Institution: University of Strathclyde
Unit of Assessment: 9
1. Unit context and structure, research and impact strategy

The University of Strathclyde was founded by natural philosopher John Anderson more than two hundred years ago as “a place of useful learning” and is today a leading international technological university. As a consequence, Physics is one of the institution’s most significant departments in terms of research output. Physics Research is organised into four strategic divisions, all of which address optical and electromagnetic science and technology in its broadest sense. These are Nanoscience, Optics, Plasmas and the Institute of Photonics, with each division made up of two or three research groups. The table below sets out the central research areas of each group, together with the divisional academic staff FTEs and headcount. There is extensive collaboration between groups and divisions and all groups have world-class research facilities housed in dedicated state-of-the-art laboratories enabling a balance of theoretical and experimental research.

Nanoscience 12.8 FTE 13 headcount	**Physics of Life Sciences (PoLS)** focuses on using optical and computational methods to measure and understand the fundamental processes of life.
	Semiconductor Spectroscopy and Devices (SSD) combines studies of optical processes in advanced semiconductor materials and the realisation of practical optoelectronic devices.
Optics 17 FTE 17 headcount	**Computational Nonlinear and Quantum Optics (CNQO)** uses theoretical, analytical and computational techniques to investigate light and its interactions, quantum gases, many-body physics and nonlinear optical devices.
	Experimental Quantum Optics and Photonics (EQOP) explores the fundamental interactions of single atoms and photons, through to spectroscopy and quantum technologies.
Plasmas 7.95 FTE 9 headcount	**Atoms Beams and Plasmas (ABP)** concentrates on topics in free electron physics, accelerator science, plasma physics, atomic and molecular spectroscopy.
	Strathclyde Intense Laser Interaction Studies (SILIS) investigates radiation-beam-plasma interactions at large field intensities, including the production of high-energy particle beams and high brightness radiation pulses.
Institute of Photonics 8.9 FTE 9 headcount	**Advanced Lasers (AL)** specialises in the physics and engineering of diode-pumped solid-state and semiconductor lasers, taking novel laser concepts to a systems-ready level.
	Neurophotonics (NP) develops devices to interface with neural systems in order to understand human neural processing.
	Photonic Materials and Devices (PMD) fabricates and researches into gallium nitride micro-LEDs and the use of these high-density arrays of micro-structured light-emitters in instrumentation and scientific applications.

Research and Impact Vision

Our vision for physics research at Strathclyde is one in which all researchers are enabled to deliver world-leading discoveries, with a focus on optical and electromagnetic science and technology. Realisation of this vision has moulded a Department whose activities span curiosity-driven research that enhances our fundamental knowledge of the workings of the universe, through to application-inspired research that makes a direct contribution to the UK economy via a range of knowledge exchange and impact-related activities.

At an institutional level, the Department's research aligns with four of the University's strategic research themes: Health and Wellbeing; Ocean, Air and Space; Measurement Science and Enabling Technologies; and Energy (see Institutional Statement). Our research is central to many aspects of these themes and four members of the Department lead University sub-themes. It is also central to the University's Quantum Technologies, Space and Health Tech research clusters, which are associated with the Technology and Innovation Centre Zone.

Organisation of Research and Impact Strategy

Our research and impact strategy is led by a Research Director and a Knowledge Exchange (KE) Director. The Research Director chairs the Departmental Research and Knowledge Exchange Committee which meets regularly, including as members the KE Director, representatives from each research division and the Head of Department. The committee develops and implements policy on all research and KE matters, including appointments, funding, infrastructure and impact strategies. It coordinates responses to initiatives both from within the University and from external agencies, including UKRI's Research Councils and Innovate UK, UK government departments, the Scottish Government, European and other international funders, industry and other funding bodies. In this it is supported by pan-University professional services departments, Research and Knowledge Exchange Services (RKES) and Innovation and Industry Engagement Directorate (IIED). Decisions and policies developed by the committee are communicated to the Science Faculty and University, ensuring ongoing alignment with, and informing of, institutional research and KE strategies.

Research Strategy and Implementation

Building on the Department's performance in REF2014, from 2014 the Department renewed its programme portfolio to enhance the research base, making in the succeeding years substantial new strategic investments in both people and place. This allowed us to refocus and refresh each of the research divisions to tackle the challenges of future priorities through strategic recruitment initiatives, including the Chancellor's Fellowship Scheme and Global Talent Programme (section 2), and support for both new and existing staff via improved infrastructure, such as new research labs in the John Anderson Building and in the cross-disciplinary Technology and Innovation Centre (TIC) (section 3). This was a continuation of a strategy that began significantly before 2014 and has transformed the Department from one with research excellence in a number of areas to one where all groups undertake research of the highest quality. This change in research culture has had a transformative impact on existing staff and has helped attract appointees of the highest calibre to the Department.

The Department has delivered on the investments in infrastructure and recruitment during this period through increased competitively-won research funding, higher postgraduate research student (PGR) numbers (sections 2 and 3) and growth in the number of high-quality research outputs, with more than half the research outputs in the submission published in Science/Nature group journals or Physical Review Letters.

Our approach has led to an agile research base able to respond to a wide range of external initiatives, allowing the Department to take leading or significant roles in many discipline-specific and interdisciplinary collaborations within the UK and overseas. These collaborations form a key

component of our on-going strategy to deliver research excellence. The following three are of particular note:

- The Department was, in 2004, a founding member of the Scottish Universities Physics Alliance (SUPA), a strategic partnership in research and advanced training across eight Scottish universities. Physics staff are active across several of SUPA's five cross-institutional research and impact themes (section 4) and contribute to training provided by the SUPA Graduate School, of which all PGRs are members (section 2).

- The Department has a key role in the University's pan-institution strategic partnership with the National Physical Laboratory (NPL), a tripartite partnership also involving the University of Surrey established in 2015. Within Physics, this includes, to date, a co-funded and co-located joint appointment, an NPL Measurement Fellow (Rossi), and 24 studentships (including 4 NPL EPSRC iCASE) who are members of NPL's cross-institutional Postgraduate Institute in Measurement Science (section 2).

- The Department has a major involvement in the National Quantum Technologies Programme, where the quality, reputation and broad scope of research in the Optics Division and the Institute of Photonics resulted in Strathclyde being the only institution with investigators directing research programmes in all four of the Quantum Technology Hubs, in both five-year phases of the Programme.

These, and the broader range of collaborations, are described further in section 4.

Impact Strategy and Implementation

The successful transfer of research knowledge from academia to industry and other societal beneficiaries is reflected in Strathclyde's founding ethos as 'a place of useful learning' and is a fundamental objective of its mission. The Department's strategy is aligned with the University's mission and has grown from a longstanding desire to see our research deliver real world benefits through a culture that enables and encourages staff with ambitions to make that happen. Our approach is to capitalise on both departmental and wider University expertise and investments to maximise exploitation opportunities. Early focus on commercial spin-outs has broadened, particularly during the current REF period, to encompass a wider range of impact opportunities, including impact via existing companies (Diamond Photonics Impact Case Study), and engagement with mechanisms to enhance the effectiveness of the technology pipeline between academic research and commercial exploitation (Fraunhofer Impact Case).

The Department's impact culture dates from academics' 1977 founding of IBH Ltd to develop fluorescence lifetime spectroscopy products, an example of ongoing collaboration and related impact for over 40 years (Fluorescence Products Impact Case). Other spin-outs followed including:

- Microlase (1992) to commercialise Ti-Sapphire laser research, which subsequently led to the founding of M Squared Lasers
- Cascade Technologies (2003) to commercialise quantum cascade laser-based spectroscopy (Laser Spectroscopy Spin-out Impact Case)
- mLED (2009) to enable commercial application of GaN micro-LED arrays.

Building on the success of these companies, each was subsequently bought by a larger international organisation (respectively, HORIBA, Coherent, Emerson and Oculus, part of Facebook) with most retaining substantial R&D and manufacturing facilities locally. Three of the companies have contributed to Strathclyde academics (Birch, Dawson) or graduates (Nils Hempler of M Squared) winning the Institute of Physics Dennis Gabor Medal for the application of physics to industry, commerce or business during this REF period (section 4).

The Department's research in GaN micro-LED arrays has had wide influence in the field, both academic and commercial, with the sale of mLED to Oculus in 2016 the largest such financial transaction the University had overseen. This area offers strong potential for future impact underpinned by Strathclyde research, which we would expect to submit to a future REF.

The Department continues to create intellectual property based on its research, maintaining a pipeline of current and future commercial impact. In the REF period, 36 invention disclosures have been made, resulting in the filing of 19 new patents. A new spin-out, Neuro VLC, is in the process of being launched. Two recent Innovation/Enterprise fellowship awards in the Institute of Photonics are supporting efforts to identify additional commercial partners.

The Department's strengths in application-inspired research and its impact track record were key factors in attracting the UK's first Fraunhofer Centre to the University and in the development of the £89M TIC Technology and Innovation Centre (TIC) at Strathclyde, where several new Physics research laboratories are housed. Established in 2012, the Fraunhofer Centre for Applied Photonics (Fh-CAP) is an important intermediary organisation in the photonics and wider technology sectors, creating impact by enabling partner companies to accelerate technology and product development Fh-CAP maintains a close relationship with the Department, through Dawson's role as its Director, joint appointments and PGRs. This partnership is a significant differentiator in the Department's impact.

The Department has a prominent role in the second phase of TIC, a £150M project which is part of the University's wider contribution to the Glasgow City Innovation District (see institutional statement). The Department is central to the Quantum Technology Cluster and contributes strongly to the Health Technology and Space Technology clusters and their industry-facing research-based technology transfer programmes.

In terms of organisation, the Physics KE Director represents the Department on the Faculty KE Committee, influencing wider policy in this area. The Director is responsible for development and coordination of KE and impact activities in line with University policies and provides local expertise to enable prompt and appropriate responses to new initiatives. In order to facilitate impact and to attract associated funding, the Department has made two appointments, a KE Associate and a Professor of Industrial Practice (PIP), the latter a former Chief Technology Officer at major UK technology company, QinetiQ. This was the first PIP appointment in the University. The Department is also supported by a Commercial Business Development Manager to help capitalise fully upon emerging opportunities and to support the growth of licence deals. These appointments quickly delivered results, the KE Associate successfully supporting Knowledge Transfer Partnerships and the PIP helping establish an industry-led EPSRC Prosperity Partnership involving the Department and M Squared Lasers, which secured £2.2M funding to study Rydberg atom quantum computing.

The pipeline for future impact is supported through a broad portfolio of activity across the Department, illustrating an embedded impact culture. This includes work in many research themes emerging as industrially relevant, such as Quantum Technologies, Manufacturing, and Space, underpinned by substantial EPSRC funding that has an innovation component (Quantum Technology Hubs, Prosperity Partnerships and Manufacturing Programme Grants). We continue to develop these themes, having already leveraged further support from the Industrial Strategy Challenge Fund (ISCF) in four cases. In total, there were 16 Innovate UK awards to the Department in the REF period (six of which were funded by the ISCF) with total funding of £3.7M (£2.4M of which is from the ISCF). The Department currently holds six Innovate UK awards totalling just over £2M. Since 2014 there have been more than 70 research and KE projects with industry worldwide, involving more than 50 companies, supported by funding of approximately £3.61M from industry and

£2M from licensing, CPD and Consultancy. In the academic year 2019/20 alone, funding from industry was nearly £410k.

Interdisciplinary Research

The Department has always had a significant focus on interdisciplinary research, particularly in the Nanoscience Division, where researchers work at the interfaces with chemical and life sciences, and the Institute of Photonics, which interfaces with engineering and life sciences. Such collaborations are reflected in the output profile of the Department. Interdisciplinary research in facilitated greatly by the University's strategic research themes, all of which cross disciplines. As a consequence, members of the Department lead joint projects with the Department of Pure and Applied Chemistry and the Strathclyde Institute for Pharmaceutical and Biological Sciences (SIPBS) within the Science Faculty and participate in multiple collaborations with the Engineering Faculty. Examples include in novel imaging techniques that require complex signal processing and in the development of a National Nuclear User Facility (NNUF) at the Scottish Centre for the Application of Plasma-based Accelerators (SCAPA), which was commissioned to serve both as state-of-the-art Physics infrastructure and to provide beams for applications.

Open Access and Research Integrity

The Department is fully-compliant with Open Access (OA) requirements, facilitated by the University's Open Access Service, which provides support, advice, advocacy and training on research publishing using compliant Green and Gold OA routes, together with general advice on the issues surrounding open scholarly communication. The Service also administers the Research Councils UK (RCUK) Gold fund, provided by RCUK for the payment of Gold article processing charges and the Charity Open Access Fund. The Open Access Service supplies advice on compliance with the Green HEFCE policy on OA for REF2021, as well as other funder-specific OA mandates. Within Physics, a senior academic has responsibility for OA compliance and liaison with the central service. The main mechanism for OA compliance under the above scheme is the depositing of articles on the University's publicly-available institutional repository. These are linked to publicly-available datasets where appropriate. Training on both OA and Research Data Management is regularly provided within the Department and is an integral part of the induction for any new member of staff in Physics. Every new PGR student must complete a research data management plan which is held on the University's central PGR management system.

Both the Department and the University are committed to the highest standards of research integrity and the University Research Code of Practice fully supports the principles of the Universities UK Concordat. As subscribers to the UK Research Integrity Office, the University delivers training and support on research integrity, augmented by the Department during staff induction. Academic policies and procedures within the University are designed to encourage research integrity and examples include the Research Code of Practice, Policy and Code of Practice for Postgraduate Research Study and the Code of Practice on Investigations Involving Human Beings.

2. People

2.1 Staff

In order to deliver and enhance our vision for internationally-leading research in optical and electromagnetic science and technology, Physics at Strathclyde has grown significantly, from 27 FTE submitted to REF2014 to 46.65 FTE (headcount of 48) at 31 July 2020, an increase of 73%. Alongside growth via recruitment, the Institute of Photonics became part of the Department in 2014 (staff submitted to UOA13 at REF2014). Academic staff are distributed across the four divisions as follows (headcounts in brackets):

- Nanoscience: 12.8 FTE (13)
- Optics: 17 FTE (17)
- Plasma: 7.95 FTE (9)
- Institute of Photonics: 8.90 FTE (9).

Research staff are integral to the Department's success; with 75 employed at 31 July 2020, including Senior Fellows, Fellows, Associates and Assistants, compared with 66 in 2015.

Academic Employment Strategy

Our academic employment strategy is based around attracting talented researchers at all levels, based on strategic cases made to the Science Faculty and University. The Department does not look simply to replace vacated posts, but examines the newest, most exciting directions in the relevant areas of physical science across the divisions and then seeks out exceptional individuals in these areas. Prior to 2014, this strategy focussed on the appointment of new senior professorial staff to fill research leadership roles, but since then the main focus has been on expanding the research base by appointing talented junior academics with significant potential. On this basis the Department has attracted 17 new academics since 2014 using the University's Chancellor's Fellowship and wider Global Talent Programme. This has enabled each division to invigorate its research, not only to include new areas but also to consolidate existing capabilities and enable linkages between areas of existing strength.

The University's Chancellor's Fellowship Scheme, directed towards early career research leaders, has enabled the Department to be especially successful in expanding an already strong research base by the international recruitment of 15 junior academics across all divisions (*Caspani, Cippiccia, Gray, Griffin, Henrich, Herrnsdorf, Hurtado, Kirton, Massabuau, Patton, Piani, Pritchard, Rossi, Tagliacozzo, van de Linde*). This five-year development programme fast-tracks from young research stars to mid-career skilled academics and nurtures the Department's future leaders. The quality of these new academics is underpinned by four having already been promoted to senior lecturer. Furthermore, four have won prestigious external fellowships, two of which (*Patton, Cameron*) were Royal Society University Research Fellowships (RSURF).

At a more senior level, the Department made a Readership appointment in *Lagoudakis* (from Stanford) via the Global Talent Programme, who is setting up a new research stream of Experimental Quantum Nanoscience as part of the Nanoscience Division. This was a very targeted recruitment in an area identified as important not only for Nanoscience Division but also in terms of providing, along with the appointment of *Rossi* as Chancellor's Fellow, strong potential in an area bridging between Nanoscience and Optics divisions.

Key to the attraction of the above researchers has been both investment in the physical research infrastructure, via expansion of the John Anderson Building and the new laboratories in the TIC, and the changed culture in the Department.

The inherent flexibility of our recruitment strategy facilitates joint appointments and exchanges with industry and other bodies, and enables the appointment of staff who work at facilities outside the Department for part of their duties. Examples include Rossi, a joint appointment with NPL; Caspani, joint with Fh-CAP; Bingham, joint with the Central Laser Facility at Rutherford Appleton Laboratory (RAL); Sheng, a joint appointment with Shanghai Jiao Tong University; and Oi, Researcher in Residence with the Satellite Applications Catapult at Harwell.

These new appointments, together with the incorporation of the Institute of Photonics into the Department in 2014, have complemented the Physics research base, both by enhancing existing activities and broadening its scope, and have contributed to the increase in submitted FTE to the UoA. The Science Faculty's strategic plan includes a further expansion of staff for Physics and the Department will continue to appoint the highest quality researchers in the coming years.

In addition to the academic staff detailed above, as already discussed, the Department has appointed two KE posts, a Professor of Industrial Practice and a KE Associate with a photonics background. These colleagues have been instrumental in developing the significant external impact of Physics research at Strathclyde.

Early Career Researcher Support and Staff Development

The internal culture of the Department is one that strives to enable all research-active staff to produce research of the highest quality and to maximise the societal impact of their research. Senior staff mentor junior academics to help nurture the best research ideas, advising on fellowship and research grant applications, and research publication strategies. The Department operates an internal review process for all local funding applications over £50k before final approval in order to maximise the chances of success. Particularly helpful for ECRs, this is has resulted in an overall 38% success rate for funding applications in the period 2014-2019.

The Department provides all new junior academics with a research support package, averaging around £100k. This includes a guaranteed a PhD studentship once an appropriate project and candidate are identified, and can also be used to fund, for example, a piece of lab equipment, computational resources or conference travel. Their research time is protected through significantly reduced teaching commitments. For example, a newly-appointed Chancellor's Fellow will start by typically working in tutorial classes or a laboratory for two years before gradually taking on more responsibility, progressing to a full teaching load only towards the end of their 5-year fellowship period, by which time their research should have become fully established.

As a research-led department, Physics has a large community of ECR RAs/Fellows (currently 75) who make a vital contribution to the output and success of the Department. They are encouraged to develop research independence within the framework of their particular research project. This is a significant aspect of their career development, and more generally, is vital to the attractiveness of Strathclyde as a research environment. Together with the training programmes described below and local mentoring, the Department aims to provide and environment that allows research staff to produce high quality research and to develop their career skills.

Departmental support and mentoring are complemented by a range of University development programmes designed to support staff at all stages of research and academic careers. Part of the University's Researcher Development Strategy and Plan, the Researcher Development Programme (RDP) is comprehensive set of discipline-specific and generic skills courses which forms part of the University's approach to implementing the Concordat to Support the Career Development of Researchers. The programme is primarily for ECRs, both RAs and junior academics, and PGRs, but the flexible programme includes courses suitable for staff at all levels, including senior research leaders. All new early career academics undertake the Strathclyde Programme for Academic

Practice, Researcher development, and Knowledge exchange (SPARK). The Strathclyde Programme in Research and Leadership (SPIRAL) aims to develop and strengthen leadership skills across research and KE.

The positive impact of the Physics' strategy for staff development is demonstrated by continued growth in research awards (section 3), high quality outputs and international interactions (section 4).

Staff Management, Support and Promotion

All staff participate in the University's annual Accountability and Development Review (ADR) process. The ADR meeting enables discussion of the previous year's activities and future objectives for research, impact and other aspects of academic development. Outside the formal ADR process, customised management and development support is available for staff at all career stages. This may include informal quarterly or six-monthly discussions as appropriate.

ADR also informs the biannual academic promotion cycle. Sustained achievement in terms of the volume and quality of research outputs, and in obtaining significant research or KE funding are regularly recognised by promotion. A similar set of criteria apply at each level, but with increased expectations at higher levels. Professors are grouped into four zones and progression to the next zone is achieved by a sustained increase in the level of performance. Promotion cases are reviewed internally by the Professorial Advisory Group, which convenes specifically to advise the Head of Department on the promotion-readiness of all staff and to review applications that could be forwarded for consideration by Faculty and University promotion panels. Since 2014, there have been 20 academic promotions involving 18 academic staff, including 6 to Reader, 4 to Professor, and 5 Professors promoted through rezoning. In addition, a vibrant research staff community has seen promotions to Senior and Principal Research Fellow. There are also internal mechanisms to allow career flexibility by transferring between job families, for example from research to teaching and vice versa. Significant contributions by staff at all levels can also be rewarded by salary increases.

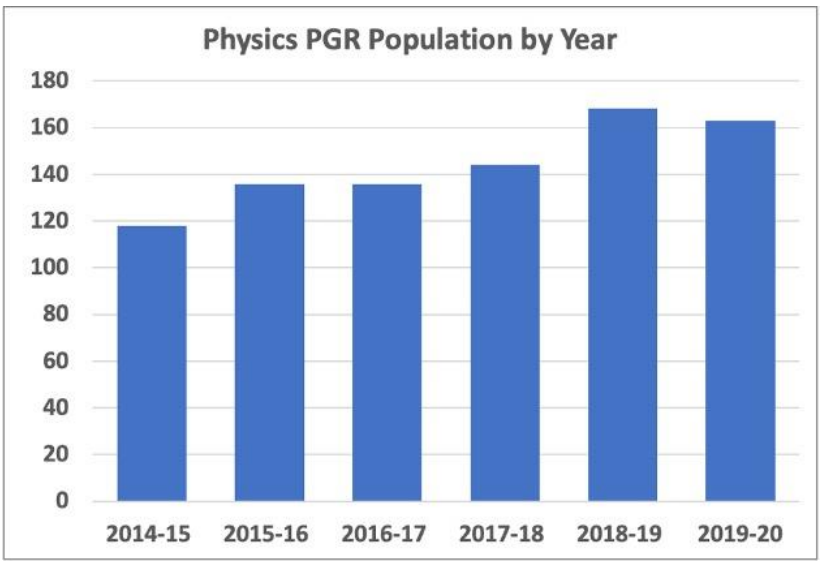
Procedures for Exchanges and External Links

The Department strongly encourages exchanges with a wide range of industry and other bodies, facilitated via University-wide and external mechanisms. The University initiative "Engage with Strathclyde" provides a framework for initial contacts between academics and external organisations to develop partnerships. The Department has many such partnerships with e.g. Fraunhofer-CAP (Fh-CAP), the Cockcroft Institute, the International Max Planck Partnership (IMPP) and NPL. There are several joint studentships with NPL and one ECR is based there. The Department also has researchers based at RAL and at Culham. Links with partners are often facilitated by competitively won funding and the team at RKES typically assists with this process. There are also University resources that can be used such as the Impact Acceleration Account, specifically for projects more associated with research impact and KE.

2.2 Postgraduate Research Training and Supervision

Recruitment

The number of enrolled PGRs is one of the University's Key Performance Indicators. The Physics Department has increased the number almost year on year since 2000. Recruitment events are held in the Department every year and, coupled with an increase in PGR funding from various external sources, the PGR population has grown. As shown in the chart, right, 2019/20 enrolled PGRs numbered 163 (151 PhD, 9 EngD, 3 MPhil), up from 118 in 2014/15, an increase of 38%. We expect this level of growth to continue in line with new academic appointments until the Department reaches around 200 PGRs within a few years.



We successfully work with University central administration on the recruitment of PGR students. A Departmental administrator coordinates local procedures under the guidance of the Postgraduate Tutor, who has overall responsibility for offers of student support. Applicants apply for advertised projects linked to particular supervisors and the Department engages promptly with applicants to explore their interest in joining the Department.

Studentships

Studentships are funded via a variety of mechanisms. The University provides partial support from funding allocated to Strathclyde by EPSRC and other UK Research and Innovation (UKRI) agencies (totalling £630K for 2019/2020). The Science Faculty usually also provides partial support, matching that from the supervisor or Department. The remainder of the funding comes from a variety of sources, external companies or other bodies, and from departmental or research group funds. Different funding mechanisms result in varying funding periods for PGRs from 36 to 48 months, with 42 months typical in Physics.

Many studentships are associated with a range of Centres for Doctoral Training (CDTs) and equivalent groupings, both national centres and local equivalents established by the University, and with the Quantum Technology Hubs, each of which provide studentship funding. During the REF period, this includes:

- As a partner in RCUK CDT programmes (hosts in brackets)
  - 2013 round: Applied Photonics (Heriot-Watt); Diamond Science & Technology (Warwick); EPSRC/MRC CDT in Optical Medical Imaging (OPTIMA) (Edinburgh/ Strathclyde)
  - 2018 round: Industry-Inspired Photonic Imaging, Sensing and Analysis (Heriot-Watt)
- As the leader of an EPSRC CDT-Lite on Application of Next Generation Accelerators
- Recognising its strength in the area, as the initiator of a new Scottish Graduate School in Quantum Technologies in 2019 (jointly with Heriot-Watt and Glasgow Universities), which received significant financial support from companies and organisations including M Squared Lasers, AWE and NPL
- As the leader of local Strathclyde CDTs in laser-driven plasma and fusion science; plasma-based particle and light sources; and industrial quantum technologies

- As a partner in the NPL Postgraduate Institute for Measurement Science.

In addition, in 2019, Physics obtained six studentships from the Defence Science and Technology Laboratory (DSTL). Students enrolled on CDT and equivalent programmes benefit from specially designed taught material which broadens their training experience.

PGR Monitoring, Support and Progress

The Department monitors and supports PGRs in line with the University's Policy and Code of Practice for Postgraduate Research. Specifically, PGRs have two research supervisors, nominally a first and second supervisor, although the extent to which both are involved in the day-to-day research varies. PGRs may also choose another academic as Counsellor, to provide independent advice if required.

A PGR student's progress is monitored via 3-monthly reports throughout their studies. At the end of their first year, PGRs submit a report/literature review of their area of research, together with any initial research results. They present their work orally at the Department's annual postgraduate conference, followed by an hour-long end-of-year viva with their supervisors, chaired by an independent senior academic, at which progress is assessed. Recommendations are made based on the outcome of this process and, if all is satisfactory, the student continues to second year. At the end of second year, students present their research via a poster and also submit a thesis plan and a research paper, either in draft or published form. The end-of-year viva focuses on the thesis plan and the timeline to ensure that the student completes their research and writes the thesis within their funding period. The PhD process concludes with the final viva examination, conducted by External and Internal Examiners, both of whom write reports on both the thesis and the examination and make a recommendation on the award. The examination committee is chaired by an independent convener.

Training and Skills Development

All PGR students are enrolled in the Strathclyde Doctoral School (see institutional statement) and attend courses offered by the University Researcher Development Programme (section 2.1), by the SUPA Graduate School and by the Department, as well as CDT or equivalent training as appropriate. This provides comprehensive training enabling our PGRs to master the competencies necessary for both academic research and future technical leadership in industry or elsewhere. PGRs attend training across four categories, obtaining a postgraduate certificate in the process.

SUPA, as the largest Physics graduate school in the UK, offers over 60 advanced technical courses (over 800 hours of lectures) for physics PGR students and RAs across Scotland, as well as professional development training tailored to a physics background. Courses, accessing the knowledge and skills of world leading researchers drawn from across the partner universities are mostly delivered by live video links using SUPA's e-learning portal with dedicated state-of-the-art video classrooms. There are also tutorials, lab classes, workshops, careers workshops and international summer schools. Each SUPA PGR student must take at least 40 contact hours of Advanced Physics courses (with formal assessment) and 20 hours of Professional Development (skills) courses in their first two years. The SUPA Graduate School has grown substantially over the REF period from 90 graduations to 149 in 2019/20. In 2019/20 Strathclyde hosted 163/849 (19%) of SUPA's student population, and 23 staff have provided teaching on around 10 courses per annum.

Within the Department, students design and complete their own Data Management Plan and are trained in Cybersecurity. They also attend regular Departmental Colloquia and more specialised Research Division talks given by invited external speakers.

2.3 Staff and Postgraduate Student Wellbeing

The following policies and procedures ensure that an ambitious research culture prospers in Physics at Strathclyde, that staff at all levels thrive in their careers and that the Department remains one of the most attractive environments for physics research in the UK.

Equality and Diversity

The University implements a range of equality and diversity policies and associated procedures (see institutional statement), with all protected characteristics covered in line with the Equalities Act 2010. The Physics Department values diversity and is committed to achieving and promoting equality of opportunity in its teaching, research and working environments. We ensure these environments support positive relations between people and instil a culture of respect. The Department's reputation for excellence in teaching, research and KE is enhanced by a collegiate, inclusive environment in which staff and students are supported to achieve their full potential. The University has extensive policies on flexible working including the recently lunched Agile Working Toolkit, in particular to support families, carers, and people with disabilities or those working in other challenging personal environments. Staff make use of many of these policies, including both permanent part-time working and flexible reduced hours arrangements, to support work-life balance either on an on-going basis or short-term to meet specific family commitments.

The Department has held an Athena SWAN Bronze Award since 2013 (renewed 2019). In 2019, the Department introduced a new action plan to increase the diversity of its workforce and advance equality across recruitment, promotion and career progression. It strengthened the role of the Equality and Diversity Committee, chaired by the Head of Department, and added two new support groups whose members include undergraduate and postgraduate students and staff from all categories and levels in the Department: the Women in Strathclyde Physics Association (WiSPA) and the Equality, Diversity, Equity and Inclusion group (EDEI). Leadership in this important area has been fostered by senior members of the Department attending the University's unconscious bias course. The John Anderson Building, the Department's main base, has 'parent and baby' spaces used by staff and students, as well as spaces devoted to those with particular protected characteristics.

Health and Wellbeing

The Department recognises its duty of care to all staff and postgraduate students. The Head of Department has overall responsibility for Health and Safety, with regulatory compliance and best practice overseen by the Department's Health and Safety Convener. Staff wellbeing more generally comes under the auspices of Occupational Health, Safety and Wellbeing, and is facilitated by ancillary services such as the University's new Centre for Sport and Recreation.

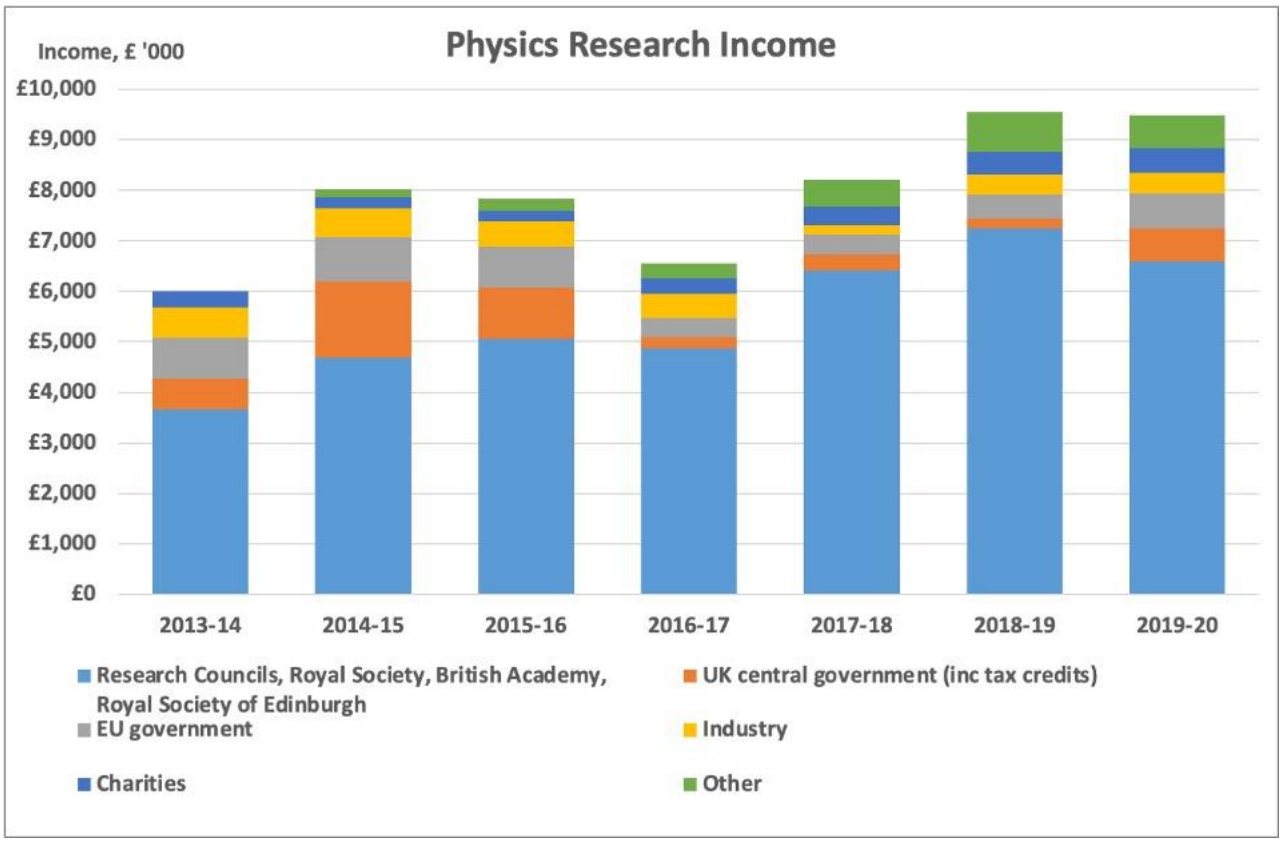
Applications for leave are managed on a case-by-case basis by the Head of Department in line with University Policies and Procedures set out by the University's Human Resources Department, keeping in mind the potential benefits to the Department and employee and the requirements of the Department. Applications for long term study leave are normally underpinned by a funded sabbatical, or are granted after a period of service in a senior Departmental management/administrative role. University policies are adhered to concerning leave of absence for staff suffering from ill-health or for those with caring responsibilities. Since 2016, 27 staff in Physics have benefitted from flexible working or periods of temporary leave.

Part-time staff have the same rights and expectations as their full-time colleagues and assessment of their contributions and development needs are considered equally, but with expectation reduced pro-rata. This also applies to fixed-term staff, who can progress to an open contract after four years of continuous service. Eight of our staff have made this transition during the REF period.

3. Income, infrastructure and facilities

3.1 Research Income

Strathclyde is typically in the top 10 of EPSRC's most highly funded physics departments and has significant research funding profiles with other government and industrial bodies. The Department's 2019/20 income of £9.5M comprises 50% of Science Faculty funding (for 25% of the academic staff) and more than 10% of the University portfolio as a whole. Annual research income has increased from £6M in 2013-14 to around £10M and is the highest per academic FTE in the University. This excludes Research Council in-kind income which totalled £4.65M over the REF period. This increase is set to continue with an award total in 2019/20 of £16M. Each of our research divisions has attracted extensive funding in the REF2021 period.



The Department is unique within the University in having a funding portfolio at five of the UK Research Councils, complemented by other government and charitable bodies. Funders include EPSRC, the National Environmental Research Council (NERC), the Science and Technology Facilities Council (STFC), Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC), Innovate UK, the UK Space Agency (UKSA), the Scottish Funding Council (SFC), the EU, The Royal Society, the Leverhulme Trust and the Carnegie Trust. Both the breadth and size of the portfolio have been accomplished via a clear funding strategy, based on senior members of the Department taking a leading role or being involved in large consortium grants, and holding platform and programme grants at the major funding bodies. This has led to a diversified funding portfolio that provides sustainability and resilience in the Department's research and KE funding.

In the first round of funding for the National Quantum Technologies Programme, Strathclyde was the only institution included as a partner in all four Quantum Technology (QT) Hubs – a consequence of the University's significant investment in Physics over many years in a broad spectrum of optical-based quantum science and technology. The Department is also a participant in all four Hubs in the

second round. This investment in the University's QT portfolio is entirely in Physics, involves three of our four divisions, and supports research that underpins both current and future impact.

3.2 Infrastructure Overview

During the REF period, the Department's success in winning research funding alongside the University's commitment to large, sustained investments in infrastructure in support of its commitment to its overarching research themes, has enabled the Department to create a set of well-founded laboratories in each division to support internationally-leading research and the generation of a high impact KE portfolio.

The Department is mainly housed in the John Anderson Building, which has undergone major refurbishment in the last decade. The University spent £12M on building a new wing to house research laboratories for Experimental Quantum Optics and Photonics (EQOP) and for the unique Scottish Centre for the Application of Plasma-Based Accelerators (SCAPA). Together with other laboratory refurbishments for new members of academic staff, the University has spent an additional £6.5M on the upgrade and maintenance of the John Anderson Building.

The £89M Technology and Innovation Centre (TIC), opened in 2015, houses modern labs for the Atoms Beams and Plasmas (ABP) group and the electron microscope facilities operated by the Semiconductor Spectroscopy and Devices (SSD) group. TIC also serves as the base for the Institute of Photonics, whose facilities include 12 photonics labs and a clean room microfabrication facility, totalling over 1000m^2. Support for Physics activities will be maintained as the University continues to expand into two new buildings similar to TIC, a £150M project with six research clusters, one of which is Quantum Technology. Other unique Strathclyde facilities include our quantum gas microscope and the high-resolution optical microscopy labs. Furthermore, the Department is one of the biggest users of high-power laser facilities at the national Central Laser Facility and also uses the Diamond Light Source Synchrotron and the ISIS Neutron and Muon Source, all located at RAL, the CLARA accelerator facility at the Daresbury laboratory and a number of international laser, accelerator and other research facilities.

The Department has access to shared University facilities such as ARCHIE-WeSt, a regional supercomputing centre for the West of Scotland set up in 2012, which supports both research excellence and economic growth. The main computer was upgraded in 2018, with EPSRC core equipment funding of £858k, and comprises more than 2500 INTEL Skylake 6138 cores for distributed parallel computing, two 3TB RAM large memory nodes and 210TB of high performance GPFS storage. Several of the Department's research groups make extensive use of this £2.4M facility. Other cross-divisional facilities include the Centre for Space Science Applications, which brings together a diverse set of researchers in Nanoscience, Plasmas and Optics to work on a broad range of physics-based problems including ocean colour remote sensing, rocket propulsion, space radiation hardness testing and space-based quantum technologies.

Technical support staff, comprising a pool of 17 specialist mechanical and electrical technicians, coordinated by two technical managers, make a vital contribution to the Department's research. Some technicians are attached to specific research groups while others are deployed across the Department. There are 12 local professional services staff, including project managers and administrators, a high-performance computing manager, a team of local IT staff, and an overall departmental manager who supports both teaching and research.

3.3 Divisional Research Funding and Facilities

The investments described enable the Department's research groups to develop and maintain well-staffed and funded state-of-the-art research laboratories. These are outlined below, together with description of division-specific research funding.

Nanoscience

The Department has traditionally had a strong research base in the interdisciplinary area of nanoscience, and this has grown considerably over the review period. Facilities include: four scanning electron microscopes for analysis of hard and soft matter; the Centre for Nanometrology established in 2005 by the Physics and Chemistry Departments; and the Mesolens Lab, a high-resolution optical microscopy facility. Also, a suite of laboratories for high-resolution optical microscopy has been created to grow research aligned to the University's strategic themes of Measurement Science & Enabling Technologies and Health & Wellbeing. The consolidation of our internationally-leading optical microscopic imaging equipment from several laboratories has already created new collaboration opportunities and helped to attract several new internationally leading researchers to the Department (Patton, van de Linde, Massabuau).

The division currently holds in excess of £10M in research grants funded by EPSRC, NERC, BBSRC, MRC, SFC, the EU, The Royal Society and the Leverhulme Trust. In the Physics of Life Sciences (PoLS) group, Chancellor's Fellow van de Linde joined in 2016, securing research funding from the Academy of Medical Sciences and Wellcome Trust to underpin work in super-resolution microscopy, a new income stream to the Department. Patton, also appointed in 2016, brought a Royal Society URF to set up a lab on super-resolution microscopy and adaptive optics with nanodiamonds. Funding from the MRC and BBSRC (£1.53M, £150k) allowed McConnell's laboratories to devise, produce and apply the mesolens, which can image the internal details of every cell in a 100 mm^3 sample.

The SSD group has expanded considerably in the REF period, holding a research funding portfolio in excess of £3M. Staff have been Co-Is in two EPSRC Programme Grants (with Strathclyde partners including the Institute of Photonics and Chemistry), a Platform grant (also with the Institute of Photonics), and have led a £2.7M Strategic Equipment grant, that funded nanoscale analysis equipment, in collaboration with Chemistry and the Centre for Continuous Manufacturing and Crystallisation. Hourahine leads an EPSRC-funded programme (£846k) on the characterisation of advanced materials using electron channelling contrast imaging. Lagoudakis, recruited in 2018 from Stanford, is leading work to develop hybrid quantum technologies. Rossi, recruited to a Chancellor's Fellowship in 2019 as a joint appointment with NPL, is developing a research programme in quantum metrology. Both Lagoudakis and Rossi have set up new laboratories with initial University funding and will strengthen interdisciplinary research activity with the Optics Division.

Optics

The Department is a leading centre in quantum optics and quantum technologies, represented by both the CNQO (theory) and EQOP (experiment) groups, with 22 researchers working in quantum technology. Division members are currently investigators in all four of the QT Hubs of Phase II of the UK National Programme [QuantIC (Jeffers), QComm (Oi), NQIT (Daley, Kuhr) and Sensors and Metrology (Riis, Griffin, Arnold)]. The total quantum technology funding portfolio of the Department since the start of the QT Hubs Phase I in December 2014 is in excess of £25M, most of this being in Optics. Highlights include Pritchard, who won an EPSRC Quantum Technology Fellowship to develop hybrid quantum technologies exploiting Rydberg atoms coupled to superconducting circuits, and whose laboratories have now begun producing world leading outputs. Pritchard also led a successful EPSRC Prosperity Partnership bid in this area (£4.4M) together with M Squared Lasers. Other successes by more junior researchers include Cameron, working as a theorist on the interaction of chiral molecules with light exhibiting orbital angular momentum, who won a Royal

Society URF from October 2019 (£620k). Large Strathclyde-led collaborative grants secured during the review period include the EPSRC Programme Grant "DesOEQ" (Daley, £5.8M total, with £2.7M for Strathclyde), the H2020 ETN "ColOpt" project (Ackemann, €3.9M total, £802k for Strathclyde) and the "CMSIN-II" project to develop a satellite-based multispectral imager, funded by the UKSA Centre for Earth Observation Instrumentation (Oi, £899k). In 2019, the Department won six four-year quantum technology studentships from the DSTL, five of these in the Optics Division (£750k).

Both research groups have excellent facilities commensurate with their funding success. EQOP laboratories are housed in the new wing of the John Anderson Building, with several laboratories dedicated to quantum gases, such as that for the quantum gas microscope and others for cold atoms, atomic magnetometry and timing, Rydberg atoms and imaging. The CNQO theory group has a dedicated suite of offices surrounding a group hub for students and RAs, consisting of local discussion rooms, with a computer facility housing its own fast servers and terminals.

Plasmas

The Strathclyde Intense Laser Interaction Studies (SILIS) group commissioned the SCAPA facility during the REF period. Directed by Jaroszynski, this is a flagship SUPA II project, jointly funded by the Scottish Funding Council, the University and EPSRC. The group has an internationally-leading track record in the development of laser-driven radiation sources, with part of SCAPA's purpose to develop these potentially transformative sources for wide-ranging applications. SCAPA's newly constructed, state-of-the-art suite of laboratories and facilities include 350TW and 40TW lasers, and the first electron beam was generated in 2019. An EPSRC Strategic Equipment grant (£1.7M; PI: McKenna) was secured in 2017 to establish three beamlines at SCAPA and funding was committed via our partnership in the Cockcroft Institute to purchase a kHz laser. Hidding also secured an ERC Consolidator grant (€2M) for a project to develop next-generation plasma-based electron beam sources. Other significant new grants secured during the review period include: responsive-mode EPSRC grants: Lab in a Bubble (PI: Jaroszynski; £4.4M); Relativistically Transparent Plasmas (PI: McKenna; £1.1M) and an STFC grant on Wakefield acceleration (PI: Hidding; £600k); EPSRC/BEIS funding for Plasma Accelerators for Nuclear Applications and Materials Analysis (PANAMA) a National Nuclear User Facility based at SCAPA (£3.2M; led by Civil and Environmental Engineering with Physics Co-Is: Jaroszynski and McKenna). The group also secured substantial indirect funding via access time on national and international, laser and accelerator research facilities.

The ABP group transferred their research laboratories to the TIC building during the review period. Significant EPSRC grant funding was secured for research into multi-wave interactions in plasmas (Ronald; £762k), high power THz radiation (Cross; £361k), and tokamak plasma science via a Programme Grant led by the University of York (Co-Is: Ronald and Phelps). Other significant grants include a US Air Force Office for Scientific Research programme linking dispersive pulse compressors with fast wave amplifiers (Ronald, $625k). The group also secured significant KE funding, including €450k from ESA (Ronald). They have also contributed significantly to the international STFC Muon Ionisation Cooling Experiment (MICE) that demonstrated in 2020 a key technique required for future lepton accelerators and neutrino factories. The group also have multiple research interests relevant to magnetically confined plasma environments, including development and maintenance of the ADAS atomic database, used at fusion facilities worldwide.

In April 2017, the University became a full member of the Cockcroft Institute of Accelerator Science and Technology (a research pooling partnership between the Universities of Lancaster, Liverpool, Manchester, Strathclyde and STFC). Academics within both groups and one from CNQO are now members of the Cockcroft Institute and were co-investigators on a Cockcroft STFC grant running during the REF period (£10.7M total, £1.5M to Strathclyde).

Institute of Photonics

The Institute of Photonics research activities are strategically focused to ensure academic excellence is combined with strong industrial engagement. Its key objective is to bridge the gap between academic research and industrial applications and development in photonics. An impact-related highlight from the REF period was the 2017 sale of spin-out company mLED Ltd. to Oculus, part of Facebook. Members of the Institute helped form the Fraunhofer Centre for Applied Photonics (Fh-CAP), led by Dawson and also based in the TIC building (see impact case). The Institute has a principal investigator cohort of 9.6 FTE with and total of 60 staff and PGR students. Based in the TIC building, its facilities include twelve photonics labs and in-house semiconductor microfabrication facilities within a 500m^2 cleanroom suite.

The Institute currently holds around 20 competitively-won research grants totalling £10.4M, including a significant portion of the Department's Quantum Technology portfolio (Dawson, Strain, Hastie). Notably, in 2019 Mathieson was awarded a prestigious Royal Academy of Engineering Research (RAEng) Chair in Emerging Technologies to work on neural interfaces for the understanding and treatment of neurodegenerative conditions (£2.69M, 2019-2029). Recently, Laurand was awarded a 5-year Leverhulme Trust Research Leadership award (£840k) to work on self-assembled optically-active resonators. Hastie was local PI on the Phase I QT Hub in Sensors and Metrology (£3.98M). In 2014 Kemp was awarded a Fraunhofer UK / RAEng Research Chair in Laser Engineering (£200k) and in 2016 was awarded £730k by EPSRC to investigate applications of Fibre-Laser Pumped Diamond Raman Laser applications. Dawson was awarded £1.43M in 2018 to investigate transfer-printing for heterogeneous integration in manufacturing.

4. Collaboration and contribution to the research base, economy and society

4.1 Collaboration

Physics, as with all sciences, functions best via sustained cross-seeding of ideas between researchers. Strathclyde Physics is no different in this regard, but what is noteworthy is the breadth of its collaborations. These are on multiple scales: locally within the city of Glasgow; in Scotland via, for example, the Scottish Universities Physics Alliance (SUPA) and other SFC research pooling initiatives; across the UK via large national collaborations such as the Cockcroft Institute; and internationally via EU projects and the International Max Planck Partnership (IMPP). The University actively supports staff involvement in such collaborations, and along with Faculty and Department, provides financial support via a variety of mechanisms, such as allocation of studentships or leveraged funding deployed from central or local strategic resources. Further, the University has around 35 Partner Universities around the world; academics from Physics have been funded by the University to visit many of these partners, for example the University of Waterloo in Canada and Nanyang University in Singapore, to explore research linkages, in particular via setting up joint PGR studentships.

The University has provided support for the pan-Scotland SUPA collaboration which, under the SUPA-II agreement with SFC, the university partners provide one third of the funding for the initiative. With Strathclyde the largest beneficiary of SUPA-II funding (£12M out of a £48M total), it was also the largest academic contributor of funds to the collaboration. Staff are active in theme leadership roles within SUPA including: Physics & Life Sciences (McConnell), Nuclear & Plasma Physics (Jaroszynski, until 2018), Photonics (Hastie) and Energy (McKenna, until 2018).

The Department participates in several other research pooling initiatives including the Scottish Universities Life Sciences Alliance (SULSA) and the Marine Alliance for Science and Technology for Scotland (MASTS) which is supported at University level via the institutional Ocean Air and Space research theme. MASTS also links to other University initiatives such as the Marine Enterprise

Innovation and Research studentships, for which the University matches any company financial contribution.

As part of our strategic partnership with NPL, jointly with the University of Surrey, the University has contributed during the REF period to 24 studentships in Physics in the joint Postgraduate Institute for Measurement Science, as well as to the funding of a joint appointment via a Chancellor's Fellowship (Rossi). Collaborations between Strathclyde, Surrey and NPL combine the three institutions' complementary academic strengths in precision measurement, which contributes to the Strathclyde research theme in Measurement Science and Enabling Technologies.

The University, Science Faculty and Physics Department have an intrinsically positive culture towards engaging with outside initiatives. The most visible example of this is the response to the UK quantum technology initiative. Strathclyde has for many years had a highly respected but deliberately diverse portfolio in quantum optics and atomic physics research which precluded it from bidding to lead a Quantum Technology hub devoted to a single topic. However, the portfolio was recognised internally and externally as a strength and so Strathclyde Physics researchers were investigators in many of the original Hub proposals and were members of all of the successful bids. The University has ensured that the Department makes pivotal contributions to the QT Hubs by providing financial support (extra RA salary and equipment purchase), studentships (7) and other contributions for the whole programme.

The IMPP in Measurement and Observation at the Quantum Limit was the first partnership of its kind entered into by the Max Planck Society. Strathclyde was a founding member, together with four other Scottish institutions and five Max Planck Institutes in Germany. It began in December 2013, securing initial funding of £10M over 5 years, with the aim of fostering new scientific collaborations at the highest level in quantum technology, specifically in gravity-wave interferometry, quantum optics and quantum information.

SU2P is an innovative Strathclyde-led initiative, a partnership between the photonics groupings of five Scottish universities and Stanford University in California, USA. SU2P sponsors fellowships, projects, staff and student exchanges, workshops and an annual symposium. Notable benefits and successes include the recruitment of Mathieson, who before appointment and subsequent promotion was an SU2P Fellow at Stanford. Several UK-based photonics companies are partners in SU2P (e.g. Coherent, M Squared, Optos and Kaiam).

Members of both the Plasmas and Optics divisions worked collaboratively with the Cockcroft Institute while the University was an associate member. The success of Strathclyde's contributions and the international reputation of the Physics Department in the field led to the University becoming a full member in 2016. This allowed the Plasma division to help drive the Institute's laser-plasma accelerator science and technology research, keeping the UK at the forefront of the development of future tools for physics, the broader scientific community and society. Furthermore, academics and researchers from Plasmas are members of the laboratory for Laser and Beam-driven Plasma Acceleration at the Deutsche Elektronen-Synchrotron Hamburg (DESY) and participate in projects at the Stanford Linear Accelerator Center (SLAC). Division members are also contributing to several pan-European projects such as the large Extreme Light Infrastructure (ELI) project which aims to perform science at ultrahigh laser intensities, and the EU COST network on Inertial Fusion Science. The Department is a member of the LaserLab-Europe consortium and is part of the Muon Ionisation Cooling Experiment collaboration. It is also a partner in the multinational International Thermonuclear Experimental Reactor (ITER) Fusion project, via the Department developing and hosting the Atomic Data and Analysis Structure (ADAS) codes used by the project for its detailed modelling.

Members of the Nanoscience division and the Institute of Photonics are active in the UK Nitrides Consortium (chaired by Martin since late 2017) the UK research community on group III-nitride semiconductors, which has around 200 UK and Irish academic and industrial members. The PoLS group's research in fluorescence lifetime imaging has underpinned impact in a wide range of pharmaceutical and biomedical research applications worldwide via commercial exploitation by HORIBA (Fluorescence Products ICS). This resulted in the company being awarded an Institute of Physics Business Innovation Award in 2019. This same award was won by M Squared Lasers in 2017, established by the founders of Microlase, which contributed to one of our impact cases in REF2014. M Squared Lasers still works closely with the Department, for example in the previously mentioned Prosperity Partnership and in the International Doctoral School in Quantum Technology. In another part of the Nanoscience division, the Mesolab is currently transforming bioimaging for medical research, interacting with biomedical scientists and providing them with access to this transformative next-generation imaging technique.

All of these examples clearly demonstrate that membership of such collaborations helps to drive our research. In turn, our own researchers provide innovation and direction to the collaborations.

4.2 Societal contribution and outreach

The Department's societal contribution spans economic activity and wealth creation via the impact built on our underpinning research (see impact strategy and case studies), the provision of skilled staff for a wide range of employers and a variety of outreach activities engaging with young people and the general public.

In photonics and quantum technology in particular, Strathclyde provides an underpinning set of researchers, trained PhDs and undergraduates for employers locally in the central belt of Scotland, an important centre for the photonics industry, and in the UK and beyond. Alongside the user-informed research of the Institute of Photonics, this was an important driver behind the decision to locate the first UK Fraunhofer centre, Fh-CAP, in the TIC building at Strathclyde. Established with financial support from Fraunhofer-Gesellschaft, the Scottish Government, Scottish Funding Council, Scottish Enterprise and the University, Fh-CAP focusses on commercial applied research, with its Director and some other staff joint appointments with the Institute. The centre is an important intermediary organisation in the technology sector, enabling its partner companies to accelerate technology and product development, with associated business strategy and economic benefits.

The Department has an Outreach Coordinator and undertakes a range of outreach activities in local schools, as well as hosting public lectures which included a 2017 lecture by Nobel Laureate, Bill Phill ips. The David Elder Lecture series, which we have run in partnership with Glasgow Science Centre since 2015, provides talks by a wide range of speakers including scientists, science writers and broadcasters, mostly with a space theme. Aimed at teenagers and adults, these run monthly during most of the year.

Most members of the Department involved in quantum technology participate in outreach events organised by the QT Hubs. In 2019 and online in 2020, Strathclyde took a unified approach to the annual Quantum Technology Showcase in London and presented its full research portfolio to delegates at a dedicated stand. More locally, academics regularly contribute research talks to the student Physics Society.

4.3 Contribution to the research base

Members of the Department make many and varied contributions to the wellbeing of Physics as a discipline and as a community. All academics are active in peer review for journals and for funding bodies, with several on the peer review colleges of UKRI. Staff make strong contributions to UKRI strategic groups, panels and committees and to the development of science policy. Several

academics serve as journal editorial board members and editors. These are all detailed in the tables below.

As noted previously, several academics have served as SUPA theme leaders, supporting advances in their area in Scottish physics. The Department supports the Scottish Universities Summer Schools in Physics (SUSSP), a Scottish charity that has held 75 International PGR level Summer Schools since 1960. Jeffers was Director of SUSSP71, Frontiers in Quantum Dynamics and Quantum Optics, hosted at Strathclyde in 2015, and is the current Chairman of SUSSP and its board of trustees.

A number of Physics Department academics have been recognised for their contributions to the discipline during the REF Period. Amongst the most notable were two awards presented to Dawson for outstanding contributions in two areas, the Dennis Gabor Medal of the Institute of Physics "*For his vision and leadership in applied photonics, including pioneering contributions to optically pumped semiconductor lasers, diamond photonics and gallium nitride optical microsystems*." and the Aron Kressel Award of the IEEE Photonics Society for important contributions to opto-electronic device technology. The Institute of Physics Dennis Gabor Medal was awarded to Birch in 2020 "*For pioneering the UK fluorescence lifetime industry through research publications and the market-leading company IBH, which he cofounded*." Furthermore, ex-Strathclyde Physics PhD graduate Hempler, now at M Squared Lasers, also won the Dennis Gabor Medal in 2018.

Lockerbie shared in the 2016 Royal Society of Edinburgh (RSE) President's Medal and two academics were elected as RSE Fellows during the REF period (Jaroszynski, McConnell) bringing the total to nine (also Birch, Dawson, Ferguson, Firth, Ledingham, Oppo, Phelps).
The tables below detail contributions during the REF period including:

- Further details of the research leadership, policy and editorial roles summarised above
- Information on additional awards and prizes not already mentioned
- Summary of prestigious research chairs and fellowships won

UKRI leadership roles

McKenna	STFC Science Board EPSRC Capital and Equipment Strategic Advisory Team STFC Future Light Source Strategy Group
Dawson	EPSRC Quantum Technology SAT/SAN working group EPSRC Advisory Groups on Quantum Technologies and the National Quantum Computing Centre
Martin	Chair of Steering Panel of EPSRC National Epitaxy Facility
Hidding Jaroszynski to 2015	STFC Accelerator Strategy Board
Hidding McKenna to 2016	Member of STFC High Power Laser Facility Access Panel
 McNeil Hidding	*Coordinators for STFC 2017 Accelerator Strategic Review* Light Source Novel Accelerators

Other leadership roles

McKenna, until 2018	Energy Technology Partnership Directorate
Martin (chair) and Massabuau (member)	UK Nitrides Consortium Committee

National Reviews

Riis, Dawson	2018 House of Commons Select Committee report on Quantum Technology
McKenna	2017 BEIS Review of National Large Facilities at Harwell
Dawson	UK Government BEIS Member, Quantum Computing Expert Group

Example Scientific Journal Editorships and Board Memberships

Birch	Editor in Chief, *Measurement Science and Technology* (until 2016) co-founding Editor in Chief, *Methods and Applications in Fluorescence* Board, *Journal of Biomedical Optics*
Dawson	Editor, now Editor-in-Chief, *Progress in Quantum Electronics*
Oppo	Editorial Board, *Physical Review Letters*
Robb	Board, *Optics Express* and *Atoms*
Kuhr	Editorial Board, *Physical Review X* Associate Editor of *Science Advances*
Papoff	Editorial Board, *Scientific Reports*
McConnell	Board, *Journal of Microscopy*

Awards:

Phelps	2017 IEEE Plasma Science and Applications Award
Ferguson	Optical Society (OSA) 2019 Robert E Hopkins Leadership Award
Birch	2017 HORIBA Lifetime Achievement Award
McConnell	2019 Royal Microscopy Society Mid-Career Scientific Achievement Award

Learned Societies:

	Institute of Physics
McNeil McKenna Robb Badnell	Chair, Particle Accelerators and Beams Group Large Facilities Forum Quantum Electronics and Photonics Committee Chair, Atomic and Molecular Interactions Group
Dawson	*Royal Society*: International Networks Committee, Commonwealth Science Conference Grants Committee *IEEE Photonics Society:* Elected Member of Board of Governors; Vice President Conferences; Technical Affairs Committee; Joint Awards Committee
Birch	Royal Society, International Exchanges Panel
Ackemann	European Physical Society, Board Member, Quantum Electronics and Optics Division
McConnell	Royal Microscopical Society, Chair, Light Microscopy Committee

Advisory Committees for international facilities

McKenna	APOLLON 10-Petawatt laser, France
Jaroszynski, McKenna	Extreme Light Infrastructure facility, Europe
McKenna	HIBEF project at the European XFEL, Germany

Prestigious Research Chairs and Fellowships

Won during the period:

Mathieson	RAEng Chair in Emerging Technologies (2019)
Cameron	Royal Society University Research Fellowship (2019)
Herrnsdorf	EPSRC UKRI Innovation Fellowship (2018)
Pritchard	EPSRC Quantum Technology Fellowship (2015)
Laurand	Leverhulme Trust five year Research Leadership Award (2020)
Tagliacozzo	Ramon y Cajal Fellowship from the Spanish Ministry of Science (2018)

Held during the period:

Kemp	RAEng Research Chair (2014-19)
McKenna	EPSRC (Senior) Leadership Fellow (2012-17)
Patton	Royal Society University Research Fellowship (2013-)
Henrich	EPSRC Research Software Engineer Fellowship (2016-21)
Capdessus	EPSRC (Postdoctoral) Fellowship (2017-20)

The above evidence demonstrates our commitment to the discipline in terms of producing, directing and contributing to the management of research of the highest quality. This commitment extends to translating that research into useful technologies for the benefit of Physics, science in general and wider society, and to explaining the purpose and meaning of its research to the public, in alignment with the founding principles of John Anderson's institution as "A place of useful learning".