Institution: Lancaster University
Unit of Assessment: B9

a. Context

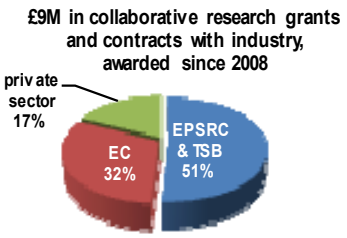
Physics research generates economic impacts and stimulates Europe's future prosperity and growth. The end-users that benefit from our research include SMEs in the UK and multinational companies specialising in oil exploration, software products, optoelectronics, communications and high-tech instrumentation. Through our public engagement activities, our research impacts society and culture, with the audience including professionals, school pupils, and the general public. By using international networking, building research communities, and working with national and EU decision-making bodies we contribute towards the globalisation of science and technology and facilitate the integration of national research policies with the international effort.

b. Approach to impact

Innovation and impact generation in Physics is built upon world-leading research and the unique expertise of our staff. Building pathways to impact is a substantial and constituent part of our academic routine, firmly incorporated into staff development, workload allocation model, and University promotions criteria. In our approach to impact we balance the following four elements:

i. Development of pathways from our curiosity-driven studies to innovation platforms for future technologies, involving key stakeholders in our pioneering blue-sky research.

- We attract users by our excellence and take every opportunity to generate the physical presence of businesses on-campus. Our effort in channelling knowledge into innovation is coordinated by the Knowledge Exchange Committee in Physics and is assisted by the HEIF-funded Head of Business Partnerships and Enterprise. Examples include our work with QinetiQ (Jefferson was an honorary professor at Lancaster, collaborating on 3 CASE/ICASE awards) and Asahi-Kasei Microdevices Corporation in Japan (Fujita seconded to Lancaster for a joint quantum dots project in 2012-2014). The University Contracts Office helps us formulate and exploit IP rights, and three spin-out companies have been created, based on know-how derived from our research: Anasys Instruments Ltd; Quantum Epitaxial Devices Ltd; and Lancaster Cryogenics Ltd.
- To build long-term relationships with industry, based on common goals in functional materials and instrumentation development, we develop impact plans and engage with companies, from the first stage of grant applications. Our TSB-EPSRC-, and EC-funded projects involved 24 end users such as IBM, Fiat Research Centre, Nokia, RWEnpower, VARTA Microbattery, Veeco Instruments, Thales, NT-MDT Europe, Bluefors Cryogenics (up from 9 in 2001-2008).



- Broad dissemination of exploitable results of our blue-sky research and our search for new partners has been facilitated by access to the EPSRC Pathways to Impact Award. For example the 2011 workshop *Geomagnetically Induced Currents in National Power Grids*, at Lancaster, led to new partnerships with UK National Grid, Scottish Power, and the Department of Energy and Climate Change.

ii. Demand-driven research contracted by industry, fulfilling needs-driven innovation.

- We help companies, large and small, to solve pressing problems, improve processes and products, develop specialised instruments, and win/defend market position. This effort is facilitated through institutional support from ERDF, HEIF, Business Partnerships and Enterprise Unit, and the Contracts Office. We participate in a £0.6M EPSRC Impact Acceleration Account scheme that provides seed funding for projects with a clear collaborative exploitation plan with named businesses, 12-month post-doctoral fellowships, co-funded 50-50 with the private sector and 6-month PG fellowships addressing tightly focused innovation objectives; 7 such grants have already been awarded to Physics. Further exploration of previously established collaborations enabled us to attract new research contracts and studentships from BP, NPL, Oxford Instruments, Oxley Development, HMGCC, Kidde International, and Oclaro: over £1.5M in 2008-2013, including 7 CASE, ICASE and Centre for Global Eco-innovation awards.

- Responding to the needs of industry, we developed a new class of super-surfactants in the British Petroleum *Enhanced Oil Recovery* project. Backed by the EPSRC Science & Innovation Award '*Maximising Impact of Graphene Research on Innovation*', our theorists helped SME Graphene Industries Ltd to optimize production and market a new product. We develop dilute nitrides and Sb-based quantum dots for diodes, gas sensing (with Tyco Fire Protection Products Ltd), telecommunications lasers (with Oclaro Plc), thermo-photovoltaic arrays to harvest waste heat in glass and steel industries (with Pilkington, Tata Steel, IQE, CST), and tools for large area nano-cross-sectioning and subsurface nano-mapping of semiconductor devices and nanomaterials (based on 3 filed patents). Our new image processing techniques for remote camera systems with night-vision capability have helped a consistent annual expansion of EnvironVision Solutions, a South African company focused on fire prevention of commercial forests and the urban interface.

iii. Outreach facilitating public understanding of science, professional training and education, from the local to international level.

We give public engagement and outreach activities a very high priority. Most of our staff actively participate in public engagement and dissemination events, facilitated by our dedicated IoP/Ogden Trust Teacher Fellow, an STFC Science in Society Fellow, the Lancaster-based IoP branch, and the University support for public events and school talks. With a median of 760 attendees per year over the REF period, our 2012/13 activities involved 1000 participants (school pupils and public) who returned an enthusiastically positive feedback (89% marks 4/5 and 5/5).

- Examples of our activities include '*Physics Enrichment Days'* and laboratory visits for school pupils, the *Ogden Physics Residential course*, support sessions for school science teachers, the regional public lectures series '*Making Waves'*, participation in the 2010 Royal Society Summer Exhibition, the 2012 Cheltenham Science Festival, 2012 British Science Festival, and the 2009/13 Big Bang Fairs. Research in space weather and the Lancaster-based *Aurora Watch* has attracted over 100,000 individual users, several BBC broadcasts, and featured in the IoP produced film '*Physics Lives'*, which won a 2013 British Film Institute Award. We developed and maintain a *Particle Physics Masterclass* aimed at filling gaps in secondary school teaching that provides updates on particle physics discoveries and LHC research, and includes a purpose-developed virtual laboratory simulation package, which is recommended by the IoP to their Physics Champions and is part of the CERN Particle Physics Outreach package.

iv. International networking, at all levels, aiming to optimise and advance the UK and European science and innovation policies.

The reputation and esteem of our staff enable them to form communities and develop relationships with decision-making bodies and policy makers.

- The portfolio of our influence on the innovation policy in Europe includes shaping the international graphene community (co-organized 14 conferences), initiating a 16-country €7M ESF Eurocores Programme, driving the *Graphene Science and Technology Roadmap* [Nature 490, 192 (2012)], and leading roles in setting and running a €1Bn European *Graphene Flagship* initiative in FP7 and Horizon2020 EU framework programmes.
- The Grid user interface GANGA, developed by our particle physicists with Birmingham, Bristol and ICL, is being used by ImensePictureSearch, IlexIR and Econophysica. Our large scale data handling was highlighted by The Rt. Hon. George Osborne MP in his 2012 speech at the Royal Society and led to two white papers prepared with Dell Inc.
- Our space weather research has influenced the development of a UK space weather strategy. Following a Parliamentary Select Committee investigation "*Scientific Advice and Evidence in Emergencies*", a *Space Environment Impacts Expert Group* was set up to provide advice to the Cabinet Office (chaired by Prof. Hapgood, visiting Professor at Lancaster), leading to the inclusion of space weather in the *UK National Security Strategy* (since 2010) and the *UK National Risk Register* (since 2012).

c. Strategy and plans

Our long-term strategy is to employ, consistently and systematically, our approach to impact (i-iv), additionally enhanced by the following new initiatives and targets:

- **To bring industrial R&D and SMEs onto campus, by providing access to our research infrastructure.** In a new initiative, spearheaded by our Quantum Technology Centre (QTC) and facilitated by the Business Partnerships & Enterprise Unit, we will use *Technology Access*

Vouchers to cover external access to our established core research infrastructure, the QTC nanofabrication suite commissioned in 2013, and a new *IsoLab* characterization facility. New strands of QTC research will contribute to the EU *Interreg IVB North West Europe project NANORA* focused on knowledge exchange in nanotechonology. We will expand the development of devices for advanced optoelectronics and energy harvesting; create quantum repeaters/routers for quantum networks (founding a new company with Cisco); devise transferable standards for electrical resistance and current (with NPL Plc); and create new instruments for scanning microscopy (with Bruker UK and Anasys Instruments Ltd). Our latest spin-out company Lancaster Cryogenics Ltd will expand commercialisation of our know-how in cryogenic technologies and develop the next generation of marketable ultra-low temperature cooling techniques and metrology, and we shall design and test new ultra-low thermometry tools with Oxford Instruments. From 2017-2018, we plan to embed these activities into the new Lancaster University Innovation Campus initiative.

- **To broaden the users group and widen participation of staff and PhD students in our engagement with businesses.** We will consistently support researchers with a track-record of working in partnership with businesses. Our engagement with companies will be enhanced by the EPSRC Impact Acceleration Account scheme, participation in the North of England Universities Partnership *N8*, involvement in the *National Graphene Institute* at Manchester, the ERC Synergy grant *Hetero2D*, and the EU *Graphene Flagship*. Co-design of innovative early-stage ideas will be explored via potential opportunities workshops and one-day *ImaginationLabs* (using design-led approaches developed by the Lancaster Institute of Contemporary Arts), helping staff to resolve their concerns with regard to the formation of university-SME partnerships and via short secondments of early career researchers and PhD students to enterprises with suitable profiles.
- **To improve education and culture by facilitating public understanding of research.** We will broaden our engagement with public audiences at the local, regional and national level, supported by Lancaster's commitment to the RCUK *Concordat for Engaging the Public with Research* and the '*Inspiring the Next Generation of UK Researchers*' grant (RCUK). We will use these resources to embed media skills training and active outreach engagement into our structured PhD training program and the professional development of researchers and staff. Our new strategic partnership with the South Lakes Teaching School Alliance will enhance direct, regular, and structured engagement with students, and we will use our research findings to support teachers in their professional development. We will expand the *Particle Physics Masterclass* and *Physics Enrichment Days* program. Building on experience and best-practice from recent activities we will target major science festivals and venues (for example, we will co-develop museum-scale graphene S&T exhibitions for Universeum in Gothenburg, Deutsche Museum in Munich and the Science Museum Group in the UK).

The key metrics we will use to monitor the progress in the realization of our strategy will be:

- the resultant cash value of industry-funded contracts (including SME expenditure on collaborative R&D with Lancaster), with a target to double its volume over the next REF period;
- the volume of joint publicly-funded projects with industry (to be maintained) at the current high level) and the number of joint PhD projects with companies (which we plan to double);
- the number of members of the public engaged in our outreach activities (which we aim to increase by 50%) and their feedback (which we will sustain at the high satisfaction level).

d. Relationship to case studies

Our Impact Case Studies illustrate how curiosity-driven research in our key subject areas has led to innovation, commercial exploitation and cultural enrichment of the public. We report on how nanoscale photo-thermal microscopy for chemical analysis of materials, developed and patented at Lancaster, created a successful spin-off *Anasys Instruments*. We show how technology, developed for extreme performance dilution refrigerators at Lancaster, has been transferred to manufacturers of cryogenic equipment. We show how our science-driven modeling effort helped a SME *Orcina* to improve their commercial software package for controlling offshore marine systems. The '*Aurora Watch*' case drills into how our citizen science activities contributed towards cultural enrichment of the population of the UK. The lessons learned from these and other similar efforts helped us to formulate our approach to impact employed in the REF period and to set our plans for the future.