Future Horizons for Photonics Research- 2030 and beyond

Dr John Lincoln, PLG meeting 3 June 2020

Summary at www.photonicsuk.org

Motivation

"There is no new photonics research"

"Photonics is mature"

"Photonics has no vision for the future"

"Quantum 2.0 is the only future for photonics"

"Photonics is passé"

- Significant gov focus on science and innovation

  " we are following the scientific advise"

- Clear and inspiring vision for the future direct of photonics research needed

One step at a time

1. Horizon scan for future possibilities
2. Fit to policy and macro environment
3. Industry interest, relevance & support
   - from UK Government office of science Future toolkit

- Divide and conquer the traditional roadmap process

Aims to expand horizons, defining what may be possible in the photonics future.

To inspire the next generation of researchers and stimulating industry and policy interaction in the UK and internationally.

How

- 26 of UK leading photonics researchers
  - Handpicked from across UK photonics
  - Think out-of-the-box across photonics represent whole field

  - Outputs compiled by 4 early career fellows

Dr	John	Lincoln	PLG
Dr	Kasia	Balakier	University College London
Dr	Natalie	Wheeler	University of Southampton
Dr	Rob	Richards	University of Sheffield
Dr	Richard	Carter	Heriot-Watt University
Prof	Polina	Bayvel	University College London
Prof	Gerald	Buller	Heriot-Watt University
Prof	Richard	Curry	University of Manchester
Prof	Martin	Dawson	University of Strathclyde
Prof	John	Girkin	University of Durham
Prof	Harold	Haas	University of Edinburgh
Prof	Jon	Heffernan	University of Sheffield
Prof Sir	Colin	Humphreys	Queen Mary Uni, London
Prof	Thomas	Krauss	University of York
Prof	John	Marsh	University of Glasgow
Prof	Dominic	O'Brien	University of Oxford
Prof Sir	David	Payne	University of Southampton
Prof	Richard	Penty	University of Cambridge
Prof	Alwyn	Seeds	University College London
Prof	Duncan	Hand	Heriot-Watt University
Prof	Anatoly	Zayats	Kings College London
Prof	Maurice	Skolnick	University of Sheffield
Prof	Tim	Spiller	University of York
Prof	Peter	Smowton	University of Cardiff
Prof	Robert	Bowman	Queen's University Belfast
Prof	Graham	Reed	Southampton

Context

Nine Great Challenges

Data
- Speed & capacity
- Timing & delay
- Security & accuracy

Health & Aging
- Productivity
- Capacity
- Ease of adoption
- Cost & scale

Physical Pollution
- Air, land & sea
- Recycling & reuse
- Packaging
- Production waste

Mobility & Transport
- Efficiency
- Availability
- Risk

Climate Change
- Sustainability
- Energy efficiency, use & generation
- Measurement

Defence & Security
- Agile
- Available
- Affordable

Economic Patriotism
- De-globalisation
- National capability
- Uncertainty

Scale
- Volume
- Production ramp
- Timing
- Variable demand

Food Production
- Quality
- Efficiency
- Supply security

70 topics on research Horizon

PHOTONICS LEADERSHIP GROUP

- In four research areas
- Loosely prioritised by challenge impact

Materials

2d materials & hetrostructures for photonics	Optimised (AI) design of next generation photonic materials
Reconfigurable adaptive & programmable photonic materials	Direct bandgap silicon & new silicon photonic materials
Low threshold power non-linear materials	Materials for >100 GHz optical modulators & sub ps switching
Biocompatible Photonic Material	Efficient phase change materials
Electrochemically stable materials for solar-hydrogen	Expanded spectral capability of materials in UV & IR
High-speed operation organic materials	Negative n2 materials
Sustainable/ bio-degradable photonic materials	Very high efficiency, easily integrated single photon sources

Optical & Physical Phenomena

New quantum phenomena at the macro-scale	Chemistry & chemical reaction pathways controlled by light
Compact attosecond physics	Extreme high energy pulsed phenomena for breaking vacuum
Focal volume manipulation	Functional topological devices at room temp
Light controlling movement beyond few nm	Light-matter interaction, control & assembly on a molecular scale
Optical imaging of the nervous system	Opto-mechanics for RF-microwave-THz-optical interface
Photonic enabled synthetic fuels & energy storage	Precision optical measurements for testing fundamental physics
Quantum limited detection in mid-IR	Ultra-short temporal pulse-shaping

Processes

Integration processes at scale (1000+ elements)	Nanophotonic devices for on-chip optoelectronic integration
Integrated quantum sensing, imaging, processing & communications	Processes for integration of new functionalities with photonics
High volume processes for point-of-care testing	Efficient integration of plasmonics
Flexible optical manipulation for limited access volumes	High speed nm optical imaging for process control
Integration of 2d materials	Low energy manufacture of photonics
Optical cell manipulation for regenerative medicine	Processing of materials for repurposing & reuse
Scanning probe techniques for photonic nano-material assembly	Solar driven chemical processing
Testing of massively complex systems at wafer scale	

Devices & Systems

Beyond CMOS integrated photonics & electronics	Fully optical internet & required components	Optical point-of-care diagnostics
Neuromorphic photonics	Coherent comms across entire RF/THz/Optical spectrum	Deep tissue optical imaging
Extreme high power /energy amplified laser systems	Flexible, reconfigurable & programmable optical circuits	Hybrid quantum & conventional communications systems
Large scale optical switches	Large detector arrays at multiple wavelengths	Miniature THz sources at room temperature
Next generation non-mechanical lidar	Quantum repeaters & entanglement distribution	Quantum communications in space & at long wavelengths to THz
Single Photon detectors for SWIR & MIR	Sub nanometre optical imaging	Ultrawide bandwidth optical networks, amps, modulators & fibres
Very high efficiency lasers (>95%)	Efficient & high bandwidth PV cells	Flexible laser material processing systems with multi/ variable lasers
High-speed, ultra high-sensitivity detectors in visible spectrum	High speed, low energy, ultra high density & secure memory	Merging of AI & photonics sensory data (e.g. artificial noses)
Optical memory from fast RAM to ROM	Quantum computing to 10^4 Qbits	Chip level systems in the ultra-violet

Photonics Leadership Group 2020

Summary released on www.photonicsuk.org

Recommendations

- Convert the identified research topics into UK based world leading research activity
- Fund photonics research in people, facilities and capability across the UK encouraging engagement with multiple societal challenges
- Balance support accross research activites from materials to systems, championing their interdependency.
- Follow-up with a detailed study of the fit and support to policy, its development and interests of industry.
- Integrate this map of photonics futures with the roadmaps of Industry Strategy Challenge Fund and other priority areas.
- Consider future topics equitably, recognising that photonics underpins wealth creation through diverse pathways in many markets.
- Champion this rare vision of the future of photonics to the world

Next-steps

- Generate a full report
  - Co-released with the Photonics and Quantum APPG
    - Text in ~final draft, prior to pro layout – target July release
  - Targets: Support agencies (UKRI, EPSRC , Innovate) , Gov departments, Photonics research and innovation community, Trade press
- Follow-up
  - Industry input
    - PLG ?KTN workshop @ October meeting?
  - Policy and impact
    - Resilience & communications to the fore, Life science bandwagon, Budgets of gov and industry