as marine. However, as indicated there are still broad regional areas that are associated with particular strengths.

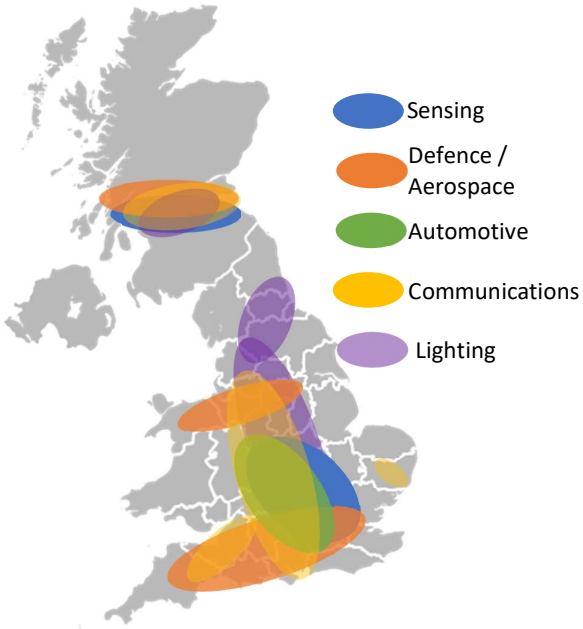


Figure 5: Broad clustering of photonics expertise in the UK by application focus, based on company location. Note- clustering is not exclusive and significant companies operate outside these locations

Sensing has long been a strength in the central belt of Scotland – in part due to association with the Oil and Gas industry and more recently

renewable energy. Glasgow hosts both the Off-shore Renewable Energy Catapult and Censis, the Centre of Excellence for Sensor and Imaging System technologies. There is also significant strength in sensing across the Midlands down to Oxfordshire, based on industrial sensing applications, e.g. machine vision and process monitoring. Northern Ireland is also has a cluster of strength in high performance imaging for scientific, defence and security applications.

Companies focusing on **defence and aerospace** applications are generally relatively uniformly distributed with companies from Great Yarmouth to Torquay, Belfast and Glasgow. The central belt of Scotland would however be seen as a particular cluster, building on Thales operations in Glasgow and Leonardo in Edinburgh (Leonardo have one of the largest R&D budgets of any company in Scotland). The South West, particularly, the greater Bristol area also has a long association with aerospace and defence, although the photonics and microelectronics companies associated with this sector are distributed more widely over the greater South West region particularly into the Torbay and Yeovil area.

UK photonics companies focusing on **automotive** applications are harder to identify, in part due to the highly internationalised nature of the automotive supply chain. The automotive industry is also a major and increasing user of lasers and sensors in production, however many of these systems are imported. However, the more general **laser processing sector,** including marking, welding and cutting can be mapped and has a distribution very much aligned to the area of strong UK heavy and semi-heavy manufacturing i.e. Midlands through the North West. However the 2017 "Laser for Productivity – A UK strategy" notes there are specialist 'job shops' providing laser based materials processing on a contract basis distributed throughout every region of the UK, including the South West.

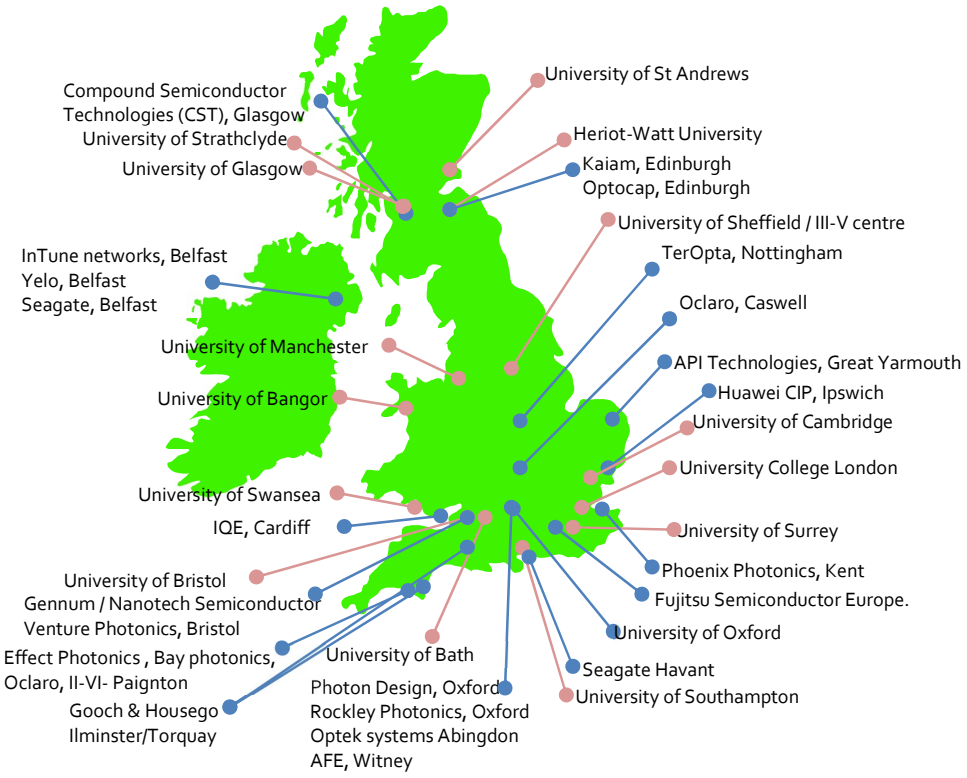


Figure 6: Distribution of optical communications expertise in the UK

Photonics and microelectronics for **communications** has long been a UK strength, both for optical fibre communications and radio/wireless comms. The South west including Torbay and Bristol areas are known for expertise in this area, as is the Solent area, the South East, Midlands, parts of East Anglia and the central belt of Scotland.

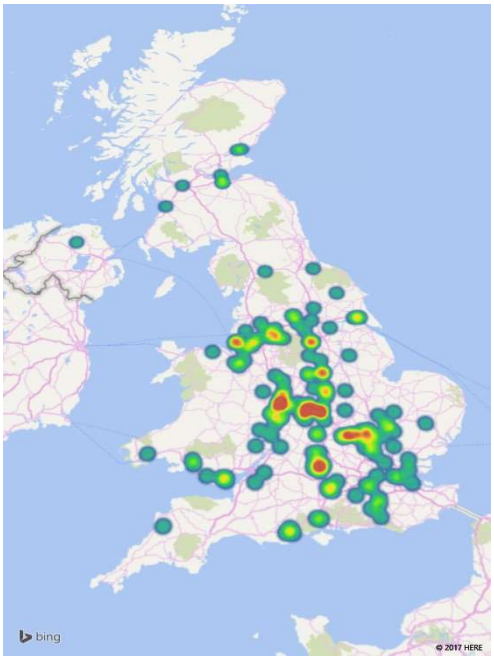


Figure 7: Distribution of laser processing firms around the UK (Source Lasers for Productivity a UK Strategy 2017)

Lighting, both consumer and industrial, is an increasingly important sector driven by the penetration of LED lighting into retail, leisure, office and home environments. Many companies focusing on this market concentrate on the design and production of lighting solutions, from light fixtures (luminaires) to lighting services with a loose clustering through the Midlands. However, lighting includes high value niches in healthcare, which have been strongly supported in the North East. There are also a small number of prominent suppliers producing the core underling LEDs, most notably Plessey in Plymouth.

The above regional comparisons are of course general groupings and there are multiple companies in the sector mentioned operating outside the regions described. Further searchable detail on the precise location of different firms in these and other sector categories will be available from the Photonics UK landscape scheduled for online publication in Autumn 2017 by the Knowledge Transfer Network[3]. However, comparison with other regions in the UK and Europe is available through the Cluster Observatory – see below, - which puts the SW region as the leading employer in the UK in 'instruments' and 'lighting and electrical equipment' manufacture.

4.1 Origins and impact of clustering

Photonics and micro-electronics companies generally sell into highly globalised supply chains. Most companies export over 75% of their output, many over 95%. Therefore, clustering in photonics and microelectronics is rarely driven by proximity to local customers. Rather the regions of specialisation identified above are a result of **historical associations and availability of local expertise**.

In a market where skills are in high demand, availability of expertise is an increasing drive for locating an organisation in a particular area. Willingness to relocate tends to be inversely related to seniority and experience and thus in a national and international mobile industry like microelectronics and photonics it is often easier to go where the expertise is.

[3] The UK photonics landscape tool will have the same category and geographic search capabilities available from previous landscape analysis in other sectors eg. medical devices http://mdlandscape.ktn-uk.org/

There are notable examples in the HotSW area where Oclaro, II-VI and Gooch and Housego have maintained and continue to grow operations based on local skills availability in high performance optical communications. The same is true in the West of Scotland and the proliferation of laser suppliers e.g. Coherent Scotland and M Squared laser who draw on a regionally loyal labour pool. **Accessing local expertise** rather than market access should therefore be at the core of inward investment pitches.

Some of other regions have long had excellent incubation facilities, e.g. at the West of Scotland Science park. The development of the Electronics and Photonics Innovation Centre (EPIC) will provide a viable alternative in the HotSW area and, correctly leveraged, further reduce barriers to companies locating and/or growing operations in the region to tap the local pool of expertise.

5 Regional unique selling points / core expertise

The strengths of the HotSW photonics and microelectronics cluster have been previously illustrated in the context of the following network.

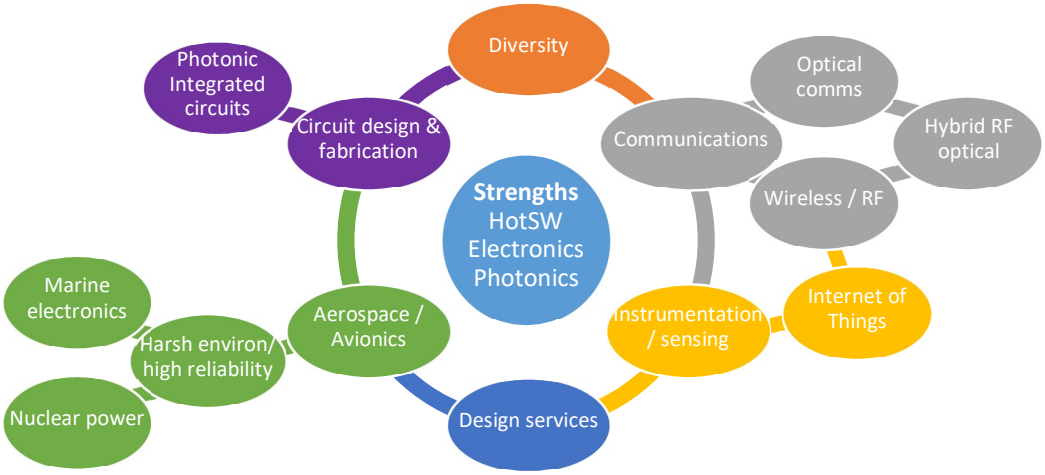


Figure 8: Core technical and market strengths of photonics and microelectronics in the HoSW region (source Microelectronics and Photonics Cluster in Heart of South West Region 2015)

These represent a mix of technical capability and application knowledge that can be summarised into following four key elements:-.

Manufacture, design and test of high reliability photonics and electronic components and systems

Strength and depth in all terrestrial communications technologies- radio frequency, integrated photonics and fibre optics.

Pool of the most experienced harsh environment and high durability photonic and microelectronic design engineers.

Pioneers in next generation integrated photonics design and packaging/ encapsulation

Figure 9: Key elements which in combination make the HotSW unique selling points in photonics and microelectronics

This gives the region some highly valuable strengths, namely:-

- In depth knowledge of the multiple dependencies of the digital world on photonics and microelectronics. These technologies provide the interface between the real and digital world with sensors and displays, the technologies to move data almost instantly around the globe, and the technologies to process and interpret that data to make it useful and beneficial to society, whether that be in form of entertainment, healthcare or high-value manufacturing.
- Vastly experienced photonics and micro-electronics workforce, many of whom have been working in the industry for over 35 years, often in and around communications technologies of all types. Skills from which are increasingly important to many other applications from digital healthcare to defence and security.
- The increasing focus on delivering high value solutions for extreme, failure intolerant environments, from satellites to ocean floor cables to aircraft. A focus that is driven by customer recognition of the value of experience.

- That same experience also enables the region to identify the biggest opportunities, understand the hurdles holding development back and seek out novel solutions. Hence the increasing activity in the region on photonics integration i.e. putting more functionality onto a single chip and on novel way of encapsulating photonics components into packaged devices, ready for seamless system integration.
- A dedicated Electronics and Photonics Innovation Centre (EPIC) in which to incubate and foster the rapid growth of new companies taking advantage of these opportunities and the pool of local engineering skills and experience.

Other areas in the UK and Europe also have competencies in these areas individually, but the combination would appear almost unique to the south west area.

5.1 Key promotional messages and strengths

Building on the above strengths, the following key messages, or variants thereof, are recommended for use with in promoting the regions photonics and micro-electronics capability.

Enabling the future digital world

- Leading the competition in the digital world and keeping ahead on productivity depends on harnessing the power of light (photonics) and microelectronics.

Built to survive

- Home of manufacturing photonics and microelectronics for the most extreme environments on and off the planet.

Hub of integrated photonics design.

- Putting more functionality on the inside, to deliver greater cost effective benefit to customers on the outside.

All communications solutions in one place

- Neighbours designing and manufacturing cutting edge optical fibre and radio (wireless) communications solutions.

Pioneering next generation photonics enclosures

- From multi purpose high performance packaging to lower costs semi-hermetic solutions.

Experience

- Home to many of the most experienced photonics engineers in the world.

Figure 10: Key messages for promoting photonics and microelectronics capability in the HotSW region

6 Opportunities

6.1 Intra-regional collaboration

The strong international focus of photonics and microelectronics firms means they are often unware of potential customers in other sectors that maybe on their doorstep. The rapid development of technology in photonics and microelectronics also means potential users are often unaware of relevant local capability.

Opportunities for new local collaborations are thus most prominent where there are other strong regional sectors in areas that would benefit from greater application of photonics and microelectronic expertise i.e.:-

Nuclear control and monitoring

- Radiation hardness is a requirement of space components and nuclear monitoring and both require fail safe operation of control systems. Developments at Hinkley Point should provide local markets for harsh environment photonics and microelectronic solutions suitable modified for this application

Marine electronics

- Knowledge and understanding of developing solutions for robust and harsh environments could be efficiently redeployed to marine electronics, monitoring and control solutions.

Aerospace

- Aerospace is a vastly complex industry and although some area have started to adopt photonics solutions for cost weight and power savings, there remain many opportunities to penetrate more aerospace applications

Photonics integration

- The development of the compound semiconductor applications catapult in Cardiff and the mosaic of compound semiconductor facilities announced for South Wales, presents significant opportunities for leveraging the HotSW photonics packaging expertise and supporting its integrated photonics developments

Figure 11: Sectors offer best promise for new partnerships with photonics and microelectronics within the HotSW region

6.2 Inter-regional collaboration

The same core local competencies identified above determine the external regions with which the HotSW will have the most productive collaborations, however there are there are two opposing dynamics at play.

On one hand collaborations are often most successful where there is a common understanding and respect between partners, i.e. **between regions with similar end market foci**. To this end collaborations between the HotSW region and the central belt of Scotland and/or the Solent area should be productive and have historical precedence. Both regions are renowned for expertise in communications and for Scotland in particular aerospace / defence applications. Indeed there are many cases of photonics and microelectronics firms in the HotSW area collaborating with supply chain partners in Scotland, from Universities to end users in these areas. Indeed, such collaborations are at the origin of the HotSW photonics activity, as Gooch and Housego's first move into optical fibre technology over 30 years ago was due to a collaboration with Strathclyde University.

Inter-regional collaborations

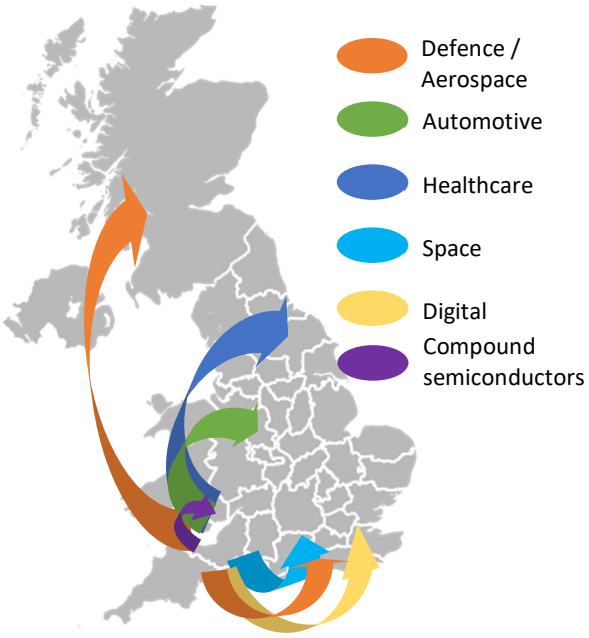


Figure 12: UK Other UK regions which offer new partnership opportunities for with the photonics and microelectronics sector in the HotSW region

The contrasting dynamic is that collaborations with regions with complimentary skills or market foci should generate more strategic collaborations that foster expansion into new markets. Such opportunities are less easily defined as the perfect partner(s) may be working in an end market sector that is not currently using or familiar with photonics, but is likely to benefit from the HotSW particular expertise in the future. The best regions to work with are therefore those with strength in the hot area for future photonics and microelectronics expansion namely:-

- Autonomous vehicles - Midlands,
- Digital manufacturing – Midlands
- Digital economy - Datacentre clusters around Slough
- Healthcare diagnostics - North East
- Space – Oxfordshire (Harwell campus)
- Compound semiconductor / integrated photonics – South Wales

However, immediate understanding of the benefits of partnership may be low, given that some of the most promising applications in these markets may be new to using photonics and unfamiliar with the importance of the accessing the HotSW skills. Additional work may be required to make the connection between the application challenges and potential solutions – see action 2 below.

Given the benefit of closer proximity intra-regional collaborations should be efficient and easier to facilitate that inter-regional collaborations. However, as most photonics and microelectronics companies are not focused on local customers this requires looking beyond the region even to create new partnerships within it leading to a combined action plan.

7 Action plan

A seven point action plan to increase cross-sectorial awareness and build inter and intra-regional partnerships including and inward investment is recommended:-

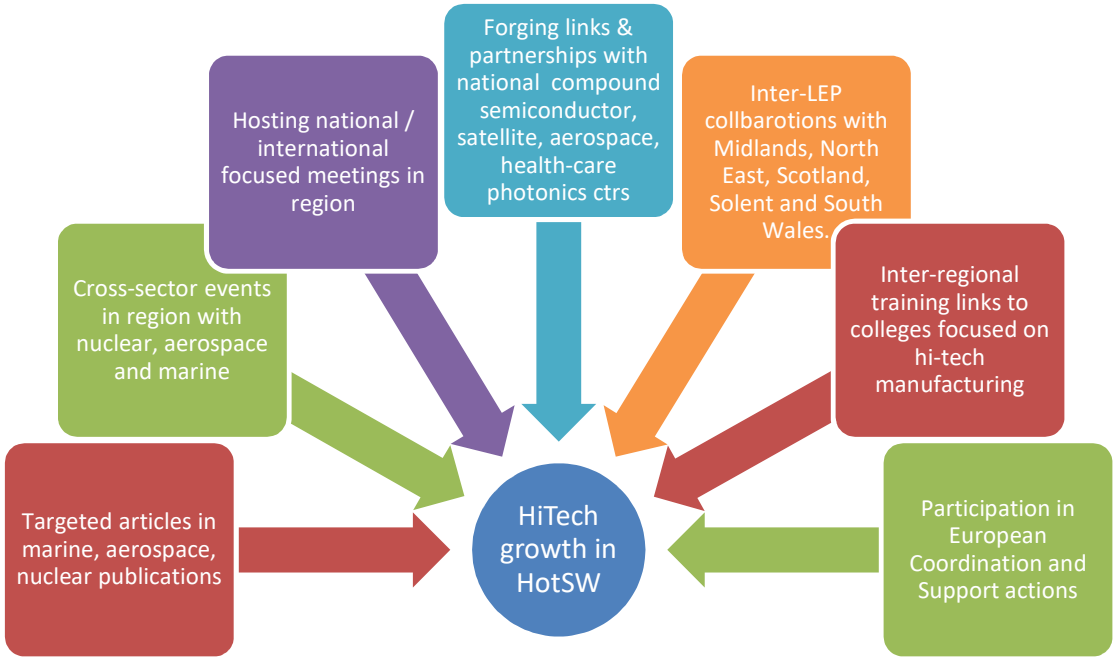


Figure 13: Seven point action plan for to increase partnerships and inward investment around photonics and microelectronics in the HotSW region.

7.1 PR in end user sectors

A focused ~18 months public relationship program should be undertaken into the UK and international trade press covering target sectors including marine, nuclear and aerospace. This should focus on placing featured articles in key trade press publications/portals highlighting innovation from regional photonic and micro-electronics companies that are relevant to these sectors. Editors are, in general, interested in articles that inform readers of future trends. Therefore, such articles should not focus on established products, but future developments and use copywriters who are briefed to make the connection between the regional core strengths (below), the needs of the target industry and case studies drawn from regional companies of parallel developments that could fine relevance to these other sectors. Examples include:-

- High bandwidth data communications on aircraft or autonomous vehicles.
- Redeployment of aerospace component to the sub-sea environment.
- Leverage of space qualified components to nuclear monitoring.

The initial focus should be on end sectors that are also regional strengths, before extending to end markets that are strengths of other regions and where inter-regional collaboration maybe sort for such targeted marketing.

Potential target publications include:-

- HIS Jane's Defence weekly
- Marine Technology Reporter

- Nuclear Power Engineering Magazine.

Confirmation of suitable target publications should be sort with regional leaders in the above sectors.

The typical budget for placing such PR is dependent on how such project are constructed. Importantly, it is critical to secure agreement for article placement in advance, by talking to relevant editors about the stories they are looking for and when they fit their editorial calendars. This requires more up-front investment than pure copy writing. Indeed the major value-add is in securing the article placement. Many copywriters will only quote for writing an article, not its placement, and assume they write first and seek placement after, which provides substantially less value. Rather one should only pay for a specifically article to be fully written one a place for its publication is secured.

7.2 Joint cross-sectorial events in region

To compliment raising awareness in other strong regional sectors , events should be held in the region that being together these sectors. Given that cross community understanding of what is possible and what is needed is lacking such workshops should focus on bridging this gap by:-

- Review of end market size in relevant sectors of e.g. nuclear and marine instrumentation to create interest in addressing these markets.
- Overview of photonics and microelectronics solutions already developed / understood for other harsh environments e.g. satellite, sub marine cable. This should break down preconceptions about what is possible.
- Interactive discussion of challenges e.g. marine or nuclear instrumentation and how these can be address with local photonics and microelectronics solutions.

Standard workshop formats presenting current products in both fields are unlikely to be useful. Structured discussion that draws out ways of applying local technology solutions to known problems, e.g. in marine, is likely to be most beneficial in leading to longer term win-win collaborations.

7.3 Hosting focused national and internationals event in region.

Seeing is believing and thus one of the more productive methods of promoting the regions unique capability is hosting national and international workshops in the region. Focused technical workshops on highly targeted topics are increasingly popular with both industrial and academic communities and well suited to the HotSW. Given that such meetings are typically 1-2 days in duration with an overnight stay, travel time to the region is insignificant and certainly no worse than to similar meetings frequently hosted in Spain, Berlin or Glasgow. Indeed, it is notable that European regions and devolved administration in the UK, put considerable effort into encouraging and supporting such events.

Such meetings can be made even more attractive if they are combined with project meetings for European or UK projects in which regional companies are participating, or industry days for major EPSRC / research council funded academic projects (e.g metamaterials CDT @ University of Exeter)

Potential events include:-

- European Photonics Industry Consortium AGM
- Optical Interconnect in Data Centers Symposium (previously held in conjunction with ECOC)

- National Infrared Photonics meeting (scheduled for November September 2017 at Exeter Uni)[4]
- ILAS (UK Industrial Laser symposium), organised by AILU traditionally in Midlands.
- Photonics packaging meeting (with EPIC) (previously in Scotland)
- Photon18 (although note this IOP meeting is mostly academic in focus)
- Fibre optics in Harsh Environments Conference (FOHEC) previously organised by AV Optics in Swindon last held in 2010
- European Workshop of Optical Fibre Sensors (www.EWOFS2016.og) last held in Limerick.

Typically such meetings will attract 50-150 participants and will be seeking a subsidy of ~£50 to £100 per head i.e. £5k for a 50 person meeting, either directly or via subsidised venue cost. The objective should not be to make such meeting free (they are often undervalued if they are), but to make them competitive to being hosted elsewhere. It is also highly beneficial to have a professional event organiser deal with the registrations and venue organisation (typical cost ~£20/head) and leverage local industrial leaders to chair and invite key speakers.

It is also important to target meetings which are traditionally multi-day / overnight. Or to construct meetings to fit this format e.g. afternoon arrival, dinner / plenary talk with active session following morning until 4pm, followed by local tours. This vastly eases delegate travel and the provision of networking in the evening is often highly valued. The time it takes to organise a good meeting and secure valued speakers should also not be underestimated.

To be successful such meetings should have strong market / application focus. Generic regional showcase meetings, whilst have a different value, but do not necessarily attract significant national and international audience at the industrial engineering or senior management level that will instigate specific new long term inter-regional partnerships and collaborations.

7.4 Links to national centres

There are multiple national centres where greater link to the HotSW region would be mutually beneficial including:

- Compound Semiconductor Applications Catapult and Cardiff area compound semiconductor 'mosaic' including
  - Compound Semiconductor Centre www.compoundsemiconductorcentre.com *(Private / Cardiff Uni collaboration)*
  - The Future Compound Semi-conductor Hub at Cardiff University http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/P006973/1
  - The Newport Compound Semiconductor Foundry- http://www.bbc.co.uk/news/uk-wales-south-east-wales-39837876

  These various inter locking initiatives are generating a critical mass of activity around compound semiconductors in South Wales that is highly complementary to the HotSW regions skills in photonics packaging, integrated photonics, optical and RF communications.
- Satellite Applications Catapult (Harwell Campus, Oxfordshire) https://sa.catapult.org.uk. Originally focused on leveraging 'big data' coming from satellites this Catapult has more recently taken greater interest in satellite hardware, making it more relevant to companies in the HotSW area.

[4] Note Harlin has a declared interest as a potential co-organiser of this event.

- Satellite test facility. Announced on 21 April with £99m in funding over 4 years[5]. This facility could help support HotSW companies access the highly lucrative satellite hardware market.
- The Future Photonics Hub at Southampton and Sheffield Universities www.photonicshubuk.org. Supporting next generation optical fibre, IR lights source, silicon photonics and integration.
- Aerospace Technology Institute, www.ati.org.uk providing directed calls for focused aerospace innovation. Working with the ATI, to increase awareness of the expertise available will open up ATI collaborative programs to participation from HotSW photonics and microelectronics companies.
- Centre for Doctoral Training (CDT) in Integrated Photonic and Electronic Systems (UCL & Cambridge Universities). Supporting development of integrated photonics and electronic systems.
- National Healthcare Photonics Centre (Sedgefield) being created from Centre for Process innovation (CPI) part of the High Value Manufacturing Catapult. Unique capability in evaluating clinical potential of photonics innovation.

Additional sector deals are likely to emerge from the UK industrial strategy with an addional £2bn a year committed to the industry productivity fund by 2020. The satellite test facility announced above is just one such initiative. Others in batteries, drug manufacture, robotics for harsh environments, driverless cars and composites have already been announced. More will follow, providing additional opportunity for collaboration.

A sector deal in photonics has also been proposed by the Photonics Leadership Group, with further potential for direct involvement.

7.5 Links other LEPs / devolved administrations.

To a great extent the location of the above national centres and those regions with complimentary foci ie. Midlands, Northeast, Oxfordshire, Solent and central belt of Scotland and South Wales define the location of LEPS with which the HotSW should seek partnerships around photonics and micro-electronics.

In some cases, there is more than one LEP in these broad regional areas e.g. Solent and M3. Businesses are not generally sensitive to such LEP boundaries and thus this can require working with more than one LEP in an area.

7.6 Training links

There is much greater emphasis on vocation and technical training within the government's latest industrial strategy. This is of significant interest to many photonics and microelectronics firms who have for many years found that traditional technical / vocation educational courses do not provide training relevant to modern clean hi-tech manufacturing.

Companies in the HotSW area have worked with South Devon college to provide improved solutions and these may provide a template for improving training in skills area to photonics and micro-electronics nationally. Links to other strengths of training in these areas e.g. in Bangor North Wales and Eastleigh outside Southampton, would encourage spread of best practice. With the greater focus on spreading productivity to the regions and encouraging fit for purpose vocational

[5] https://www.gov.uk/government/news/business-secretary-announces-industrial-strategy-challenge-fund-investments

training in the industrial strategy , training provision for photonics and micro-electronics could be a regional strength that the HotSW can export to other regions.

7.7 Engage in Eu Coordination and Support actions.

Many cluster organisations across Europe participate in European Coordination and Support actions (CSAs) aimed at fostering inter-cluster collaboration across Europe e.g RespiceSME, Aspice, Eprise, Pics4All, Photonics4all, Phablabs4.0[6]. Two or more of these CSAs have been funded in photonics in every round of H2020 funding over the last 5 years, i.e. approximately one per year. They have proven to be an excellent way of fostering links and awareness of the capabilities of other clusters across Europe. The benefits for individual companies involved are modest, but the raising of awareness of a regions capability with other EU regions for those participating from past programs is clear.

The new National Healthcare Photonics Centre in Sedgefield is a partner in Eprise[7] supporting the use of photonics in the life-sciences. The Torbay EPIC centre or Hi Tech forum, or similar structure in HotSW area could benefit in engagement in CSA's around photonics packaging and integration. Although the long-term future for UK participate in such programs is unknown, participation is still welcome up and to the point of Brexit. Therefore there is a short term opportunity to make the most of access to these programs whilst it is still open.

7.8 Action priorities

A coordinated action plan covering all seven areas identified above will have the greatest impact. However, action in some areas could be considered more timely namely due to external socio-political events.

Technical training will be a priority for the current parliament. Forging links that put the HotSW at the centre of the new vocational technical training agenda and actively participating in the definition of that the technical training policy should be given priority.

Participating in EU CSAs is predicated not only on the UK membership of the EU, but also the end of the H2020 program. The window for participation is therefore closing rapidly and requires building bridges to potential partners and submitting proposals within the next 12 months.

[6] A comprehensive list of recent and ongoing CSAs in photonics is available at https://www.swissphotonics.net/photonics21/coordination-support-actions

[7] https://www.uk-cpi.com/news/new-eu-project-will-shed-light-potential-photonics-life-science-regional-level/

8 Conclusions

The photonics and microelectronics sector in the HotSW region has been identified as having unique capability in the **design and manufacture of solutions for the highest reliability, failure-intolerant applications**. This capability is derived from combining the regions expertise in high reliability photonics and electronics systems, especially in all forms of communications technology. Built up over many decades this gives the region a pool of the most experienced harsh environment and high durability photonics and microelectronics engineers in the county. This experience is also being applied to identify the next generation of opportunities making the region early pioneers in integrated photonics.

The underpinning nature of photonics and microelectronics means it has direct impact to all the priority sectors and society challenges identified in the latest UK industrial strategy. Crucially many of the biggest challenges and thus highest impact innovations in the next 20 years will require a new level of reliability from our technology. From autonomous vehicles, to remote healthcare, to defence, failure of any of the critical components will have devastating consequences for users. Adoption of such innovations will thus require the most dependable underpinning photonics and microelectronics, delivery of which is the core competence of the HotSW region.

Bringing such innovations to market will require collaboration with those that have expertise in end markets. Opportunities for intra-regional collaboration are identified with the nuclear, marine, aerospace sectors which are also HotSW regional strengths. Inter-regional collaboration opportunities are identified with central belt of Scotland and Solent area due to their similarity in market focus and expertise and with the Midlands, North East, Oxfordshire and Slough areas which have strengths in end markets in advanced manufacturing, automotive, healthcare, space and data applications.

A seven point action plan has been identified that focuses on raising awareness of the regional capability with users that most need its high durability solutions. Action is also highlighted to forge partnerships with national centres to deliver both photonics and microelectronics solutions and the parallel need for vocational technical training to enable adoption.

Based on the HotSW strengths in photonics and microelectronics the recommended promotional message are:-

- Enabling future digital world
- Built to survive
- Providing a hub of integrated photonics design
- A single location for all communications technologies.
- Pioneers of next generation photonics enclosures
- Experience

Photonics and microelectronics are becoming critical to our daily lives. Data is no long a luxury but an essential. These technologies are the modern coal face- creating data, transporting and interpreting and acting on it. The 21st century will see society using data not just to inform but to undertake critical elements of our daily lives. This will make society fully dependent on the photonics and electronics technologies that sit behind that data. Failure of these technologies will not be an option. As long as they are aware of the capability, this vulnerability will cause firms to look to the HotSW region for the most experienced engineers and the most robust photonic and microelectronic solutions.

Appendix - Clustering in Europe and Rest of World

Positioning the South West photonics and microelectronics cluster relative to other clusters in Europe depends on how clusters are defined, with three main types of clustering commonly used:-

- Self-organising industry sector clusters with associated cluster organisation.
- Regionally self-identifying industrial strengths.
- Economically defined regional clusters.

a. Self-organising industrially clusters

There are approximately 43 photonic cluster organisations spread throughout the globe[8], with the highest concentration in Europe and North America. Such organisations are mostly membership based groups of industrial and

Europe	North America	Asia / Pac Rim
Comité National d'Optique et de Photonique	Arkansas Photonics Industry Alliance	The Australian Optical Society
bayern photonics e.V.	Arizona Optics Industry Association	South Australian Defence Photonics Cluster
Electronics, Sensors, Photonics Knowledge Transfer Network, UK	Carolinas Photonics Consortium	Korean Assoc. for Photonics Industry Development
Fotónica21 (Spain)	Colorado Photonics Industry Assoc.	
Hanse Photonik e.V.	Florida Photonics Cluster	Optics Valley of China
Lithuanium Laser Association	Michigan Photonics Cluster	
Optec-Berlin-Brandenburg e.V.	Montana Photonics Industry Alliance	
Optence e.V. Networking in Photonics	New Mexico Optics Industry Assoc.	Optics & Photonics Soc. of Singapore
Optics Valley France	New York Photonics Industry Assoc.	
OpTech-Net e.V.; Duisburg	Arizona Optics Industry Association	
bayern photonics e.V.	Rochester Regional Photonics Cluster, Inc.	
OptecNet Deutschland e.V.	CIPC / Photons Canada	
OptoNet e.V.	Ottawa Photonics Cluster	
PhotonAIX e.V.	Quebec Photonic Network	
Photonic BW		
Photonic Net		
Photonics Bretagne		
PhotonicsNL		
Photonics Finland		
Photonics Leadership Group, UK		
PhotonicSweden		
POPSUD - OPTITEC		
Route Des Lasers		
Scottish Optoelectronics Association		
SECPhO – Light Technologies Cluster		
Swissphotonics		
The Welsh Opto-electronics Forum		

Table 3: Principle global photonics clusters

[8] Global photonics clusters identified by SPIE - http://spie.org/industry-resources/photonics-clusters . Additional EU cluster list available at http://www.epic-assoc.com/membership/member-clusters/

Figure 14: Location of principle European photonics cluster organisations (Source: SPIE)

research organisation, representing a focus of activity in a region or country. They vary greatly in their structure, funding and level of activity from informal self-organising voluntary organisations, typified by clusters in the USA, to formal companies with premises, permanent staff and substantial annual budgets supported by membership fees and funding from regional government, typified most French and German clusters.

The degree of regional vs. national focus varies significantly and reflects the degree of centralisation of government in different countries as well as national size. Thus, France and Germany, with significant local government, provide strong support for regional cluster bodies, leading to the many regional clusters seen in these countries. Although even in France there have been recent consolidation between clusters (e.g. Route des Laser and Elopsys) to increase scale, diversity and reduce inter regional competition.

Within the UK, the Scottish Optoelectronic Association (SOA) and the Welsh Opto-electronics Forum (WOF) have existed for over 25 years, significantly predating devolution. However, SOA has been absorbed within Technology Scotland, to facilitate its continuation. In England, the abolition of the regional development agencies is correlated to the disappearance of regional photonics cluster bodies in England, the rise of national bodies (e..g Photonics Leadership Group). In the last 10 years the Knowledge Transfer Network(s) have also taken on the role of the community building commonly associated with cluster organisations, subsuming much of the activities that are associated with regional sector clusters elsewhere in the world.

The vastly different local political across Europe makes comparison of photonics and microelectronic clusters, based on their associated cluster organisation problematic. A strong photonics clusters organisation, e.g. Photonics Bretagne, can be more a reflection of the strength of regional government and local support for industrial clusters than the local strength of the industry. There are therefore best used as a source of information about other regions, and a point-of-contact and conduit to access companies in those regions.

b. Regionally self-identifying industrial strengths

Since around 2010, the European Commission have had a strong focus on industrial clustering as a driver of economic growth and thus a mechanism of identifying focus for regional support. To this end the Commission have supported a number of activities designed to identifying and enable comparison of regional strengths. These include the Smart Specialisation platform which encourages regions to identifying their industrial strengths as part of accessing European reginal development funding. One output results is a public database of regions which have identified a strengths in a particular

area[9]. As shown this can be searched to identify those regions across Europe which have identified

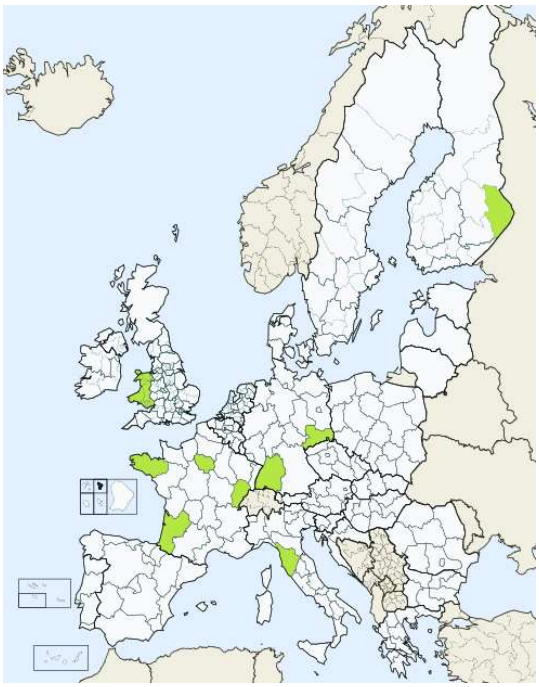


Figure 15: Regions identifying photonics in their smart specialisation strategies (source European Smart Specialisation platform)

specific key enabling technologies as a specialisation of their region, including photonics which is defined as a key enabling technology by the EU.

However, only 12 EU regions have explicitly identified photonics within their smart specialisation strategies, and only Wales in the UK. This lack of identification is attributed to many factors, including

- Adversity to selecting specific technical sectors (micro / nano-electronics is also only identified 13 times).
- Lack of knowledge, or evidence base, on specific sectors with those submitting Smart Specialisation Strategies.
- Bias to selecting priorities at a higher level to enabled greater aggregation e.g. key enabling technologies are identified by almost all EU regions as a strength in some form or another and identified in 271 different priorities.
- Interaction with national industrial strategies. Advanced materials is identified 81 times, although surprisingly despite this being identified as one of the 8 great technologies in the UK, only 4 UK regions specifically identify the area in their submitted Smart Specialisation strategies.

In principle the Smart Specialisation Platform should provide a toolbox for identifying other EU regions with similar strengths to the HotSW region. However, the inconsistencies in the data returned for the UK, call in to question the validity of data for other EU regions, substantial devaluing the platform as a comparison tool.

c. *Economically defined regional clusters*

The issues of self-selection and region political background bias in the above cluster locators should be revolved if economic data on employment, output and number of firms is used. This is the objective of the European Cluster Observatory, which enables mapping and comparison of regions according to industrial activity[10]. However, this data leverages standardised industrial classification (SIC) codes and NACE codes to aggregate industrial activity. Such codes lack specificity and data must be extracted from separate national databases, which has required 'splitting' aggregated data, 'translation' from different classification systems and for much UK data taking data from 2005. This is even before the difficulty next generation technology companies have, e.g. in photonics, in identifying a suitable SIC code for their business in the first place.

[9] http://s3platform.jrc.ec.europa.eu/

[10] www.clusterobservatory.eu

Figure 17: Combined employment in aerospace, electrical equipment, instruments and lighting by Eu region (Source European cluster observatory)

Removing aerospace, and focusing on employment in **'electrical equipment' and, 'instruments and lighting' the SW is still the largest employer in the UK** and in the top 20 regional employers in EU in these sectors.

Some high-level comparisons are however possible. The following map compares different EU regions for employment in aerospace, instruments and lighting and electrical equipment[11] (circle size = total employment, segments split between 3 sectors). **The South West region** (Gloucestershire, Wiltshire N. Somerset) **has the highest employment in the UK across these 3 sectors**, even more so if Dorset, Devon and South Wales are included. European wide this analysis puts the SW in the top 10 employers across Europe across these sectors. The map shows big difference in the division between these sectors compared to other Northern EU regions, aerospace being much less prominent in Germany.

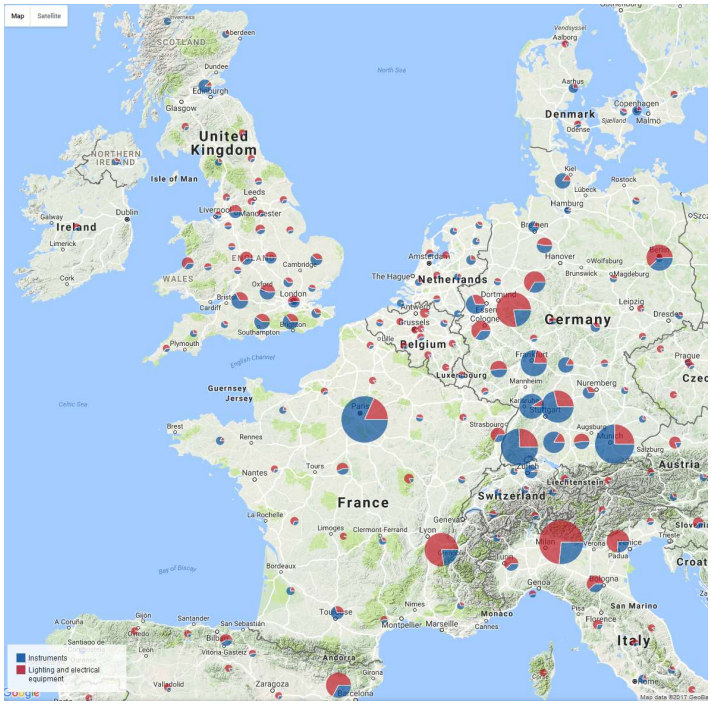


Figure 16: Combined employment in electrical equipment, instruments and lighting by Eu region (Source European cluster observatory)

11 http://www.clusterobservatory.eu/index.html#!view=regionalmapping;i=V16140;y=2011;r=NC10;rsl=2;rp=NC10;s=CC20-aero,CC20-inst,CC20-lght;sp=CC20-STND;p=map;ll=51.878435,1.11709;z=7