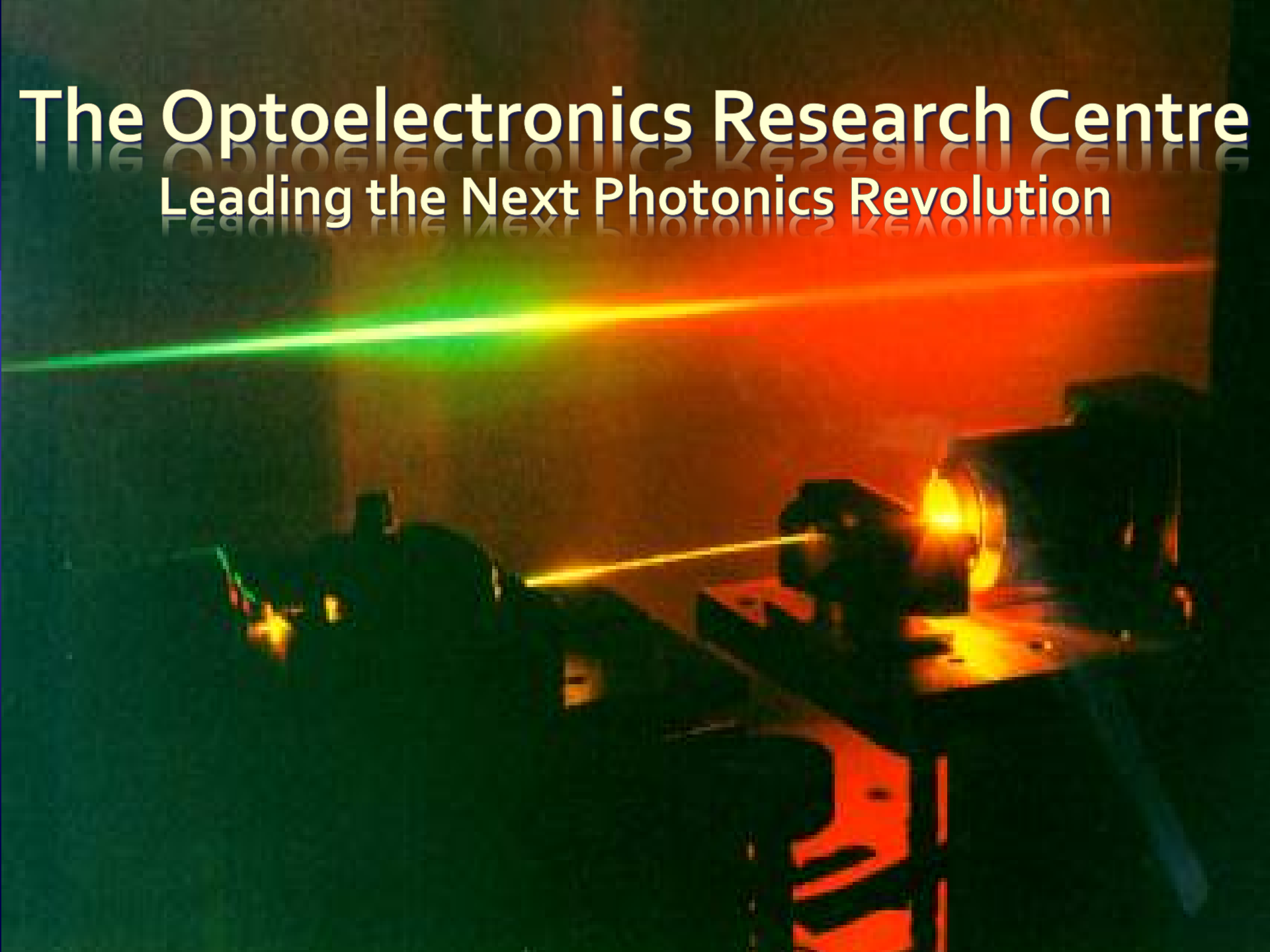
The Optoelectronics Research Centre

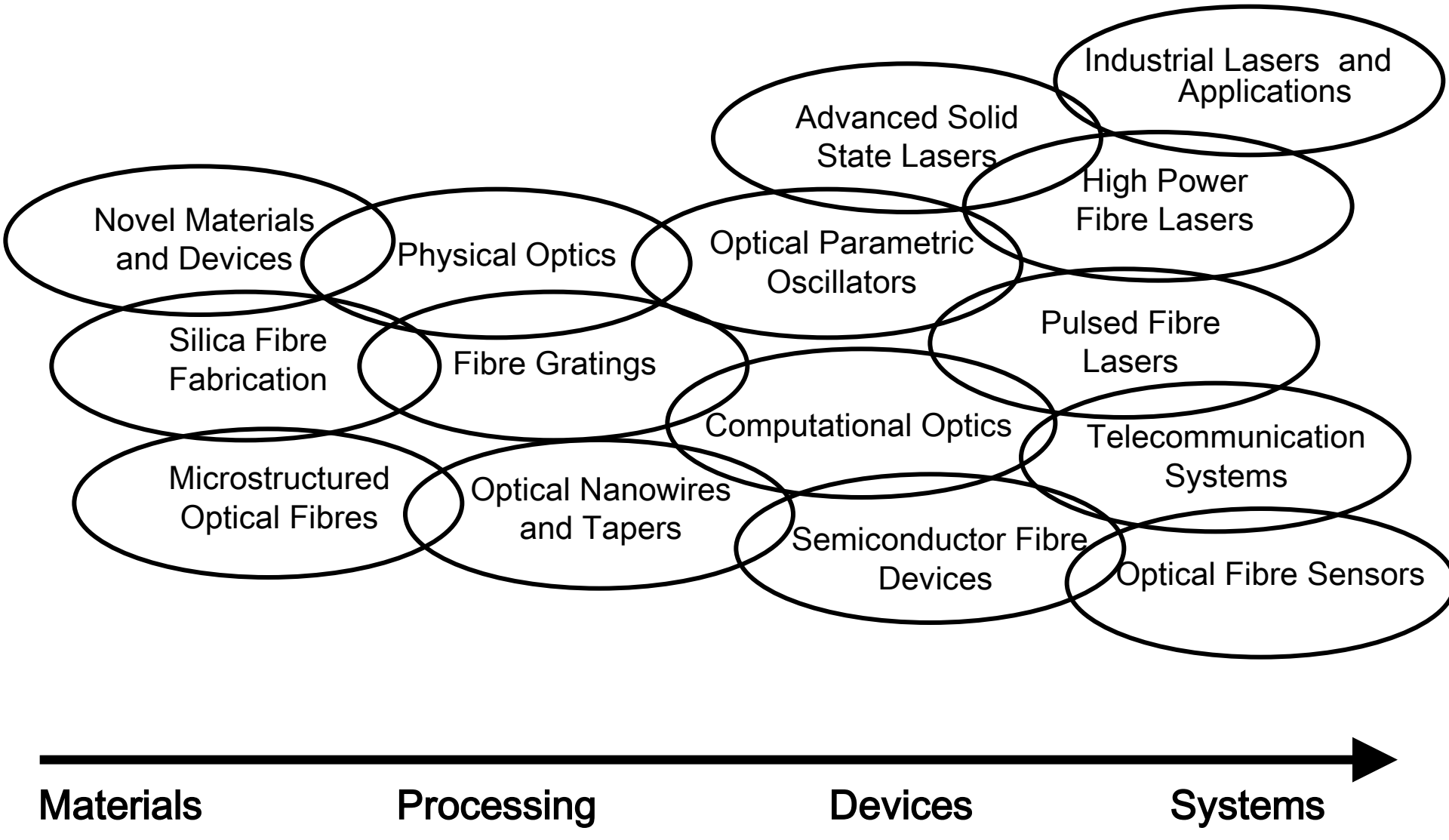
Leading the Next Photonics Revolution



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

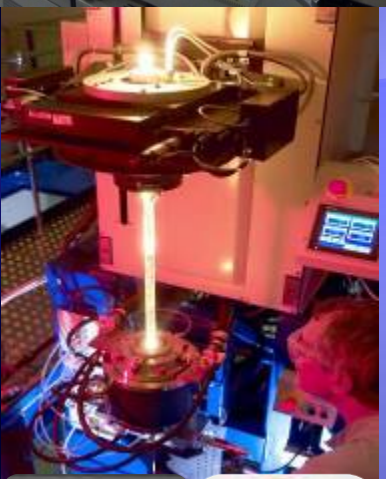


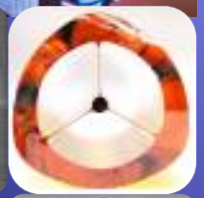
The Zepler Institute

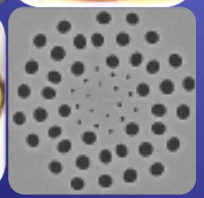
- **£120 million research investment**
  - 944m^2 Class 100-1K Cleanrooms
  - 564m^2 Class 1000 Cleanrooms
  - 4 fiber draw towers/3 lathes
  - New PECVD/FHD/PLD systems
- **New activities/facilities:**
  - Silicon photonics
  - Metamaterials
  - Nanophotonics
  - Biophotonics
- **Fully functional from 2010**
- **Closer integration and a resource for photonics/electronics/materials research across the University**

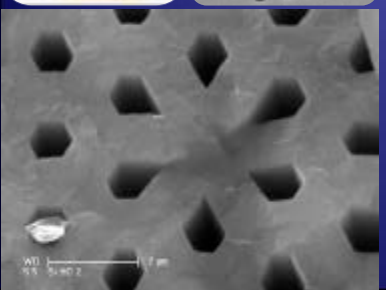
The Mountbatten Clean Rooms:

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

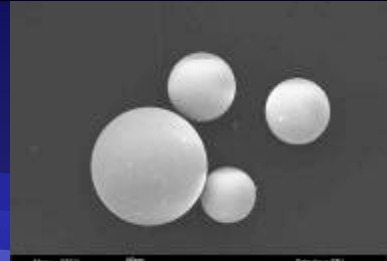


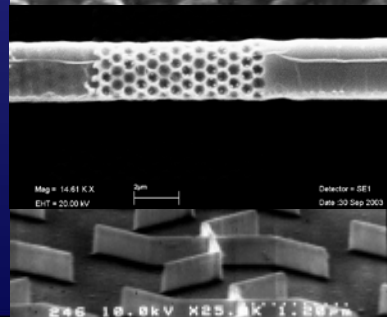






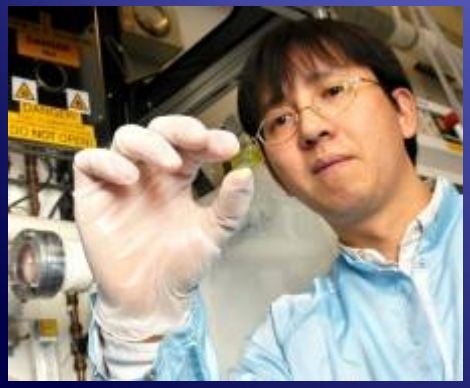
- Silica Fibre Fabrication
- Compound glass fibre fabrication
- Microstructured fibres
- Photonic planar waveguide fabrication
- Electron-beam lithography with 10nm resolution, JeolJBX 9300
- Photolithography
- Robotic aligner, EVG 620TBR
- 2 x FIB/SEM, Zeiss & FEI Nanolab
- Helium Ion Microscope
- Dry-etch 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



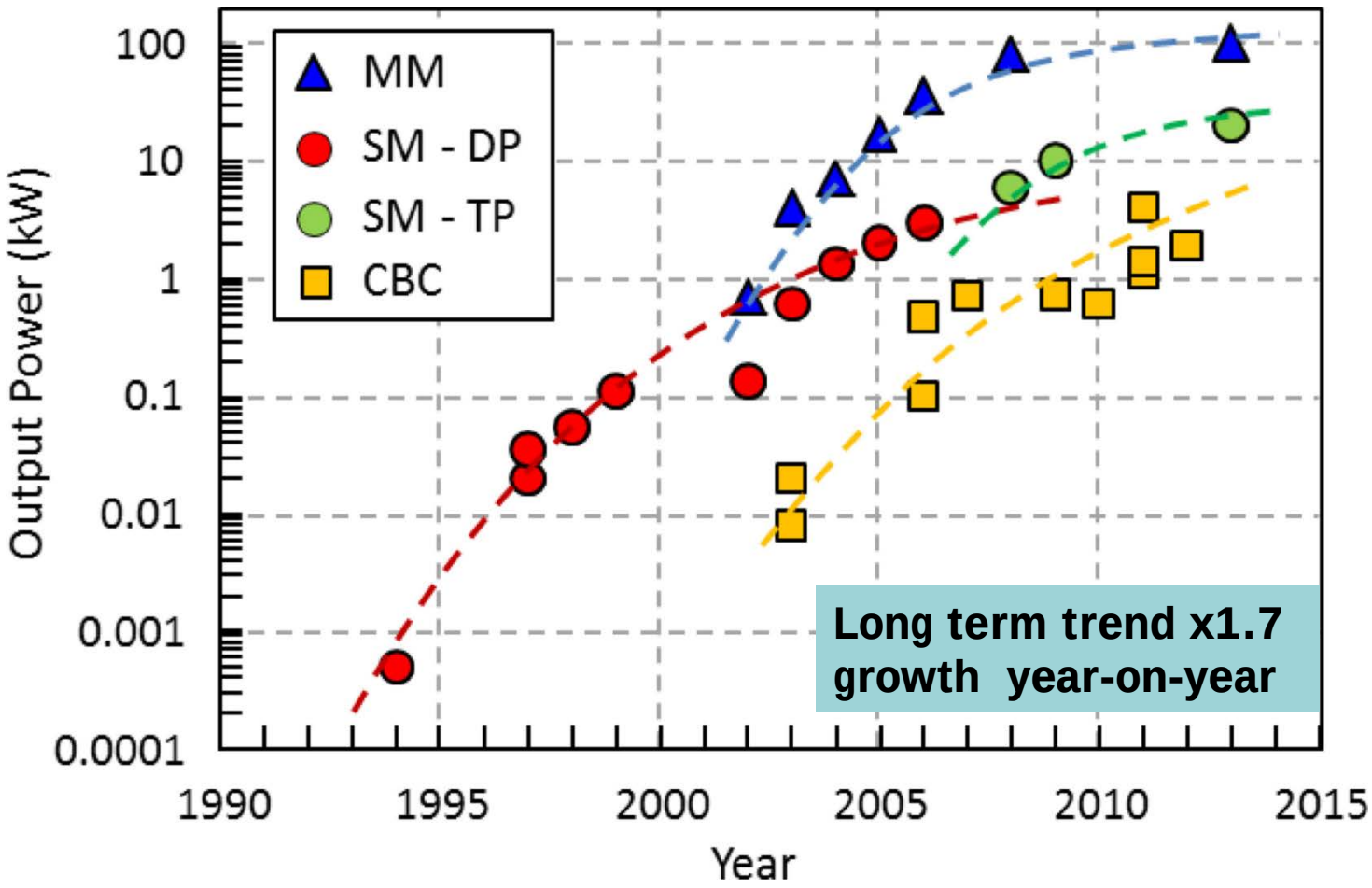
What makes us get out of bed in the morning?

- 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

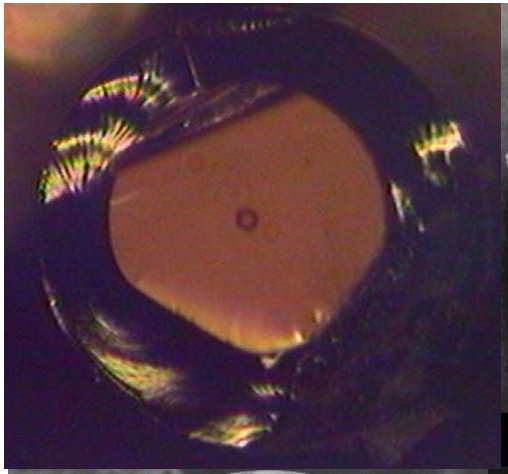
- *High powers (multi-kW)*
- *New wavelengths & wavelength conversion*
  - *EUV – UV – visible – NIR – MIR – THz*
- *Ultra-short pulses*
- *Pulse energy up towards 100 mJ*
- *Narrow linewidths*
- *Spatial beam control*

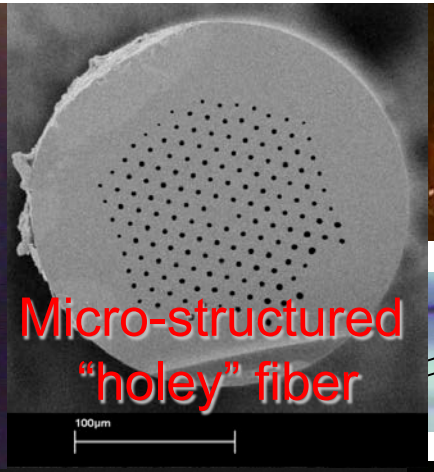
- *Industrial*
- *Aerospace, defense, security*
- *Pump sources*
- *Biomedical*
- *Scientific*
- *Telecom*
- *Beam combination*
- *And more!*

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

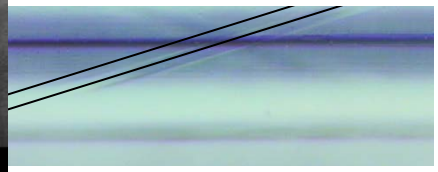
All fibers made in Southampton

Large core / large mode area

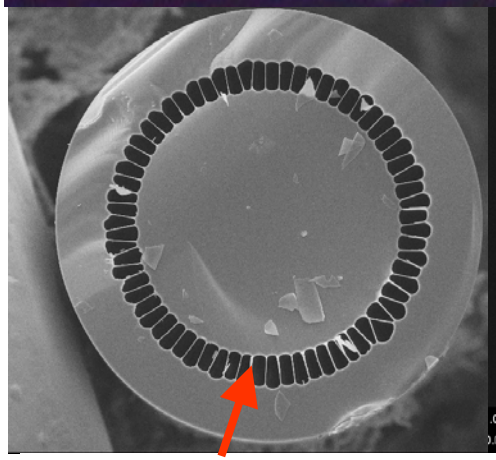




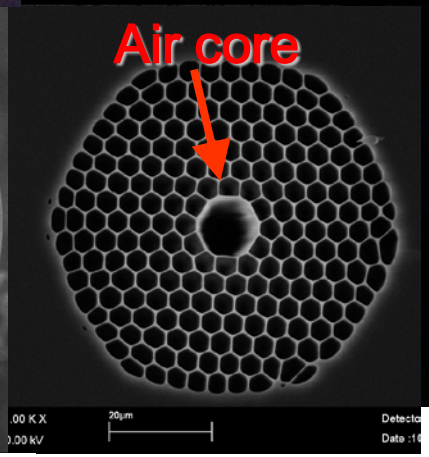
Multi-core ribbon - *Scalable!!*



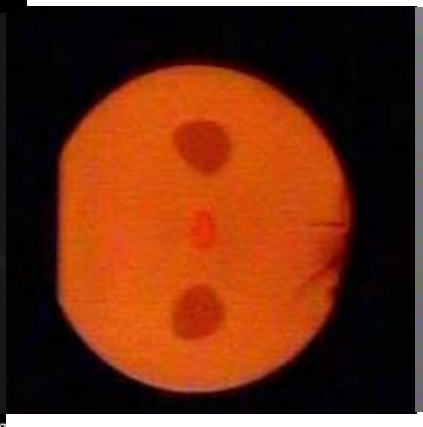
Helical core fiber
Circular birefringence
Filtering



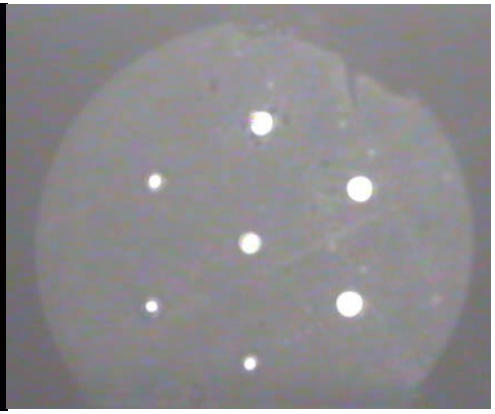
Air clad
High pump-NA



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.

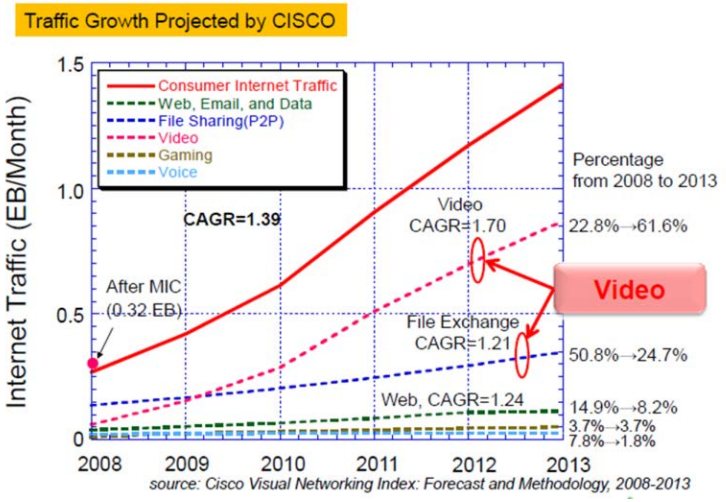
- DERA / DSTL / MOD

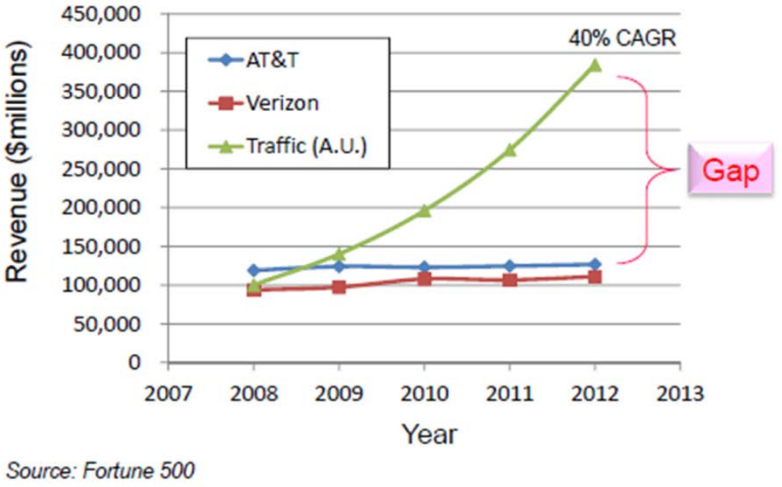
- ARL
- NRL
- AFRL / AFOSR / EOARD
- JTO
- DARPA

- EU
- EPSRC

- Other government agencies
- Companies

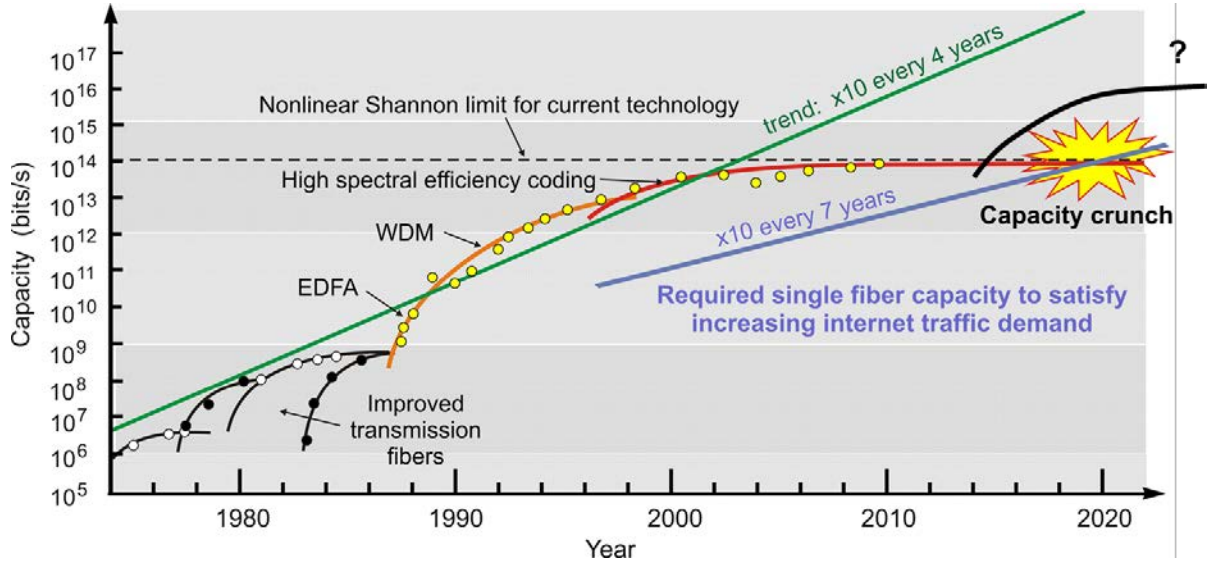
Telecom Challenges





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

MODE GAP

Nokia Siemens Networks · eblanaphotonics · Phoenix Photonics · ofs · TU/e Technische Universiteit Eindhoven University of Technology · UCC · University of Southampton Optoelectronics · ESPCI ParisTech

Transforming the Internet Infrastructure: The Photonics Hyperhighway

University of Southampton · EPSRC Pioneering research and skills · University of BRISTOL

UCL · COMIMO · University of Oxford · EPSRC Pioneering research and skills · University of Southampton · University of Cambridge

SAFARI

DTU · University of Southampton · Coriant · NTT · Fujikura

COSIGN

Alcatel·Lucent Bell Labs Research

YOFC 长飞 Delivering Signals Smartly

The Royal Society

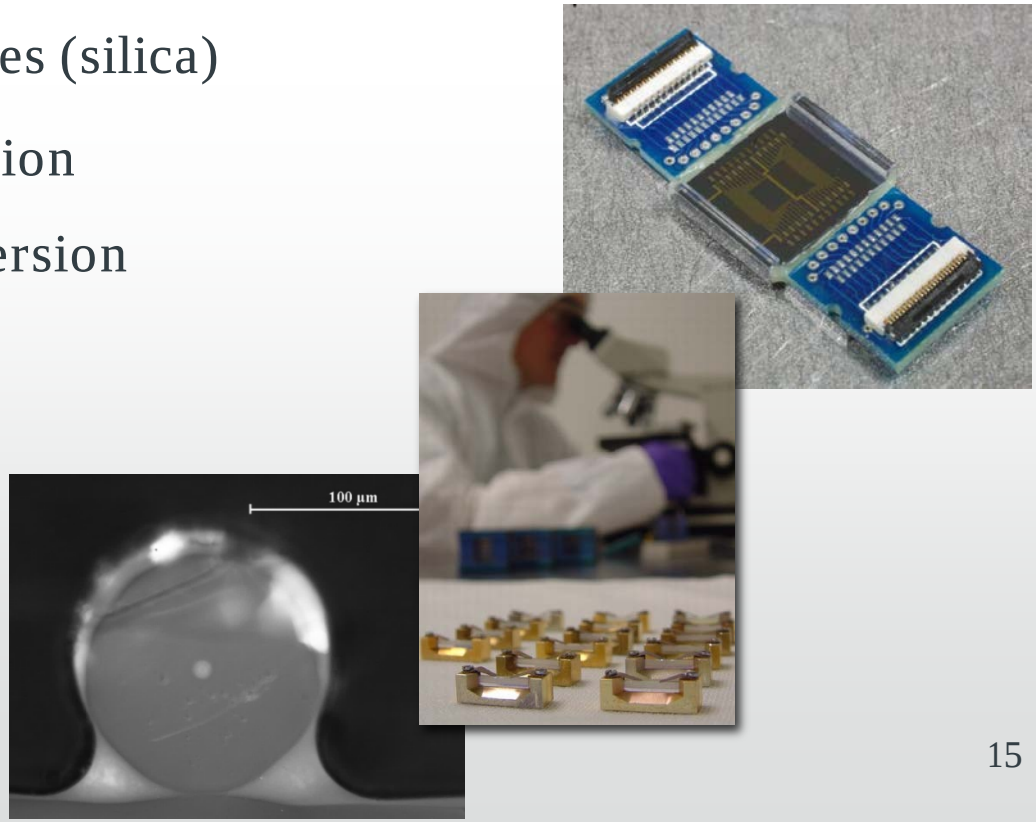
UNIVERSITY OF Southampton
Optoelectronics Research Centre

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,

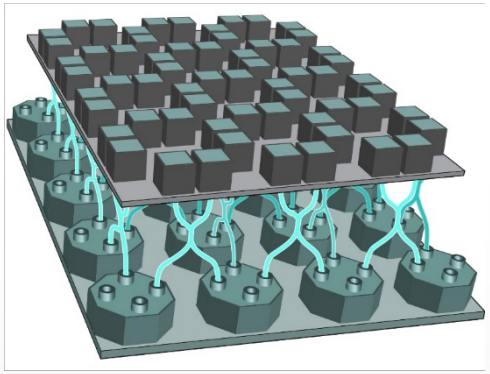
- University of Oxford led QT hub

  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 Covesion

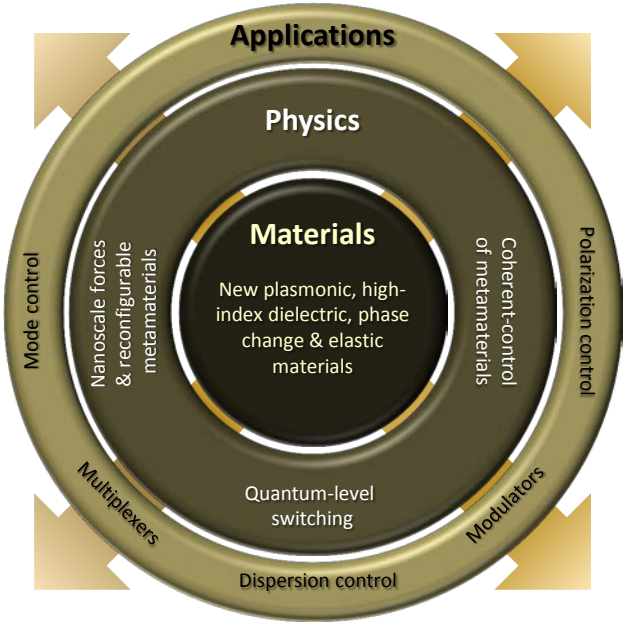


Nanostructured Functional Photonic Materials and Metamaterials I

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

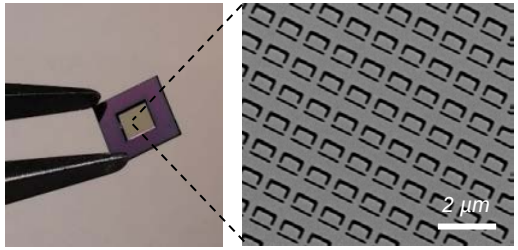
Nature Mater. 11, 917 (2012)



New materials for metamaterials

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

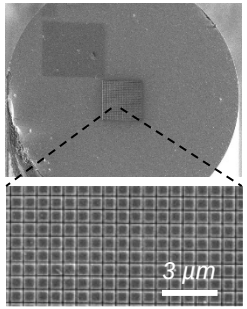
Nature Nanotech. 11, 16 (2016)



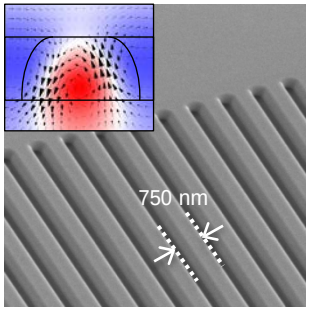
Free-standing Si metasurface

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

Opt. Express 21, 26714 (2013)



Ge metasurface on fibre



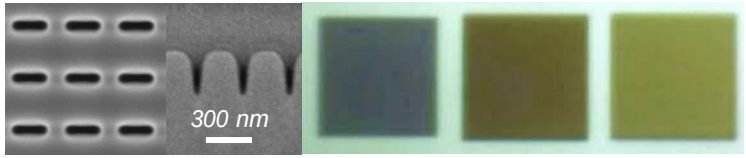
Ge:Sb:Te switchable metasurface filter

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

Adv. Mater. 25, 3050 (2013)
arXiv:1604.01330 (2016)

- 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'

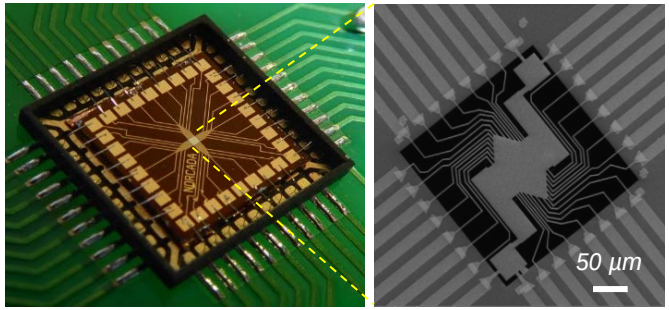
- Nano-mechanical systems driven by current/voltage, magnetic field & light
  - ➢ Ultrafast, low-energy, tuning and switching
  - ➢ Extreme nonlinearities up to sub-GHz frequencies
- Re-writable flat optical elements and metasurfaces

Science 348, 973 (2015)

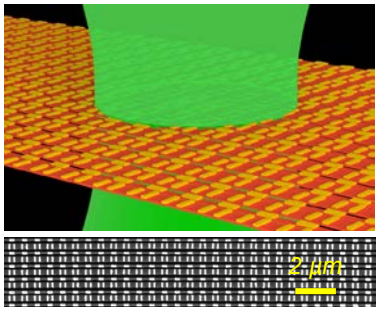
Adv. Mater. 28, 729 (2016)

APL 107, 191110 (2015)

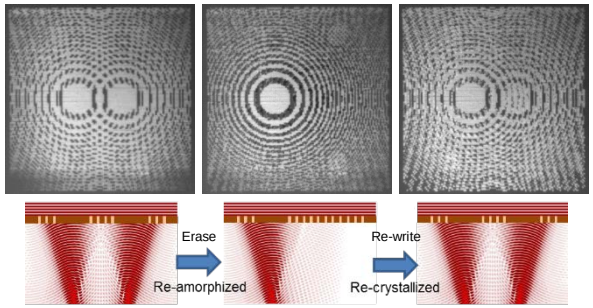
Nature Photon. 10, 60 (2016)



'Random access' addressable metamaterials



Optomechanically nonlinear metasurfaces



fs-pulsed laser (re)writable greyscale GST optics

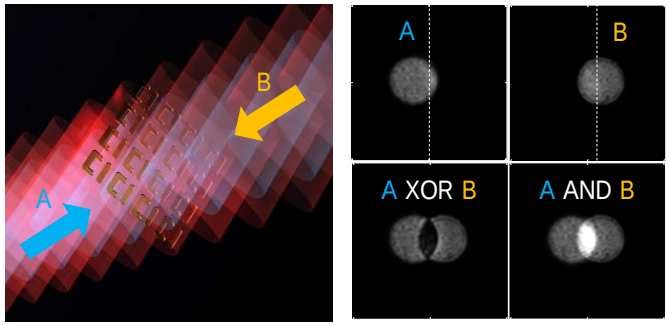
New paradigms for controlling light

- 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

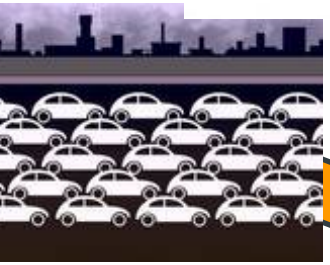
Silicon Photonics: Applications

UNIVERSITY OF Southampton

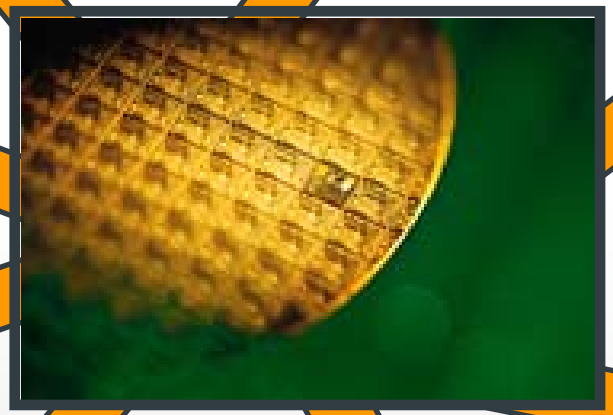
Interconnects

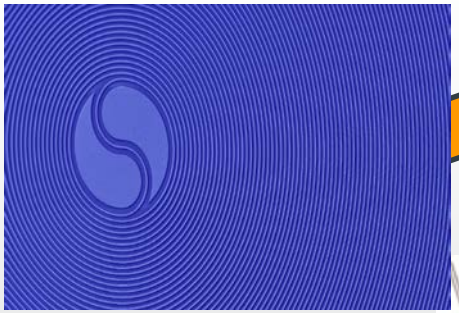
Fibre to the home

Medical applications



Environmental sensing

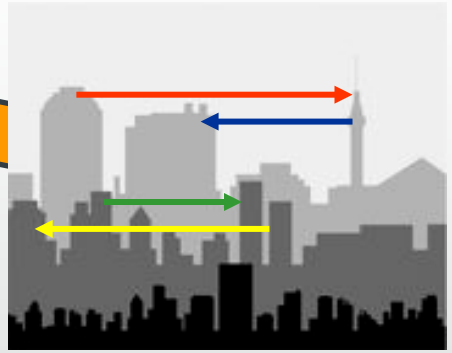




Quantum Photonics

Chemical / biological sensing

Military applications



Free space optical communications

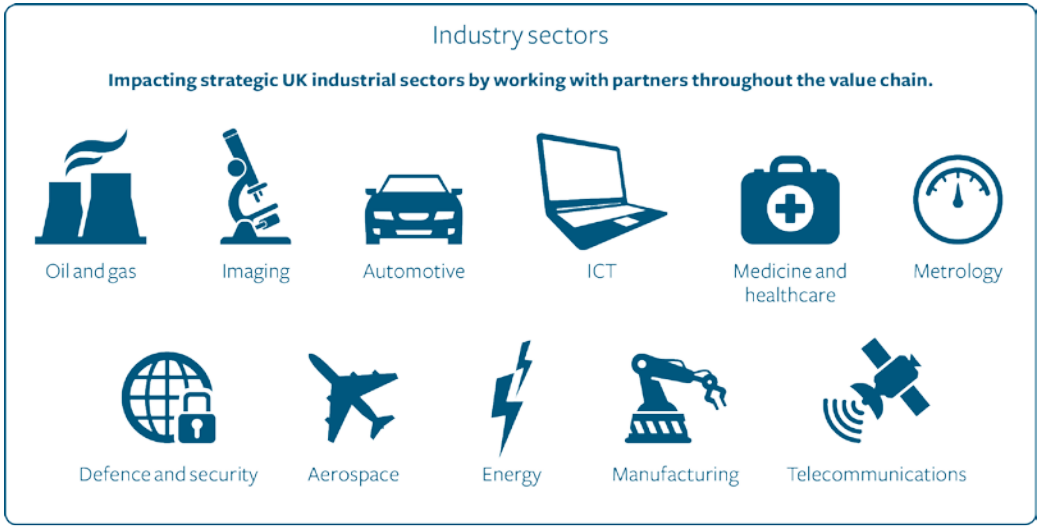
Grand Challenge – Integration

- **Top level challenge-**

INTEGRATION

"Develop novel transformational manufacturing technologies ....that enable greater integration... of photonics"

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

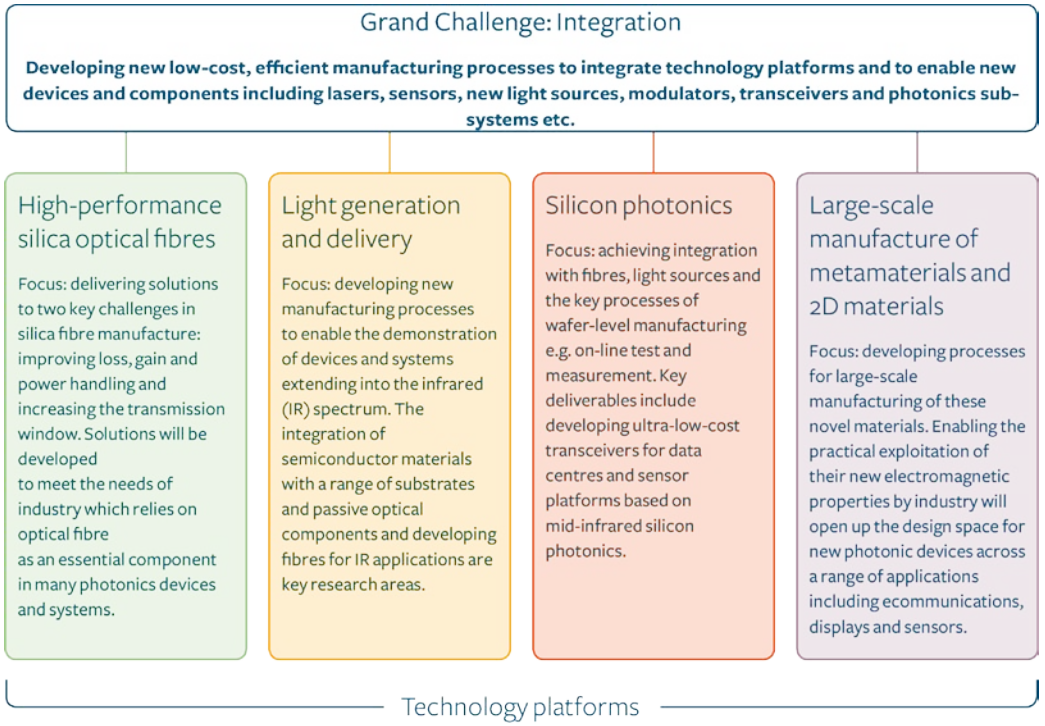


Grand Challenge: Integration

Developing new low-cost, efficient manufacturing processes to integrate technology platforms and to enable new devices and components including lasers, sensors, new light sources, modulators, transceivers and photonics sub-systems etc.

Technology platforms

- **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



Industry support

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