Institution: Bangor University

Unit of Assessment: Panel B, UoA13, Electrical and Electronic Engineering, Metallurgy and Materials

a. Context

Bangor University, School of Electronic Engineering (BUEE) has used its research to: support industry and industry-facing government initiatives; provide expert advice in legal processes; and engage in outreach activities.
The main types of impact effected by BUEE were: supporting two company spin-outs and one transfer of a company from the public to the private sector; actively working with organisations and participating in projects supporting industrial activity; providing the manufacturing industry with access to its expertise and facilities; and implementing educational outreach initiatives.
The research, expertise and networks of the Organic & Bio-Electronics (OBE) and the Optical Devices & Systems (ODS) groups in BUEE has enabled both to contribute to all such types of impact.

b. Approach to impact

Staff interaction with key non-academic users has been effected by engaging successfully with international, national and regional schemes which facilitate interactions with non-academic users including industry and the wider public, winning support from the EU (ESF, ERDF and Inter-Reg funds); UK national programmes (KTP, TSB and the HEFCE/ HEFCW HE-STEM programme) and the Welsh Government £70M 'Academic Expertise for Business' (A4B) scheme. The capability for such engagement is provided by the availability of the infrastructure and equipment which also underpins research. BUEE has enabled its staff to provide (a) both open and commercial access to its facilities and (b) expertise to industry and notably to SMEs and micro-businesses. BUEE has also commercialised its research via Laser Micromachining Ltd and Smarter Light as shown in the accompanying Impact Case Studies.

The nature of relationships with the industrial sector is evidenced by the in-house SME Industrial Development Bangor (IDB) Ltd which has traded for well over 30 years. In 2011, with support from BUEE for legacy activities, the transfer of IDB to the private sector was effected. IDB has served as a vehicle for exploiting research expertise including electrostatics (**Taylor)** and radio navigation (**Last**) and led to recent expert witness activity: the former in relation to a US patent rights case (2010) and the latter to the analysis of GPS data to determine the location of criminal trial defendants (2011-2012).
BUEE is a partner in the Swansea University-led ERDF-funded pan-Wales project on advanced manufacturing 'ASTUTE' (2010-2015) through which BUEE provides industry with access, including technical support, to its state-of-the art clean-room and surface analysis facilities.
Plastic electronics research led by **Taylor** underpinned an A4B (Academia for Business) project 'An Inert Environment Fabrication and Characterisation Facility' (2008-2009) which has enhanced clean-room capabilities and led to close interactions with SmartKem Ltd (a start-up developing inks for the plastic electronics sector). Beginning with small, confidence-building projects and developed through sKTP, KTP, A4B and ASTUTE projects, his group has become the primary vehicle for initial electrical screening of SmartKem's new materials. **Taylor** and IDB were invited to participate in a TSB project on printed security tags (CHBS/004/00091C,2008-2010) with industrial collaborators General Vacuum Equipment (GVE), Scott-Bader, CAMVAC and several small companies and consultancies, who supported a successful follow-on bid for a Flagship Grant to the Innovative electronic-Manufacturing Research Centre, Loughborough (FS/01/01/10).
Spencer led a collaboration with Swansea University in a Knowledge Transfer Centre in Semiconductors and Photonics (2010-2012); **Kettle** is leading engagement in the Wales-Ireland Network on Innovative Photovoltaic Technologies (WIN –IPT), an industry-driven ERDF-funded Inter-Reg project (2012-2014) designed to promote innovation and enhance business opportunities for SMEs (Solar Print, Pure Wafer Solar and Haydale Engineering) in Photovoltaic technologies.
Other international industrial interactions include participation of **Tang** and **Giddings** in the EU ICT advanced optical communications 'Alpha' project (2008-2011) involving 12 European companies.

Optoelectronics research led by **Shore** led to his engagement, since its inception in 1995, with the Welsh Optoelectronics Forum – the photonics trade association in Wales. Building on that engagement **Shore** conceived and led the pan-Wales Photonics Academy (PA) for Wales (2005 - date) which develops education and training in photonics to meet industry needs. With support from the Welsh Government and the Sector Skills Council SEMTA the PA pioneered photonics technician training via the Technicians in Opto-electronics (TOP) project (2006-2009). In 2011 the Photonics Academy of Wales@ Bangor (**PAWB**) was established as a focus for BUEE activities in photonics outreach, training and pedagogical research. **Campo** was the lead organizer of the Materials Research Society Spring 2013 Education Symposium on "Towards a Lab to Classroom Initiative".
Interactions between BUEE and the wider community have also been enabled via the prestigious Annual Engineering Lecture series with, for example, the 2010 presentation being made by Richard Parry Jones, then CTO of the Ford Motor Company.

Follow through to identify impact is evidenced from **Taylor's** KTP programmes with Smartkem in which Watson (KTP Associate) has supported (a) the generation of new production processes relating to organic semiconducting inks, (b) exemplification of SmartKem materials resulting in the publication of 8 patents (WO/2012/ 164282 and the series WO/2013/124682 to 124688). These activities have led to a full understanding of SmartKem's semiconductor material characteristics, generation of characterisation data for product sheets and supported early ink sales. The use of extensive bespoke TFT test data for the display industry has been significant in supporting the creation of new customer joint development agreements and marketing opportunities, specifically with a major European chemical company and a prominent Taiwanese display manufacturer. Through publication of test data in the press and academic and trade journals, SmartKem has gained national and international recognition as a leading supplier of organic semiconductors for flexible display manufacture (finalist at the upcoming IET Innovation Awards, IdTechEx Asia Winner for New Materials, invited to speak at FlexTech 2014, SID 2014, expert member of IEC standards committee for Printed Electronics and invited member of the Plastic Electronics Leadership Group, in addition to invitations from a publishing house to draft a book on Flexible Displays). TSB-supported work by **Taylor** with GVE and CAMVAC improved the marketing position of both companies. In the project final report GVE confirmed that pressure to improve selective metal coating resolution for organic electronics led directly to the sale of 3 high-resolution, high-value machines to Asia. **Tang** received A4B funding (2009) for a feasibility study into 'The Development of High Speed Optical Modems' which is now being commercialised via the Smarter Light spin-out. **Shore** obtained funding from the 2010-2011 HEFCE/HEFCW HE-STEM programme to support work by PAWB developing techniques for photonics up-skilling. This led to PAWB (a) achieving Europe-wide impact of its work through delivery of a photonics challenge to 27 EU post-graduate students at the 2011 European Society of Precision Engineering and Nanotechnology (EUSPEN) summer school held at the Institute of Manufacturing, Cambridge University and (b) gaining the ERDF-funded work-based-learning project 'Optics and Photonics Up-skilling for Industry' (2013-2015) which will raise skills levels in the photonics industry cluster in Wales.

An agile approach by BUEE to achieving impact is evidenced by the broad spectrum of activities indicated above. The readiness to rapidly respond to such a variety of opportunities is rooted in activity within the 2001-2008 Welsh Government 'Centres of Excellence in Technology and Industrial Collaboration' (CETIC) scheme in which both of BUEE's research groups were funded to establish 1) the Institute for Bio-electronic and Molecular Microsystems (IBMM) led by **Taylor**; and 2) Industrial Commercial Optoelectronics (ICON) led by **Shore**. IBMM and ICON employed dedicated commercial managers who provided practical means for interaction with industry and government including participation in both in-coming and out-going international trade missions. **Spencer** has been pro-active in the development of the regional economy including the development of nearby Anglesey as an 'Energy Island' and in the establishment of the University Arts and Innovation Centre 'Pontio'. Within Pontio BUEE will lead activities in a £9M innovation/ engagement space aimed at fostering interdisciplinary research to strengthen the local economy. The parallel development of a Bangor Science Park with a £10M Welsh Government strategic investment will provide a focus for future spin-out of BUEE research activity.

Staff are enabled to achieve impact by the provision of specialist equipment e.g. under the ASTUTE project, **Kettle** installed a solar test bed used to assist the SME Egnitech and is key to the WIN-IPT Inter-reg project; **Taylor** was provided with an environmental chamber used in work with SmartKem. Staff may take leave of absence or reduced working time to commercialise their research. **Burt** has been 70% seconded to the LML spin-out since 2008; **Tang** has had reduced teaching duties to spin out Smarter Light. The research and development work performed by **Tang** was recognised in his early promotion to a personal chair.

Institutional support for these activities is provided by the Research and Enterprise Office (REO) which assists in establishing links to sources of government support (e.g. Finance Wales) and access to patent and proof of concept funding. For example, REO has provided support for IP protection and introductions to venture capitalists in respect of the spin-out of Smarter Light. University policy allows staff to undertake consultancy either in a private capacity or via Bangor University Ventures.

c. Strategy and plans

The core of the BUEE strategy is to utilise its expertise and infra-structure to both advance research and to deliver non-academic impact of its research in Organic Electronics and Photonics. The development of a 'Green Electronics' research theme following appointments in 2012 of **Campo, Chen, Giddings** and **Wang** and in 2013 of **Hong, Nezhad** and **Pelago** enhances the scope for generating impact and specifically in relation to the Anglesey 'Energy Island' Initiative. In the longer term, the prospect of new nuclear power capacity will provide many opportunities for delivering non-academic impact, including provision of technical support and work-force up-skilling. Two major infra-structure investments will further enhance future capabilities:
Kettle leads the 'Centre for Lifetime and Reliability Testing', established in 2013 with £500k A4B funding to provide a facility, managed by a dedicated Business Development Manager, for organic electronics research and the support of industrial end-users. **Shore** is leading the procurement in 2014 of a £2M A4B-funded facility for 'Precision Optics Fabrication with Ion-beam Technology' which will provide a major development for precision optical manufacture in collaboration with Qioptiq and Cranfield University. Impact will be further enabled through:

- The £9M Welsh Government-funded National Research Network (NRN) (2013-2018) in Advanced Engineering supporting collaborative PhD projects between industry and HEIs ;
- The £46M Bangor University Arts and Innovation Centre 'PONTIO' which, from 2014, will operate as a centre for cross-disciplinary developments to support the regional economy.
- The Bangor University Science Park, planned for completion in autumn 2014, and which will provide facilities for business incubation and university spin-outs.

In-house developments with commercialisation potential for products and services in the health care sector include work led by **Hancock** on Medical Microwaves.

In addition to delivering work-based learning approaches to photonics up-skilling for industry, activities within PAWB will be extended to outreach activities including schools and community groups. Having supported efforts by the European Physical Society to obtain UN designation of 2015 as 'The Year of Light', PAWB will participate enthusiastically in the opportunities thereby offered for public outreach. Educational outreach will also be pursued within the MRS 'Towards a Lab to Classroom Initiative'.

d. Relationship to case studies

The LML Case Study encapsulates the BUEE approach to achieving non-academic impact: research-driven investment in laser micro-machining facilities led to industry-facing activity within the IBMM CETIC and the DTI-funded UK Laser Micro-Machining Centre which led to the spin-out of LML. Exploitation of pioneering research in optical communications technology was initially enabled by a feasibility study undertaken with A4B funding which established a pathway for exploiting the technology including the establishment of the Smarterlight spin-out company.