Institution: Durham University

Unit of Assessment: 9/Physics

a. Context

The measurable impacts of Durham Physics over the REF period are predominantly economic, including **creating new businesses via spin out companies, improving the performance of existing businesses** and **commercialising new products**. However, we also have impact on **informing public policy, progress towards sustainable development, improved National Security, healthcare** and **cultural enrichment**. This range in impacts reflects the breadth of research in the Department. Research groups working on understanding and developing new materials (Condensed Matter Physics CMP) and on building advanced technology (Centre for Advanced Instrumentation CfAI) have multiple opportunities for potential economic impact. The less applied research groups (Astronomy and Astrophysics, Elementary Particle Physics, and Atomic and Molecular Physics) instead have a long history of contribution to cultural enrichment, especially in public understanding of science.

Durham also has Institute structures which cross departmental boundaries, enhancing multi-disciplinary collaboration. Physics hosts two of these (Institute for Particle Physics Phenomenology and Institute for Computational Cosmology), has leadership of the Biophysical Sciences Institute (BSI, Director is Prof Girkin, Physics) and makes major contributions to the Durham Energy Institute (DEI), the Institute for Advanced Research Computing (iARC), the Wolfson Research Institute for Health and Wellbeing (WRI) and the Institute for Advanced Study (IAS). Proctor & Gamble (P&G, a US $80Billion turnover company) Vice President for Global Business Development recently cited Durham University in general and the BSI in particular as a global leader in multidisciplinary research in a speech to all 50 US State Governors, while their Vice President for Technology used Durham Physics as an exemplar University-academic partnership in a letter to the UK Prime Minister, David Cameron.

b. Approach to impact

The Physics Department has a proven track record of commercialisation of research, established over decades of working with industry. Our approach is to engage flexibly and creatively with external stakeholders to maximise the impact of our research. We make use of University-wide facilities to support this, with the Research Office (RO) facing towards grant providers, the Communications Office facing towards the public and the Durham Business and Innovation Services Unit (DBIS) facing towards Industry. DBIS is especially relevant for many of our impacts, as it promotes contacts with Industry, facilitates knowledge exchange, and advises on commercialisation via licensing/patenting as well as supporting spin out companies from early stage proof-of-concept onwards. It also encompasses legal services for contract negotiation with both single companies and large scale industry-academic partnerships, including MoUs and issues with Intellectual Property (IP). DBIS was formed by merging existing, more scattered, support mechanisms in the University into a 'one stop shop'. It is well-tailored to Physics requirements, in part because the Dean for University Enterprise (with responsibility for DBIS) is a member of our Department (Prof. Tanner associated with Case Studies Kromek and Jordan Valley). Prof Tanner received a Queen's award for Enterprise Promotion in 2012, the UK's highest accolade for business success, for his work on promoting enterprise skills both nationally and internationally over the last 30 years.

Another key University-wide facility for capturing and exploiting impact is NETPark (North East Technology science park), in Sedgefield, County Durham. This was started as a Durham County Council initiative for a science and technology business park, backed by Durham University taking a 20 year lease. Its focus is on developing technology in the physical sciences, supporting this by access to the early stage venture capital and taking it to market readiness,. The University uses NETPark's incubator as a place for spin-out companies once they outgrow accommodation within the University.

Durham Physics plays a major leadership role in NETPark, with its CfAI group and Kromek spin-out company as anchor tenants (see Case Studies Precision Optics and Kromek). The other large stakeholder is the Teeside based Centre for Process Innovation (CPI). They made a

commitment to move into printable electronics and successfully lobbied Government (BIS) for £20.5M investment in a national Printable Electronics Technology Centre (PETeC) at NETPark, helped in part by the research activity from Physics (see Case Study on Polymer Lighting). This stimulated a second phase of development on NETPark in 2008, with new buildings to house PETeC (opened by Lord Mandelson), and Kromek (opened by Prince Andrew). There is a three-way MoU brokered by DBIS between NETPark, CPI, and Durham University, committing the partners to working together to promote research, business and career opportunities in the North East.

The Department also supports interaction with its external stakeholders via:

1) Staff appointment, progression and promotion: Departmental strategy is to raise awareness of the Impact agenda, and to develop a culture in which the exploitation of IP generated in the course of research activity is a normal and automatic consideration. Impact is explicitly considered in appointments of new staff, and is a factor in staff progression e.g. Brinkman was promoted to Chair in 2007 with a citation which stressed his contribution to the Kromek spin-out company. The University also recognises and rewards impact in its Award for Excellence in Knowledge Transfer, which was won by Prof Brinkman in 2010. The Annual Review process for all staff members in Physics includes a section on potential impact of the research program to ensure that this is explicitly discussed, and there are mechanisms via DBIS to mentor staff who want to develop industrial links. The Department also encourages senior staff to have impact on public policy. Prof Frenk (FRS) was a panel member of the influential Wakeham (2010) report on funding UK Universities, while Prof McLeish (FRS) is Vice President of the IOP and Prof Love is a Council member.

2) Knowledge Transfer: Six postdocs in the Department have been funded through the KT route during the REF period. An example of the type of project covered is a £2.7M EPSRC Knowledge Transfer Account grant (PI Prof Tanner in Physics) to take Physical Sciences and Engineering research into the healthcare sector by collaboration with clinicians in Newcastle. The various EPSRC funding streams which come under this category (KTP/KTA/PIPPS/ follow on funds/pathways to impact/impact accelerator account) are all brokered and managed by DBIS. There is a strong tradition of our PhD students (140 trained over the REF period) and postdocs choosing to work with spin-out companies (see Case Studies).

3) Strengthening links with Industry: A key strategy to encourage impact and engagement is using the University Visiting Professor route to build relationships with senior scientists within Industry. Examples include Prof Michael Duncan (P&G Global Director of Connect and Develop, responsible for open innovation), Prof Geoff Williams (Thorn Lighting, see Case study on Polymer Lighting, who gained his PhD in Durham Physics) and Prof Keith Bowen FRS FREng (ex-Director of Bede PLC, see Case Study Jordan Valley). Prof Dave Robertson in the CfAI group holds a Royal Society Industrial Fellowship to work with Microsharp, where he has developed and patented techniques to produce thin film Fresnel lenses (see Case Study Precision Optics). The Department also supports secondments of personnel to/from Industry e.g. with P&G and Pragmatic Printing on NETPark.

4) Hosting Start-ups: The Department hires out space and infrastructure for early stage projects. All the spin out companies in our Case Studies started in this way. NETPark facilities are then available for companies which outgrow this space.

5) Outreach: Physics has a full time Outreach Officer (the first in the UK to be funded by a Research Council), who has had direct contact with ~15,000 school children across the age range, and over 500 of their current and future teachers over the assessment period. Additionally, teaching materials such as the DVD 'Gravity, Gas and Stardust' is seen by 100,000 secondary pupils per year. This work in strengthening science teaching and engaging children with education lies mainly outside of the REF definition of Impact but the significance of the program is enhanced by being in the North East, an area of high social deprivation. All students and staff have the opportunity for training in outreach activities, and we also host a series of Christmas Lectures for local schools, and have contributed several displays for the Royal Society Summer Exhibition. One of these was the Cosmic Origins 3D movie, a visualisation from an ultrahigh resolution computer simulation of the growth of a galaxy such as our own, an outcome of research published in Nature by Prof Frenk and his team in the Institute for Computational Cosmology (ICC). The movie won first prize at the international Stereoscopic Displays and Applications conference, held in Silicon Valley, California, beating Disney's 3D version of Sleeping Beauty'! Over 10,000 members of the

general public have seen the movie to date, directly engaging them with forefront research,

6) Student training: The training course for all postgraduate students includes sections on innovation and enterprise, IP identification and protection, and technology transfer mechanisms. At undergraduate level there is planned engagement with industry built into our third year syllabus, where students participate in a Team Project. Each Physics-related problem is set by an external organisation (mostly local industry), and is tackled by a group of ~6 students. An example project with Cottam Brush (an engineering company based on Tyneside with 30 staff and £3M annual turnover) explored the design of steel brushes used to detect flaws in natural gas pipelines. The team determined the efficiency of magnetic flux coupling through various types of brush, showing that the Cottam products outperformed those of a competitor, with direct impact on sales. The success of these team projects has led the Institute of Physics (IOP) to set up similar activities at other Physics Departments in the UK as part of the National Higher Education STEM Programme. These Undergraduate Industrial Group Projects based on the Durham model have now been rolled out in over 15 University Physics Departments, directly impacting other HEI.

The overall goal is that impact is embedded in Departmental culture, even in the less applied groups. The success of this is illustrated by an Astronomy research project using ultrahigh energy gamma ray telescopes. These rely on the atmosphere to form part of the detector system. Dr Chadwick developed a CCD based system to monitor haze in the atmosphere, and is exploring commercialising this for use at airports which currently use much more expensive technology. Another example is from the ICC 3D movie described above. Tracing galaxy formation across cosmic time requires enormous numerical simulations which stretch the capabilities of current computer systems. The ICC built links with SUN Micro-systems, who contributed an equivalent of $1.5M in equipment to build the massively parallel Cosmology Machine, the then largest supercomputer for academic research in the UK. Skilled staff in Durham benchmarked the performance and uncovered a problem in the use of shared memory on large multi-core machines. The solution by SUN led to a factor 50 improvement in performance. This was fed into openMPI, the standard open source operating system for parallel machines worldwide, with both commercial (e.g. banks) and research users benefiting.

c. Strategy and plans

1) Develop existing mechanisms to identify and quantify Impact, both from unexpected opportunities and where it is a planned outcome of a research programme.

The University has made an annual sum of £250,000 available for an Impact Seedcorn fund, allowing individuals, project teams or departments to bid for sums of up to £20,000 to support new Impact-generating activities. This is in implementation of its strategy “To deliver research in every discipline that addresses questions and issues with the potential to make significant impact on knowledge, people or the economy, or to enhance or change society for the better”.

2) Build long term, large scale strategic partnerships between Industry and academia, especially using the multi-disciplinary Institute structures.

Such partnerships can address the fundamental science that underpins commercial activity, where typical projects have a 5-10 year horizon before being close to market applications. An example of this is the relationship built between Durham University and P&G. This was initiated with a project based in the Physics Department to develop detergents that can wash at lower temperatures and with smaller amounts of water to minimise energy costs and environmental damage. P&G were using optical microscopy to image the effect of detergent on fatty stains. However, fat itself acts as an optical element, so the images were distorted. Prof Girkin (BSI and a member of CfAI in Physics) used techniques from Adaptive Optics, developed to remove atmospheric distortion from large astronomical telescopes, into the process. This results in much higher resolution images, revealing new aspects of the physics and the chemistry taking place in as molecular bonds are broken and reformed in the washing cycle. This is interesting scientifically as well as being commercially important to P&G, and illustrates how cutting edge technology developed for research can have much wider applications.

This project also required input from Chemistry and Biology, and the ease of multi-disciplinary working was a factor in Durham being recognised by P&G as Global Business Development University Partner of the Year in 2011, and in being selected as 1 of only 20 out of an original ~200 Universities which P&G will maintain as partners. Another key factor was that DBIS set up a Master Collaboration Agreement to establish Durham University as a core strategic research partner. This framework makes it easy to start up new projects, as structures are already in place

for IP, circumventing the hidden barriers in starting up a single collaboration, where these issues have to be negotiated from scratch with each individual academic and/or Department. DBIS (rather than the company) identifies expertise and interest across the entire University relevant to any potential P&G project. This relationship was used as an exemplar in the Government report on 'Review of Business-University Collaboration' (Wilson 2012), and has secured more than £10M in external funding.

A similar strategic partnership has been set up with IBM, with an MoU signed in May 2013, and ones with Akzo Nobel (who bought ICI), the BG Group (formerly British Gas PLC) and several other global companies are close to completion.

d. Relationship to case studies

The Department's multiple approaches to promoting impact are illustrated by the Case Studies. These can be broadly classed into three categories:

1) Research driven Commercialisation: This includes the classic spin-out company model where the impact can be directly developed. One example of this is **Kromek**, set up with support from the University structures which are now part of DBIS. Initially the company was hosted on University premises until it outgrew these and moved to NETPark. **Ingenia** instead illustrates the mechanisms by which our undergraduate students can engage with the impact agenda. Prof Cowburn (FRS) set a final year research project to gather data on speckle imaging as a unique 'fingerprint' of the material. The results from this study were published in Nature, with the project student as a co-author, and this intellectual property formed the basis of the anti-counterfeiting spin-out company. Commercialisation can also be achieved by partnering (via DBIS) with an appropriate existing Industry, as illustrated in the **Polymer Lighting**, or via licensing as demonstrated by **Castep**,

2) Industry initiated commercialisation: Departmental structures are welcoming to Industry, as evidenced by Case Studies **Peratech** and **Farfield,** both of which started with an approach from industry. By contrast, **Durham Precision Optics,** which is still formally part of the Department, provides a specialist service to industry, again supported by DBIS.

3) Large scale programs with multiple industrial partners: A research area identified as having potential for impact can be developed in a large scale collaboration involving multiple academic and industrial partners. These are funded through a combination of grants and Industry, supported by the RO and DBIS structures e.g. the **Jordan Valley** Case Study. Such large scale engagement with industry is encouraged and is normative in Departmental culture. Similar programs (not chosen as Case Studies) include the Multiscale Polymer Processing collaboration, where Prof McLeish (Durham Physics 2008-present) led a 10 year systematic program with major international academic and industrial partners to develop a basic understanding of the bulk properties of plastics, including their flow behaviour in a broad range of environments. The research breakthroughs were incorporated into a set of tools which have revolutionised polymeric material design in Industry. Similarly, the £6.1M EPSRC SUPERGEN collaboration (PI Prof Durose: Durham Physics till 2011) mobilised 9 Universities, and 9 Industrial partners to investigate technological issues for all types of Photo-Voltaic cells for solar power generation. Prof Hampshire (Durham Physics and DEI) is part of the €15Billion ITAR project which is building the first commercially viable fusion tokomak. This uses low temperature superconducting materials to carry the large currents required to confine the plasma by magnetic fields. His current project is to detail the response of the system to the resulting thermal strains, but his ultimate goal is to re-design the next generation tokomaks using newer, room temperature superconductors. Long term, complex challenges currently facing society such as climate change, environmental sustainability and energy security can only be addressed by such large scale, multidisciplinary collaborations between academic science and industry. Durham Physics aims to be at the forefront of this by combining forefront research with real world applications to generate transformational impact.