Institution: King's College London

Unit of Assessment: 9 (Physics)

a. Context:

Background: Physics at King's College London has undergone a major evolution in recent years, with the present department focusing on three areas of research, all developed since 2000. 26 staff have been appointed to the Department since 2003, 15 of them since September 2010. These include the Heads of all three Research Groups: the Theoretical Particle Physics & Cosmology Group (TPPC), Experimental Biophysics & Nanotechnology Group (EBN) and the Theory & Simulation of Condensed Matter Group (TSCM).

Main types of impact relevant to research and associated beneficiaries:

Impacts on society: Research in all groups (particularly TPPC) leads to the stimulation of public interest and engagement in science, through the enhancement of science education in schools and through media engagement.

Health impacts: Research in EBN and TSCM underpins biomedical research and innovation. While academic biomedical researchers are the principal beneficiaries, the insight into disease mechanisms and the design of therapeutic intervention gained through the use of these techniques will ultimately lead to patient benefit. Photonics and nanoparticle research also leads to the development of diagnostic and medical technology, which can underpin new drug development.

Economic impacts: Nanophotonics research leads to new devices for the information and communication technology sectors, and for bio- and chemical sensing, while the development of new bioimaging modalities is relevant to optical microscopy and drug discovery instrumentation manufacturers. Research in functional nanomaterials leads to the development of novel nanoparticles for the biotechnology, solder and the paints & adhesives industries. Research in the theory and simulation of condensed matter is relevant to a wide range of industrial sectors with the need to develop, understand, or control materials. These include: new photovoltaic and thermoelectric materials; new nanomaterials for catalysis; molecular adhesion at surfaces for biotechnology; corrosion at surfaces for the petrochemical industry; embrittlement of steel for turbine manufacture; rock fracture for minimisation of energy consumption and risk assessment in the mining industry. Examples of companies with whom we have built long-lasting links include: BP, EDF, Henkel, INTEL, OSRAM, Rio Tinto, Schott Glass, Schlumberger, Seagate Technology.

b. Approach to impact

Our approach to impact during the REF period has been based on:

- The creation of centres and networks, with other academic partners within London, to ensure critical mass;
- Development of a research profile spanning fundamental science to applied, with an environment enabling the mix and cross-fertilisation of expertise.
- The creation of a culture for successful impact;
- The creation of a vibrant public engagement programme;
- Development of sustainable partnerships (e.g. with industry, with schools,...), to provide effective pathways for impact;
- The identification and protection of patentable intellectual property.

Centres and Networks: A focus on developing strong partnerships, both within King's College London and with other London institutions, has ensured the creation of critical mass of activity in our research areas to attract, seed and facilitate meaningful interaction with stakeholders.

An example is the development of the Thomas Young Centre (TYC) for the Theory and Simulation of Materials, of which the TSCM group is a founding partner. The TYC is an alliance of over 80 research groups from KCL, Imperial College London, QMUL and UCL, dedicated to using theory and simulation to tackle materials problems that are important to industry and society. It is an internationally recognised centre of excellence in the field, a cornerstone of its creation being its role as a point of contact for industry requiring advanced materials simulation capability. Simulation

methods that the TYC employs or provides are routinely used across industry to provide fundamental understanding, increase efficiency and accelerate product development. Impact is achieved not only through collaborative R&D, but also through training and technology transfer. For example, BP commissioned a training course that tackled a range of topics from the basics of atomistic modeling to coarse graining, along with opportunities to discuss real-life problems and future projects. KCL Physics collaborates with both BP and Rio Tinto in research programs involving advanced condensed matter systems modelling, aimed at elucidating chemical effects and microscopic mechanisms which influence the mechanical properties of these systems

An example at the interface with health sciences is the KCL Centre for Biophotonics, led by the Department, which brings together a critical mass of research activity across KCL concerned with the development of optical biological imaging, closely linked to the strong biomedical research presence in KCL. This area was strengthened further with the establishment, in a collaboration with Nikon Instruments, of one of the worldwide Nikon Imaging Centres at KCL (NIC@King's).

Impact Culture: The appointment of Group Heads to each of the three Research Groups, with track records for transforming research to impact in their respective areas, has been an important strand in the creation within the Department of a culture for enabling impact from research. Zayats (EBN) enjoys strong links with industry including, e.g., Seagate and Intel; van Schilfgaarde (TSCM) has held appointments at Stanford Research Institute and Sandia Laboratories, both with a technology transfer mission; Ellis (TPPC) has a well-established outreach and media profile.

Public Engagement: To maximise the engagement of the public with its research and the resulting impact, the Department has provided outreach training for its staff and research students. Activity associated with the stimulation of public interest and engagement in science has followed a number of strands. The Department has used the 150th anniversary (2010-2015) of Maxwell's productive five-year tenure at King's to engage the public's interest in science, exploiting the many links between current departmental research and Maxwell, from fundamental theory to photonics. It has also exploited the discovery of the Higgs boson, through its strength in particle phenomenology and its links to Higgs, a King's alumnus. The Institute of Making, which emerged from the Materials Library in 2011 as a result of an EPSRC Bridging the Gaps Grant, was led by Mark Miodownik while at King's (TSCM group); events involved a strong engagement with the public to promote awareness of materials in the world around us. This included the 2010 Royal Institution Christmas Lectures by Miodownik, which were broadcast on BBC4. The Department's research in fluorescence was show-cased at the Big Bang Fair 2012. Academic staff have made a number of appearances on radio and television; for example, John Ellis provided many interviews for the BBC and other broadcasters worldwide about the LHC and the Higgs boson.

Partnerships with Industry: Research outcomes in nanophotonics (EBN group) form the basis of new devices with unprecedented functionalities for light focusing and guiding, imaging and sensing, and all-optical signal processing applications. All these applications have a strong presence in the UK industry and the Department is working with leading companies in the respective areas to achieve impact in the most promising areas, including: Seagate Technology (plasmonic transducers for high-density data storage); INTEL (sub-wavelength photonic interconnects, all-optical and electro-optical plasmonic switching); OSRAM (plasmonic enhanced LEDs); SMEs in improved lighting and imaging applications (XEnics, Vigo). Research in the development of functional nanomaterials has involved close interaction with leading companies such as Henkel and Schlumberger (high temperature electronics) and SMEs such as Sirigen (nanoparticle biomedical labels). The Department has developed an association with the National Physical Laboratory (NPL) in nanoanalysis, facilitated by the proximity of the two institutions.

Intellectual Property: Where research has resulted in intellectual property with the potential for commercial exploitation, applications for patent protection have been made. This includes filing of patents for: new plasmonic devices (3 filed in 2013); a new approach to coherent anti-Stokes Raman spectroscopy (CARS) for Raman imaging (WO2012/017201); a new class of conjugated polymer nanoparticles for application as fluorescent imaging probes (WO 2011/039535).

c. Strategy and plans

Leadership and Support: We believe we will best enable impact from future research through leadership in the Department, to foster a culture of translating research into impact. This is provided through the presence of Group Heads with reputations for high impact in their respective areas, while overall the Department has a pool of considerable successful experience in working directly with industrial and business partners, in forming and managing successful spin-out companies, and in public engagement. We will exploit this in supporting and mentoring the engagement of staff in developing pathways for the impact of their research. Activities associated with commercialisation and leveraging of Intellectual Property arising from research are supported by a dedicated IP and Licensing Manager for the Departments of Maths, Informatics and Physics.

Networks: KCL Physics will continue to play a key role in the leadership of the TYC which, as it establishes itself as an international centre for commercial services in materials and molecular simulation, will develop further as an important conduit for industrial impact from the research of the TSCM Group. The Department works closely with the London Centre for Nanotechnology (LCN) which, because of our distinctive contribution, we have been approached by UCL and Imperial to join; the LCN provides an additional route for the establishment of collaboration with industry and for technology transfer, to support and enable impact from the Department's research in this area. The close interaction with the NPL will also be developed further; the NPL acts as a central point of contact for UK industry for technology expertise, particularly in new and emerging technologies, and is well connected to all major technology sectors.

King's College London is a major centre for biomedicine, a partner of the Francis Crick Institute (1,500 staff with £100M+/y operating budget in a £800M facility) while King's Health Partners (KHP) is of five Academic Health Science Centres in the UK, providing a strong pathway to impact for research at the physical-life sciences interface. The Department is well connected to take advantage of this, through strong links (including joint appointments) enjoyed by EBN and TSCM with health sciences research divisions within the College. More generally, the Department forms the core of a wider integrated physics research activity across the College, with a number of applied physics research programmes embedded within KCL Health Sciences (UoAs 3,4,5,15).

A microscopy methods development laboratory (MMDL) has been established by the Department, through funding from the Wolfson Foundation, in adjoining space to NIC@King's. Their co-location creates a synergy between the NIC as a commercial user facility and the Wolfson MMDL as a collaborative centre, involving the development of novel and innovative optical microscopy techniques and methods. Together they provide a pipeline for research and innovation in optical imaging, with the Wolfson MMDL driving the growth of new and improved instruments for the community and NIC@King's representing a focus for optical imaging in biomedicine for KHP, one of the main themes of its research strategy being the creation of shared core facilities and expertise to feed the translational pipeline leading to enhanced clinical research and practice.

Public engagement in science: The Department will continue to expand its outreach programme, co-ordinated by its Director of Outreach. In addition to the expansion of conventional activities for the involvement of the public, particularly schoolchildren, in the understanding and appreciation of science, the participation of King's Physics in the LHC MoEDAL experiment is anticipated to bring significant benefits, including the engagement of schoolchildren in research at CERN.

d. Relationship to case studies

The case studies concerned with the Higgs boson and with dark matter exemplify the development of public engagement activities within the Department. Because the pathway from underpinning research to impact can be the most rapid for public engagement, these case studies reflect most strongly the impact strategy established in the department following its redevelopment. The case study by Ellis also highlights the key role played by the appointment of experienced staff as Heads of Group in the Department's impact strategy.

The case study on NQR spectroscopy highlights the exploitation of patentable intellectual property and the development of collaboration with industry. The case study on the sale of a biophotonics start-up exemplifies impact resulting from the development of the Department's research programme in bio- and nano-photonics.