

## Photonics Leadership Group

# UK Photonics Future Growth Opportunity Analysis

Draft 4 17/01/2014

### Introduction

The major opportunities for future growth within the UK photonics sector are identified within this report. Areas are highlighted where the UK can be an international leader in significant markets and what should be done to maximise these opportunities. This report acts as a guide for developing and reaffirming business and investment strategy, research direction and partnership development by providing guidance on the 3 key questions of:-

1. Where is UK photonics growth coming from?
2. What strength have we got in the area to build on?
3. What action essential to make growth happen?

The initial basis for this analysis has been the European multiannual roadmap for photonics compiled by Photonics21 (<http://bit.ly/1hxm8Kk>). From this extensive pan European study, we have highlighted the areas of particular relevance to UK, clarified the definition of these opportunities and linked them to core UK strengths.

The Photonics21 roadmap will be the basis for investment by the European Commission over the next 7 years, via Horizon2020. This report indicates where UK photonics organisations should be involved in H2020, stimulating the maximum UK participation in European programs.

UK photonics is already a significant international supplier and innovator of photonics solutions and has unique strengths, capabilities and weaknesses. Thus there are additional growth opportunities for the UK that do not appear in the broader European analysis that are also identified here.

Actions to make the most of these key UK growth opportunities are identified. In some cases these refer to maximising participation in EU programs, in other cases there are UK specific actions. In all cases they require active and collaborative engagement by a combination of industry, investors, support and research organisations to create the critical momentum in the various supply chains. Fully exploited these areas represent significant growth prospects for UK business over the next 5-7 years not just in photonics but also in the many industries enabled by photonics.

The analysis is split into a number of sections representing major photonics sectors:-

1. **Optical Communications**
2. **Manufacturing, materials processing and industrial photonics**
3. **Photonics for Health and Life sciences / Bio-photonics**
4. **Lighting & Displays (split into 3 areas)**
  - i. **Lighting**
  - ii. **Plastic electronics/ OLED**
  - iii. *Displays*
5. *Security, sensing and defence.*
6. *Components*
7. **Research, training and education**

<p>Areas in italic are not included in this initial draft</p>
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For each sector a priority area is identified likely to be the highest impact growth opportunity.

As an underpinning technology enabling advances in many end markets and applications the supply of photonics solutions is highly globalised. Most UK photonics companies export 75-95% of their output. The opportunities discussed in this report address global markets and growth of UK organisations in these areas is expected to add significantly to UK.

We are extremely grateful to the experts who have contributed their time to this analysis and its further development.

## 1-Information, Data and Optical Communications

	Future UK Opportunity	Supporting UK Core Strength/Justification	Action(s) Required
Broadband	<p><b>Next Generation Broadband</b> giving Gigabit connectivity will require fibre to within 100m of the end user.</p> <p>Increasing merging of wireless and wired broadband provision based on 4G development and Future 5G</p> <p><b>Development of Radio on fibre</b></p>	<p>Smaller cell sizes for 4G and 5G will require closer integration of fibre and wireless infrastructure</p> <p>UK has well established mobile networks development centres..</p> <p>UK universities and specialist companies have world class skills in radio over fibre vital for future 4G and 5G for base station front-haul and back –haul</p>	<p>Skills training in installation and maintenance of optical networks. Involvement in future standards generation and European collaborations on 5G.</p> <p>Support research programmes that investigate the cross-over of radio and fibre technologies</p> <p>Increase links to those developing models of future cities.</p>
	<p>Growth in Data Centres, Cloud storage, electronic trading and Financial services.</p> <p>Growth in Big data and data based services.</p>	<p>UK major centre for high speed financial services</p> <p>Many UK businesses are increasingly dependent on the large data centres and looking to leverage big data.</p> <p>This will require Terabit interconnectivity supported by high performance optical networking.</p> <p>Key suppliers of cloud storage equipment have substantial manufacturing and design centres in UK</p>	<p>UK led collaborative research programmes involving operators, service and technology providers to develop higher capacity and energy efficient optical interconnect architectures.</p> <p>Development of next generation of core network technology capable of supporting growth in Cloud services</p>
Data	<p>Quantum information. Major UK opportunity at all points in supply chain from hardware to system design and implementation</p>	<p>Significant integrated photonics design and fabrication capability in academia and industry.</p> <p>Substantial research base in quantum technology.</p>	<p>Coordinate quantum technology investment to ensure full system value can be captured in UK.</p>
Components	<p><b>Optoelectronics component manufacture</b></p> <p><b>Next generation integration will combine optics and electronics into single chip based solutions for data centres, fibre to home, quantum computing and communication</b></p>	<p>Multiple world leading industrial and academic design centres in integrated photonics</p> <p>Significant wafer and chip level fabrication capacity especially in III-V semiconductors.</p> <p>Established export channels to network equipment suppliers globally</p>	<p>Support for collaborative R&amp;D in photonic integration (PICs) e.g. Integrated Silicon and/or III-V photonics.</p> <p>Development of foundry services to maximise use of fabrication assets</p> <p>Support commercial automated/high value packaging approaches compatible with UK manufacturing</p>
	<p>High reliability components &amp; systems for Satellite Aerospace and Undersea communications</p>	<p>UK has world leading capability in manufacture of high reliability components, including undersea optical fibre communications, space and aerospace (civil &amp; defence) communications.</p>	<p>Build capability to mission qualify components and systems (especially for aerospace &amp; space)</p> <p>Increase academic research into high reliability devices.</p>
	<p>Growth in use of valued added /Enabling Materials e.g. compound Semiconductors, Metamaterials</p>	<p>Major manufacturer and exporter of epitaxial wafers for global optoelectronic/ communications industry</p> <p>World leading research in metamaterials at multiple UK universities.</p>	<p>Promote routes for the exploitation and commercialisation of novel materials (e.g.metamaterials) that capture value in UK whilst fitting with complex global supply chains</p>

Priority areas offering highest opportunity for growth and impact in red

## 2- Industrial manufacturing with lasers

Focus of future UK growth		Supporting UK core strength	Action (s) required
Adoption	<p><u>Increased Use of laser based processing by UK industry</u></p> <p><b>Forecasts for significant increase in utilisation of laser processes in manufacturing (e.g. automotive 5-30%)</b></p>	<p>Catapult centre in High Value Manufacturing and EPSRC Centre for Innovative Manufacturing in Laser-based Production Processes</p> <p>Well established national trade association (AILU) for industrial laser users/developers</p> <p>Vibrant engineering subcontract sector, in laser cutting but also welding, marking etc</p>	<p>Raise awareness of laser process with UK manufacturing community via Manufacturing advisory services (MAS) etc</p> <p><i>New method for funding the adoption of laser processes that substantially increase efficiency of established manufacturers (loan guarantee?)</i></p>
	Laser based additive manufacturing	<p>UK suppliers of laser based additive processing equipment. Early adoption by UK aerospace, Funding for additive processing for aerospace at High Value Manufacturing catapult.</p>	<p><i>Support for additive processing developers to develop systems jointly with UK lasers manufacturer.</i></p>
Manufacturing efficiency	<p><b>Short pulse materials processing</b></p>	<p>Long established knowledge base in short pulse laser material interactions</p>	<p>Increased support for developing and characterising <u>industrial</u> processes using short pulses e.g. surface modification</p>
	<p>Surface processing /modification</p>	<p>Extensive metrology expertise</p>	<p>Integrated systems development</p>
	<p><b>Laser processing of carbon fibre composites</b></p>	<p>Vital for next generation of automotive and aerospace manufacturing</p>	<p><i>Identify key processing challenge with user groups.</i></p>
Lasers and laser components	<p><u>Ultra-short pulsed, high power high repetition rate lasers</u></p> <p>Efficient, industrial MIR laser systems (up to 1 kW) e.g fibre lasers</p> <p>Flexible lasers (e.g multi-colour, pulse / colour tuneable)</p>	<p>Large number of UK laser manufactures with strong export</p> <p>Significant UK capacity in laser components from coatings to specialist optical fibre to modulators</p> <p>Strong laser research in multiple institutions</p>	<p>Long term backing for Centres developing industrial lasers and laser industrial processes.</p> <p>Research into ps/fs &gt;1kW laser</p> <p>Support for new approaches to ultra high power industrial lasers</p> <p><i>Develop new volume processes for manufacturing laser systems themselves (laser industrial working group?)</i></p>
	<p>Coatings and components for high power / high intensity laser beam</p> <p>Fibre delivery for high power and/or ultra-short pulses</p> <p>Laser arrays, multiple fibre arrays</p>	<p>Globally leading suppliers of laser components</p> <p>Multiple specialist optical coating suppliers</p> <p>Specialist optical fibre fabrication capability in research and industry</p>	<p>Research into alternative approaches for beam combination and steering.</p>
Quality control & automation	<p>Precision measurement to increase manuf. efficiency</p> <p>Multimodal sensors combining sensing techniques &amp; multi/hyperspectral imaging.</p> <p>Combination of laser technology with online non-destructive testing</p>	<p>Strong UK machine vision capability integrating imaging chips into control and monitoring systems</p> <p>Photonics hardware development combines well with UK strength in embedded systems and automated image processing</p>	

### 3-Photonics for Health and Life sciences

	Focus of future UK growth	Supporting UK core strength	Action (s) required
Health	<p><b>User friendly mobile point-of-care equipment using light to <u>detect</u> and/or <u>monitor</u> disease / patient condition with, high sensitivity, accuracy, reliability and speed</b></p> <p>Improved, safer and personalised treatment (therapy and monitoring) and <b>highly targeted therapies</b> e.g target photo dynamic therapy Non-invasive people centric solutions</p>	<p>Depth of expertise in techniques</p> <p>Major academic and industrial strength in Raman and other spectroscopic techniques applied to diagnostics</p> <p>Strength of medical device design industry with numerous hand held point of care device designs</p>	<p>Involvement of NHS, bringing clinical, life science and/or medical physics and photonics communities together</p> <p>Lab on a chip not chip in a lab.</p> <p>Improved links to chemical sensing</p> <p>Better integration of the development of life science solutions with high value manufacturing (see HVM in healthcare roadmap, HealthKTN)</p>
	<p>Development of multiband photonic <u>imaging</u> methods to analyse age and life-style related diseases<sup>1</sup> allowing clinician/patient to make informed decisions. Must be either label-free or based on already safety- approved labels</p>	<p>Biological imaging research</p> <p>Major academic and industrial strength in optical coherence tomography and biological imaging research</p>	<p>Improved connectivity to design consultancies developing instruments for healthcare.</p>
Life Science	<p><b>Next generation of Biophotonic tools to understand the origin of diseases.</b></p> <p>Solution to efficiently developing and supplying photonics technology to the large number of subtly different (niche) life science applications, e.g. one light source for multiple instruments</p> <p>Photonics tools for online process control of drug manufacture</p> <p>Photonics instruments for quality control and counterfeit drug protection</p>	<p>Extensive track record with extensive exports in supplying bioinstrumentation</p> <p>Very strong pharmaceutical and biotechnology presence in the UK</p> <p>UK research groups have pioneering numerous photonics techniques extend understanding of biological systems.<sup>2</sup></p> <p>Extensive supply of lasers into life science instrumentation</p>	<p>Greater collaboration with big pharma research, therapy and manufacture, to match photonics capability with need e.g.</p> <ul style="list-style-type: none"> <li>• New process analytical techniques for improving drug manufacture</li> <li>• New techniques for rapid screening drug candidates</li> </ul>
Food	<p>lower-cost and faster methods to control water and food safety/ quality. E.g spectroscopic techniques.</p>	<p>Experience in hand held device development</p>	<p>Involvement of medical device manufacturers, pharmaceutical industry can clinicians</p>

<sup>1</sup> Age and life-style diseases refer to conditions that increase in prevalence with age or life style choices, e.g, diabetes, many cancers, coronary conditions, eye disease etc.

<sup>2</sup> Examples include Fluorescence Lifetime Imaging Microscopy (FLIM), confocal and multi-photon microscopy, Fluorescence Resonance Energy Transfer (FRET) and Stimulated Emission Depletion (STED) techniques

#### 4- Lighting including solid state LED lighting (also see analysis from PELG)

Future UK opportunity		Supporting UK core strength / justification	Action (s) required
LED and OLED's	III-V nitride materials and devices: Lower cost manufacturing processes and materials - substrates, epitaxy, devices Improved high power, high efficiency LED device structures	UK has a substantial cluster of academic institutes and companies specialising in III-N materials, fabrication, design & characterisation, including volume manufacturers. Growing market for quality GaN devices in high frequency power electronics and laser diodes.	Access to affordable finance required, to grow capital-intensive volume manufacture opportunity. Leverage strong UK defence industry applications for low defect, high-power devices. Increase awareness of LED properties, strengths and limitations within UK lighting industry.
	Test and Measure Instrumentation for: LED wafer and device manufacture luminaires and lighting systems Certification and standards enforcement	Existing UK base of instrumentation manufacturers and test and measurement services companies. Emerging standardisation for solid state lighting.	Representation on relevant standards bodies. Support for development of novel test and measurement equipment and services. Improved standards enforcement
	Enhanced Organic light-emitting materials with better efficiency, colour, stability, reproducibility, Materials and manufacturing processes that enable area OLEDs to be price-competitively	UK and EU has invested substantially in OLED materials and manufacture processes. Globally recognised strength in architectural creativity utilising novel technologies.	Identify and support leading core research particularly in materials chemistry and hybrid systems. Close monitoring of potential OLED lighting market Support from UKTI, BIS, SDI, etc to promote UK IP to overseas stakeholders in existing markets.
Light fixtures	<b>Innovative designs of LED luminaires based on replaceable fixtures - not 'replacement bulb'</b> Thermal management of packaged LEDs in luminaires Materials for effective and efficient light extraction and control from luminaires	UK lighting industry includes several large, multi-national companies and 1000 SMEs. UK has a global reputation for lighting design which should be leveraged by luminaire and lighting systems manufacturers.	Grow market by raising awareness of the benefits of SSL. Support and facilitate cross-supply chain engagement. Support education and training in engineering and manufacturing skills Seed fund technical problem solving activities in SME sector. Encourage collaboration with academic research institutes.
Systems and control	Intelligent control of lighting systems including self-learning and integration with other building control systems Integration with PV and other renewable energy sources & DC networks Integration with other city networks and systems <b>Human Centric Lighting: health benefits of controlling the lit environment</b>	Strong UK base of companies and research in photonic sensors electronic drivers and UK has a global reputation in structural engineering, architecture and commercial building design and construction.	Higher up-front costs will require access to investment capital. closer involvement of several industries across the value chain, e.g. architecture, construction, building management, power generation. Leverage state-owned infrastructure (government buildings, NHS, schools, etc), validation and drive market uptake. Increase understanding of human response to LED lighting
Visible light comms	Fast-switching LEDs, sensors, components, systems and systems integration	UK photonics research in VLC (Li-Fi) components and systems is currently world-leading. SME spin-outs commercialising into early adopters.	Develop roadmap for this emerging market and identify priority applications and stakeholders Support from UKTI, BIS, SDI, etc to engage global stakeholders

## 7- Research and Education

	Focus of future UK growth	Supporting UK core strength	Action (s) required
<b>Science and Research</b>	<p>The UK has a world class science and research base in at least three disruptive research fields that offer step change improvements in a range of applications:</p> <ul style="list-style-type: none"> <li>- Nanophotonics (sensing, imaging, energy generation)</li> <li>- Quantum optics and quantum information (computing, secure communications, imaging)</li> <li>- Extreme light (sensing, imaging, material characterisation and processing, advanced manufacturing)</li> </ul>	<p>EPSRC has made large scale investments in photonics including the three disruptive research themes<sup>i</sup></p> <p>UK investment of £270m in quantum technologies.</p> <p>Multiple UK companies have active interest/investment in disruptive research topics<sup>ii</sup>.</p> <p>Often requires skilled intermediary (Catapult, Fraunhofer,</p>	<p>Significant opportunities within Europe for funding collaborative projects:</p> <ul style="list-style-type: none"> <li>• Better co-ordination of UK engagement with Photonics21 &amp; EU Commission</li> <li>• Continue to <b>Generate awareness of research opportunities and mechanisms to academia, National Laboratories, large scale industrial players and SMEs.</b></li> <li>• <b>UK Symposia/ roadshows in collab with IOP/IET in target research areas to focus UK communities and help UK industry identify the opportunities.</b></li> <li>• UK engagement with EU Extreme Light Infrastructure development (ELI)</li> </ul> <p>Increase UK industry investment in translation of low TRL research into products</p> <p>Increase number of small companies willing to commercialise research, e.g removing barriers to start-up and increase access to risk capital.</p> <p>New collaboration models and better use existing models for SMEs to engage with academia (CIMs, CDTs, Fraunhofer, innovation vouchers etc)</p> <p>Increase flexibility in commercialisation/license arrangements from Universities, particularly toward the needs of SME's ('Kite mark' for the best?)</p>
<b>Education and training</b>	<p>Significant and growing demand for photonics skills at all levels from management to assembly to R&amp;D.</p> <p>Significant demand for photonics familiarisation training for none technical staff, e.g. operations, legal manufacturing, More integrated approach linking training provision to market/industry demand for skills e.g vocational training in hi-tech 'clean' manufacturing.</p>	<p>Large number of UK universities offering undergraduate and postgraduate courses in photonics.</p> <p>Centres for Doctoral Training incorporating photonics</p>	<p>Increase awareness of the role photonics plays in our lives to ensure that the brightest individuals chose photonics as a rewarding career.</p> <ul style="list-style-type: none"> <li>• Accessible stories into press (via PLG/ESPKN etc)</li> <li>• Outreach to undergraduates and schools highlighting career opportunities in photonics in collaboration with IET/IOP/IEEE/OSA, ILU &amp; STFC</li> <li>• <b>UK industry to provide examples of career opportunities /role models</b></li> </ul> <p>Develop a UK industrial perspective on training needs</p> <p>Increase the photonics content in non-photonics specific courses</p> <p>Ease restrictions on employing none EU nationals with specialist Engineering skills and/or increase number of UK/EU Engineering graduates.</p>
<b>Infrastructure and facilities</b>	<p>Increase access for companies to University and publically funded facilities</p> <p>Further increased open access to large scale facilities hosted in the UK and Europe.</p>	<p>A number of large scale facilities are hosted and or operated from the UK and scheduled for further development e.g. Diamond light source, km square array</p>	<p>Increase awareness within vertical application markets of opportunities for working with large photonic facilities.</p> <p><b>Develop a UK "map" of photonics facilities and expertise extending recently launched National Photonics portal <a href="http://ukphotonics.org">ukphotonics.org</a></b></p> <p>Reach into specialist Engineering firms, consultancies and catapults so they know where to source for photonics knowledge / facilities</p> <p>Fully leverage large scale European facilities e.g Silicon foundries</p>

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<sup>i</sup> Examples of large scale grants in these areas include:

- Centre for Nanostructured Photonic Metamaterials (Southampton)
- Active Plasmonics: Electronic and All-optical Control of Photonic Signals on Sub-wavelength Scales (King's College)
- Graphene Flexible Electronics and Optoelectronics (Cambridge, QMUL, UCL)
- Soft NanoPhotonics (Cambridge)
- Building Large Quantum States of Light (Oxford, Southampton)
- Challenging the Limits of Photonic structured light (St. Andrews, York)
- Semiconductor integrated quantum optical circuits (Sheffield, Heriot-Watt, UCL)
- Centre for Innovative Manufacturing in Photonics (Southampton)
- Centre for Innovative Manufacturing in Laser-based production processes (Heriot-Watt)
- EPSRC support of 14 Manufacturing with light grants (£3.6m)

<sup>ii</sup> Just a few examples include

**Nanophotonics:** De La Rue, Renishaw Diagnostics, Kodak, NPL, Du Pont-Teijin Films, BAE, Qinetiq etc

**Quantum optics/information processing:** Hitachi Cambridge Laboratory, Toshiba, NPL, Gooch and Housego etc.

**Extreme Light:** Rutherford Appleton Laboratory, AWE, Rofin-Sinar UK, SPI Lasers, Coherent Scotland, M-squared, Gooch and Housego etc

## 5 &^ Sensing security and components

these topics would be more appropriate sensing and /or components section

	Focus of future UK growth	Supporting UK core strength	Action (s) required
Large scale component	Capability for processing optics >1m diameter vital for the UK for applications in fusion and satellite communications. Large format imaging systems for satellite's, science and space	Establish commercial expertise satellite imagery hardware Substantial track record in supplying large scale scientific projects, e.g. telescopes.	