Institution: Royal Holloway, University of London

Unit of Assessment: B9 Physics

a. Context

The strategic focus of our fundamental research programmes in both Particle Physics and Condensed Matter Physics at an internationally competitive level has driven the development of advanced instrumentation, systems and devices. This work has impacted on a range of beneficiaries who use or commercialise these developments. The intrinsic interest and appeal of this research underpins a spectrum of public engagement activities.

The main non-academic user groups, beneficiaries, and types of impact are: Companies, such as Oxford Instruments Nanoscience (OIN) or Kinesense, where we have contributed directly to new instrumentation and algorithms through knowledge exchange, consultancy and the people pipeline; National Measurement Institutes (NMIs) in the UK (National Physical Laboratory, NPL), Finland (MIKES) and Germany (PTB-Berlin), through PhD training, project partnerships and joint metrology research programmes, influencing metrology protocols; users of quantum technologies, exploiting functional quantum matter and devices; governmental organisations, such as the Police Service of Northern Ireland, through licensed software commercially developed by Kinesense; Large Scale Facilities (LSF), Diamond Light Source (DLS), ISIS and proposed future national facilities, that benefit from the John Adams Institute for Accelerator Science's (JAI) development of advanced accelerator diagnostics techniques and support from the Hubbard Theory Centre (HTC); industry and applied sciences users of LSF – for example, biomedical, engineering, surface and material science based companies, as well as users of medical therapy accelerators, that benefit from the core simulation and measurement systems developed by the JAI. Society benefits from the improved law enforcement and reduced security risks that derive from research on motion distillation algorithms (Case Study 2), and sensitive THz detectors with potential security and medical applications. Outreach and public engagement activities benefit students, teachers and the general public through a range of instruments.

b. Approach to impact

The Department's approach to impact has been to develop close working links with businesses that use or commercialise the outputs of our research and to participate in outreach and other networking activities that present the research to the wider community encouraging a greater public awareness and understanding of science.

Developing impact culture within the Department – To nurture impact activity within the department two *impact officers* have been appointed (Boogert/Particle Physics, Casey/Condensed Matter), ensuring exchange of best practice between groups. They work in close collaboration with the Department's Director of Research, are members of the departmental Research Committee and liaise with the coordinators of relevant institutional Research Themes. Their remit is to liaise with research staff to promote the generation of impact and monitor its development. One objective has been to **support initiatives by early career researchers which have direct impact**; a research staff forum was created to propagate best practice and identify possible sources of impact, leading to several positive outcomes (see below).

Collaboration and knowledge exchange with industry – The relationship with NPL and other NMIs is reinforced by 3 current European Metrology Research Programme (EMRP) grants, which effectively transfer our research expertise into metrology. PDRA Shibahara was mentored through to a successful application to an EMRP Researcher Excellence grant for noise thermometry. The long-standing relationship with Oxford Instruments, underpinned by a record of expertise transfer through the "people pipeline" (5 former students/research staff), has benefited from significant joint investment in facilities in the London Low Temperature Laboratory (LLTL), supporting industry-relevant projects. An MoU codifies arrangements for knowledge transfer. Royal Holloway also incubated easyLab, a start-up by former LT group PhD student Siqueira, in its Enterprise Centre. easyLab is now an international company with 15 employees. The JAI and Dark Matter groups have both recently obtained grants where a key part of the proposal was transfer of the research to non-academic beneficiaries. The JAI has an industrial liaison group which meets yearly to explore commercial opportunities arising from accelerator science. PDRA Lyapin obtained Innovation Partnership Scheme funding from STFC in collaboration with Oxford FMB, a local SME, to develop a commercial beam device. PDRA Walding obtained a Leverhulme early career fellowship to develop dark matter detectors with 50% of his activity to investigate commercial medical applications. SEPnet (South East Physics Network) has provided an effective framework for a

coordinated approach to regional engagement, culminating annually in the Summer Interns Expo at the Royal Society, with industrial participation, coordinated by the Employer Liaison Officer.
Incentivising impact – Impact activities feature explicitly in recruitment and promotion criteria (SL to Reader, Reader to Professor). "External engagement and impact" is an explicit measure in the annual professorial banding exercise. Impact activities (consultancy, industrial meetings, outreach and knowledge transfer) are part of our quantitative work-load model for academic staff, and are incorporated in the annual individual research plans and appraisals.
Supporting impact – The university provides a wide **range of expert support from its Research and Enterprise (R&E) Office** to assist academic staff in the drawing up of research and development projects with industry. R&E also provide legal and financial advice to departments during the drawing up of agreements and partnership with external agencies, commercialisation activities, setting up spin-out companies, patents, licenses and IP rights. The Department accesses Royal Holloway's two seed funds to support commercialisation projects: the Park Fund (focused on identifying routes to market for IP derived from recent research) and the Gateway Fund (supporting the exploration of new ideas with the potential to meet a social or market need); e.g. Park funding was awarded for the commercialisation of noise thermometry (£40k).
Strategic investment in research with impact potential – At senior and professorial levels, **the impact agenda has informed appointments** across all departmental research areas, in dark matter detection (Monroe and Nikkel), metrology and national measurement programs (Tzalenchuk, also NPL), nano-technology (Astafiev, formerly of NEC Japan, joint with NPL) and proton accelerators (Gibson).
Impact through approaches to PhD training – To facilitate links with business, Royal Holloway supports the unit by funding **joint Impact Studentships** in collaboration with national or European research institutes and companies. This typically takes the form of at least 50% funding, including a fee waiver, from the institution and reciprocal support from the research or industrial partner. Over the assessment period Condensed Matter group staff have developed a strong relationship with NPL. Through the institutional strategic Royal Holloway/NPL partnership we fund three Impact Studentships in physics per year. In accelerator science multiple post-graduate training initiatives funded via the EU have occurred in the last 5 years, including the Diagnostics Training Network (DITANET) and Optimisation of Particle Accelerators (OPAC). Industrial partners form approximately 25% of the network and student training includes secondments with them.
Outreach and public engagement – This is supported by a departmental outreach officer (SEPnet) and a Science Faculty outreach officer, who work with the departmental academic outreach team, which monitors reach and evaluates effectiveness of activities. Examples are Case Study 3 and our participation in the Big Bang Fair (Excel Centre, 2011). Activities have included Particle Physics Masterclasses, Physics taster days, low temperature physics demonstrations and events aimed specifically at GCSE Physics students and their teachers (e.g. IoP Teachers Conf. 2011). We **engage directly with the wider public** through visitors to the Department during the increasingly popular annual Royal Holloway Science Open Day (4000 visitors in 2012), **and indirectly** through media coverage (in the UK and beyond) of insights resulting from our research. Examples are the participation of G Cowan and Petrashov, respectively, in the BBC4 "Beautiful Equations" documentary (Dec. 2010) and the BBC4 "Beautiful Minds" documentary on the 2010 Physics Nobel Prize (April 2012). Increasingly, the Department also uses online/social media to grow research visibility. It ensures academic/research staff and PG students are trained in the institutional research information system (PURE); this is publicly accessible, allowing beneficiaries easy access to information on the research outputs of individuals and research groups.

c. Strategy and plans

The strategy of the Department of Physics to develop its long-term impact follows complementary strands. The first is to build on and develop the existing links with industry so that opportunities for exploiting research are maximised, academic staff become exposed to and attuned to the needs of industry and can, where appropriate, adjust the focus of their work to address those needs. The existing links with organisations such as NPL and Oxford Instruments will continue, as exemplified by their close collaboration, as "co-creators", on a bid for an EPSRC Centre for Doctoral Training submitted in 2013. The second strand of the impact strategy is based around extending the reach and significance of our work on the public engagement with science.
Our strategy is aligned with SEPnet2, which aims to develop a **collaborative impact strategy** across its partners, expanding the types of impact, and the reach and significance possible with a

larger grouping of physics departments. Currently it actively engages via industrial placement of undergraduates with national companies and institutions. SEPnet2 will expand its employer internship programs and develop a regional Graduate Network (GRADnet), **increasing industrial beneficiary engagement** with Royal Holloway. SEPnet2 is in discussion with STFC to host an Innovation Partnership Scheme Fellow, tasked with generating economic impact from STFC-funded research. The Fellow will broker researcher engagement with business, and provide support for leveraging funding from business and commercialising outputs.

Establishing networks of expertise – We will continue to **seek major funding opportunities with significant academic and industrial collaborative partners** that allow us to **maximise impact**. We will access the Royal Holloway Research Strategy Fund for seed funds to develop new partnerships. **(i)** The JAI, with industrial partners, is seeking EU funding which will define how Europe engages with large accelerator projects. **(ii)** The Dark Matter group – part of the Radiation Detection & Instrumentation SEPnet theme – will collaborate with organisations on new particle detection technologies (e.g. neutron detection) with applications to security and medical imaging. **(iii)** The LLTL is a founder member of the European Microkelvin Collaboration, which is proposed to expand within the Horizon 2020 EU framework programme for Research and Innovation, with enhanced links to European Industry. **(iv)** Research on Quantum Devices and Quantum Technology will impact on UK manufacturing industry and metrology, supported by the strategic NPL partnership. **(v)** Funding for an EPSRC network on thermoelectric functional materials is being sought, led by the Quantum Matter group. **(vi)** The HTC will continue providing theoretical support for physics at national research facilities (ISIS, DLS) which have impact central to their mission.

Investment in leadership, infrastructure and management support – The Department will also expand significantly **fundamental research with direct impact** during the next REF assessment period, i.e. Dark Matter particle detection, the JAI and Quantum devices. **(i)** The recent professorial appointments in nanotechnology (Astafiev and Tzalenchuk) will promote leadership roles in the planned advanced metrology laboratory at NPL and in quantum technology. The University has supported this link with NPL further by investing £0.8M in 2013 for equipment intended to allow research underpinning the link to be conducted on the Royal Holloway site. **(ii)** The appointment of Monroe created the Dark Matter detection group, with the impact potential discussed above. **(iii)** The Department will continue its policy to further invest in its world class experimental facilities, taking into account both the advancement of fundamental science and future impact.

Involvement with the end user beneficiaries at all stages of the research – **(i)** We are further developing the culture among PhD students, whereby the impact of their research, engagement with industry and understanding the routes to exploitation are embedded into the programme in order to provide future leaders. This is promoted through Impact Studentships and is at the core of our European Initial Training Networks. **(ii)** SEPnet2 will expand its employer internship programs within GRADnet to promote increasing industrial engagement via PhD placements. **(iii)** Commercialisation of research will be **assisted by University seed funds** (see Section b). The university is currently in discussions with Surrey County Council and the Local Enterprise Partnership Enterprise M3, regarding an Innovation Centre based on Royal Holloway expertise; it is anticipated that the Department would establish a strong presence at this centre.

Public Engagement – Our existing strategy for outreach and public engagement (see Section b) will be consolidated, with improved focus on outward facing web-content, use of podcasts and social media. The Communications and Press Office will support growing public engagement activities to widely disseminate outcomes of our fundamental/applied research, and improve engagement with national media to extend reach.

d. Relationship to case studies

Case Study 1: The London Low Temperature Laboratory: impact on ULT thermometry and cryogenic platforms – Example of research activity in direct collaboration with industrial beneficiaries, leading to development of new products. This activity benefited from capital investment to strengthen infrastructure and capability of the group (see REF5). Initial exploitation was supported by a Park Fund grant, and the collaboration is supported by a matched funding Impact Studentship in 2013. **Case Study 2: Faster CCTV video content analysis –** Example of basic research leading to novel applications and the setting up of a successful company, with licensing of the first algorithm by Royal Holloway R&E. **Case Study 3: Engaging the public with current research in Particle Physics –** Public outreach activities promoting public understanding of particle physics, the discovery of the Higgs boson, dark matter and accelerator science.