ICT Programme Theme Day

Photonic Materials and Devices

Wednesday 10 June 2009

The George Hotel, Edinburgh

Executive Summary

This workshop, the fourth in a series of five being organised by the ICT programme for EPSRC was attended by 34 members of the UK Photonic Materials and Devices Community. Delegates were invited as being leading researchers in the EPSRC portfolio with additional invitations made to industry. This series of workshops are aimed at providing baseline knowledge for the programme on the community's view of the research portfolio in the UK and will feed directly into programme strategy in the coming years. Key messages and observations taken from this particular workshop are:

Perceptions

- The international profile of the research was felt to be strong with 100% of respondents either agreeing or strongly agreeing with this statement
- The future of the area in the UK was also felt to be strong again with 100% of respondents agreeing or strongly agreeing with this statement, however only 76% agreed that there is a rising generation of future research leaders
- Respondents were not too convinced that borders between disciplines are being crossed, there is good user collaboration and that research in this area is creative and adventurous with only 20, 24 and 69% respectively agreeing with these statements.
- Only 14% of respondents agree or strongly agree that the area's researchers are sufficiently resourced

It is acknowledged that this portfolio covers distinct research communities, a more complete description and breakdown by area can be found in the report.

SWOT Analysis

- Key strengths of this portfolio were captured as being a very strong academic community with good international links and a critical mass of leading researchers. There was seen to be a strong collaboration culture and academic strengths were seen in a wide variety of disciplines across the topic.
- Weaknesses identified include a fragmented community, lack of connectivity across research areas, and ill defined boundaries. There is not always interest from medium/large companies and the economic impact of Photonics is perceived to be underrated. There is felt to be a poor industrial base and not enough UK funded PhD students.
- Photonics was described as all pervasive and able to deliver a competitive advantage in the global market place. The ability of the subject to address contemporary issues was seen as was the ability to underpin lots of other science and technology areas.
- The primary threat to the health of the discipline in the UK that were identified included funding with concerns over the current recession and strategies which may emerge afterwards and international competition from the US, Germany, Switzerland and China.

Future of Photonics

In order to achieve the aims of the Photonics community between now and 2050 and beyond, input from all communities is needed with open communication, system integration and strategic funding.

Conclusions and Next Steps

The outputs from all of the theme days across the ICT portfolio will be collated and common issues identified. Potential future actions to address these issues will, where appropriate, be considered by the ICT programme. The reports from all workshops will be published alongside an overall response to the issues raised.

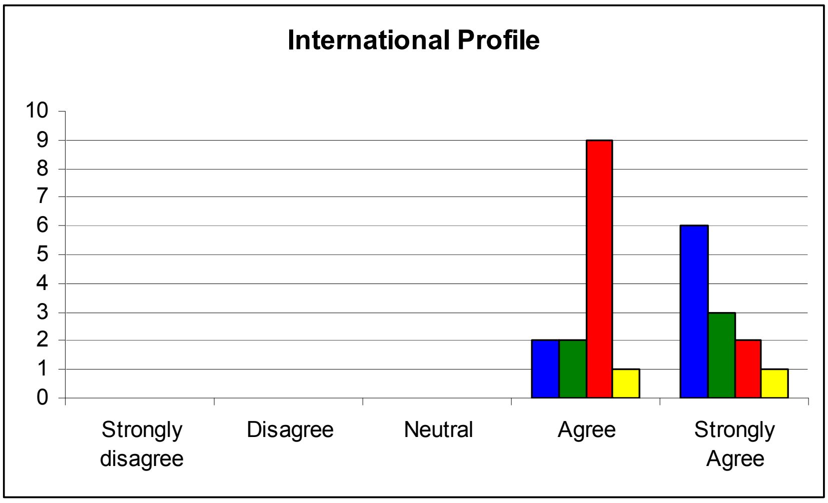
Photonic Materials and Devices Theme Day

The ICT programme organised a series of theme days for each of the sub programme areas across its portfolio. The theme days are part of an on going community engagement strategy and aimed to provide baseline information and achieve a consistent view of the research landscape in order to inform future strategy for the programme. Three of the four exercises were common to all theme days with the final afternoon session being individual to a particular community. The exercises consisted of the completion of a Perceptions Chart, answers to general questions pertaining to research funding, a SWOT analysis of the area and look at what the future may hold for Photonics. The outputs from each session are presented below:

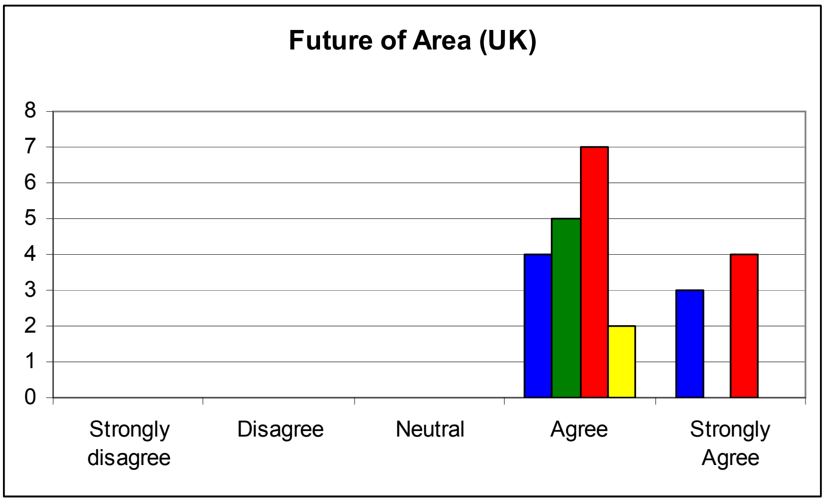
Perceptions of UK Photonics Research

In this exercise, the delegates of the workshop were invited to provide their perception of how their area of research measures up to different criteria. The topics represent the different areas of research covered by the Photonics portfolio and delegates were asked to provide votes against criteria that match those used in the wider EPSRC landscape documents published on the website.

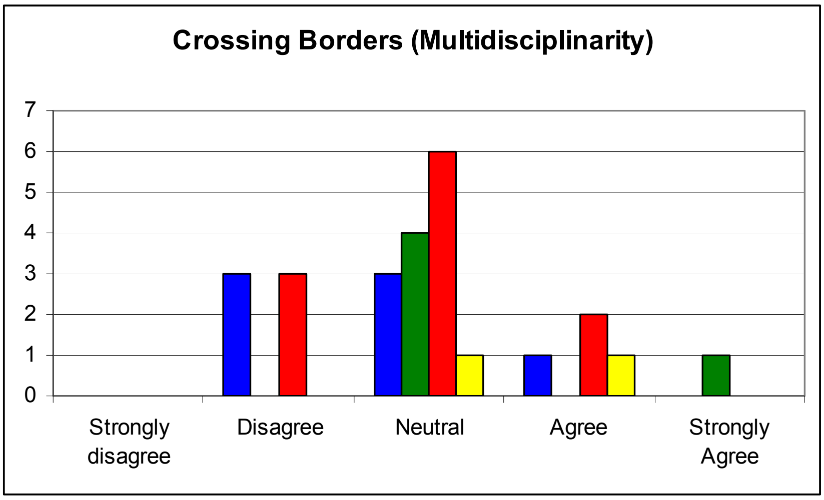
Optical Communications
Optoelectronic Devices and Circuits
Optical Devices and Subsystems
Applied Optics



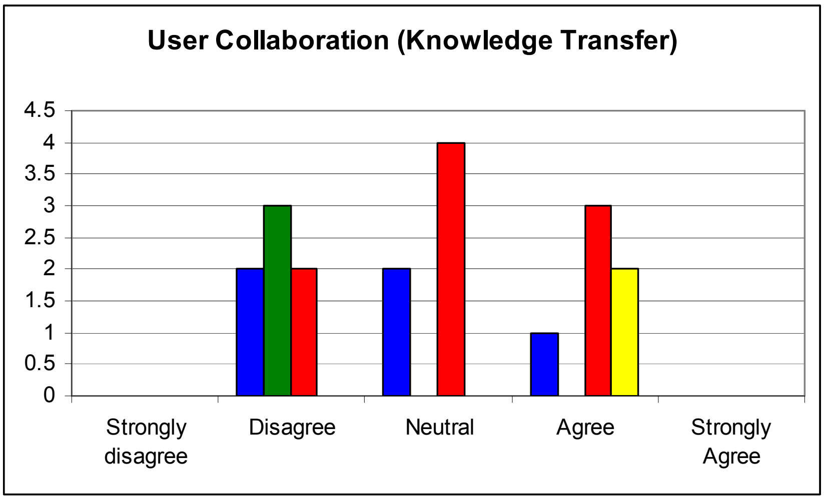
The research area is of high international standard, with researchers collaborating extensively internationally and the researchers are recognised as world



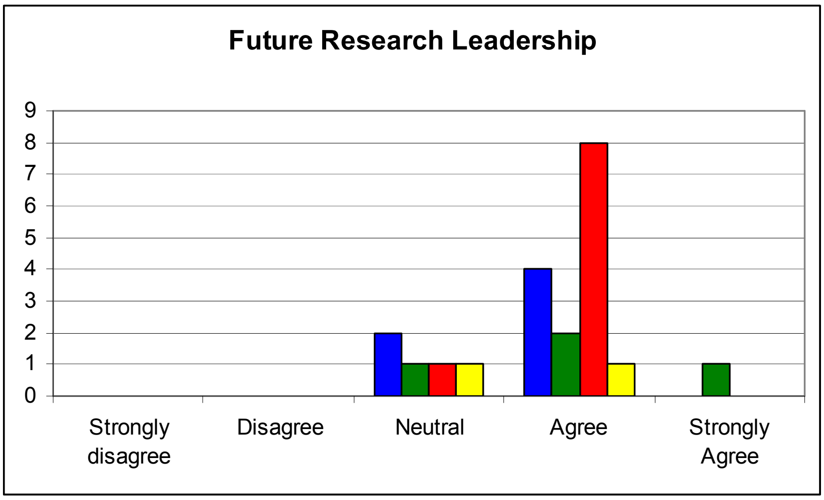
Research area has a bright future, with plenty of novel and adventurous research and without areas of stagnation.



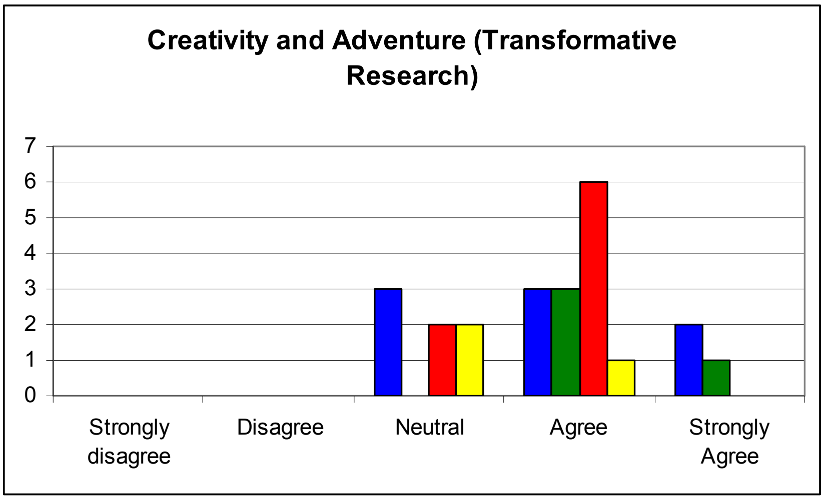
Research area crosses borders between disciplines where necessary, as evidenced by many multi-disciplinary projects and good engagement with other research councils.



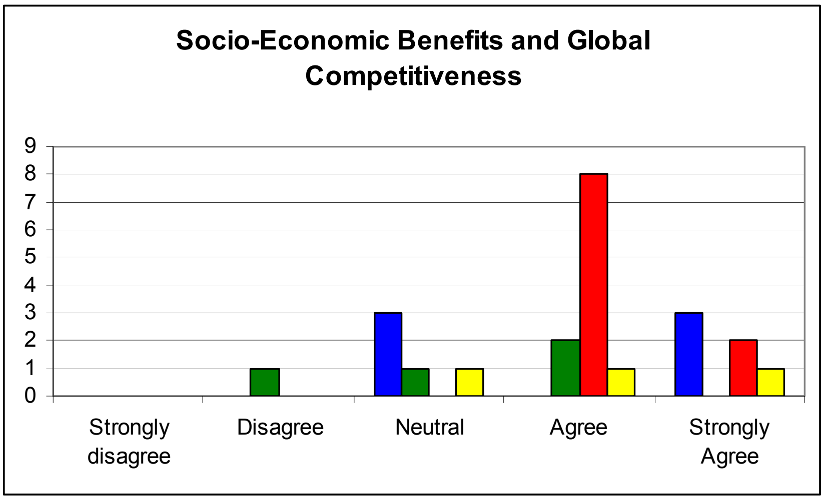
The level of collaboration and two-way knowledge flow with users, both in terms of quantity and quality is sufficient to assure that the knowledge generated makes a difference.



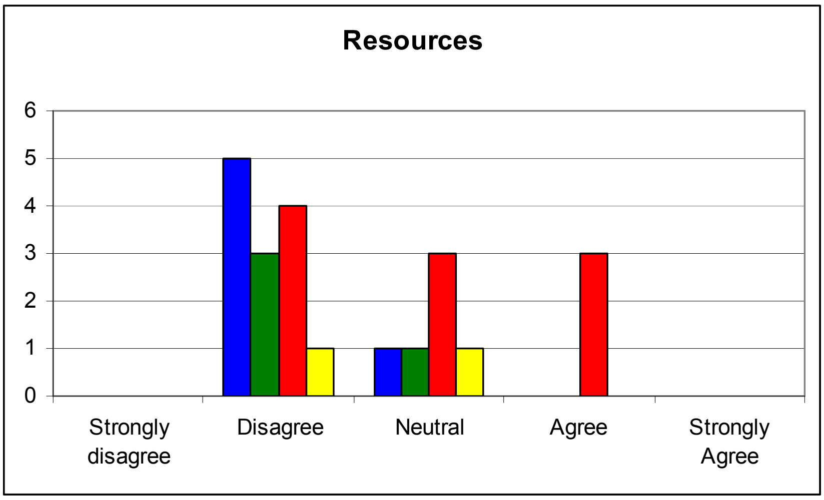
There is a rising generation of future research leaders in this area, suitable to ensure its future development, evidenced by numbers of Career Acceleration/ Postdoctoral Fellows,



Research area is highly creative and adventurous with potential to lead to a step change, resulting in new areas of research.



Research area is addressing topics of potential value to both UK society and the UK economy and will increase the global competitiveness of the UK.



Researchers in this area are sufficiently resourced in terms of facilities, equipment and availability of non-EPSRC funding, ensuring maximum leverage of EPSRC funds.

Wider Issues

The purpose of this first session was to pose general questions that are common issues across the ICT portfolio and where a broad view from the communities within ICT would be useful. The set of questions was identical for all five of the sub-programme theme days.

1. **What would you expect to see in a cv for an internationally leading group?**
    - 4* outputs normalised by impact factor for research area
    - Outstanding individuals
    - Invitation to give plenary talks
    - Academic and industrial exploitation of outputs
    - Good international links, including European Collaboration Coordinators
    - Prominent role in international community
    - Recognition outside own research area – strong industrial links, public engagement, producing research leaders of the future
    - Patent portfolio
    - Spin out (as applicable)
    - Standards
    - RS URF and Advanced Fellows joining group
    - Recruitment of staff by external international groups in academia and industry
    - Research prizes

- Long term sustainable funding including large grants, industry and overseas (critical mass of group 4 PDRAs/Exp offers/Research Fellow)
- Substantial number of invited talks given by group members

2. What is the exploitation by industry like in your area? Is this an issue?

- Liquid crystals – global (but UK didn't make than much money from it although it is absolutely essential) – an issue as it is not over as far as R&D, major issue – comms companies in UK are now small, need to find good engagement routes, no more Nortel/Marconi
- Network control and management – global, enabling new industry (cloud computing), lack of UK industry, >90 % photonic companies are SMEs, 70% are micro <10 people, large companies do not call themselves photonics companies so getting large amounts of cash from them for research in photonics is very difficult
- III-V Photonics and Electronics
- Mid-IR and Terahertz – niche applications but plenty of potential, linkage in expertise across disciplines, lack of large company investment
- Si Photonics - lack of UK industry, fabs etc
- Polymer optoelectronics – potential for many new applications, driven by materials not "physics"
- Inorganic GaN light emitting devices (e.g. LEDs) – many UK SMEs, huge global industrial interest and competition, considerable UK industrial interest in exploitation.
- Optically activated silicon switches – not very much, needs more research
- Need better support to UK domiciled defence

3. What metrics should be used to measure research quality

- Impact normalised to topic
- Publications and citations
- Patents (and licensing/long term)
- Knowledge transfer/spinouts
- Well developed infrastructure
- Invited talks (global acknowledgement of peers)
- Attracting funding from diverse sources (imperfect metric)
- International collaborations
- Coordination of large programmes

- Standards activity (only applies to certain areas)
- Trained people/fellows/personal development
- In-service training/courses
- Attracting leading researchers
- Awards and fellowships/prizes/scholarships
- (Subjective – whatever method chosen will cause issues, need to get out and make personal assessment, use impartial experts

4. **How can we identify and sustain young/new talent in ICT?**
    - Career Development opportunities
    - Increase research fellowships
    - Enhance PhD+
    - Fellowship to continue
    - EPSRC either pay off student debt or pay PhD students a competitive salary
    - Widen/extend first grant scheme
    - Increase industrial fellowships
    - Simplify post-doctoral fellowships
    - Supportive environment but freedom to develop
    - National research and innovation competitions for young people
    - For DTA funded studentships, how about writing off a % of their student loan

5. **Where do you think the competition is globally in your research area?**
    - USA - everything
    - China - everything
    - Japan – displays LED, comms access
    - Taiwan – displays Led, OLED
    - Korea – displays, plastics
    - Sweden, Denmark, Finland – III-V, Comms, LED
    - USA, Japan – high speed opto and optical comms
    - USA, Gemany, Asia – nanophotonics
    - Germany – plastic OES, lasers, photovoltaics
    - France – optical fibre
    - Canada – comms
    - Australia – photovoltaics, optical processing, comms
    - Japan, Korea, Taiwan, China – liquid crystal displays
    - Japan, USA – ferroelectrics
    - Ghent, TUE, TUD – III-V/silicon photonics
    - Switzerland – lasers, high fields physics

- USA, Japan, Korea – optical comms
- Germany – high power lasers, LEDS
- USA, Japan – LED research
- USA, Taiwan, Japan, Korea, Germany – LED exploitation
- USA and Far East – projection and light modulation

6. What would you expect to see in a good first grant?

- Meaningful support from employer
- Cohesive achievable plan
- Potential for follow on projects/growth
- Foundation for career development
- Enthusiasm for topic – new thoughts
- Ability to apply for 3-year project studentship
- A plan for further long term research development
- Future potential rather than track record
- Potential for independence
- Innovation, quality and vision
- Fresh ideas
- Potential for collaboration and development of interactions

7. What would you expect to see in a CV for an internationally-leading researcher?

- Good portfolio of plenary/keynote/invited talks
- Significant number of high quality relevant publications/book chapters
- Portfolio of grants (PI)
- Links with industry
- Supervision of PhD students/PDRAs
- Number of primary patents and patents that create wealth
- A combination of citation index, H index (depends on the area)
- Chairing conferences/TPCs
- Editorship International journals
- Fellowships (FRS/FREng/FOSA)
- Awards (Nobel, Millennium Prize, IEEE, OSA, IOP etc)
- Influencing/advising national and international policy (gov and sector
- Visiting positions
- Spin out activity
- PDRAs moving onto academic jobs/high profile industry labs
- Research outputs influencing new research and/or products/society
- Coordination of large research projects

- Invited to review international projects
- Leading visionary research initiatives

8. What is the next quantum leap for research in your area?

- Fast, low energy optical switch
- Electronic/optic integration
- 1eV materials lattice matched to GaAs for photonics
- Efficient green LEDs
- Active camouflage
- Non-quantum classical approached to key distributions (secure communications)
- Deep UV laser (semiconductor)
- Deep UV LED
- Nanophotonics source/waveguide/detector integration
- Highly dynamic highly granular networks
- Low power system components (green photonics)
- Green semiconductor laser
- Silicon light source
- AI technique in networks
- Optical buffer
- Ultra low power, ultrafast optical switch
- Integration of photonic components at approaching CMOS scales
- Materials for light modulation and projection devices
- Green VCSEL
- High brightness green LED
- True exploitation of mid-IR sources and the means to transfer light
- Effective single photon sources
- Fully printable high efficiency devices (displays, photovoltaics etc)
- On chip/on board interconnects (printable photonics)
- Faster switching electro-optic devices
- Application programmable optical routers (hardware)
- Fully integrated fs sources (OPO/Ti:Supp replacement)
- Pure semiconductor while lighting
- Reducing the cost of high brightness LEDs (requires basic research!)
- Converged communication and sensing networks
- Polarisation based devices
- Material with low optical loss
- Tb/s to the chip
- Large area printed photonics (reel to reel)
- Non-industrial chemists producing new organic electronic materials

9. **What is your perception of multidisciplinary working?**
    - Multidisciplinary (different disciplines working effectively together on a common problem) vs interdisciplinary (problem is defined at boundaries between disciplines)
    - All disciplines must be strong and targeted properly
    - Communication is key (initial effort required to communicate effectively)
    - Leadership is important/essential – a team of leaders
    - Beneficial intellectually and supports small groups by enabling broader interaction
    - Assessment – how to rate value of research
    - Conception
    - Hard work but worth it – many new insights and advances from such work
    - Difficult to review
    - Stimulating – essential, no one has the answer by themselves to any particular sensing problem
    - Critically important for the breakthrough
    - Application/user driven systems and technology development
    - Peer review problem – often "caught in the middle"
    - Current peer review process not suitable to correctly assess multidisciplinary proposals
    - Peer review and panel evaluation not fit for purpose
    - Research in new measurement systems to solve problems, lab or industrial, needs multidisciplinary team - applicants

10. **Of all our funding mechanisms (fellowships, first grants, platform grants, networks) which do you think are most effective and which needs to be encouraged more?**
    - Responsive mode
    - Programme grants
    - Fellowships – to individuals, not just PDRA funding, excellent for right individual, best targeted at early stage career
    - First grants – 2 years too short – allow PhD support (3-3.5 years), higher success rate expected, universities need to provide real commitment, £125k for first grant not enough, first grants should be 3 year duration – competitive with project student
    - All can be effective
    - All are important for different purposes

- List above omits responsive mode, achieving 30% success rate on these should be top priority
- Need a balanced portfolio of types of grant
- Responsive mode: kill off programme grants

11. What should the balance be between fundamental/applied, hardware, software research in the ICT programme?

- Fundamental research should be informed by system/applied constraints – best research is a balance between both, use road-mapping to inform research portfolio
- Managed balance vs panel outcomes
- In photonics spectrum – fundamental – applied
- Fundamental: no application known 25% of money, Applied: some possible application envisaged 75% of money
- Hardware: 90-80%, Software: 10-20%
- Funding reflect the fact that hardware/device research is expensive, software is cheap
- Fundamental research should have an application focus

12. What are the barriers to international collaboration?

- Money for joint research non EU collaborations especially USA, Australia, Japan etc
- Different national economic and political priorities
- Double jeopardy – refereed by both national funding agencies using different peer review systems
- EU system of reviewing poor
- EU funding more akin to TSB funding in UK
- Lack of properly designed international collaboration programmes
- Same procedure for big grants and for collaborative grants
- More small with easy evaluation process collaborative grants
- USA/NSF difficult
- Not enough bilateral funding mechanisms
- Funding
- EU funding over bureaucratic
- Taking on overseas students from an often excellent Master's pool

13. How would you like EPSRC to engage with you in the future?

- Consider NSF model of academic secondment to run programmes in EPSRC
- Direct contact with researchers

- Like: focused, personal emails on new calls, helpful staff when phoned/contacted, mock panels (especially new lecturers)
- Suggest: visit our labs and talk to us directly
- More researcher and potential user input to balance programme
- Better continuous dialogue with the community
- Community/user sandpits
- Let us know well in advance of new funding rules

SWOT Analysis of UK Photonics Research

The objective of this exercise was to seek the views of the community on the key Strengths, Weaknesses, Opportunities and Threats of particular relevance to the Photonics community. EPSRC will then look across the ICT portfolio to identify common issues from the different Theme Days where there is a need for intervention or to work with communities to build on strengths, exploit opportunities and seek to address weaknesses and threats.

STRENGTHS

There was a consistent view that the UK academic community was strong in Photonics with a critical mass of leading researchers with a strong international profile and a strong science base in Universities. A strong collaboration culture and willingness to engage with industry was identified as was an excellent record of start up companies and a string community of SMEs. Strengths across a wide range of photonics were identified as being in the UK for example semiconductor lasers, organic optoelectronics, optical communications, terahertz technology etc and some delegates felt there was good collaboration between researchers. The community was also felt to be a strong driver in European photonics initiatives (eg CLEO Europe and Photonics21). A notable strength is that photonics underpins a lot of other science and technology areas and is relevant to global issues such as energy and healthcare.

WEAKNESSES

The community was felt to be fragmented, lacking connectivity across research areas with ill defined boundaries regarding what is regarded as Photonics. It was thought that research council spend on Photonics is lower than international competitors and that timescales, a competitive environment and the ICT panel lead to funding issues. A development funding gap was also recognised as a weakness. A lack of support for start up companies was identified as was a lack of infrastructure. It was noted that only a limited number of medium/large companies are interested in Photonics in the UK and that there is a lack of appreciation for the impact Photonics could have on the economy. Delegates considered there to be a poor industrial base compared to the East and that leading R&D happening in the UK often fades away. A consistent observation was the lack of undergraduates in engineering and UK funded PhD studentships as was government policy and coordination between the research councils and TSB.

OPPORTUNITIES

There was a strong message that Photonics is thought to be all pervasive and can deliver a competitive advantage in the global marketplace. A major opportunity in Photonics was identified as its ability to address contemporary issues and underpin lots of other science and technology areas with Photonic integration and "green Photonics" hi-lighted as being important. The relevance of Photonics to interdisciplinary research was identified and various themes such as "computing in photonics", "photonics for energy", photonics for health" etc were identified. Sandpits to address key areas were also thought to be a good idea as well as a holistic systems approach to multidisciplinary working. Senior fellowships were seen as an opportunity as was the high quality of overseas students attracted to the UK. However, the UK community should be able to retain them. More generally, a Fraunhofer type model was suggested as was collaboration with the strong groups in the East.

THREATS

The biggest threat was thought to be a financial one with concerns over government funding, the impact the recession is having on industry, lack of profitability of SMEs, keeping up with the Obama spend and government funding strategy post credit crunch. International competition was also raised by most groups in particular the US, Germany, Switzerland and China and the lack of UK based industry and failure to manufacture was also noted. It was felt there is a lack of national strategy for applications of photonics and a failure to coordinate research councils and TSB. PhD recruitment was also felt to be a threat by some as was retiring academics. It was also thought that although programme grants offer opportunities for some, for others they are a threat.

The Future of Photonics

The aim of this session was to consider how Photonics has evolved in the past few decades and to spend some time thinking about what would be an ideal way for it to proceed in the future. Delegates were asked to hi-light what they felt the key developments have been since 1950 and what they would like to see happen by 2050.

1950 – 1970

- Photovoltaics
- Photodiodes
- Thermas/IR imaging
- Nonlinear optics
- Optical fibres
- Adaptive optics
- Laser invented
- First laser communications
- Holograms and holographic imaging
- Electromagnetic surface waves
- Liquid crystals
- Semiconductor lasers (Nobel prize)

1970 – 1990

- Liquid crystal displays
- Maitland and Dunn at St Andrews – Laser pioneers
- Surface enchanced spectroscopies
- CD invented
- Erbium optical fibre amplifier

- Optical fibre – first optical fibre comms link
- Diode pumped SSLs
- Femtosecond lasers
- Tunable semi laser
- Photonic crystal
- Laser printers
- Internet
- Organic LED
- Quantum well optical devices
- Commercial epitaxial systems
- STN-LCD UK invention
- STN-LCD for TV
- Quantum dot laser diode
- Optical fibre sensing

1990 - 2010

- GaN (GaN LEDs)
- Holographic displays
- DVD Blu-Ray
- Widespread internet
- Optical data storage
- 1st Blue LED
- 1st blue/violet LD
- Plastic optoelectronics
- Optical processing
- Flat screens
- Polymer displays
- Quantum dot lasers
- Multispectral sensing imaging
- Metamaterials
- Quantum cascade laser
- Gigabit Ethernet technology
- Microstructured fibre
- OCT/Imaging

2010 - 2030

- Optical wireless convergence
- Green semiconductor lasers and LEDs
- Laser pico-projects

- Printed photonics
- Plasmonics
- Networked managed power grid
- Large area fast switching ferroelectric LCDs
- Autonomous network operation
- Orbit solar power station
- Pure semiconductor white lighting at low cost
- Full spectrum solar cell
- Fibre to the home
- E-paper for all
- Photovoltaic paint
- 3D displays
- HD laser TV for home cinema
- Low loss conductive material for nanophotonics
- Tuneable climate control films
- Widespread use of polymer-based lighting
- Practical quantum crypto
- 1GE to the end user
- Commercial polariton lasers
- Immersion displays for vehicles
- Remote diagnosis surgery
- New HCI technology
- Photonic-electronic integration
- Photonic bio-implants
- Optical switching
- 20 Tb/s to the chip
- Global distributed computing
- Optical regeneration
- Artificial eyes and retinas
- Adaptive camouflage
- Solar panels widespread
- Photonic elements in quantum computing
- Optical buffers
- Mid-IR sources
- Dynamic all optical networks
- Laser fusion
- Sub diffraction limit imaging
- Metamaterial applications
- Secure QC systems

2030 – 2050

- Carbon communications
- Optical tricorder – compact multisensory device
- Hybrid opto/bio/silicon computing
- Artificial photonic nervous system
- Head up displays for all
- Optical computers
- Low cost industrial laser
- Photonics on the chip
- Quantum computation
- Nanoscop
- Light emitting fabric
- 3D displays
- Optical memory
- Switchable volume hologram ("holodeck")
- Fibre to the home

And Beyond…

- Replace electronics, last transistor mode
- Politicians support UK Photonics and fund adequately
- Distance unlimited secure communication

Delegates were then asked to use these ideas and in their groups discuss how they would achieve a vision for the future and who and what they would need.

Photonics Enabled Society

End to end Photonics and enabling systems:
Sensing
Communications
The Human Interface
Energy

How do we get there?
Full integration of IT and commuications
Unite the community under many grand challenges – to get a strategic direction from all of the community
Social and business verification – influences

What do we need?
Now to 10-50 years to social impact
Strategic funding (£30-40M over 3 year initially)
Lots of input from all communities (business, media, social, medical, public)
Communities talking same language and openly communicating

Solar Panels in Space
- power transmitted back to earth/bring sunshine

What is needed?
Space station
Big solar cells (broadband)
Concentrator
Fibre lasers
Greenhouses
? Non linear optics
Reverse to super-continuum
Energy from sun converts to 1 wavelength – photosynthesis

Who is needed?
ESA
Glass specialists
Biologists

The Last Transistor

Large scale optical integration for information processing
Low power
New type of fabrication
Why? Overcome Moores

How do we get there?
Expertise – materials, device concepts (interface physics and engineering), systems architecture, brain experts, physics, biophotonics
Who to influence – national security agencies, Intel, military
Proposal timeline – 30 years
Steps along the way – 1a Integration of photonics and electronics
1b All carbon approach
2 Optical logic gate (materials that switch)
3 New fabrication technology
Number of people globally = 5000

Number of people feasibility = 30

Ubiquitous (Tricorder) Sensor

Compact multifunctional sensor:
Integrated system
Data transmission
Drug delivery application
Energy harvesting devices
Full health evaluation/monitoring

How do we get there?
Interconnects – human/computer interface
Fast readout
Biocompatible
Label free
Fast IT interface
Pattern recognition/machine learning
Reconfigurance hardware (electronics)
Micro-machining
Multipowered System (harvesting)

What do we need?
More funding for long term medical device research
Systems integration

Appendix 1 – Objectives and Agenda

Objectives

- Bring together the research community covering Photonic Materials, Devices and Design in order promote dialogue and a constructive relationship with EPSRC
- Gather and exchange views on the health of the discipline in the UK and explore upcoming opportunities and threats for the area
- Stimulate discussion about innovative approaches to further raise the profile of Photonic research in the UK
- Feed into a future strategy for the ICT programme

Agenda

10:00 Registration & Coffee
Delegates are encouraged to complete the "Perceptions of UK Photonics Research" poster over coffee.

10:30 Welcome
Katie Blaney – Portfolio Manager, Photonic Materials and Devices

10:40 Introduction to the ICT Programme
Liam Blackwell – Head of ICT Programme

11:00 Plenary Session 1: Wider Issues
Delegates will be asked to consider a number of general questions relating to ICT/EPSRC funding and policy in small groups.

11:45 Plenary Session 2: Open Q&A
Your chance to ask the ICT team any questions that you have.

12:30 Lunch

13:15 Breakout Session 1: Analysis of UK Photonics Research
Delegates will break out into small groups to provide a Strengths, Weaknesses, Opportunities & Threats analysis of the UK Photonics research.

14:15 Plenary Session 2: Feedback and Discussion of Opportunities
Groups will feedback their key opportunities for the community with time for discussion.

14:35 Coffee Break

14:50 Breakout Session 2: The Future of Photonics
Delegates will breakout into small groups to explore how Photonics research has developed over the past 50-60 years and how they would like it to develop over the next 50 years

16:20 Wrap Up and Finish

Appendix 2 – Delegate List

Richard Abram	Durham University
Duncan Allsopp	University of Bath
Ivan Andonovic	University of Strathclyde
John Bagshaw	BAE Systems
Martin Dawson	University of Strathclyde
Andrew Evans	Aberystwyth University
Ian Galbraith	Heriot-Watt University
Nathan Gomes	University of Kent
John Goodby	University of York
Denis Hall	Heriot-Watt University
Matthew Halsall	University of Manchester
Duncan Hand	Heriot-Watt University
Mohamed Henini	University of Nottingham
Ian Henning	University of Essex
Tim Holt	University of Strathclyde
Colin Humphreys	University of Cambridge
Edmund Linfield	University of Leeds
Stefan Maier	Imperial College London
John Marsh	University of Glasgow
Goran Mashanovich	University of Surrey
Steve McLaughlin	University of Edinburgh
Eoin O'Reilly	University College Cork
Chinthana Panagamuwa	Loughborough University
Richard Penty	University of Cambridge
David Richardson	University of Southampton
Patricia Scully	University of Manchester
Angela Seddon	University of Nottingham
Alwyn Seeds	University College London
Dimitra Simeonidou	University of Essex
Benn Thomsen	University College London
Martin Tillin	Sharp Laboratories Europe
Sergei Turitsyn	Aston University
Tao Wang	University of Sheffield
Ian White	University of Cambridge