

The Optoelectronics Research Centre

Leading the Next Photonics Revolution

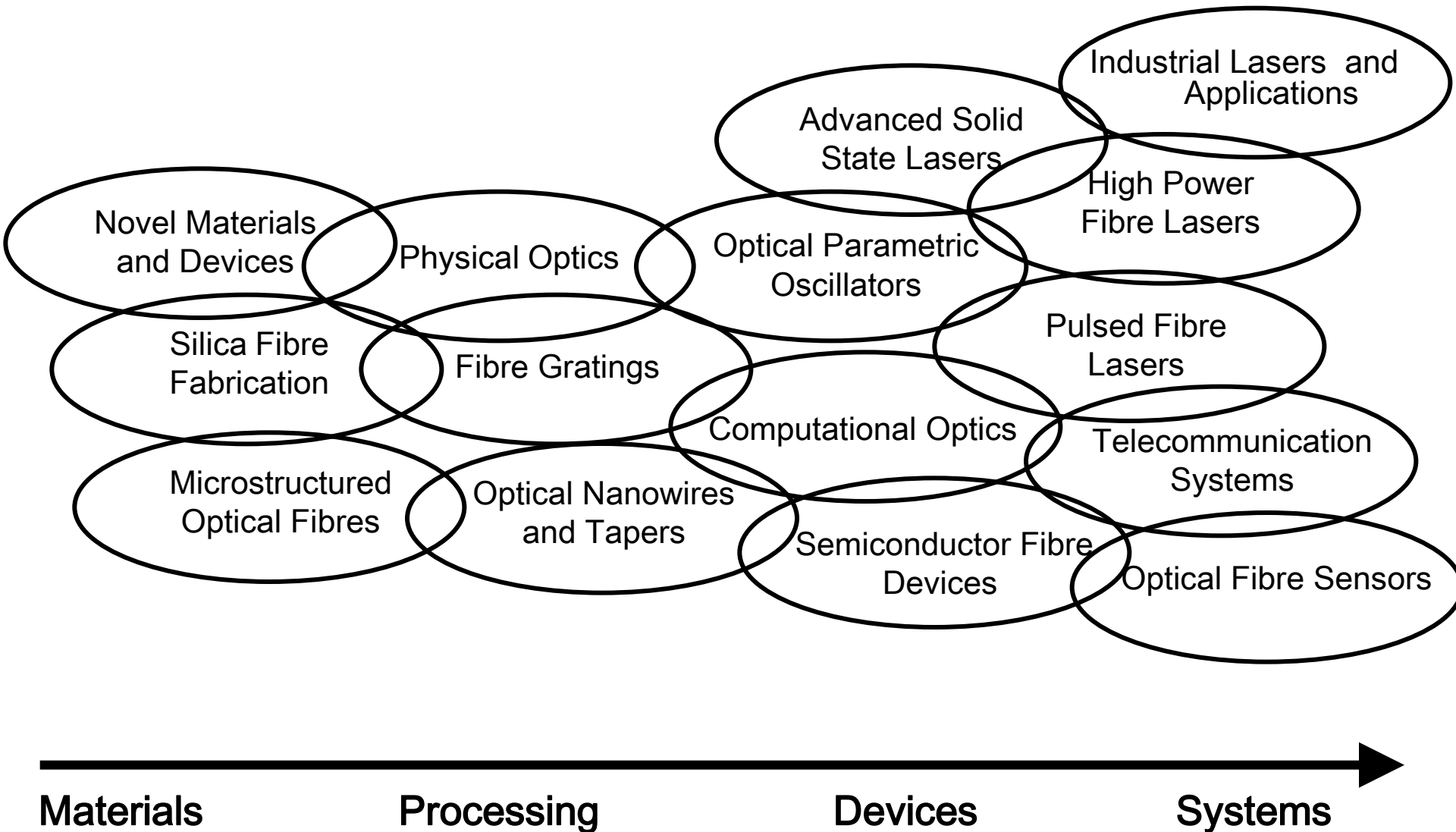


Who are we?



- Largest Institute of its kind in UK
- 50 year history at the forefront of photonics
- >200 staff
- £56M of secured research funding
- ~100 laboratories
- £120M clean room asset
- 300 Publications/15 Patents per year (50 Invited/Plenary)
- Generates a large proportion of University IP
- A cluster of 10 spin-out companies

Vertical Integration: Our Secret to Success



The Zepler Institute

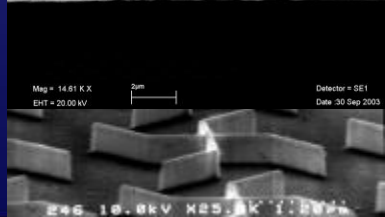
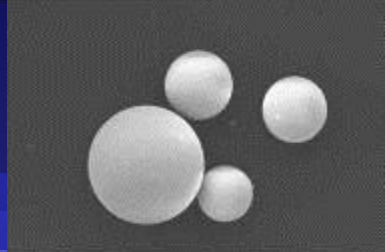
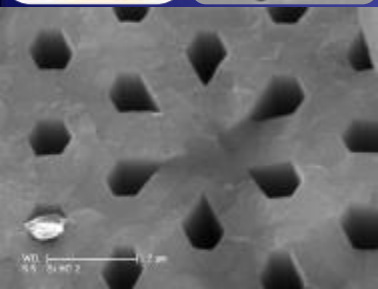
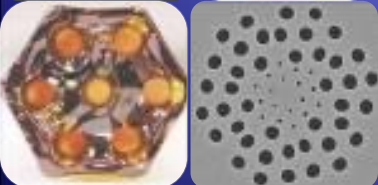
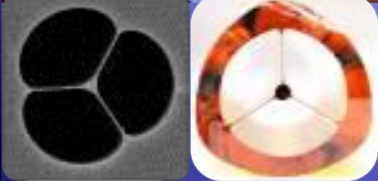
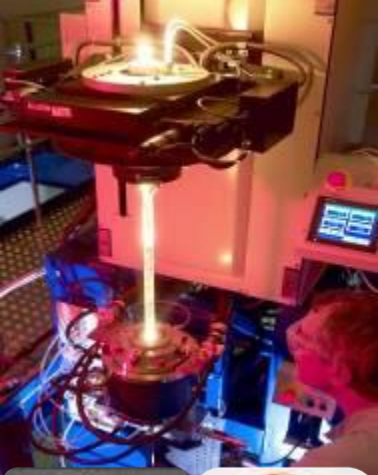
- **£120 million research investment**
 - 944m² Class 100-1K Cleanrooms
 - 564m² Class 1000 Cleanrooms
 - 4 fiber draw towers/3 lathes
 - New PECVD/FHD/PLD systems
- **New activities/facilities:**
 - Silicon photonics
 - Metamaterials
 - Nanophotonics
 - Biophotonics
- **Fully functional from 2010**
- **Closer integration and a resource for photonics/electronics/materials research across the University**



The Mountbatten Clean Rooms:

a world-leading flexible facility for materials, processes and devices

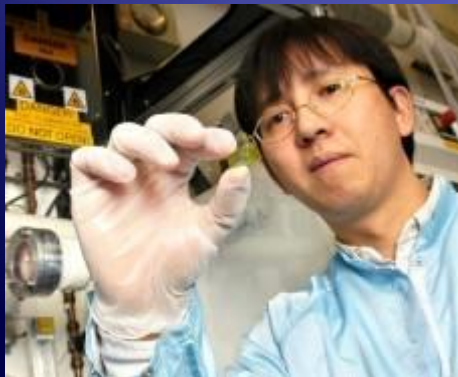
- Silica Fibre Fabrication
- Compound glass fibre fabrication
- Microstructured fibres
- Photonic planar waveguide fabrication
- Electron-beam lithography with 10nm resolution, JeolJBX 9300
- Photolithography
- Robotic aligner, EVG 620TBR
- 2 x FIB/SEM, Zeiss & FEI Nanolab
- Helium Ion Microscope
- Dry-etch and reactive ion etching
- FEGSEM Jeol JSM 7500F
- Epitaxial systems for SiGeC growth, Ge quantum dot growth
- Polycrystalline and amorphous SiGeC deposition
- Atomic layer deposition system
- Deep silicon etcher
- Ion-beam deposition
- Sputtering, e-beam and thermal evaporation
- Diffusion to 2300K
- Nanoimprint tools
- CVD carbon nanotube growth
- PECVD Nanofab for Si and Ge nanowire growth
- Oxide and nitride deposition
- Rapid thermal annealer, furnaces, wet chemistry facilities
- AFM, metrology equipment for layer thickness measurements
- DC and RF on-wafer device characterisation
- Chalcogenide materials deposition
- Microscopy, profilometry, & SEM



The ORC Photonics Cluster



- ◆ SPI Lasers
- ◆ Fibercore
- ◆ Sensoptics
- ◆ Fianium
- ◆ Photon Kinetics
- ◆ Pointsource
- ◆ Sensa
- ◆ Stratophase
- ◆ Covesion
- ◆ ChG

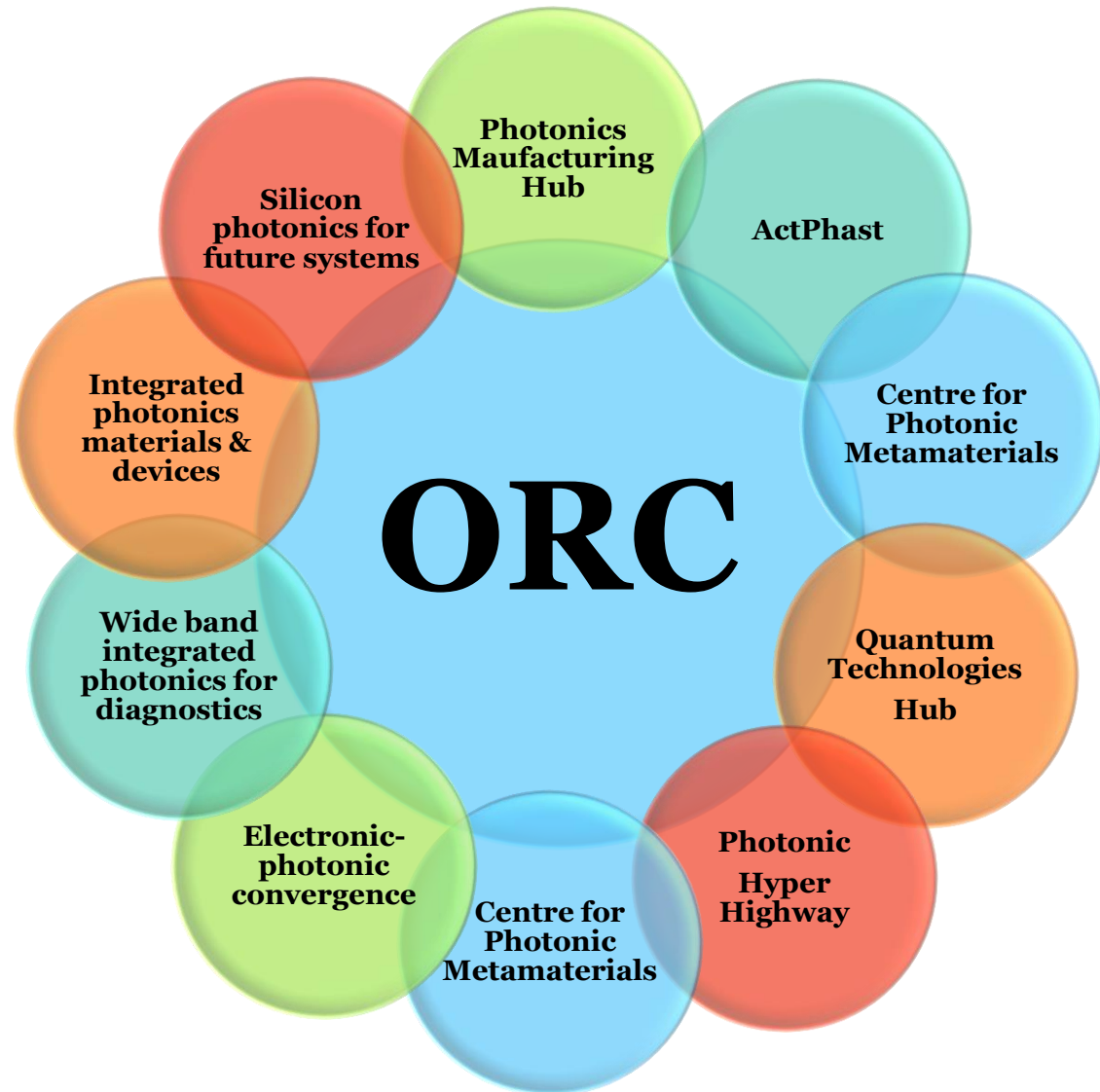


What makes us get out of bed in the morning?

- ◆ There are more fibre drawing plants in Southampton than in any city worldwide
- ◆ Fibres invented and made in Southampton are on the Moon And Mars
- ◆ Our ideas navigate airliners, cut steel, mark iPads, manufacture life-saving medical devices and power the global internet
- ◆ Over 700 of our alumni are in key positions all over the world – some of the millionaires
- ◆ More than 500 people in the Southampton area owe their jobs to the ORC

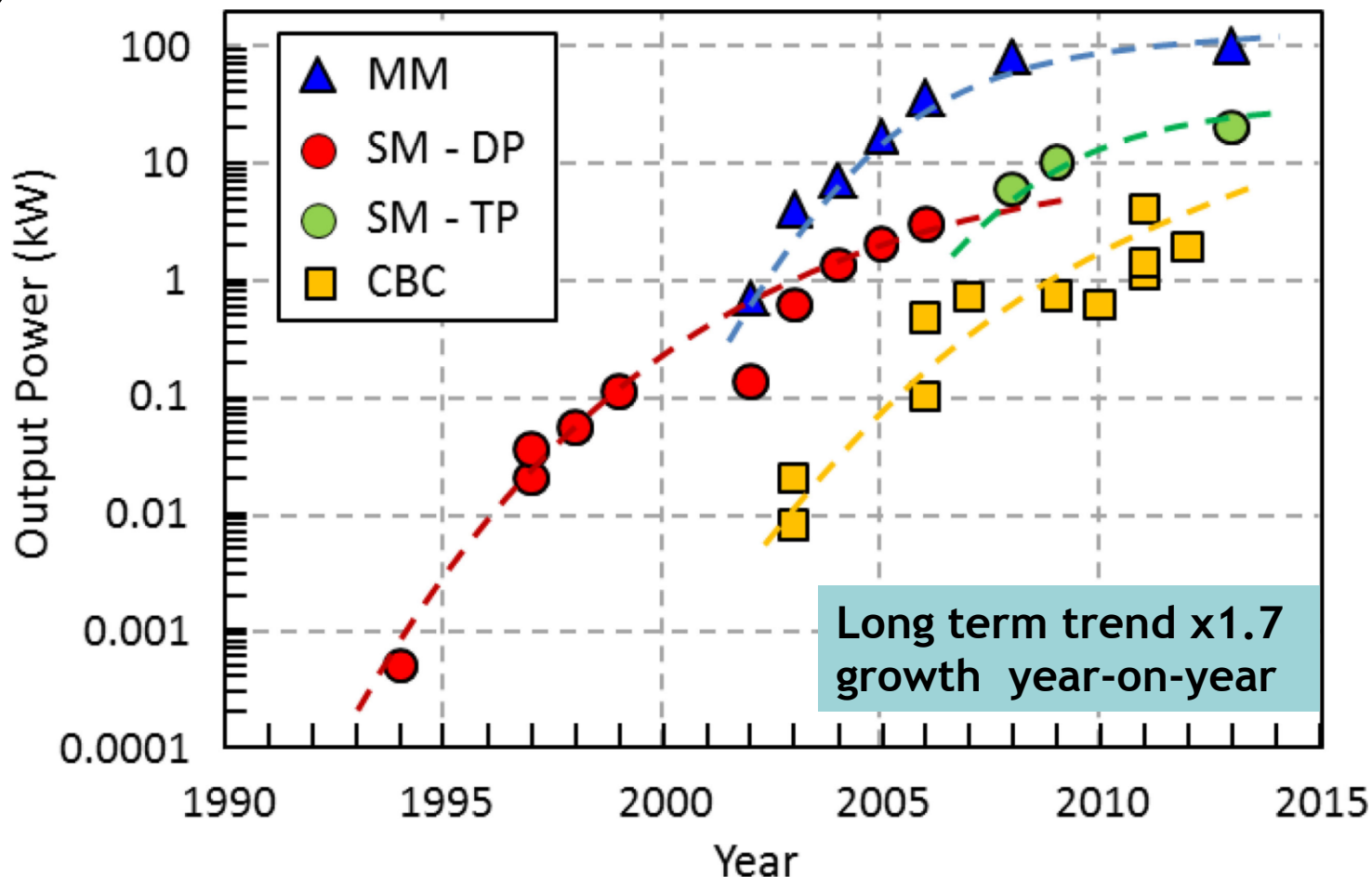
The ORC: Strength and Depth

- **Most comprehensive portfolio of platform, program & EU grants in UK**
 - Long term strategic research
 - Supported with suite of EPSRC research grants
- **Each one is major multi-year research program**
 - Many opportunities for industry to engage





Power Scaling in Yb Fibers



Same picture of growth for all wavelengths and modes of operation

D.J. Richardson, J. Nilsson and W.A. Clarkson *JOSA B*, 27(11), B63-92 (2010)

M.N. Zervas and C. Codemard, *IEEE JSTQE*, 20(5), 0904123 (2014)

ORC high-power laser activities & interests

- Rare-earth doped fiber lasers
 - Yb, Tm, Er, Ho, (Nd and Bi)
- Raman lasers
- Planar lasers
- “Bulk” lasers
- OPOs
- Delivery fibers
- Radiation-hardened fibers

- *Industrial*
- *Aerospace, defense, security*
- *Pump sources*
- *Biomedical*
- *Scientific*
- *Telecom*
- *Beam combination*
- *And more!*

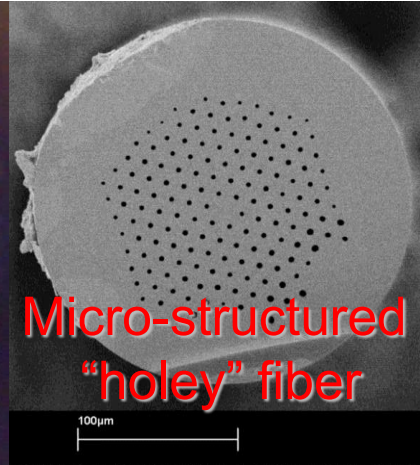
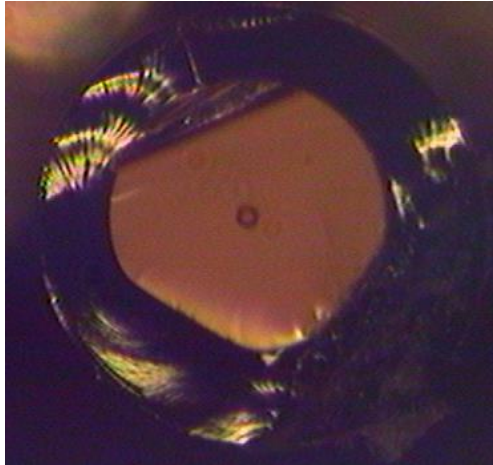
- *High powers (multi-kW)*
- *New wavelengths & wavelength conversion*
 - EUV – UV – visible – NIR – **MIR** – THz
- *Ultra-short pulses*
- *Pulse energy up towards 100 mJ*
- *Narrow linewidths*
- *Spatial beam control*

- Materials synthesis & purification
- Fabrication
 - Fibers, planar, gratings...
- Device research
- **Applications research**

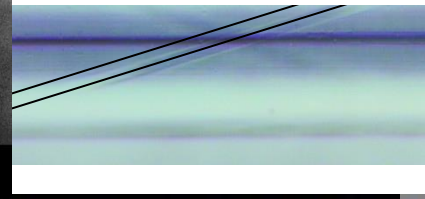
All fibers made in Southampton

Large core / large mode area

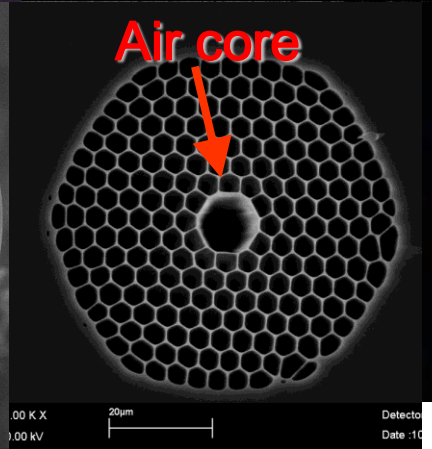
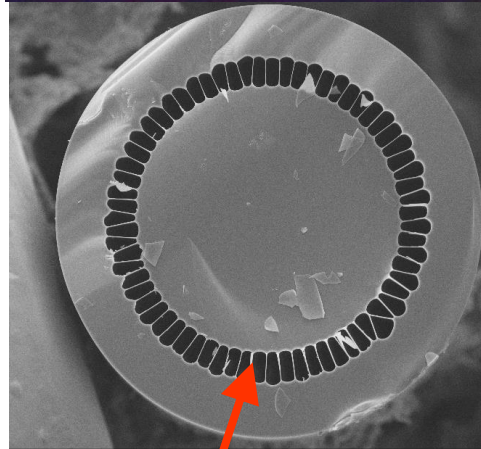
Multi-core ribbon - *Scalable!!*



Micro-structured
"holey" fiber



Helical core fiber
Circular birefringence
Filtering



Air clad
High pump-NA

Photonic bandgap
Delivery, pulse compression,
gas-filled devices

Birefringent
(stress)

Multi-core

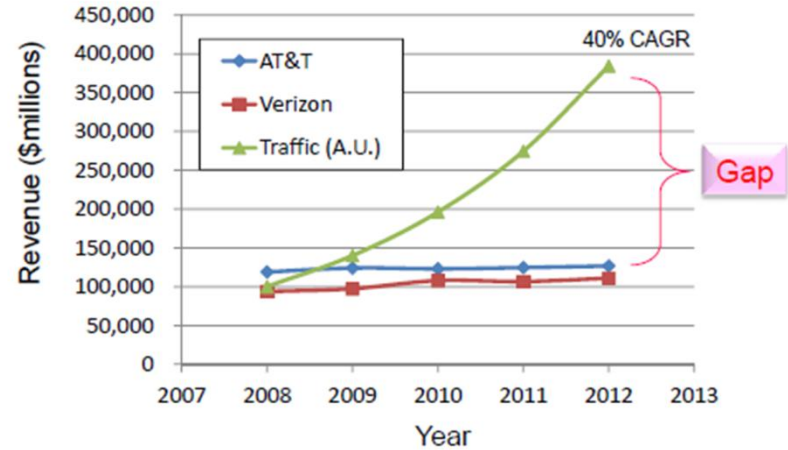
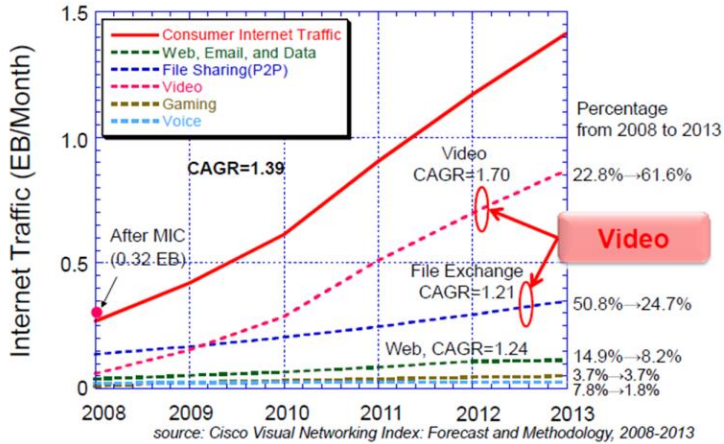
Aerospace, defense, security

- Directed energy
 - Beam combination
 - Lidar
 - Counter-measures
 - Sensors
 - Bio, remote, ...
 - Border control
 - Jet engine monitoring
 - Etc.
- DERA / DSTL / MOD
 - ARL
 - NRL
 - AFRL / AFOSR / EOARD
 - JTO
 - DARPA
 - EU
 - EPSRC
 - Other government agencies
 - Companies



Telecom Challenges

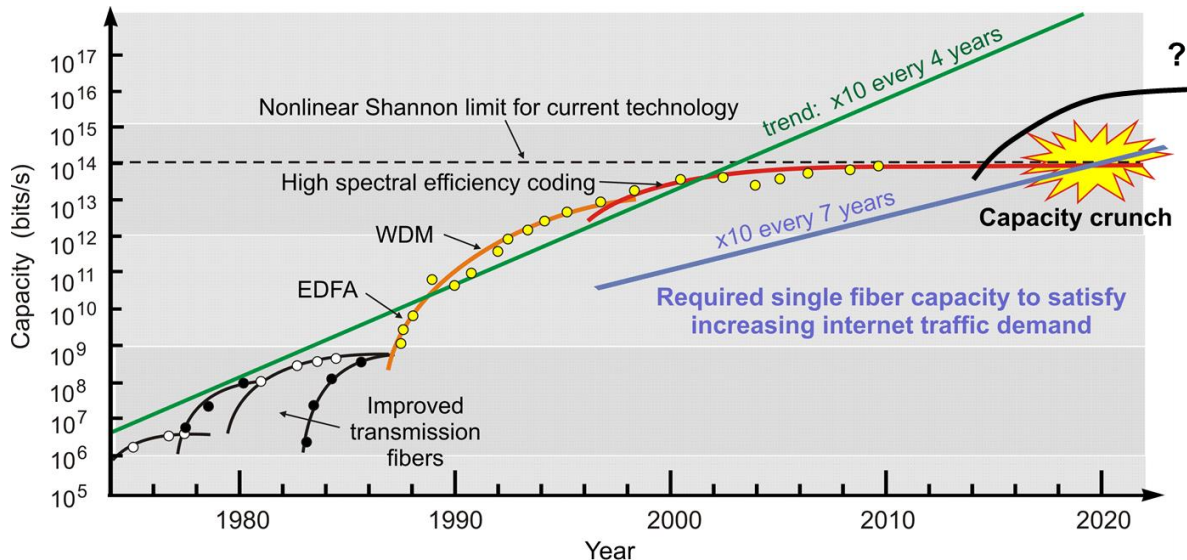
Traffic Growth Projected by CISCO



Source: Fortune 500

Unrelenting demands for increasing internet data traffic (40-50% p.a.)

Increasing costs but flat revenue



Saturation in single-mode fibre transmission capacity looming



Programs and Collaborators



Nokia Siemens Networks



COMIMO



NTT

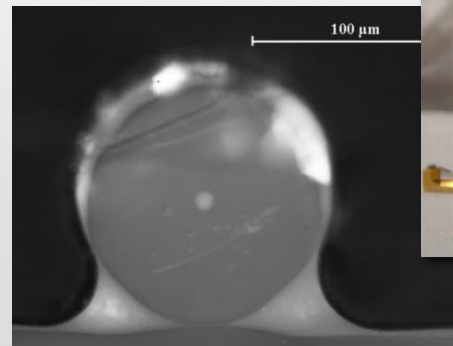
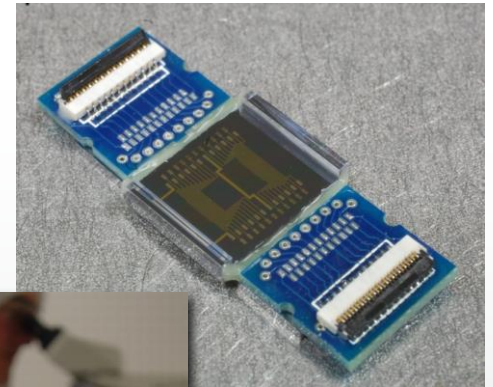


Quantum Technologies Capabilities

Over a decade experience in developing photonic system for quantum science and subsequently quantum technology (QT).

\$6m QT projects and \$3m suite of QT equipment in the ORC to develop 3 principal technologies

- Low loss planar optical devices (silica)
 - Single photon manipulation
- Non-linear wavelength conversion
 - Light matter interaction
- Optical fibre integration
 - Ultra-low loss devices



Quantum Technologies Activities

Heavily involved in the UK's Quantum Technology landscape (part of £270m UK investment):

Key fabricator for photonics in QT

Key involvements,

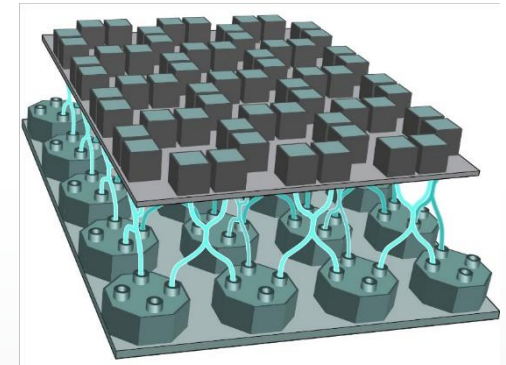
- University of Oxford led QT hub

Developing the optical interconnects and the quantum entanglement system for quantum computing.

- University of Birmingham led QT hub

Integrated optics for miniaturised atom traps

Developing new partnerships and technologies for wavelength conversion with Birmingham, E2V and Covision



Nanostructured Functional Photonic Materials and Metamaterials I

Leading UK/EU group: 3 EPSRC mega-grants >£16M (2004-2021); Overseas partners for 2 US MURI programmes

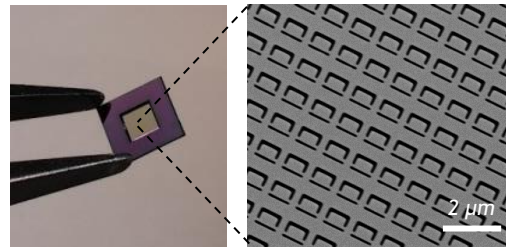
- Control of light/matter interactions on the nanoscale
- Media with properties & dynamic functionalities engineered via sub-wavelength structuring

Nature Mater. 11, 917 (2012)

New materials for metamaterials

- Flexible nano-membranes (Si_3N_4 , Si, shape-memory alloy, ...) for reconfigurable metasurfaces

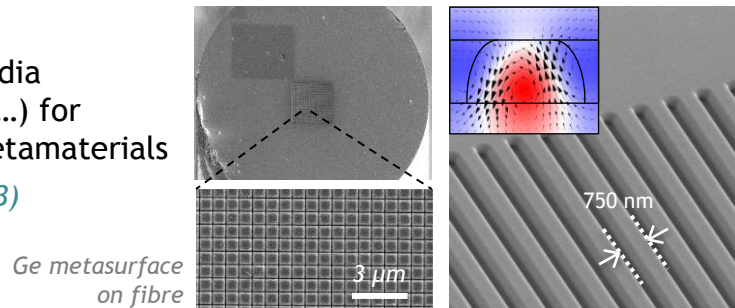
Nature Nanotech. 11, 16 (2016)



Free-standing Si metasurface

- High-index, low-loss media (Si, Ge, chalcogenides, ...) for VIS-NIR all-dielectric metamaterials

Opt. Express 21, 26714 (2013)



Ge metasurface on fibre

- Phase-change media (chalcogenides, shape-memory) for non-volatile electro/all-optical switching

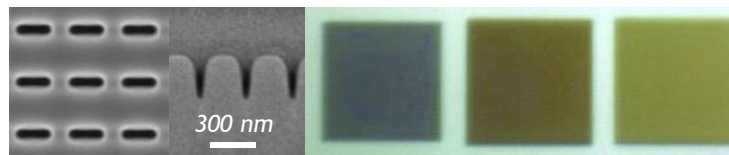
Adv. Mater. 25, 3050 (2013)

arXiv:1604.01330 (2016)

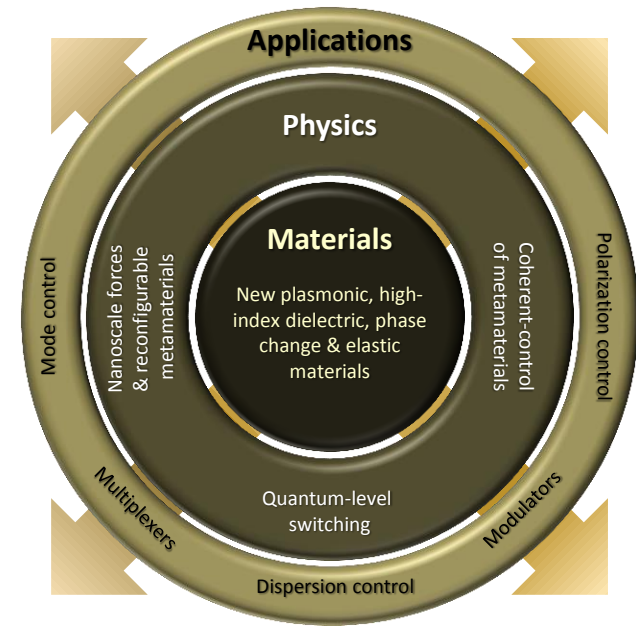
Ge:Sb:Te switchable metasurface filter

- Topological insulators for CMOS-compatible UV-VIS plasmonics

Nature Commun. 5, 5139 (2014)



Bi:Sb:Te:Se (BSTS) plasmonic resonances at VIS frequencies



Nanostructured Functional Photonic Materials and Metamaterials II

Reconfigurable nanostructures: optical properties 'on demand'

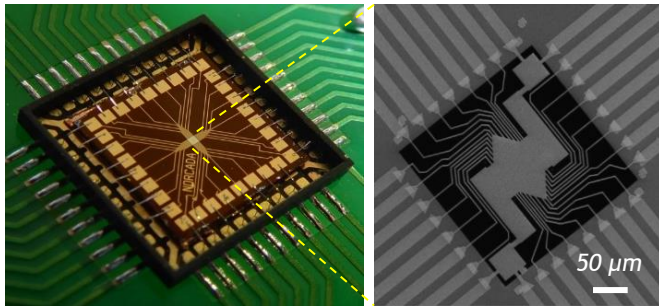
- Nano-mechanical systems driven by current/voltage, magnetic field & light
 - Ultrafast, low-energy, tuning and switching
 - Extreme nonlinearities up to sub-GHz frequencies
- Re-writable flat optical elements and metasurfaces

Science 348, 973 (2015)

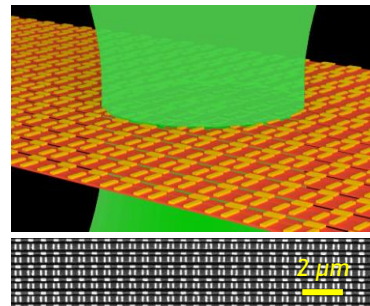
Adv. Mater. 28, 729 (2016)

APL 107, 191110 (2015)

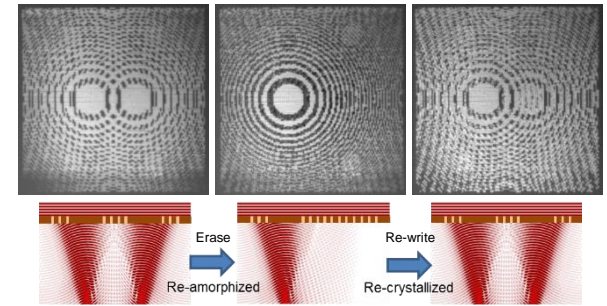
Nature Photon. 10, 60 (2016)



'Random access' addressable metamaterials



Optomechanically nonlinear metasurfaces



fs-pulsed laser (re)writable greyscale GST optics

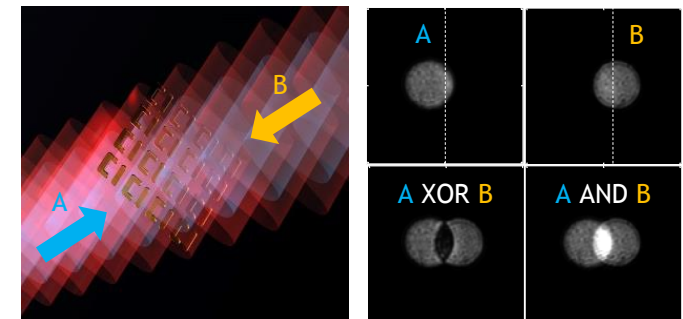
New paradigms for controlling light

- Light-by-light modulation at THz frequencies and arbitrarily low power
- Coherent optical data & image processing
- Electric/magnetic excitation-selective spectroscopy
- Active wavefront, dispersion, polarization control

Light Sci. Appl. 4, e292 (2015)

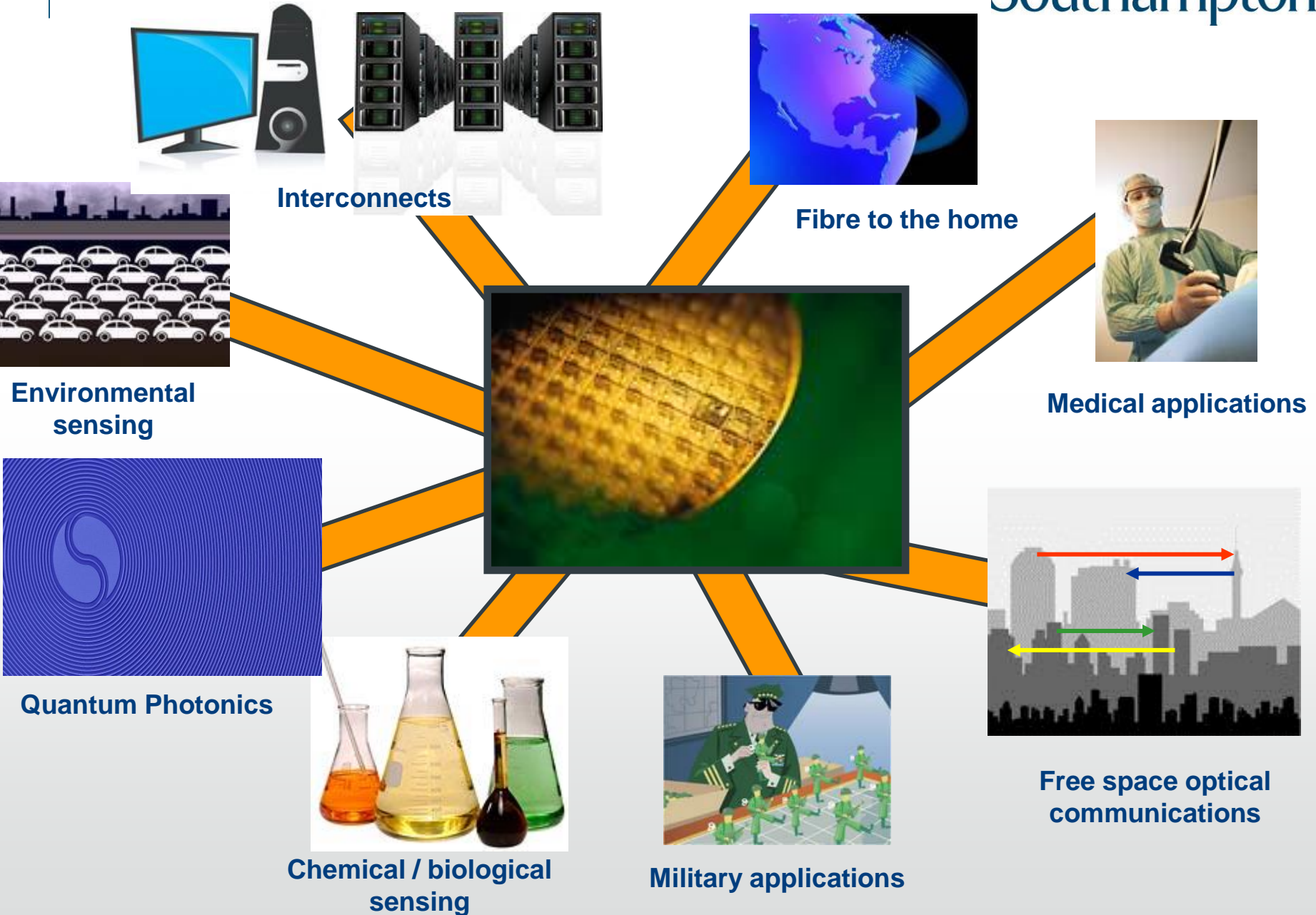
Nat. Commun. 6, 7031 (2015)

Light Sci. Appl. 5, e16070 (2016)



2D coherent optical logic on planar metasurfaces

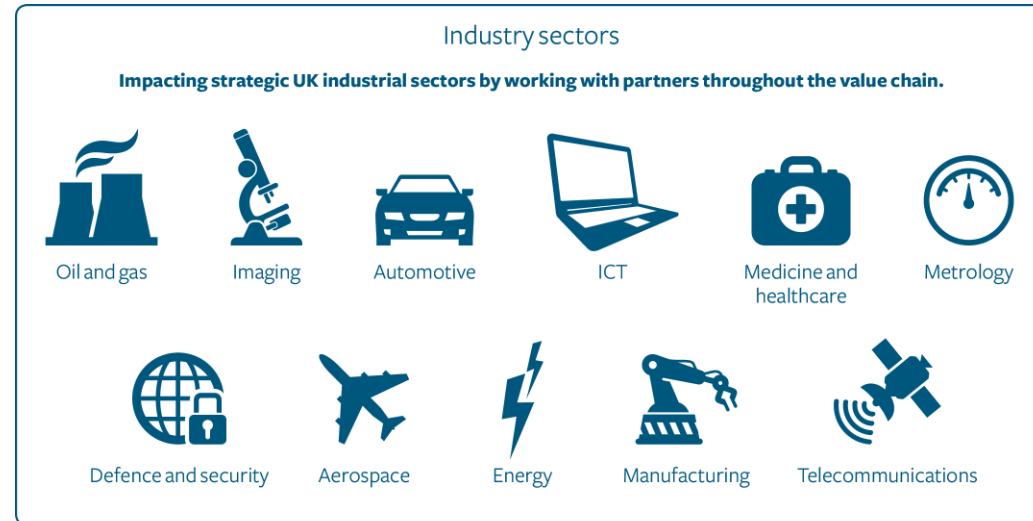
Silicon Photonics: Applications



- **Top level challenge-**
INTEGRATION

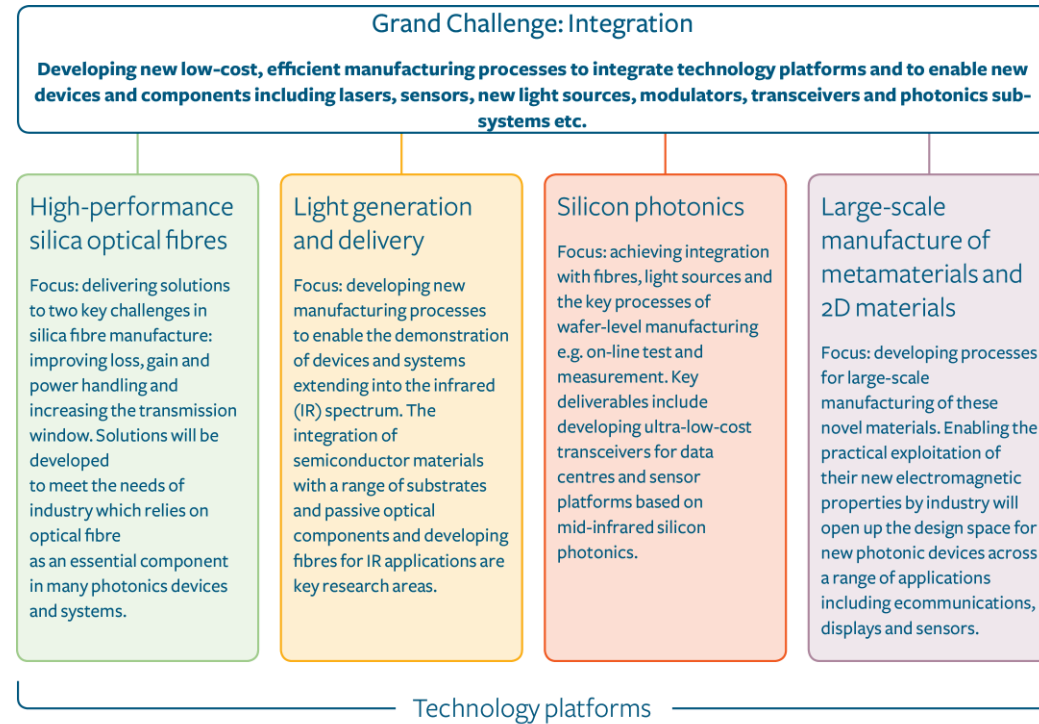
“Develop novel transformational manufacturing technologiesthat enable greater integration... of photonics”

- Underpinning industry impact
- Agnostic of technology
- Applicable to all end markets



A future manufacturing research hub

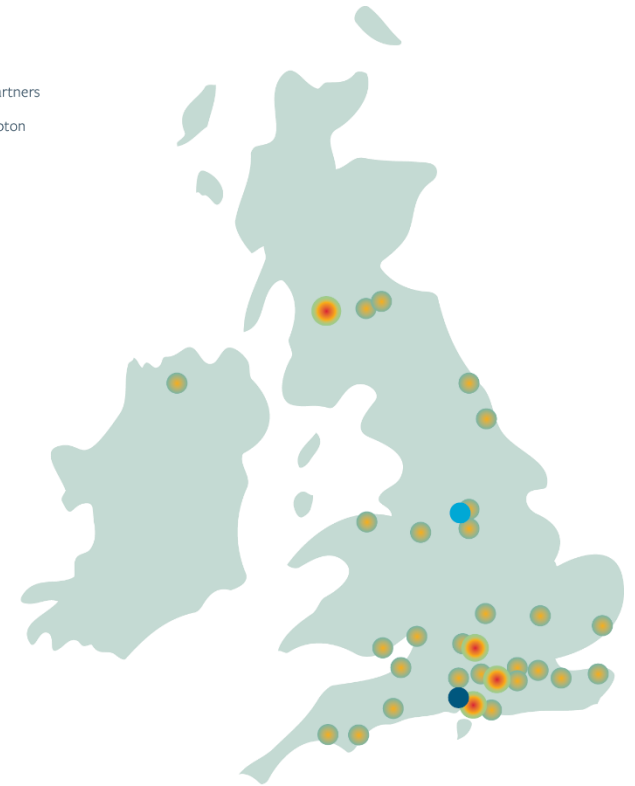
- **Four technical foci**
 - Demanded by industry
 - Matching competence
 - High UK Exploitation potential
- Detailed definitions & deliverables
 - Mix high risk adventure/ lower risk
- Company projects drive & steer platforms



A future manufacturing research hub

- Supporting grand challenge
- Platform interest
- Detail specific projects
- Geographic diversity
 - New and established partners

- UK industry partners
- Multiple UK industry partners
- University of Southampton
- University of Sheffield



A future manufacturing research hub