



IQE

New Opportunities Now for the Quantum Photonics Supply Chain

**Iwan Davies, IQE plc
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Acknowledgments:
Denise Powell, CSC
Mark Stevenson, Toshiba
David Cunnah, Innovate UK

IQE: Global Leader for Compound Semiconductor Wafers

Founded in 1988 • Listed London (AIM) • Market Cap ~ GBP 0.5Bn • ~700 staff

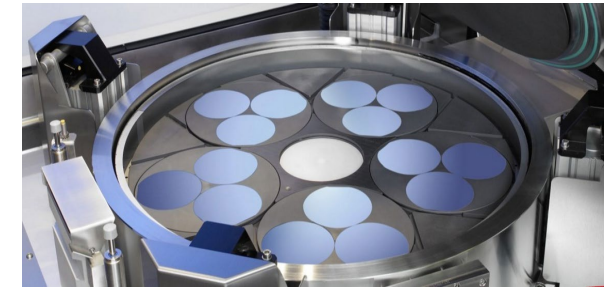
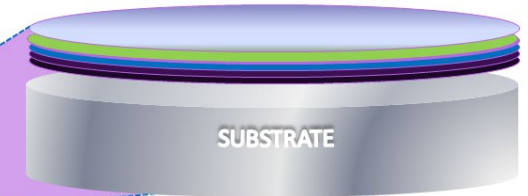


USA
4 sites
EUROPE
4 sites
ASIA
2 sites
>100 reactors total (MOCVD + MBE)



Epitaxy – engineering advanced materials

- Atomically engineered films (up to >400 individual films)
- Leading edge crystal growth technology
- Bespoke to each application



Equipment and Facilities

- 24 MOVPE tools at IQE in Cardiff/Newport
- Various characterisation tools:-
 - X-ray, SurfScan, X-Ray Topography
 - Electrochemical CV profiling
 - Photoluminescence
 - Optical Microscopes
- (External) SIMS, TEM

- > 30 years in quality assured pure play epitaxy supply
- > 35 Coll. R&D: 2015-2020+ (I-UK, H2020, ECSEL, ESA)
- Pioneered high volume epitaxy, operational excellence
- Mass scale manufacturing:
 - >300,000 6" GaAs wafers produced annually
 - >100,000 3"/4" InP wafers produced annually
- 25 years proven history of VCSEL and InP LD supply



IQE Newport, UK, Mega Epi-Foundry

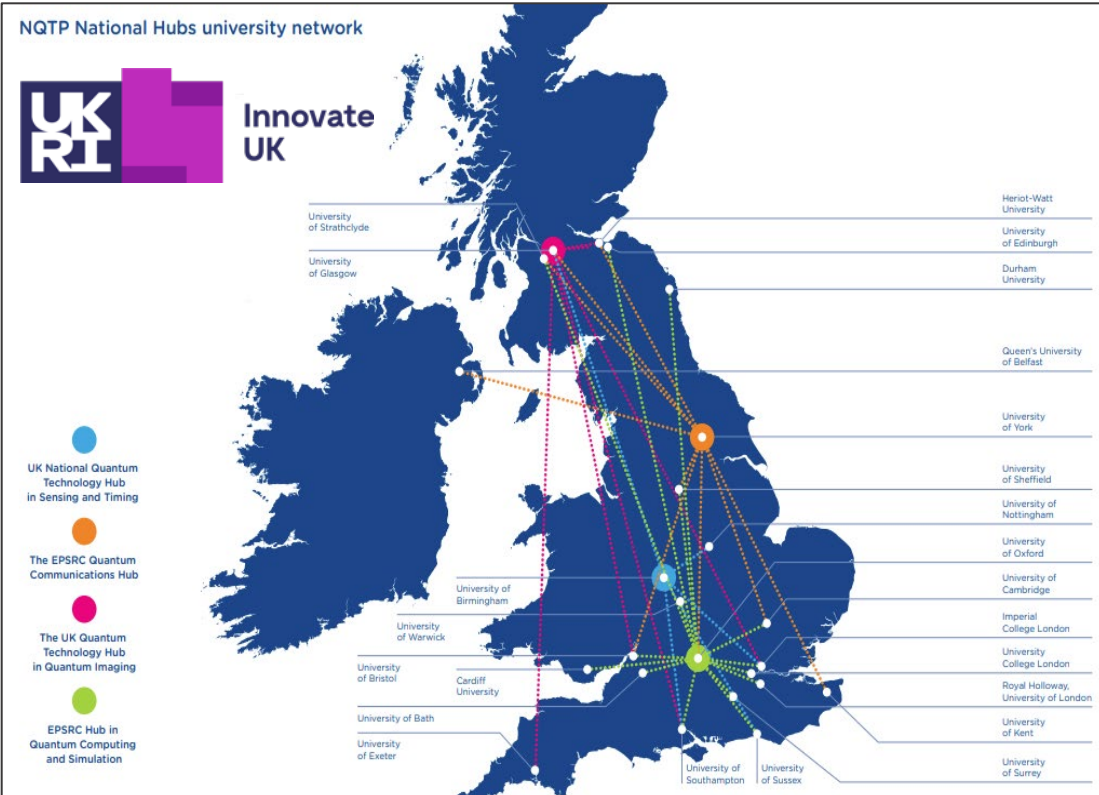


The UK Quantum Landscape

The UK's National Quantum Technologies Programme is a £1bn 10-year investment in

4 Key Technology Areas:

1. Quantum computing
2. Quantum secure communication
3. Quantum sensing and timing
4. Quantum imaging



The industrial challenge



£153m government support for the commercialisation of quantum technology

Components 19%

Computing 34%

Communications 19%

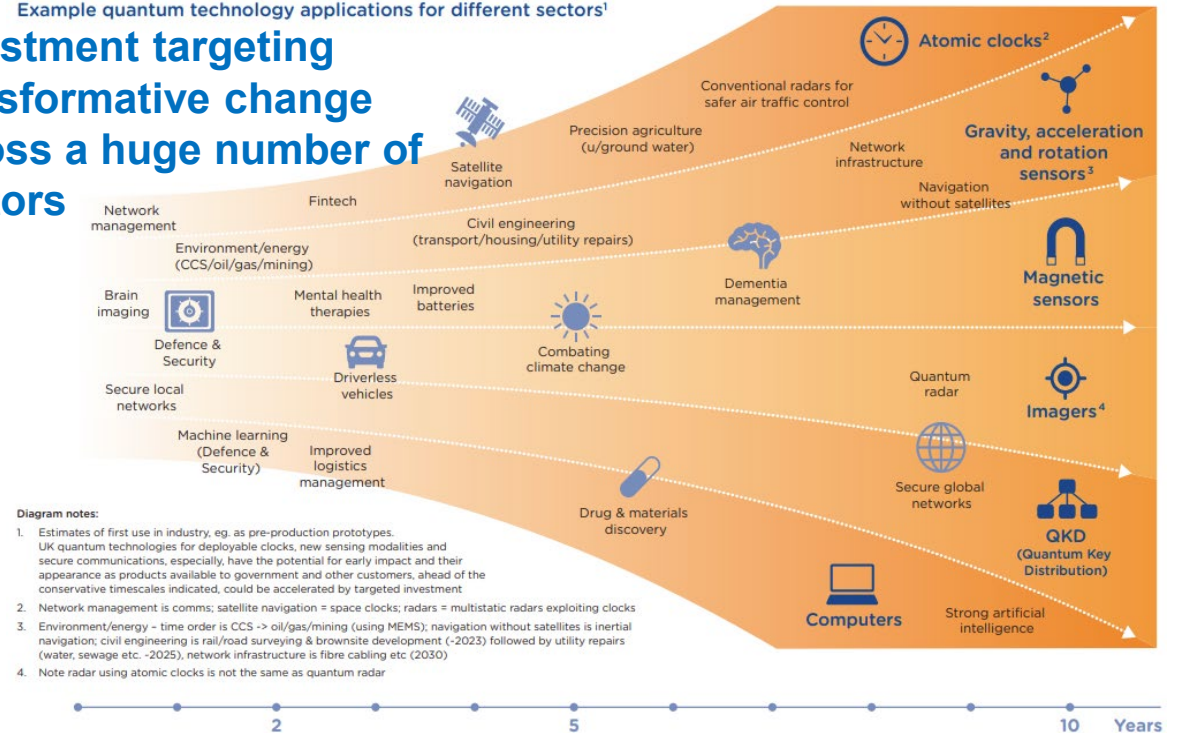
Sensing & Timing 14%

Imaging 14%

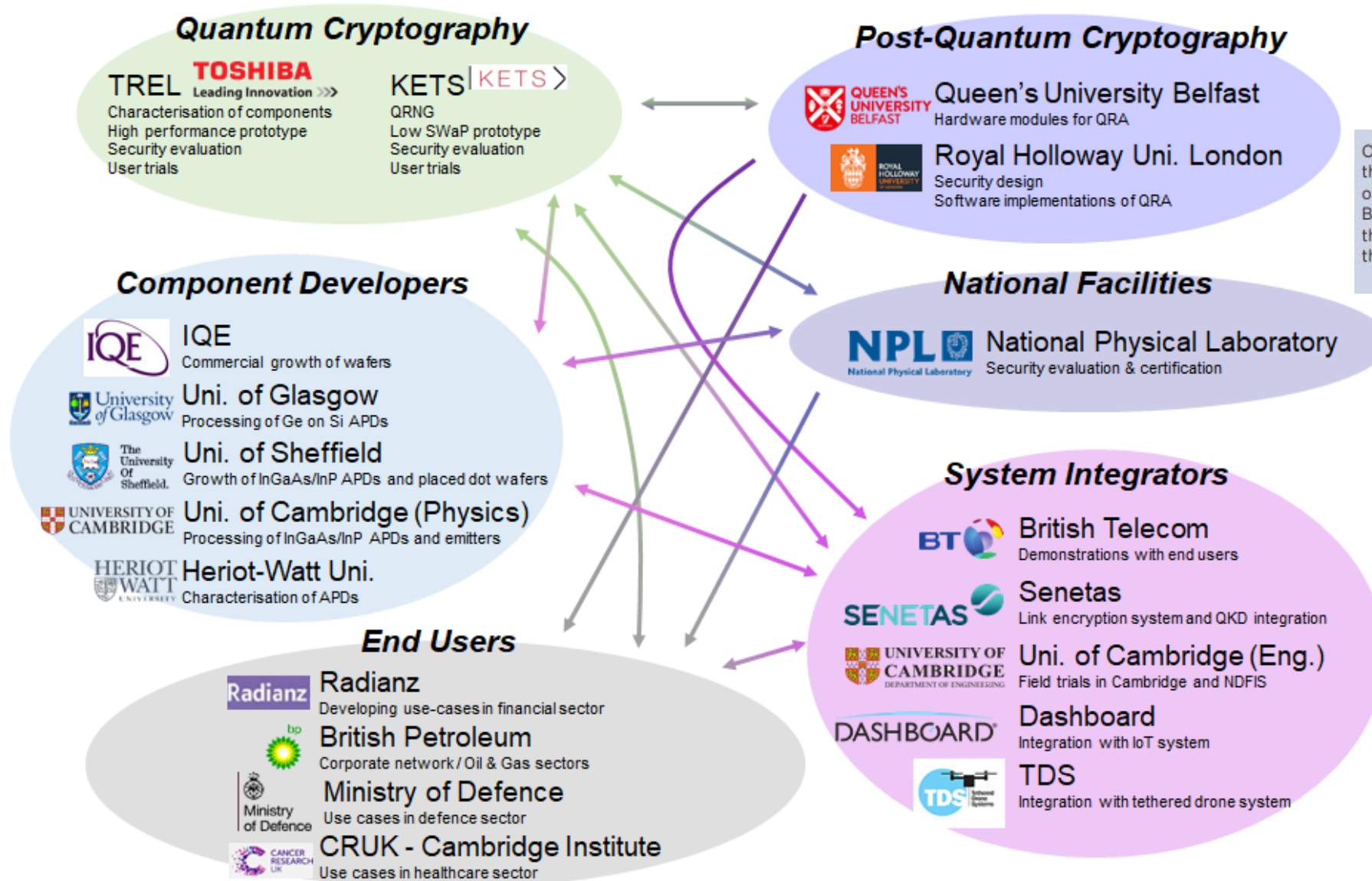


Example quantum technology applications for different sectors¹

Investment targeting transformative change across a huge number of sectors



IQE: Typical Quantum Collaborative Project – the AQuaSeC consortium

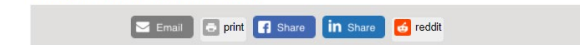


Oct. 2020: BT & Toshiba announce the UK's first industrial deployment of a quantum-secure network using BT Openreach infrastructure between the National Composites Centre and the Centre for Modelling & Simulation



Toshiba launches global Quantum Key Distribution QKD business with UK factory

October 19, 2020 //By Nick Flaherty

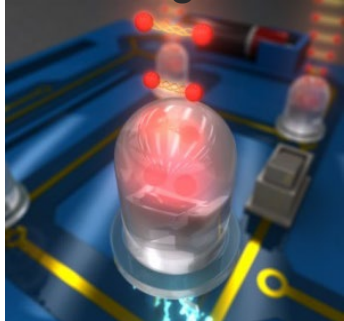


Toshiba is setting up a global business to promote QKD system and network deployments with manufacturing in Cambridge

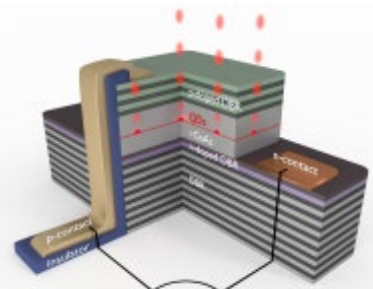


Quantum Emitters

First single photon and entangled LEDs

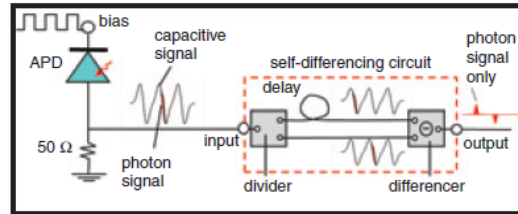


Telecom & GHz ELEDs



Quantum Detectors

First GHz SPADs



SPAD based QKD

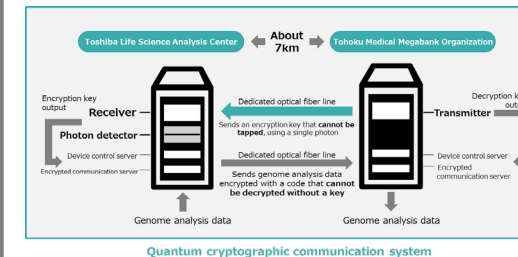


Quantum Networks

Quantum Relays



QKD Field Trials



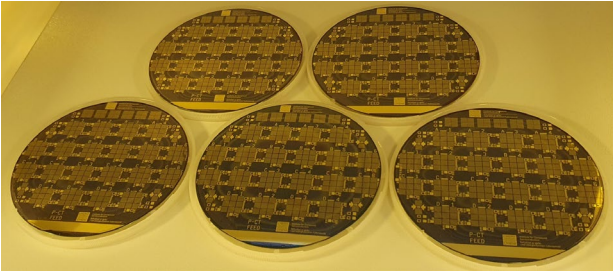
- Design and advanced characterisation of state of the art quantum devices and systems
- First entangled-LED, telecom ELEDs, and GHz single photon detectors

Toshiba Europe Ltd., Cambridge Research Lab.

TOSHIBA

[Salter, Nature (2010). Muller, Nat. Comms (2018), Muller, arxiv (2020), Patel, Elec. Lett. (2012), Xiang, Comm. Phys. (2020)]

Single-mode VCSEL Quantum Technologies

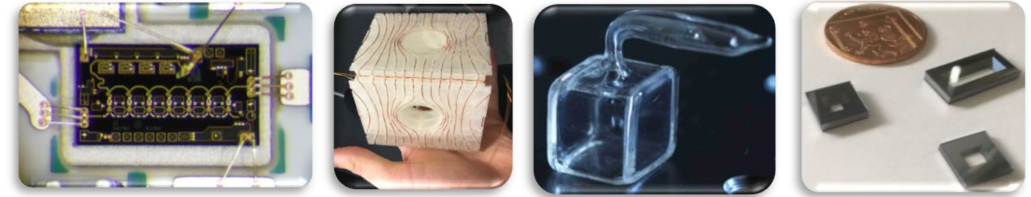


Five identically processed VCSEL wafers – fabrication at the Institute for Compound Semiconductors at Cardiff Univ. and supported by Innovate UK and EPSRC. Epi wafers provided by IQE

UK supply chain for Compact Cs Atomic Clock with fractional frequency stability at $<10^{-12}$

Demonstrated 894nm VCSEL capability:

- Suite of proprietary laser design and simulation models at Cardiff University and ICS Ltd
- High uniformity epitaxial layer structures realised at CSC, with $< 3\text{nm}$ centre wavelength tolerance
- Polarisation insensitive, single mode VCSEL performance with a linewidth of $\sim 30\text{MHz}$ and SMSR of 28dB, fabricated by ICS Ltd
- Novel VCSEL characterisation processes specifically developed for quantum applications at the National Physical Laboratory



MAGV: Develop World's first commercial miniature RF Quantum Magnetometer with $10\text{fT}/\text{Hz}^{1/2}$ sensitivity

- VCSELs targeting 852nm (D2 Cs transition) and 780nm (D2 Rb transition), with $>10\text{mW}$ output power.
- Novel laser configurations for probing Cs and Rb species.
- Wafer-cell development



RF atomic magnetometer applications



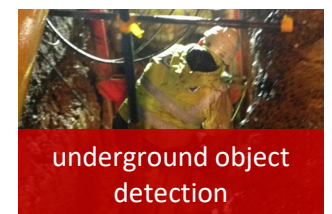
Preventative maintenance

£4 trillion global cost of CUI



Manufacturing / process control

Defect-induced margin loss



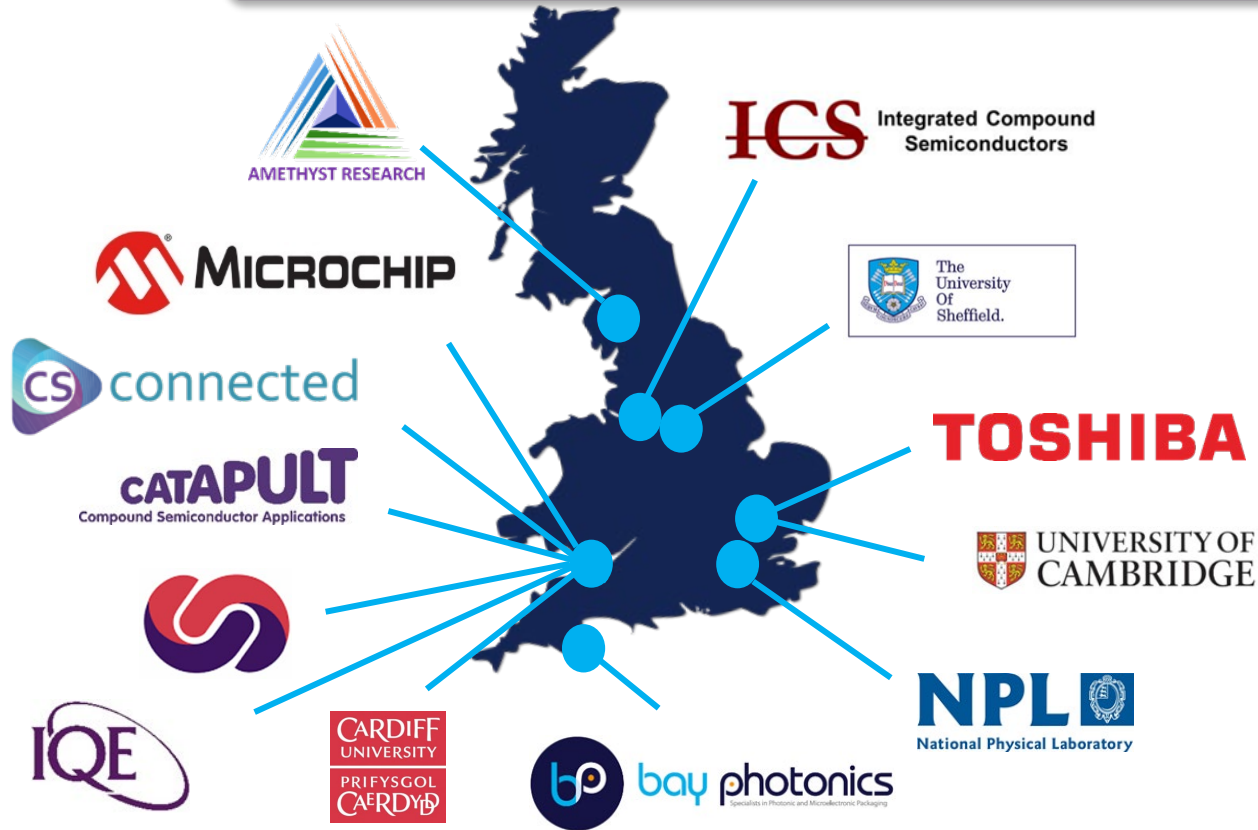
underground object detection

Excavation costs





UK National Foundry for Quantum Components



Bringing together the UK's most established supply chains to address critical challenges in device manufacturing and deliver World's first Quantum Photonic Component Foundry.

Developing key technology platforms for accelerating the uptake of quantum applications:

- Single-mode, high-stability Vertical Cavity Surface Emitting Lasers (VCSELs)
- Single-photon emitters & detectors

£5.8M, 3-year project focused on:

- ✓ Upscaling component manufacture using standard semiconductor manufacturing techniques
- ✓ Addressing barriers to adoption of quantum systems

Target Markets

- Quantum Key Distribution
- LiDAR
- MW-IR sensing
- Atomic clocks
- Quantum Magnetometers

