Institution: University of Strathclyde

Unit of Assessment: 9 Physics

a. Overview

Physics research at Strathclyde is organised into three Divisions, along scientific themes and each is further organised into research groups involving clusters of related research, as follows:

Nanoscience	**Biomolecular and Chemical Physics (BCP)**
	Semiconductor Spectroscopy and Devices (SSD)
Optics	**Computational Nonlinear and Quantum Optics (CNQO)**
	Photonics
Plasmas	**Atoms Beams and Plasmas (ABP)**
	Strathclyde Intense Laser Interaction Studies (SILIS)

Each of our Divisions has world-class research activities and typically has a balance of both theorists and experimentalists to stimulate and enable new initiatives. Each has benefitted from major investment since 2008. Highlights include:

- The appointment of five new international Chairs to enhance our international leadership and numerous new high quality young researchers.
- £8M has been invested in major new Quantum Optics and Laser Plasma laboratories, part of the £13M refurbishment of the John Anderson Building in which the Department is based.
- A large fraction of the Department's researchers is taking a leading role in the University's £89M Technology and Innovation Centre project.
- A significant increase in our number of publications in leading international journals - Strathclyde UoA9 researchers have published more than a hundred articles in Science, Nature Group and Physical Review Letters since 2008.
- The Physics Department is rated in the top 10 in the UK in the Guardian University Guide 2014 and the University was Times Higher Education University of the Year 2012.

b. Research strategy

Vision - Physics research at Strathclyde is underpinned by a vision of a Department delivering internationally-leading research centred on optical science in its broadest sense, from fundamental physical theory to applications and technology. Realisation of this vision has shaped a Department that provides both fundamental knowledge of the workings of the universe and research that makes a direct contribution to the UK economy via knowledge exchange and company spin-outs – all very much in the spirit of both Glasgow's Lord Kelvin and the University founder and natural philosopher John Anderson. The Department is a central and founding member of several ground-breaking research collaborations. Distinctive examples include the Scottish Universities Physics Alliance (SUPA), Strathclyde's Technology and Innovation Centre (TIC), the SU2P photonics collaboration between Scottish and Californian Universities, the International Max Planck Partnership in Measurement at the Quantum Limit (IMPP), the UK's first Fraunhofer Centre, the ARCHIE-WeSt Supercomputer and the Scottish Centre for the Application of Plasma-Based Accelerators (SCAPA), each of which is described below. The Department's central roles within these initiatives are providing a unique combination of opportunities to make distinctive contributions to fundamental physics research and its applications to industry and society. In this regard, the strategy for Physics aligns well with and contributes significantly to the University's vision as a leading international technological university.

Strategy since 2008 - The Department's overarching research strategy since 2008 has been to build on its existing areas of research excellence and add new initiatives of the highest international calibre. This strategy was explicitly set out and endorsed at the Departmental Strategic Review in 2009 chaired by the Principal and including external members Sir Peter Knight FRS and Prof. Geoff Pert FRS. Overall responsibility for developing and overseeing the implementation of this strategy sits with the Departmental Research Committee, chaired by the Research Director (Jeffers) and comprising the Head of Department (Martin), Deputy Research

Director (McKenna), four representatives of the Divisions (Riis, O'Donnell, Cross, Jaroszynski), the Postgraduate Tutor (Robb) and Departmental Administrator (Munro). This Committee oversees the development of large research initiatives across the research Divisions and advises the Head of Department when prioritising bids for new academic posts. Implementation of the review-endorsed strategy has resulted both in the recruitment of a high number of internationally renowned researchers and in major investments in research infrastructure befitting the Department's status as one of the most significant research Departments in the University. This process has also dynamically altered the research culture of the Department and is on-going, but its beneficial impact on research output is already substantial. Since 2008, the following significant investments were made across the Departmental research base, building on areas of strength in each research division:

(1) **Optics:** The Department has long-standing world-class research activity in quantum optics, quantum information and atom optics, covering both the CNQO and Photonics groups. In this research domain there have been two major changes since 2008, leading to an expansion of researcher numbers. Firstly in 2011 the Department recruited Kuhr, an international research star in experimental quantum information, from the Max Planck Institute for Quantum Optics in Garching (and who prior to this worked extensively with 2012 Nobel Laureate Serge Haroche). He has quickly gathered an extremely talented set of junior researchers. One example is Haller, who was recruited from the University of Innsbruck's Ultracold Atoms and Quantum Gases group. Both Kuhr and Haller have recently been awarded European research grants (Kuhr – ERC Consolidator Grant, Haller – Marie Curie Fellowship) and the team's new experimental set-up in cold atom-based quantum information is already fully established and generating significant results. The second change (following the departure of Barnett in 2013) was to take the opportunity to reinvest in quantum optics theory. This led to the further recruitment of a talented theorist in the cold atom quantum information area. Daley, a US National Science Foundation Career Award holder from the University of Pittsburgh, was appointed to a Chair in 2013. His team of students and postdocs are in the process of moving to Strathclyde and they will provide a new focus for theoretical quantum optics research in the Department. To further strengthen this area, a lecturer position in theoretical quantum optics was filled (Yao) and further lecturer-track positions are likely in late 2013 via the University's new Chancellor's Fellowship Scheme.

(2) **Nanoscience:** Another area in which the Department is leading internationally is in the interdisciplinary area of Nanoscience. In 2010 the Department added a theory grouping to BCP, at the Physics and Life Sciences (PALS) and Chemistry interfaces. Fedorov, a talented researcher in theoretical chemical physics from the Max Planck Institute for Mathematics in the Sciences in Leipzig, was appointed to a Chair. He has quickly established his group here, making an immediate impact in helping to secure £1.6M from EPSRC's e-Infrastructure fund for the West of Scotland High Performance Computing Facility, ARCHIE-WeSt, of which he is Director. Fedorov has also garnered a talented team, which has already demonstrated its credentials via the award of a Marie Curie Fellowship to a key researcher. The expertise of Fedorov's group links directly with the University's TIC Bionanotechnology research theme and his industrial links (e.g. Schlumberger) have already secured significant investment from outside of the normal research funding base.

(3) **Plasmas**: The Department has further invested in another area of world-class research: high power laser-plasma interactions. This includes establishing SCAPA, directed by Jaroszynski. The £12M investment in this flagship Scottish Funding Council (SFC) project included the appointment of two Professors and a Reader (Hidding, Sheng, Eliasson). Both Hidding, from the University of Hamburg/DESY/CFEL and Sheng, attracted from Shanghai Jiao Tong University, have experience leading research teams in laser-plasma-based accelerations and reputations as researchers of the highest calibre in this area. Eliasson, recruited from Ruhr-University Bochum, is a talented theorist specialising in plasmas and their interaction with electromagnetic waves. Sheng and Eliasson will provide theoretical impetus to this area, addressing a longstanding need. The Department has an internationally-leading track record in the development of laser-driven particle accelerators (both electrons (Jaroszynski) and ions (McKenna)) and, driven partly by these new appointments, the SCAPA project will develop these novel, potentially compact sources towards wide-ranging

applications in science, industry, medicine and security.

Implementation – Successful implementation of the Department's strategy has been aided by financial investment from the University directly, via its £89M TIC project and from SFC via SUPA. For almost a decade SUPA has successfully stimulated pan-Scotland collaborations between Physics departments and Strathclyde is a founding member. Further deepening and widening of interactions within SUPA remains a mainstay of our collective strategy in the coming five years. In 2008, the Scottish Funding Council recognised the potential of the Physics Department at Strathclyde and decided that the largest part of the second tranche of SUPA funding should be invested here. Of the £48M allocated to SUPA II, across the eight partner institutions, Strathclyde received £12M for a range of projects (33% of which came from SFC and 67% from the University itself, demonstrating its high level of commitment to the investments in Physics described above).

The £89M Strathclyde TIC project is the University's largest investment in its research and knowledge exchange capacity. The TIC strategy is to undertake research that is outward facing and focussed on real-world needs, while retaining academic and discipline excellence to underpin this approach. The agenda is set by global research challenges, which necessarily drives a collaborative and cross-disciplinary approach to research and knowledge exchange. The TIC project is organised into several research themes and the Physics Department's strategy directly underpins several of these, including Advanced Science and Technology, Bionanotechnology and Photonics. Indeed, these themes are led or joint-led by Physics academics. Most of the Physics Department's staff take an active part in these themes. Advanced research laboratories for the Department are currently being constructed within the new state-of-the-art TIC building. In addition, a new wing to the John Anderson Building, where the Physics Department is largely located, has been built to house new SCAPA and quantum information laboratories. This forms the major part of a £13M investment programme in the Physics estate.

Outcomes of strategy - The strategic investment in both the Department's research infrastructure and its people has led to an environment in which research excellence is encouraged and nurtured, as evidenced by:

- PGR population growth: The number of Doctoral Students registered in the Physics Department has increased by 25% since 2008 (from 78 in 2007/8 to 97 in 20012/13).
- Research spend: Against a background of decreasing RCUK funding in real terms, the Department's annual research income from all sources has averaged £5.8M per annum and increased to £7.2M in 2012/13. Furthermore, the total value of the research grants held by Strathclyde Physics is currently around £20M.
- Outputs: Many more papers in high impact, general physics journals than in 2008. Half of the outputs submitted under UoA9 are in Nature Group, Science or PRL compared with 29% in RAE2008 Physics submission.

Future strategy - The Department has successfully expanded its current areas of excellence, both discipline-specific and interdisciplinary, through the addition of new internationally leading initiatives and the appointment of research leaders and researchers of the highest calibre. Physics has an increasingly strong upward research trajectory that will be further boosted by major new initiatives such as the Fraunhofer Centre, the IMPP and TIC. The strategy outlined forms the initial stage of our continuing aim to make Strathclyde a centre of excellence in both pure and applied physics research. This strategy is regularly reviewed to take note of emerging areas, UK and EU research priorities and the consequent funding streams in order to ensure that these remain aligned with our overall vision and future plans.

The incorporation of the Institute of Photonics (30+ researchers) into the Department at the end of 2013, together with its more device-oriented research, will further strengthen the applied and industry-facing sides of our research. Our future recruitment plans include the appointment of high quality young researchers via schemes such as the Chancellor's Fellowships and the strategic investment in a new lectureship in chemical physics (within the BCP group), with a view to leading new research initiatives within the Bionano TIC research theme. These posts are aimed at enabling us to take advantage of emerging research opportunities and form the next stage in delivering our research vision.

c. People

Staffing strategy

The Department's staffing strategy is based on the appointment of new academic and research staff of the highest international standing to grow and complement the existing research base. In 2008 the Departmental management recognised the need to strengthen further each research Division at a senior level and so it proposed new Professorial appointments in Experimental Quantum Information, Physics and Life Sciences (PALS) and in Laser-Plasma Accelerators (two Chairs and a Readership). Each of these positions was supported with postdoctoral fellows and start-up funds. The whole strategic case formed the largest part of the SUPA II funding proposal, which was approved by SFC and the University.

The consequent international appointments of Kuhr and Fedorov, from the Max Planck Institutes, have been spectacularly successful. These researchers have taken advantage of the major improvements in infrastructure to attract a set of talented young researchers and to produce new science of the highest quality. Likewise, investment in the SCAPA project has attracted high calibre senior plasma researchers (Sheng, Hidding, Eliasson) and we anticipate a similar long-term dividend in research output in this area. The latest addition of Daley will continue the trend. At a more junior level the Department has looked to both appoint and promote international researchers on an upward trajectory, either directly to lectureships and higher positions or via the Chancellor's Fellowship Scheme. Currently more than 40% of academic staff in the Physics Department has a doctorate from outside the UK and our policy of recruiting at the highest level internationally will ensure that this is continued.

In addition the Department has a vibrant distinguished visiting professor scheme funded from various sources, such as the Carnegie Trust and the SUPA Distinguished Visitor Programme. Recent examples include Carnegie Centenary visiting Professors Jim Gimzewski and David Miller.

Staff development

The Department fosters an environment which enables our top researchers to flourish and provides structured support to develop other members of staff to achieve this level. Many of our staff who joined at a junior level have secured promotion to senior academic positions since 2008 and lead research groups or sub-groups of their own. Nine academics have been promoted since 2008, including two to Professor (McKenna and Ackemann).

We operate a mentoring scheme for junior researchers within the Department. This has several components including publication mentoring, in which a junior researcher who wishes to submit their research to a high impact journal obtains detailed comment and advice from those who already publish regularly in these journals and grant application mentoring, in which research funding applications are mentored in the same way. The University also runs annual Grant and Paper Writing Challenges, which provide full support frameworks for the whole research grant application and paper writing procedure from development of research ideas through to submission.

More generally, the University's Researcher Development Programme provides a comprehensive set of both discipline-specific and generic skills courses and forms part of the University's strategy for implementation of the Concordat to Support the Career Development of Researchers, for staff at all levels. The University achieved the EU HR Excellence Award in September 2011 for implementation of the Concordat and was shortlisted for the THE Award for Outstanding Support for ECRs in 2011 and 2012. Physics staff have taken full advantage of the University's development activities which, together with Departmental initiatives, have played a significant part in their progress as researchers, as evidenced by the growth of our success in research awards, high quality outputs and international interactions.

We seek to provide a supportive environment in which staff are given every opportunity to help them achieve their research ambitions. For example, staff are fully supported and encouraged in applying for fellowships in order to broaden their research. The staff mentoring strategy has been particularly successful in this regard with McKenna winning an EPSRC Leadership fellowship in 2011/12 and Barnett a Leverhulme fellowship in 2012/13. In addition, several more junior academics and postdoctoral researchers have received competitively-won research fellowships

from EPSRC, ERC Marie Curie and the Royal Society of Edinburgh, signalling the success of this strategy for mentoring talented junior researchers.

Staff development is monitored annually via the University-wide Accountability and Development Review (ADR) process. A key component of the process is the determination of the learning and development needs of each staff member, followed by implementation of the required actions. The ADR process takes the form of an initial reflective, self-assessment stage, followed by a later interview with a senior member of staff, during which the previous year's objectives and learning and development are reviewed and a strategy is agreed for the coming year. In this way the ADR forms an important part of the development process for all Physics staff. More informally, junior staff are more regularly monitored, directed and supported by their personal mentor to ensure that their development does not take second place to the sometimes immediate demands of academia.

The Physics Department has a commitment to Equality and Diversity awareness. All staff must participate in an E & D online training course produced for University staff. The University itself has an equality policy based on the Equality Act 2010. Its good practice in the STEM area was recognised in October 2012 when it was awarded the Athena SWAN Bronze award. The Department has been actively working towards the award of Athena SWAN Silver and submitted its application in November 2013.

Research students

Strathclyde Physics has a vibrant postgraduate research student population that currently numbers 97. There has been a significant increase in research student intake in the last few years from around 15 per annum in 2008 to more than 25 averaged over 2011 and 2012; the Departmental strategy is to increase this to beyond 30 over the next few years. In this the Department has been aided by the award of a CDT-lite in the Application of Next Generation Accelerators and by the long-running Photonics Industrial Doctoral Centre jointly with other Scottish institutions. The recruitment, training and progress of postgraduates are overseen by the Departmental Postgraduate Tutor (Robb). Each student has two project supervisors and also a counsellor, external to the student's research group, whose role is to provide independent and confidential advice should this be needed during the course of the research project.

The Physics Department has little trouble in recruiting high-calibre research students. The fact that the Department's student intake has continued to increase, despite external factors reducing the financial support available for new studentships, is testament to the resourcefulness of the Department in securing funding from industry and other sources. Recruitment is aided by the SUPA prize studentship competition, which is aimed at attracting the highest quality international students to Scotland. Due to the intense competition for these prestige studentships (only the top ~2% of applicants are awarded), high-calibre short-listed candidates who are unsuccessful typically are offered other studentships. Strathclyde currently has 5 SUPA prize students. We also use our own internal and external websites (e.g. findaphd.com), together with internal communication routes, to advertise studentships and recruitment from amongst our own final year undergraduate population is encouraged via our undergraduate projects and research laboratory visits.

Our present provision of training and support for postgraduates rivals that of any UK Physics Department. There are two main but complementary mechanisms for this: the SUPA Graduate School and University in-house training for PG students and young researchers. The SUPA Graduate School, a pan-Scotland Graduate School in Physics, provides access to over 60 technical courses over seven Physics research themes. The courses are delivered either on-site or via live videoconferencing technology from one of the SUPA partner institutions and are typically taken during the first year of the PhD. They provide training of both breadth and depth far in excess of that which could be offered by the individual Scottish Physics Departments and which exceeds that found at many Centres for Doctoral Training. In addition to the technical courses, the SUPA Graduate School offers core physics skills courses such as data analysis and programming, as well as appropriate generic skills and entrepreneurship training. The minimum amount of SUPA training required by the Department is 40 hours of technical courses and 20 hours of core/generic skills, but many students recognise the opportunities available and follow additional courses.

Further training and support is provided both by the Department and the University via its Researcher Development Programme. This provides a set of courses focussing on generic skills

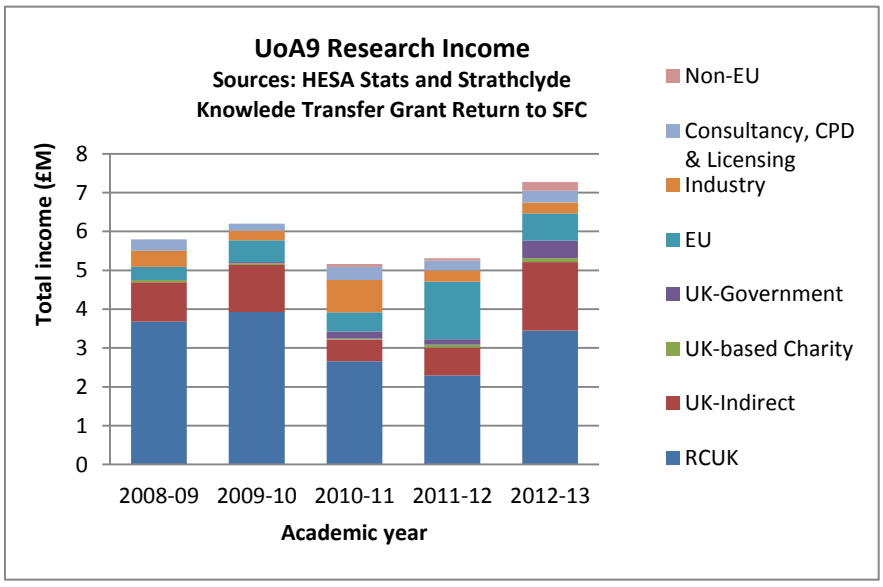
development set up by Strathclyde using the Roberts "Set for Success" money, but now funded wholly by the University. On top of this the Department provides valuable in-house training in research skills on such topics as giving research presentations; the students have ample opportunity to practise, both within their research groups at regular meetings and at the annual Postgraduate Conference hosted by the Department. All first year research students present a talk on their research at this conference and all second years present a poster. Furthermore, all students are encouraged to showcase their work at major international research conferences. The University and the Department's combined training afford all PGR students the opportunity to gain credits that lead to the award of a PG certificate in Researcher Development.

Monitoring student progress is integrated seamlessly into the training and support programme and is aided by an online software system developed in-house, which records all aspects of training and allows students to monitor and control their PDP portfolio during their research degree. In the first year, the Department's monitoring system consists of a set of reports on the student's progress, provided by the supervisors every three months. The SUPA courses are assessed, with the marks reported back to the Department. At the end of year 1, the students prepare both a report on their first year's work and a talk for presentation at the Postgraduate Conference. The report forms the basis for the first year viva, chaired by an independent member of the Department's Research Committee. At this point progress decisions are made and any remedial measures necessary are taken. At the end of the second year each student produces a shorter report that forms the basis of the second year viva. The focus at this time is on completion of the research, producing a firm thesis plan and a timetable towards submission. The overriding purpose of all our procedures is to provide helpful and constructive guidance to ensure that all postgraduate studies are followed through to successful completion of the research degree. The success of this can be measured by the fact that in the REF period the number of completing PhD students per annum has more than doubled from around ten in 2009 and 2010 to almost thirty in 2012. With our current postgraduate numbers and recruitment policy, the number of doctoral awards per annum will increase further.

d. Income, infrastructure and facilities

Income

The Department's research income is approximately £5.8M per annum. It is consistently one of the top EPSRC research grant earners in physics (typically in the top 10 Physics Departments from across the UK, e.g. 8th in August 2013). Our funding profile is augmented by major research grants from NERC, STFC, the EU, SFC, The Leverhulme Trust, the Royal Society, the Royal Society of Edinburgh, DARPA, the Fraunhofer Society and the Carnegie Trust. The training and mentoring that we provide to our research staff, including internal reviewing of proposals has helped increase our success in grant winning and has contributed to the diversification of our grant funding.



We are also one of the top earners of industrial research income - we were ranked 2nd in the 2010-11 HESA statistics for Physics for income from UK industry, commerce & public corporations. Our industry research project income in the REF period is greater than £2M and our total income from industry (and other beneficiaries of our research) is ~£4M when including consultancy, CPD course provision and licensing. A significant number of our academics provide consultancy

services to companies and other bodies. ABP group members work closely with e2v, TMD Technologies Ltd, Keating Instruments and QMC Instruments. Industrial income for this group is particularly high; Langford and Emeritus Professor Duxbury consult for Cascade Technologies, a spin out company based on applications of their research in cascade lasers. Birch, as a Director of spin-out IBH, which (now as Horiba Jobin Yvon IBH) manufactures fluorescence lifetime and spectroscopy instruments, has a fully developed company relationship that has resulted recently in part-funding of research studentships. The three cases above are more fully covered in the Impact Case Studies as part of the Strathclyde UoA9 submission. In 2013, Lockerbie secured £1.2M from the Technology Strategy Board and industrial partners (Shell, Gravitec, Guardian Global and Fugro) for the first phase of the £2M Amadeus project – a joint Strathclyde-industry venture on monitoring carbon capture and storage.

Investment in infrastructure and facilities

The Department has continued to invest in and grow its high quality research infrastructure and facilities through the REF period. It secured an investment of £12M under the SUPA II framework in 2009 and a significant portion of this was allocated to improving our research infrastructure. For example, £2M is being spent on infrastructure to accommodate the new SCAPA facility and there has been significant expenditure already on the laboratories for PALS and Quantum Information. These improvements to the research infrastructure are part of the on-going £13M refurbishment of the John Anderson Building, which houses most of the Department's research laboratories. The major part of the work is the building of a new 3-storey 1500m^2 extension to house the SCAPA and Quantum Information laboratories, costing £8M in total. The ABP and SSD groups will also receive new laboratories in 2014 as part of the new TIC building. In addition to investing in these new infrastructure projects, we have continued to develop and expand our existing high quality research laboratories. Exemplars of this include the TOPS high power laser laboratory, our photophysics laboratories, our scanning electron microscope facilities and our suite of photonics laboratories, all of which have received infrastructure investment throughout the REF period. The Department houses fully-staffed mechanical and electronic workshops, with 13 Physics-based technical staff.

The Department has also invested in local high performance computing (HPC) and data storage and handling facilities. Fedorov is Director of the Archie-WeSt HPC which is hosted at the University and funded in 2012 by a £1.6M joint investment from EPSRC and Strathclyde. This facility provides state-of-the-art HPC resource (38 Teraflops; 3,408 core-processors; ~4TB of RAM) and researchers from the Department are amongst its primary user base. In addition, significant investment has been made at Department level in smaller HPCs dedicated full-time to given research projects. A dedicated systems administrator and computing officer are employed to manage these resources.

External large research facility usage and indirect income

In addition to our in-house research facilities, our researchers have made extensive use of world-leading national and international facilities. The Department has significantly grown its indirect funding arising from competitively-won access to these facilities – our indirect income in 2012/13 alone from the use of RCUK-funded facilities was >£1.7M. We have secured more than £5M of beam time on laser systems (principally the Vulcan petawatt and Astra-Gemini high power lasers and the Lasers for Science Facility) at the UK's Central Laser Facility since 2008, for experimental campaigns led by Department academics (McKenna, Jaroszynski, Hunt). This figure more than doubles if including access as co-investigators and illustrates that we are amongst the biggest users of these world-class research facilities. Our researchers also lead or collaborate on research programmes at the Culham Centre for Fusion Energy (O'Mullane, Badnell), the Diamond Light Source (O'Donnell, Martin, Hunt) and Daresbury Laboratory (McNeil, Ronald). In addition to the Archie-WeSt super-computer, we also use HPC facilities at STFC's e-Science facility (SCARF-Lexicon) and HECToR (Fedorov, McKenna). Much of this facility usage is directly supported via RCUK research grants.

Our usage of international large-scale research facilities has also grown significantly. The equivalent indirect finance figures given in brackets below for usage of non-RCUK funded facilities are approximate, as precise figures are not available. Throughout the REF period, we have regularly won competitive-access to a range of experimental facilities. Examples include: the

PHELIX high power laser at GSI, Darmstadt (£600k-Laserlab-Europe; McKenna); laser facilities at the Max-born Institute in Germany (£60k-Laserlab-Europe; Hunt); the Grenoble High Magnetic Field Laboratory in France (£200k; Martin); experimental facilities at Brookhaven National Laboratory, USA (£40k; Fedorov); the FACET facility at the Stanford Linear Accelerator Center, USA (£50k; Hidding); synchrotron facilities at the Paul Scherrer Institute, Switzerland (£80k; O'Donnell). We have also used international HPC facilities, most notably at FZ Julich in Germany (£100k; Fedorov), at China's National Supercomputer Centre in Tianjin and Shanghai Supercomputer Center (£40k, Sheng) and the HLRN facility in Germany (£15k; Hidding). We plan to continue to expand our use of these and other external research facilities. Members of the Department are also actively involved in the planning of several new large European facilities, including the Extreme Light Infrastructure (ELI) multi-petawatt laser project and the European X-ray laser: XFEL at DESY.

e. Collaboration and contribution to the discipline or research base

Collaboration - Physics is a naturally collaborative research discipline and Physics at Strathclyde is no exception. The Department has been an integral member of several international and national research collaborations during the REF period. The increasing involvement of our researchers in such high-value collaborations is evidence of the high standing in which the Department's researchers are held. Many of the collaborations link directly with the research strategy outlined in section b. Examples include:

- The ITER fusion project: Three ABP academics led by Cross together with several researchers are involved with this major international project, as are Badnell and O'Mullane via the continually-developing ADAS code, which is used by the collaboration to provide complex atomic spectrum data to aid the detailed design of the experiment.
- Centre for Molecular Nanometrology: A £5M Science and Innovation award for a Physics-Chemistry consortium that includes Birch, Rolinski, O'Donnell and Martin.
- SU2P – A £1.6M-funded partnership between Strathclyde, St Andrews, Heriot-Watt and Glasgow with Stanford and Caltech to help sustain the considerable impact of photonics in the UK and California.
- Several high power laser-plasma consortia: McKenna, Jaroszynski, Hidding and Sheng are members of the large-scale pan-European ELI project and McKenna is a member of the HiPER project consortium. The Department is also a partner in LaserLab-Europe.
- The Intelligent Lighting Centre – A TIC-based collaboration with Strathclyde Chemistry and Electrical and Electronic Engineering Departments devoted to improving lighting technology (Martin, Trager-Cowan, Hourahine, O'Donnell involved)
- International Max Planck Partnership in Measurement and Observation at the Quantum Limit – Links with Glasgow, St. Andrews and Heriot-Watt Universities together with 8 Max Planck Institutes (Kuhr, Riis, Haller, Arnold, Oppo, Daley, Jeffers, Oi and Yao involved)
- InPho - A DARPA-funded research collaboration with Glasgow, Ottawa and Duke University dedicated to increasing information density in quantum optical communications.
- Fraunhofer Centre - the establishment of the UK's first Fraunhofer Centre at Strathclyde forms an important part of the Department's Impact Strategy and is discussed in the Impact Template.

Interdisciplinary research is key to a large part of the Department. It is encouraged as a matter of policy by the University, via initiatives such as Bridging the Gap and with the use of University and Doctoral Training Grant studentships. Within Physics interdisciplinary work is concentrated particularly in the Nanoscience Division. Several of the researchers in this Division work at the chemical and life sciences interface, applying the physics of processes at the nanoscale to topics which have potential to provide insight into major unsolved research problems in other disciplines and working closely with people in those disciplines. A clear example is Birch who, with a team of Strathclyde Physics researchers set up the Centre for Molecular Nanometrology jointly with Strathclyde Chemistry and partnered with Kings College London School of Medicine/Guy's Hospital. Further examples include the Institute of Complex Systems, which was set up by Oppo to study complexity over a wide range of systems and includes researchers from the Department's

Optics and Nanoscience Divisions along with mathematicians, bioscientists and engineers. Another collaboration is based on nanophotonics work of Papoff and Hourahine and includes local researchers in quantum optics and chemical physics and mathematics research at Southampton.

Industry and other Research Users: Research within the ABP group is partly influenced by industry needs; similarly part of the Photonics Group's research is informed and directed by interactions with Cascade Technologies. In both cases, industry has provided extensive funding for research. These industries cut across a variety of sectors including healthcare, environmental monitoring, security and defence. More details are found in the impact cases that form part of the submission. One concrete example is that TMD technologies (ABP), Cascade Technologies (Photonics) and Horiba Jobin Yvon IBH (BCP) have each made funding available for PhD students to work on particular problems associated with industrial needs.

These and other companies use our research directly to generate sales and profits, but the synergy between Strathclyde Physics Research and industry is probably best illustrated by the fact that many of them employ PhD graduates from Strathclyde and, in some cases, were founded by Strathclyde graduates (examples include Cascade, Microlase/Coherent Scotland, M-Squared lasers). The success of Strathclyde spin-outs can be measured not just by the fact that they survived the initial dangers of being a fledgling company, but that they have all matured and grow based on profits from product sales, a large part of which is export.

Contribution to and leadership in Physics as a discipline - Many of Strathclyde's researchers take a leading role in external academic bodies, acting as panel members, advising Research Councils and other learned bodies, as conference chairs and organisers. Several academics serve on editorial boards of journals, The table below summarises the approximate numbers of such activities from 2008.

RCUK Panel Memberships and Advisory Committee Members	Conference Organisation	Plenary/Invited Talks	Prizes and Medals	Research Fellowships, Awards	Journal Editorial Board Members
40	60	21/>200	6	12	14

Highlights include:

- Oppo won the joint Institute of Physics/Italian Physical Society Occhialini Medal in 2011
- Daley was awarded the 2009 Boltzmann Prize by the Austrian Physical Society (for outstanding work by a theoretical physicist under 35)
- Barnett FRS FRSE won the Royal Society of Edinburgh's James Scott Prize in 2011, The Silver Medal of the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in 2011 and the IOP Dirac medal in 2013 (before moving on from Strathclyde later in 2013)
- Fedorov won the Helmholtz Award from the International Association for the Properties of Water and Steam in 2012
- The Department currently has 8 Fellows of the Royal Society of Edinburgh
- Birch was appointed in 2012 Editor in Chief of Measurement Science and Technology, published by IOP

The developments described in the preceding sections demonstrate clearly that the Physics Department at Strathclyde is an exciting and innovative research environment that supports endeavour at the cutting-edge of the discipline and where scientific leadership is fostered. The new initiatives outlined above, coupled with the quality of the Physics Department's researchers, will ensure that this will continue to be the case in the foreseeable future.