Institution: University of Exeter

Unit of Assessment: 09 Physics

Section 1. Unit context and structure, research and impact strategy

a. Overview

Physics at Exeter is a vibrant and dynamic unit which harbours 6 IOP award winners and 4 international prize winners during the REF period, the IOP president (Sir Roy Sambles), and 2 fellows of the Royal Society. Our department has grown substantially since 2013 in terms of staff (41 to 50 FTE for REF) and PGR students (from ~1.5 to ~2.0/FTE), with research income rising steeply from £4.9M in 2013/14 to £9.1M in 2019/20. There has also been a commensurate growth in research quality: citations for our papers have increased each year since 2013, almost doubling in citations/year/FTE during the current REF period.

In step with the University level strategy (institutional level environment statement (ILES), 2.3), Physics has focussed on interdisciplinary research, and we have invested £3.4M in space refurbishment for sixteen cutting edge labs and facilities to enable this. We have strengthened links between groups to cultivate interdisciplinary research, exemplified by our cross disciplinary CDT in metamaterials, spanning physics and engineering, as well as the £52M Living Systems building adjoining Physics, an interdisciplinary hub positioned at the interface between the physical and the life sciences. We also use research-led teaching to expose our undergraduates to ideas at the cutting edge of physics: optional modules are focussed on research strengths within the department, and our taught programmes enable students to gain valuable research within our research groups. As a result, Physics has been voted the best research community in Exeter's Student Guild awards in 2013, 2015 and 2018, and voted best overall subject in 2019.

b. Research strategy

In line with future plans outlined in REF2014 we have strengthened our four core research groups and the links between them. A core principle of our strategy has been to establish world leading facilities centred on multidisciplinary research, where we can provide leadership, attract dynamic staff and secure new funding. We have also improved our staffing, recognition and equality procedures (section 2). Exceeding our growth model, our income has doubled during the current REF period (section 3) and we have greatly expanded our global partnerships (section 4).

Research and Management Structure

Research is consolidated within four research groups: Astrophysics (ASTRO), Biomedical Physics (BIO), Electromagnetic and Acoustic Materials (EMAG), and Quantum Systems and Nanomaterials (QSN). Each group has an Academic Lead (AL), who provides strategic leadership and mentoring for each of the groups. Together with the Head of Discipline and Directors of Research and Education, the ALs form the Physics Strategy Group. Research strategy decided here feeds into the wider, college level (comprising Maths, Engineering and Computer Science) and ultimately University level committees, at which the University Science Strategy and large capital investments are decided upon (ILES 4.2).

The research groups provide critical mass for research themes that can attract scholars and funding from disparate sources. Our staff have focused their interests around the group themes, and research strategy has developed with thematic advancement in mind. These themes link to cross-disciplinary areas identified and strongly supported by the University Science Strategy including Exoplanets, Functional Materials, Translational Medicine and Systems Biology, leading to collaborations with Engineering, Mathematics, the College of Life and Environmental Sciences and the College of Medicine and Health, as well as external partners such as the Met Office. At the boundary between physics and the life sciences, the University of Exeter has also invested £52M in the innovative Living Systems building, which adjoins Physics. This is the University's largest single investment in interdisciplinary science to date, and part of an overall strategic science investment of £340M since 2008.

Abbr.	Members	Research areas
ASTRO	**Prof. (6):** Bate(AL), Baraffe, Chabrier, Dobbs, Harries, Naylor **Ass. Prof. (5):** Browning, Hinkley, Kraus, Matt, Mayne, **Lecturer + Snr Lecturer (7):** Brunt, Haywood, Hatchell, Hebrard, Loren-Aguilar, Williams, Zhukovska 21 postdocs, 24 PhD students	Theoretical, numerical and observational studies of molecular clouds, star/planet formation, stellar evolution and planetary atmospheres. We develop advanced numerical tools and algorithms applied to star formation, interior and atmospheric processes in stars and planets, star-disk interaction, as well as new instrumentation for observation. Several computational areas also link to wider disciplines such as medical research and climate studies.
BIO	**Prof. (4):** Soeller(AL), Moger, Stone, Vollmer **Ass. Prof. (1):** Palombo **Lecturer + Snr Lecturer (5):** Corbett, Gielen, Kattnig, Petrov, Richards 10 postdocs, 22 PhD students	Application of physical principles and methods to solve biological problems, and development of new methods (with focus on Biophotonics) to enable the study of biological matter from nanoscale to mesoscale. Topics cover advancing the fundamental understanding of biological mechanisms and their association with disease, to the development of healthcare technologies.
EMAG	**Prof. (6):** Hicken(AL), Barnes, Hendry, Hibbins, Sambles, Vukusic **Ass. Prof. (5):** Anders, Bertollotti, Kruglyak, Ogrin, Phillips **Lecturer + Snr Lecturer (4):** Correa, Horsley, Kyriienko, Withers 16 postdocs, 34 PhD students	Experimental and theoretical studies of wave-matter interactions combining: materials synthesis and nanofabrication; imaging and characterisation using microwave, THz, ultrafast lasers, sound and synchrotron sources; numerical and analytical quantum theory, spatial transformation methods, and micromagnetic theory. Four distinct sub-themes explore metamaterials, disordered systems, plasmonic excitations and magnetic systems.
QSN	**Prof. (1):** Srivastava **Ass. Prof. (3):** Russo(AL), Portnoi, Usher **Lecturer + Snr Lecturer (4):** Hepplestone, Horsell, Mariani, Shytov 3 postdocs, 13 PhD students	Experimental and theoretical studies of matter, encompassing optical, electrical, thermal and mechanical properties of scientifically and industrially important materials including graphene, carbon nanotubes, semiconductor quantum dots and superlattices, topological insulators and dichalcogenides. QSN aims to understand these systems at the deepest possible level, to establish the underlying physics and the potential for industrial applications.

Table1: *Research groups, staff members (as of census date) and coverage.*

Group directions and funding strategies

Astrophysics (ASTRO): ASTRO has expanded to 18 staff submissions for REF, an increase of 3 since 2014. ASTRO has been extremely successful in obtaining ERC funding, with €11.7M in ERC awards during the REF period (table 2). The group also has a strong track record of successful STFC Consolidated grants (£1.7M in 2012; £700K in 2015; £1.8M in 2018). This success in grant funding has enabled two 5-year positions funded by the University, one of which (Hebrard) is now permanent. Links with the Met Office (an aim of Ref 2014) have grown, including code development and the secondment of MET Office staff to work with us in Physics. Emerging new collaborations with local SMEs specialising in digital media have led to an exciting outreach programme with huge success in developing immersive VR videos that have enthralled millions of viewers on YouTube.

ASTRO's future strategy involves capitalising on next generation observational facilities and continuing our success with high performance computing (HPC). Our most recent ERC awards (Baraffe and Dobbs) focus on HPC, and our continuing involvement as one of the main UK users of DiRAC and PRACE facilities is key. Exeter is also well placed to continue its success in observation of extrasolar planets: Hinkley is PI of one of the two main JWST programmes in this field, whilst the University's role in the £1M Terra Hunting project, aimed at finding an Earth twin, has expanded with the hiring of Haywood in 2020. Further, the University is looking to develop a new £82M building, project North Park. This has been delayed due to the pandemic, with a financial reassessment due in 2021. If it proceeds as planned, North Park will house ASTRO, as well as the Global Systems Institute (GSI) and the Institute of Data Science and Artificial Intelligence (IDSAI). Moving ASTRO to North Park is strategic, with new interdisciplinary links to GSI and IDSAI furthering cross-disciplinary research on, for example, climate science on extrasolar planets and data science projects for large observational instruments. The expansion to North Park will include our own instrumentation laboratory (Kraus and Hinkley), enabling ASTRO to apply to non-traditional sources of funding such as NERC and EPSRC. Close links with the rest of Physics will be maintained, with regular departmental meetings, colloquia/seminars and social events, as well as the continuation of our shared undergraduate/post-graduate teaching programmes.

Biomedical Physics (BIO):
In line with the institutional strategy to grow interdisciplinary research, BIO has been our fastest growing group, expanding from 5 to 10 permanent academic staff since REF2014. This expansion has been bolstered by a £2.6M University investment to create 11 new BIO laboratories in Physics, and by the £52M Living Systems Institute (LSI). The LSI is physically connected to Physics, providing BIO with an additional 6 laboratories and accommodating 5 new Physics staff members. The growth of BIO has been sustained by success in winning large research awards, including an EPSRC Programme Grant (£5.8M), Physics of Life (£2.1M), Healthcare Technologies (£1.2M), Strategic Equipment award (£1.1M) as well several fellowship awards. BIO's expansion has focused on building strategic core research capabilities in Biophotonics to enable the study of biological matter from the nano- to meso-scale. New capabilities include quantitative fluorescence microscopy (Corbett), super-resolution microscopy (Soeller), non-linear optical spectroscopy (Moger), Brillouin scattering spectroscopy (Palombo), nano/quantum sensors (Vollmer), and clinical vibrational spectroscopy/biosensing (Stone). These new capabilities are driven by fundamental research challenges in biology and medicine that cover all scales of biological organisation, from the molecular processes (Vollmer) to investigations of the plasma membrane (Petrov), neuronal signalling and morphology (Soeller), high-throughput screening for drug development (Gielen) and the development of novel diagnostic and therapeutic healthcare technologies (Moger, Palombo and Stone). BIO are also building capabilities in computational Biophysical modelling for applications such as magnetoreception (Kattnig) and cellular processes relating to the immune system (Richards).

Electromagnetic and Acoustic Materials (EMAG):
EMAG has consolidated by placing excellent people in strategic areas, as reflected by our large number of 5-year fellowship awards (Anders, Barnes, Hendry, Horsley and Phillips – table 2) and IOP award winners (Vukusic, 2014, Anders, 2015, Bertolotti, 2016, Sambles 2018, Barnes 2019) during the current REF period. Strategic gaps in capability have been filled through appointments, with Withers bringing expertise in fabrication of 2D materials, and Phillips in structured light. Activity in quantum theory has been expanded (Kyriienko, Correa) and we plan to include experimental studies in this endeavour in future. EMAG's research includes some of our most industry facing work, and we seek to grow these areas in response to the government's Industrial Strategy. Our metamaterials research theme, which covers the majority of staff in the group, responds to needs within defence and security, and we have received >£5M in investment from companies in these areas. Other themes (disordered systems, plasmonics, and magnetic systems) also deliver new materials for technological applications, particularly within information, imaging and sensing sectors. The CDT in metamaterials, a £5M EPSRC award co-funded by £2.5M investment from industry and £4.5M investment from the University, has driven research through a large increase in PhD students from 14 in 2014 to 34 in 2019. Through the CDT, EMAG

has also consolidated partnerships with industry. We lead the recently funded EPSRC Metamaterials Industrial Network (PI: Hibbins), and around half of our staff are involved with the Team A prosperity partnership, a £2.4M EPSRC investment with ~50% industry match from our partner QinetiQ. This increased industry focus has culminated in the recent creation of a Centre for Metamaterials and Innovation, a legacy that will provide the critical mass to fully capitalise on upcoming investments from EPSRC, Innovate UK and MoD, and we have set up new framework agreements with key industry partners for this, as outlined in sections 3 and 4.

Quantum Systems and Nanomaterials (QSN):
Our smallest research group, QSN houses the Centre for Graphene Science, and in recent years the group has advanced into the broader realm of 2D materials. QSN plays a pivotal role in interdisciplinary materials research, and in the past 5 years, group members have co-authored more than 40 research papers with colleagues from Engineering and other groups in Physics. Entrepreneurial activity around graphene composites has been a key driver of recent research in QSN, exemplified by the launch of the spin-out Concrene Ltd (January 2019), and we look to grow this area in the future. Concrene Ltd aims to reduce the carbon footprint of the concrete industry, has been shortlisted for an Innovation award by the Royal Society of Chemistry, and recently received £1M from investors.

Funding for QSN has historically come from EPSRC and EU sources. In the current REF cycle, QSN has diversified income, with new awards from the Leverhulme trust (>£700K in grants awarded to Mariani, Russo and Srivastava), Royal Society (>£500K Russo and Mariani; including a prestigious Theo Murphy blue sky award) and 4 Marie Curie fellowships (~£500K Russo, Portnoi). QSN has also developed applied areas of research funded by Innovate UK (>£200K Russo, Horsell) and directly from industry partners including DSTL, QinetiQ and Deregallera.

Open Access
Baraffe (ASTRO) sits on the UKRI Open Access Steering Group. Led by Baraffe, Physics at Exeter has made a strong push towards open access in recent years. In 2014 the University initiated a central fund to facilitate an open access policy. Our department spend from this fund has grown every year, and in 2018 amounted to >£60K, which allowed us to publish >50 gold open access papers. In 2013, the University set up Open Research Exeter (ORE), a centrally managed repository for publications and data authored by University staff. As of Nov 2019, ORE received over 560,000 download requests for papers from our staff. It is now mandatory for all staff to submit open access compliant versions of their papers to ORE within the 3-month REF guideline. We have developed departmental procedures to make sure that members of staff comply with this University policy, which includes email reminders to the authors of recently published papers. New staff also undergo a training session as part of their induction, in which they are shown how to upload all current and future papers to ORE. In 2018, Physics was responsible for almost 300 manuscript deposits to ORE (approaching 100% coverage), including 90 full datasets.

Research Integrity
Exeter University aims to keep the highest standards of rigour and integrity in all aspects of research and has signed the Universities UK concordat. To meet its pledge, the University has put in place a number of policies to raise ethics standards. These include:

- Open access policies to facility free availability of data (above).
- Initiation of an Exeter branch of the PGR led RIOT Science Club (Reproducible, Interpretable, Open, and Transparent Science).
- Introduction of an e-Ethics portal, through which applications for ethical approval are made.

During the REF period, Physics has appointed an Ethics Officer (Corbett, BIO), who acts as a first point of contact for anyone wanting more information, or to raise concerns, about matters of research integrity. The ethics officer also oversees research integrity by:

- Raising awareness of ethical research issues, such as responsibilities when handling personal data, working with animals or human tissue, and compliance with ethical codes.
- Dealing confidentially with allegations of research misconduct should they arise.
- Liaising with RIOT.
- Annually reviewing progress and processes to ensure that these remain fit for purpose.

Future goals

Our department has undergone significant expansion over the last 20 years, more than doubling its academic staff and its undergraduate student numbers. Looking to the future, Exeter Physics seeks to establish a global reputation in research as one of the world's top 100 departments. We aim to build on our core research groups, capitalising on the different strengths in each group, and establish a portfolio of exciting research themes in these areas. Current and future expansion is based around industry and impact, interdisciplinarity and internationalisation:

- Industry and Impact: We have made great strides here, and our aim is to embed impact at a cultural level within Physics, and to ensure that we make the most of our industry links and intellectual property. We have identified a number of interdisciplinary ideas that are well aligned with the new Research and Impact Strategy such as materials and healthcare physics, and look to establish local centres in focussed areas, establishing a Director for Impact (Corbett, BIO) to oversee and facilitate this activity. The main goal is to enhance industry interaction and to develop future partners for large research council and Innovate UK bids. The creation of a Centre for Metamaterials and Innovation, showcasing our expertise in meta- and functional materials, will be an important facet of our industry-facing research.
- Interdisciplinarity: collaborative, cross-disciplinary research is central to Exeter's science strategy. In Physics, 9% of our outputs have been highlighted for the REF 2021 panel as "very interdisciplinary" (e.g., a biology paper which contains physics content), while >25% of our papers have interdisciplinary content. Strengthening existing links, and growing new ones, is key to future success in an environment where top-down "grand challenge" calls by government are a growing feature of the funding landscape. We have several initiatives which will substantially expand scope for interdisciplinary research, such as the new North Park building, which will better enable us to address real world problems.
- Internationalisation: We are a vibrant multinational department, with the majority of our academic staff originally from outside the UK, and plan to expand the global reach of our research by significantly increasing our international visibility and strategic collaborations. To achieve this, we have Introduced a new position, Director for International Relations (Mariani, QSN), and a number of new initiatives to actively seek global partnerships with leading universities and institutes around the world.

The strategies implemented to address these aims, and the results, are covered in **section 4**.

Section 2. People

In line with the Researcher Development Concordat, we are committed to helping develop the careers of our staff: they are our greatest asset, and we endeavour to create an environment in which they feel valued, thrive, and are rewarded for success. We have grown in number by over 20% during the REF period and this growth has led to a substantial change in the Department's demographics, with an influx of early career researchers (Correa, Gielen, Kyriienko, Haywood, Hebrard, Loren-Aguilar, Corbett, Kattnig, Phillips, Richards, Withers and Zhukovska). We are also a collegiate department in which mentoring and internal peer review play a significant role in developing the careers of our staff, and our latest employee engagement survey indicated 91% of our staff have good relationships with colleagues.

Staffing strategy

New academic appointments reflect our evolving research objectives. As a first step we discuss potential posts at the Physics Strategy Group to consider the fit to our department strategy and the balance of staff across our groups. Vacated academic posts are not simply refilled but instead a full scientific and business case is made to the College. Once approved, we seek to attract the very best from a world-wide pool of talent. To do this, we advertise internationally, explicitly seeking out a diverse field of candidates and providing a competitive start-up package (see below).

The success of our recruitment strategy, and hiring of up-and-coming research stars, is demonstrated by the large number of prestigious 5-year fellowships awarded to new staff during the REF period (Phillips, Richards, Horsley, Anders, Dobbs, Kraus, Vollmer). This success has

been matched by our more established researchers, with ~20% of our staff holding a fellowship at the census date, and >25% having held a 5-year fellowship at some point during the REF period (with Dobbs and Baraffe obtaining their second consecutive ERCs in 2019). Moreover, many of our researchers are respected leaders in their fields, corroborated by a number of awards in recent years – table 7.

Support for early career researchers (ECRs)
Exeter is aligned to the International Researcher Development Framework and holds the European HR Excellence in Research award for putting in place strategies to meet the principles of the Researcher Development Concordat. A host of supporting measures have resulted. During the REF term, the probation period for new Lecturers has been shortened from 5 to 3 years, and all staff are supported to progress from Lecturer to Senior Lecturer in 5 years. A mandatory University induction is completed within three weeks of appointment, where information on HR policies and benefits including flexible working and shared parental leave are highlighted, while training covers topics such as Equality and Diversity, Information Security, Health and Safety, and (PhD) Supervision. Physics also gives local inductions for all staff, including building tours and staff introductions. We then support ECRs through a variety of means:

- Teaching and admin duties introduced gradually during the first 3 years of new appointments.
- Mentoring by a senior academic through the probation period, which enables better identification of any problems.
- Permanent new appointments supported by a PhD studentship and start-up funding.
- Support for the key ECR/Lecturer transition. An 'ECR Hub' draws together information on training and development, funding initiatives, competitions and strategic representation. We have also established a college wide ECR Network which raises opportunities for collaborative interaction and problem solving, and regularly holds focused career development workshops to elucidate promotions pathways or provide training for funding applications.

Personal development
Staff undergo a rigorous personal development review every year with their AL, where any problems are discussed, solutions sought, and plans made for the academic year. These also cover achievements, future goals and significant contributions. Training for the AL carrying out the review is mandatory, and highlights the importance of networking, attending conferences and continuous professional development. To bolster this, we have focused on increasing staff awareness of career management and enhancing our development opportunities to support them. New activities include 'Taking control of your career' workshops, CV writing skills sessions, shadowing opportunities and one-to-one career coaching. There has been positive feedback and high engagement from staff with this enhanced provision. Mentoring and Coaching Conversations skills courses have been run at the University since 2010 creating a large pool of informal trained mentors. Our new institution-wide mentoring scheme 'One Step Beyond', launched in October 2015, has seen take up at 61% amongst staff at senior lecturer level and below.

Staff recognition and promotion
At all career stages, we put a strong emphasis on career progression to retain and reward hardworking and high-performing staff, as evidence by 22 promotions within the REF period, including 6 advancements to professorial level. We have worked hard to develop a culture that attracts and retains outstanding academics in a competitive international environment, while offering our staff the highest-quality support in resources and services. Staff retention and contract type are monitored and there is a policy to reduce the percentage of fixed term contracts with a move to permanency for ECRs. A departmental promotions committee identifies staff that are viewed as credible promotion candidates and advises them to apply - a process that mitigates against the potential gender bias of a system that relies on self-promotion. Gender balance is also monitored and reported back to the Physics Inclusivity Working Group (see below). In 2017/18, the University also reviewed its promotion strategy and agreed new processes for the consideration of applications. There are now clear criteria for probation for Lecturers in Physics; and progression to Senior Lecturer, Associate Professor and Professor. Staff are regularly made

aware of the activities and standards that they should focus on, which are discussed at length during their personal development reviews, and they are encouraged to attend regular workshops aimed at making the whole process as transparent and objective as possible.

Equality, diversity and inclusion (ED&I)

Through the Physics Inclusivity Working Group (PIWG), chaired by the Head of Discipline, we strive to develop an environment where good practice and a commitment to equality and diversity are an integral part of what we do. This is seen as particularly important in our subject area, which has suffered from a historical and nationwide imbalance across many diversity aspects.

In recognition of our efforts to address gender imbalance in particular, our department was awarded IOP Juno Champion status in 2018 followed by an Athena SWAN silver award. Our ED&I work is benchmarked against the six IOP Juno principles and the PIWG keeps an action plan as a focal point for its activities. Important developments since 2014 include:

- New policies to ensure non-discriminatory appointment procedures. Single gender appointment panels are strongly discouraged for post-doc level appointments and prohibited for staff level appointments. Applicant selection lists are also closely scrutinised by PIWG, and single gender returns are referred back to the appointment panel to reassess the candidates to consider unintentional exclusion (taking into account career breaks etc.).
- Establishment of a Women in Physics group, which organises seminars, workshops on topics such as promotion applications, as well as social events.
- Embedding ED&I awareness in job descriptions for all departmental roles.
- Formation of a Parent and Carers group which organises social events and raises awareness of options for maternity/paternity/shared leave.
- An annual Pulse Check, which allows staff to make anonymous recommendations to improve culture and working environment. Results of the Pulse Check are reviewed by PIWG and used to create new actions.

Improvements to working conditions across the University include:

- Flexible work schedules for staff returning from maternity/paternity leave, and workshops to communicate information on all parental leave options.
- A new returners policy including a wellbeing and risk assessment.
- Increased maternity/adoption/shared parental pay from 16 to 26 weeks full-pay and increased paternity, maternity/adoption support leave and full-pay provision to 6 weeks.
- A new framework for managers managing maternity, paternity and carer leave, highlighting Exeter's New and Expectant Mothers standards (launched May 2014).
- A fertility policy that allows for female members of staff to receive up to 7 days on full pay.

Our gender positive policies are having a significant and measurable effect. For example, our PhD student gender balance has improved significantly: In 2013/14 only 13% of enrolled PhD students were female, which has increased over the REF period to 31% in 2018/19. This now compares favourably with national figures: 24% of A level physics students in 2020 were female. We have also been more proactive in encouraging female members of staff to apply for promotion and fellowships and have promoted two women to associate professor level (Palombo, Anders) and one to full professor (Dobbs) since 2014, doubling our female staff numbers at these respective levels. We have also had four prestigious 5-year fellowships/ERCs awarded to female staff members (Baraffe, Dobbs, Anders, Zhukovska), 33% of our fellowship holders. We realise that changes will take time to filter through to our staff distribution but are hopeful that, in the next REF period, we will see the gender rebalance now observed in our PhD and undergraduate populations translate gradually to our staff distribution. Currently 13.7% by FTE of category A staff are female, though 15.5% of our REF2021 outputs are attributed to female staff. Selection of REF outputs has been carried out by a gender representative panel of senior Physics staff across the four research groups, and post selection analysis carried out to ensure absence of gender and other biases during selection.

Minority groups have also been historically under-represented in our subject, and PIWG has worked hard to address LGBTQ and racial prejudices. PIWG were active in forming PRISM, a network for local LGBTQ professionals and students within the STEM sector, established 2018,

which organizes regular talks and workshops. PIWG has also taken an active role in encouraging ECRs from ethnic backgrounds to apply for fellowships (4 in 2020-2021) supported by an offer of proleptic appointment. In response to the Black Lives Matter movement, PIWG pledged support with several anti-racism statements, and highlighted routes for reporting racism within our department. For Black History Month, PIWG organized an online promotion which highlighted two of our alumnae via blog profiles and social media. These examples of positive actions have helped foster an inclusive environment in our department, and minority groups are better represented: students of Asian/Black/Chinese/Mixed background made up 17.9% of our CDT intake (see below), compared to the national figure for 'PhDs in Physical Sciences' of 2.6% [HESA 2015]. This inclusive environment is also reflected in our undergraduate population, with 29% female, 77% state educated, 16.5% disabled; all above the national average.

PhD application processes

We recognise the key contribution made by PGR students to our research and have increased PGR numbers by 50% over the REF period: 61 registered in 2013/14 to 91 in 2019/20, filtering through to an increase in completions from 17.5 in 2013/14 to 24.1 in 2018/19. PGR applicants come to Exeter via diverse routes. Recruitment campaigns are organised by the University, with selection being devolved to the College and then to Physics. A first stage, on-line application indicates a preferred area of study or pre-advertised project, which is then sent to Physics if appropriate. Once the applicant and potential supervisor have reached agreement an offer is made subject to financial support (considered separately and according to the source). Decisions upon doctoral training partnership and university funded awards are determined at college level on applicant quality and strategic importance.

Support and training for PhD students

Postgraduates benefit from a supportive working relationship with their supervisor, typically with daily contact and pre-arranged weekly meetings, and in turn they are expected to fully participate in research group meetings. To help our students, we have introduced a new online monitoring system in 2014: a database (MyPGR) provides the mechanism by which the student support interaction is articulated and recorded. It includes: supervisor contact expectations; a record of supervisory meetings; details of the student's record such as supervisors, pastoral tutor, assessors, programme dates and interruption record; record of supervisory agreement, training needs analysis and regular progress monitoring. With better monitoring, the incidence of students failing to complete is very small and usually the consequence of overwhelming personal circumstances.

During the current REF cycle, we have hosted the EPSRC CDT in Metamaterials (XM2) and used this opportunity to review our PhD training. Talking to industry partners and employers, it was clear that conventional "lone-scholar" PhD students often suffer from a lack of transferable skills. To address this, we have developed a cohort ethos, and the University has supported this by investing £300K to refurbish dedicated, open plan office spaces for our students. Our PhD students value the cohort approach: in our recent annual student feedback exercise, 91% agreed that "the cohort-based model has benefited my development as a researcher". Industry partners have also been closely involved in designing and delivering training modules, with new PhD workshops introduced on general topics such as Methods of Experimental Measurement, industry specific topics such as Sensing and Security, several core research areas within the department, and intensive two-day training courses in Comsol, Python, Matlab, R, Labview, Mathematica and LaTeX. We have also introduced bespoke training modules in soft skills such as Project Management, Cognitive Behavioural Coaching and Creative Thinking, all run by external experts. Alongside technical and transferable skills training, we have introduced a seminar series "Beyond a PhD" about working in non-academic environments. By ensuring they develop other skills valued by industrial (and increasingly academic) employers, our PhD students are more employable, and 33% (9 out of 28) of our recently graduating CDT students have been recruited directly by our industrial partners. Beyond 2021, we plan to continue this training endeavour through external funding, and we have put in place arrangements with our major partners including DSTL and QinetiQ.

Our reviewed training programme was recently highlighted by the EPSRC in our midterm CDT assessment as having "excellent industry engagement...now considered best practice [by the

EPSRC]". The changes in approach outlined above have been adopted across the board in Physics, embracing the cohort approach: PhD students are housed in shared PhD offices whenever possible, and we place an emphasis on social interaction, e.g. a week-long induction event for each new cohort consists of introductions, scientific talks, and social events. Likewise, training opportunities are also open to all PhD students, and have been integrated into existing procedures. A flexible approach to training is now adopted with an Individual Study Package constructed by supervisors which sets out a personalised training programme including our new transferrable skills sessions. PhD students are also encouraged to develop teaching skills by engaging with in our undergraduate teaching labs and in the supervision of undergraduate research projects. Our students also take outreach very seriously, and have formed chapters with both the SPIE and OSA, and have frequently undertaken outreach activities with local schools etc. We are now going beyond this and, in conjunction with our College Outreach Officer, we have developed a "Metabuddies" scheme, where our students are partnered with local schools for long-term outreach activities.

Together with highly innovative approaches to training adopted from our CDT, we believe our PhD students receive a well-rounded experience.

Section 3. Income, infrastructure and facilities

Exeter Physics has aggressive growth targets, as the University looks to expand core STEM subjects (see ILES 1.4). During the current REF cycle, growth has been achieved in part through expansion (the Department has recruited 14 academic staff in the period while 5 left), but more substantially through increase an in income/FTE. Between 2013/14 and 2019/20, research income per academic increased by 87%, while PhD student completions have also increased by 40%. We have also looked to diversify our research funding and achieved a 5-fold increase in funding from UK industry.

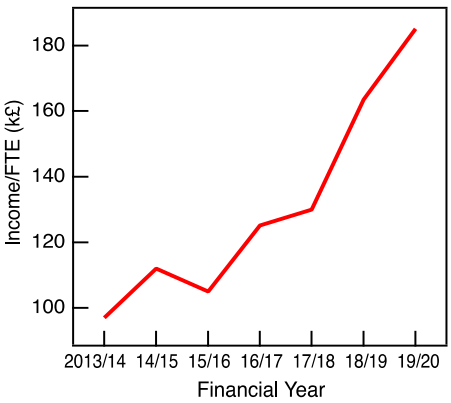

Figure 1: *Income per FTE excl. tax credits*

Support for applications

We provide multi-layered support for grant applications. The Director of Research oversees all applications and provides support where required to maximise chances of success. Academic Leads are also a major source of support for the development of research grants, and where necessary, facilitate links with the wider academic community. We pay close attention to unsuccessful applications, working closely with individuals to ensure that any feedback from panels is used to develop successful future bids. Training on grant writing and development is provided to all who need it and we regularly hold 'Research Focus Weeks' which provide focussed training/workshops on various aspects of grant development for staff at all levels. Intensive support is provided to early career researchers, returners from parental leave and those with less experience. Since 2014, we a have introduced a number of schemes to increase support staff:

- Flexible work schedules for staff returning from maternity/paternity leave, and workshops to communicate information on all parental leave options.
- A workload model to help balance teaching and research requirements. This ensures research hours awarded on grants translate fairly into reduced teaching load. A minimum research allowance for all staff (~22% of all allocated time) also guarantees time allocated to write grant proposals and research papers.
- Appointment of discipline-specific Research Development Managers and Advisers to assist with proposal ideas, writing and planning, as well as financial costing of proposals.
- Robust sifting processes for the most competitive schemes such as fellowships and ERC grants, which ensures only candidates with a relatively high chance of success move to full application, thereby managing demands on time for both academics and support staff.
- A thorough internal peer-review process for all research council and ERC applications, with feedback provided by at least two senior academics. They provide constructive feedback prior to submission, and also support the PI in responding to external peer-reviews.

- New bespoke communications training and mock panel interviews when required.
- A revised study leave programme, open to all staff. We strongly encourage staff who are working towards large and demanding applications to apply, thereby freeing up time normally allocated for teaching and admin.

Large grant awards

Our increase in income has primarily been achieved by formulating strategies to apply for and win large grants. Currently ~20% of our permanent academic staff are funded by prestigious 5-year fellowships (see table 2), a 2-fold increase during the REF period. As outlined in the previous section, we actively encourage staff to apply for these prestigious fellowships and have a robust internal review process to ensure quality. For 5-year fellowships, a PhD studentship is typically funded by the College (2 in the case of ERC advanced). This is particularly important for new/young staff who are awarded fellowships, helping combine supervision experience with increased research hours.

Fellowship Source	Group (Staff member)	Scheme	Funder Contribution
Research Council +UKRI Fellowships	ASTRO (Zhukovska)	STFC (Ernest Rutherford)	£0.6M
	BIO (Vollmer)	EPSRC (Established)	£1.6M
	BIO (Richards)	MRC (Career dev.)	£0.8M
	EMAG (Hendry)*	EPSRC (Early career)	£1.0M
	EMAG (Anders)	EPSRC (Established)	£1.0M
	ASTRO (Mayne)	Future Leaders	£1.4M
Royal Society	EMAG (Horsley)	TATA Fellowship	£0.4M
RAEng	EMAG (Phillips)	Research Fellowship	£0.6M
ERC	ASTRO (Browning)*	Starting	€1.6M
	ASTRO (Kraus)	Starting	€1.7M
	ASTRO (Dobbs)	Consolidator	€2.0M
	ASTRO (Matt)	Consolidator	€2.2M
	ASTRO (Bate)*	Consolidator	€1.7M
	ASTRO (Baraffe)	Advanced	€2.5M
	EMAG (Phillips)	Starting	€1.9M
	EMAG (Barnes)	Advanced	€2.4M
			Total = £21.0M

Table 2: *5-year research fellowships and ERCs awarded during current REF period. Post staff census date, we have also had new RAEng and Royal Society fellowships awarded to new staff members (not listed). *Completed at time of submission.*

Also in the current REF period, £18.6M in EPSRC income has been awarded in large (>£1M) grants for research led by our department (see table 3), again an approximate 2-fold increase compared to the previous REF. University investment has contributed to success of strategic applications such as the metamaterials CDT (with £4.5M in matched studentships), RaNT programme grant (with the refurbishment of an entire suite of hi-spec optics labs totalling 74 m^2) and our Physics of Life project (enabled by another substantial investment in lab refurbishment). These strategic investments have underpinned much of our collaborative work in the department and determined new research directions such as metamaterials and healthcare technologies.

Industry income

With future government investment likely linked to the needs of the UK economy, we have worked hard to increase our interaction with industry. Most of the ongoing large projects in table 3 have industry links, some with substantial monetary contributions from industry partners. This is particularly true for our metamaterials research: since 2014, our metamaterials CDT has attracted >£2M of investment from partners, with new links forged with >20 partners. Existing links, meanwhile, have been bolstered, with >£1M investment from QinetiQ for the Team A project. Our healthcare research theme has also received investment, with >£200K from partners Nanomerics, BBI and CCG for RaNT, while Syngenta have secured two-years of access to our EPSRC

CONTRAST facility (£120K) to provide new insight into the development of next generation agrochemicals.

Simultaneously, we have hugely increased our direct research funding from industry. Contract research has accounted for £1.9M of income during the REF period, a ~5-fold increase compared to the previous period, much of this coming from partners introduced through our CDT programme. In recent years, our college has also introduced a "50-50" funding scheme to allow industry collaborators to fund PhD studentships, where industry funding can be matched by internal funding of up to 50% cost. In total, since 2014, we have funded 17 studentships through this scheme, and won an additional 4 EPSRC iCASE awards, with an industry only investment in studentships totalling >£1.3M.

Grant Type >£1M	Group (Staff members)	Description	EPSRC Contribution
EPSRC programme grant	BIO (**Stone**, Moger, Palombo)	Raman NanoTheranostics (RaNT) aims to deliver applications of Raman spectroscopy both in the detection and nanoparticle-based treatment of disease.	£5.8M (Exeter: £3.8M)
EPSRC programme grant	EMAG (**Hendry**) BIO (Stone)	Terahertz robotics for surgery and medicine (Terabotics) aims to develop THz imaging for increased precision and selectivity during surgical removal of cancers.	£8.0M (Exeter: £1.9M)
EPSRC Healthcare Technologies	BIO (**Stone**)	Project to develop an in vivo Raman mammographic screening tool for early analysis of breast cancers, linked to the £18M CRUK Grand Challenge PRECISION.	£1.2M
EPSRC Physics of Life	BIO (**Vollmer**) EMAG (Anders)	Project to develop extremely sensitive trapping and sensing approaches for use in healthcare diagnostic tests of human pathogens.	£2.1M
EPSRC Centre for Doctoral Training	EMAG (**Hibbins**, Barnes, Sambles)	The XM2 CDT in Metamaterials has funded ~100 PhDs since 2014, with industry and Governmental sponsorship exceeding £2M, providing a pipeline of talented scientists for tomorrow's leaders.	£5.0M
EPSRC Strategic equipment	BIO (**Moger**, Stone)	CONTRAST: Laser laboratory aimed at developing and translating cutting-edge nonlinear optical spectroscopy for healthcare and sensing technologies.	£1.1M
	EMAG (**Hicken**, Hendry, Kruglyak)	EXTREMAG: Laser laboratory designed to explore ultrafast magnetic processes on timescales down to 10s of femtoseconds, combining capability for low temperatures, high magnetic fields, and on length scales down to 100s of nanometres.	£1.1M
EPSRC Prosperity Partnership	EMAG (Bertollotti, Hendry, Hibbins, Sambles) QSN (Horsell)	The Team A partnership builds upon the successful relationship between Exeter and QinetiQ, to develop advanced metamaterials that can be used to control and manipulate the propagation of electromagnetic and acoustic energy.	£2.4M
			Total = £18.6M

Table 3: *>£1M EPSRC awards obtained during the current REF period involving an Exeter Physics PI (bold). We include the Team A Prosperity Partnership as the majority of investigators are from our department. Terabotics is led by Warwick University.*

Investment in onsite lab facilities

As part of the Exeter's wider strategic investment aimed at rebalancing towards STEM (ILES, 1.4), we have increased capability in photonics and biophotonics with a radical overhaul of our laboratory space. Since 2014, approximately 260 m^2 of labs space has been refurbished to create

14 new cutting-edge optics laboratories and 2 new sample prep labs, almost entirely through University match funding (for the fellowship and large grant proposals listed above) from the Strategic Equipment Fund (SEF). This is exemplified by two new flagship facilities, CONTRAST and EXTREMAG, which were both part-funded by the EPSRC and SEF and are both open to external users:

- CONTRAST is a suite of ultrafast laser laboratories for the development and translation of cutting-edge nonlinear optical spectroscopy into healthcare technologies, funded in part by a £380K investment from SEF. Fully supported by an experimental officer, this is the only user facility of its type in the UK. It supports high profile healthcare technologies research at Exeter, such as the RaNT programme. Moreover, since opening at the end of 2019, the facility has a wide range of external users from Oxford, Nottingham, Imperial, MRC Harwell Institute, UCL, and Manchester, as well as industry supporters Syngenta.
- EXTREMAG, with £360k investment from SEF, is a newly refurbished laboratory designed to explore ultrafast magnetic processes on timescales down to 10s of femtoseconds. Samples are probed at low temperatures, in high magnetic fields, and on length scales down to 100s of nanometers, making Exeter's expertise in ultrafast magneto-optical and THz measurements available to the UK and international magnetism community. Since opening in late 2019, EXTREMAG has scheduled time for academic collaborators from 16 UK universities, colleagues from national facilities such as the Diamond Light Source and NPL, as well as international collaborators from IMEC Belgium.

In total, since 2014, the University has invested £3.4M to create state-of-the-art lab space for both new and existing research groups in Physics, contributed £1.1M towards research equipment and £442K to redevelop communal and office space. The new £52M LSI building has allowed completely new directions for BIO such as healthcare tech, offering new facilities such as bio wet-labs and increased interaction with colleagues from medical and biological disciplines, as well as state-of-the-art lab facilities for five Category A staff from Physics housed there. We strongly believe the investment in infrastructure and the resulting increase in collaborative activity is directly tied to our increase in research quality, with 34% of our outputs are now published in the top 10% cited journals. As we look to the future, in the next REF period we would like to rejuvenate the remaining lab facilities, which at the moment account for ~30% of lab space in our department. This will be achieved using the same approach: by focussing on and winning large project awards in strategic areas. Also in the next REF cycle, we think that the £82M University investment in the North Park building will boost ASTRO in a similar manner as the LSI has for BIO, facilitating new cross-disciplinary directions with colleagues in computing and data sciences.

Investment in computation facilities

Exeter University runs an in-house tier 3 HPC (High Performance Computing) facility which was established by a £3M investment by the University and has been supplemented by subsequent grant income. The facility is designed to serve the research computing requirements of a diverse range of disciplines and is an important tool for researchers in Physics, primarily in ASTRO and QSN. The facility combines a traditional HPC cluster with a virtualised cluster environment and was the first of its kind in a UK university, and is supported by a dedicated team based in Research IT. Governance of the facility, and other research computing matters, is overseen by a board comprising representatives from all academic colleges and Exeter IT. Our tier 3 campus-based system also supplies the environment for code development and scaling tests that underpin ASTRO's applications to national (Dirac) and international (PRACE) HPC facilities, where the group is also represented at the Dirac project Board (Bate). The University is also engaged with the national e-Infrastructure as a full partner in the GW4 Centre for Advanced Architectures. The GW4 consortium, in partnership with the Met Office, runs the "Isambard" HPC service, and is part of the national tier-2 e-Infrastructure. Isambard, funded by EPSRC, was one of the first production supercomputers in the world to be based on the ARM processor architecture.

Clean room and other facilities

Research infrastructure is supported by 4 FTE mechanical workshop technicians and 6.5 FTE experimental officers/lab technicians. Our department also has class-6 clean room facilities

covering a total of 150m^2 which house nanofabrication (dual beam SEM and electron-beam lithography/focussed ion beam milling, nano-sphere lithography, inert gas and reactive ion mills), evaporation and sputter deposition systems, holographic grating fabrication, bio-sample electron microscopy preparation, access to a rapid prototyping (3D printer) facility for sample fabrication and a helium liquefier to supply cryogenic equipment. These facilities are shared all research groups, funded by directly allocated costs on research grants. During the REF period, the University has also invested in our department facilities, with £100k to upgrade our helium liquefier, £250K to upgrade existing e-beam facilities and the appointment of new clean room technician to oversee operation.

			Contribution in Kind (K£)						
Facility Type	**Facility**	**Users**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**Aug 2018+**	**Total**
Synchrotron	ESRF	EMAG (Ogrin) BIO (Petrov)	77	232	-	77	155	-	**542**
	Diamond	EMAG (Hicken, Ogrin) BIO (Petrov, Stone, Palombo)	664	470	325	106	217	75	**1,857**
	Soleil* (€4700/8hr)	EMAG (Ogrin)	-	119	59	178	119	59	**534**
	ALS* ($5200/8hr)	EMAG (Hicken)	128	115	230	102	76	104	**775**
	BESSY* /DESY* (€4160/8hr)	EMAG (Hicken) BIO (Petrov)	-	-	46	46	-	56	**148**
Laser	LaserLab Europe* (€780/8hr)	BIO (Palombo, Stone)	-	-	14	-	-	28	**42**
Telescope	Hubble	ASTRO	33	-	74	1104	190	-	**1,401**
	ESO	ASTRO (Hinkley, Kraus, Naylor)	-	210	273	636	1504	2106	**4,727**
	Other telescopes	ASTRO (Naylor, Kraus)	97	52	53	24	11	46	**283**
Computation	DiRAC	ASTRO (Baraffe, Bate)	159	157	209	283	407	1,098	**2,313**
	ARCHER* (£0.56/kAu)	QSN (Hepplestone)	-	-	3	21	36	43	**103**
	PRACE* (£3.61/ node-day)	ASTRO (Browning)	-	-	1,502	1,002	-	-	**2,504**

Table 4: *Awards in kind recorded by UKRI and for facilities* not recorded in UKRI data* (in-kind estimated rate in brackets)*, where Exeter academic is PI. Data from Aug 2018 onwards is incomplete, and hence is presented in a combined column. Other telescopes: Isaac Newton Group, Liverpool Telescope and ALMA.*

Usage of major national and international facilities

National and international facilities are widely used. Time-equivalent value, awarded since Aug 14, is tabulated in Table 4. The value of time recorded by UKRI amounts to £11.1M, while non-UKRI international facility use accounts for £4.1M. The trends in usage per year reflect the changing research within our groups, with a decline in synchrotron usage in recent years. This is partly as a result of state of the art, local measurement facilities such as CONTRAST, EXTREMAG

and the RaNT suite, focusing research effort more in optics. The strong growth in telescope and supercomputer time reflects the growth in our ASTRO group and the wider department.

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

Industry and Impact

We work closely with the University's *Industry, Impact and Business (IIB) division*, who report to our new Director of Impact and work with individual academics to develop regional/national/international innovation. IIB offers small and medium sized grants to develop impactful activities, as well as guidance and admin support, which helps embed an impact culture within our department. We highlight below examples of our contributions to the economy and society which have resulted:

- Local and UK Economies: In 2015/16, the University of Exeter generated £1.17 billion in economic output across the UK, concentrated in the south west, where it supports >11,000 jobs. During the REF period, Physics has developed several new and important links to local SMEs. For example, our ASTRO group works closely with local digital media companies (We The Curious and Engine House VFX) to develop hugely successful VR videos depicting exoplanet research which have allowed both companies to significantly expand. IIB also provides support for patent applications and spinouts from physics research, providing finance and advice during the early years of commercialisation. Our most recent and successful spin-out is Concrene Ltd (January 2019) which aims to reduce the carbon footprint of the concrete industry using 2D material technology developed within QSN. Concrene Ltd has recently been shortlisted for an Innovation award by the Royal Society of Chemistry and received £1M from investors. We also work more with companies from across the UK: research investment from industry has more than doubled during the REF period, and we have tailored part of our PhD training towards the needs of our UK industry partners.
- Connections to regional centres: In line with goals set in REF 2014, we have developed links with Exeter's Met Office, working together in meteorology (winning the Harry Otten Prize for Innovation in Meteorology with Brunt in 2019), in generating weather data files used for thermal modelling, and in less obvious areas such as through our climate modelling of exoplanets. Led by Stone, BIO has also developed new links with the Royal Devon and Exeter Hospital and Gloucestershire Hospital. Working with NHS consultants, researchers in new hospital-based physics labs are investigating novel directions in healthcare tech.
- In the media: Media recognition is key to reaching a broader, global audience with our research. Our innovative VR Exoplanet videos are receiving millions of views on YouTube, and have also achieved global recognition, awarded the Bronze 'People's Choice Award' at the Lovie Awards – the most prestigious pan-European creative industry content awards – in 2018. Discoveries by Physics academics have also regularly featured in news media. For example, the Guardian labelled QSN's Concrene 'a game-changer' for making building construction greener, while our graphene research was also the focus of entire BBC news articles: "The battle to curb our appetite for concrete", "Exeter scientists make 'electric cloth' GraphExeter".
- Societal Impact: During the pandemic, our staff responded quickly to the shortages of medical equipment and Personal Protective Equipment (PPE) experienced during the initial stages of the Covid pandemic. Led by Physics (Phillips), an action group leveraged existing networks within local communities, companies and NHS trusts to organise help. Stockpiles of existing masks, gloves and goggles from labs in Physics were donated to the Royal Devon and Exeter (RD&E) Hospital. In collaboration with a local medical consultancy TangerineBee, a new, 3-D printable face-shield design was developed and fabricated using existing facilities in Physics, with >2000 face-shields delivered within weeks to the RD&E. Our quick response led to thousands of PPE items produced for local key workers at a time when shortages were costing lives.

  Some of our research has had immediate impacts on government policies, e.g., thermal modelling of buildings using Exeter generated data files now forms part of UK building regulations. We have also impacted policies on the world stage: Images acquired using novel microscopy techniques developed by the BIO group provided unequivocal evidence of the accumulation of microplastics in marine organisms. The visual impact of these images played

a key role in influencing government policy changes to completely ban the use of microplastics in cosmetics, first in the UK, and across Europe, North America and the UN.

Interdisciplinarity

In step with the University strategy (ILES, 1.7), collaborative, cross-disciplinary research is central to our own research strategy. During the current REF cycle, >25% of our papers have a co-author from a discipline other than Physics. Since 2014, we have focussed on interdisciplinary research in three important areas:

- Physics-Life interface: BIO, our fastest growing group, lies naturally at the interface with biological and medical sciences, focussed on our interdisciplinary hub in the LSI building. During the REF cycle, we have been awarded a series of large grants in the area of biophotonics (table 3) have enabled broader collaboration between our department and colleagues in medical and biological research fields, e.g., in applying vibrational spectroscopy for cancer diagnosis (Stone, Palombo) and developing novel nonlinear imaging techniques for plant biology (Moger). Some of our state-of-the-art laser facilities, meanwhile, have been designed with industrial collaboration in mind: The CONTRAST facility is a platform for translating our fundamental research in nonlinear optical spectroscopy into novel solution for commercial R&D. In the next REF cycle, we plan to expand this area further, specifically focussing on Health Tech (see outlook section).
- Centre for Metamaterials and Innovation: Industry's recognition of the quality of Exeter's metamaterial research, lying at the interface between Physics and Engineering, has helped us expand existing relationships and establish many new mutually beneficial industrial collaborations. To continue to showcase and expand our expertise in meta- and functional materials, and industry-facing research, we have recently formed a centre, which is part of a broader *Materials Innovation Hub* encompassing researchers across physics, engineering, mathematics, computer science and biosciences. The Hub provides an interface for industry-relevant, cross-disciplinary research in functional materials, and will allow us to continue and expand industrial links as well as capitalising on industrial strategy funding allocated by the government.
- ASTRO/Data Science: Exeter has a strong research concentration in modelling weather and climate (MET office and UoE Mathematics), as well as data science and machine learning (UoE Social Sciences/Computer Science). Many cross-disciplinary collaborations have emerged over the last years, with ASTRO research on exoplanet atmospheres at the forefront. If Project North Park proceeds, we plan to co-locate the ASTRO group with Exeter's Global Systems Institute, and the Institute of Data Science and Artificial Intelligence to forge and facilitate further interdisciplinary collaborations and innovation that can address 21st century global challenges.

Internationalisation

We are an outward-facing department and view interactions with other establishments as fundamental to maintaining and improving the quality of our research and growing our international reputation. We collaborate with over a hundred UK national labs, academic institutions and charities and have several hundred more established collaborations with overseas institutions in over 50 countries. Below, we highlight some of the approaches we have taken to internationalisation.

- International partnerships: We have actively sought partnerships with several leading universities and institutes around the world who have similar research strengths to ours. This has been planned at University level (e.g., University of Queensland, Chinese University of Hong Kong – see ILES, 1.9) but has also been driven at Physics departmental level, where we have established agreements with the TU Munich and Brown University which includes research student exchange. We plan to expand this model during the next REF cycle.
- International Networks: all four research groups are involved in national/EU/international funded research networks. We also lead from the front in heading several notable international networks, e.g., EMAG led the "Thermodynamics in the quantum regime", chaired by Anders (2013 – 2017), which brought together more than 300 researchers working in statistical physics, mesoscopic physics and quantum information theory in more than 32 countries. EMAG also leads the recently funded EPSRC Metamaterials Network (PI: Hibbins)

which brings together a host of leading groups from both academia and industry. ASTRO are deeply involved in national and international observational programmes, with Naylor chairing the Board for LSST-UK; Hatchell sitting on the JCMT Board and coordinating the JCMT Gould Belt and Transients surveys; while Kraus is President of the European Interferometry Initiative. ASTRO also leads the HST PanCET programme, the first comprehensive survey of gas-giant exoplanet atmospheres and one of the largest time allocations in Hubble's history, and is leading the development of the MIRC-X-6 telescope, the world's highest resolution infrared imager designed to study planet-forming discs.

- Visiting scholars: We regularly attract leading scientists from around the world to Exeter through seminar series within the groups and a departmental colloquium. Our recently opened laser facilities, EXTREMAG and CONTRAST, have also brought international researchers to Exeter to work with our EMAG and BIO groups. We have meanwhile hosted several visiting professors, enhancing collaborative spirit in Physics, and our own staff have held many prestigious visiting scholarships at other institutions:

Staff member	Visiting scholarship	Year(s)
Richard Townsend*	Leverhulme Visiting Professor	2015-16
Tao Yang*	Chinese VRS Programme	2016
Adam Burgasser*	Fullbright Scholar	2017-18
Takashi Manago*	Fukuoka University Sabbatical Programme	2017-18
Sophie Brasselet*	Leverhulme Visiting Professor	2018-19
Sambles(EMAG)	Distinguished Visiting Scientist, NPL	2018-20
Baraffe(ASTRO)	Biermann lecturer, Max-Planck Garching	2015
Hicken(EMAG)	GP-Spin Visiting Lecturer, Tohoku University	2019
Barnes(EMAG)	Visiting Professor, University Twente	2014-20
Anders(EMAG)	Visiting Professor, University Potsdam	2019-20
Portnoi(QSN)	Research Professorship, ITMO, St Petersburg Distinguished Visitor, IIP-UFRN, Natal Visiting Professor, Westlake University, Hangzhou	2018-20 2014,2016,2019 2019

Table 5: *Visiting scholarships. *Funded positions hosted in Exeter.*

Lead organiser(s)	Conference title	Year
Hicken(EMAG)	Optical Polarization Conversion in the Near Field	2015
Barnes(EMAG)	Plasmonics and light scattering	2015
Stone(BIO)	Clinical Spectroscopy – CLIRSPEC	2015
Stone(BIO)	13th Martin and Willis IRDG	2015
Hendry(EMAG)	Graphene Optics	2016
Harries, Brunt(ASTRO)	Star Formation 2016	2016
Baraffe(ASTRO)	3rd Exoplanet Community Meeting	2016
Hicken, Kruglyak(EMAG)	6th IEEE Conference on Microwave Magnetics	2018
Russo(QSN)	Induced Strain in Atomically Thin Materials	2018
Hicken(EMAG)	Emergent Applications of Spin Transfer Torque	2018
Bertolotti(EMAG) Phillips(BIO)	Light in Complex Materials	2019
Baraffe(ASTRO)	Stellar Hydro Days V	2019
Anders, Correa(EMAG)	Emergence and physics out of equilibrium	2019
Kraus(ASTRO)	High angular resolution astronomy	2020
Hinkley(ASTRO)	Observations with JWST*	2020
Hicken(EMAG)	International workshop on exchange dynamics*	2020
Hicken(EMAG) + IOP Magnetism	CRIM 2020*	2020

Table 6: *Conferences hosted by Exeter. *Denotes online.*

- Conferences: Staff are encouraged to present their work at international conferences and our department makes travel-funds available when necessary. Over the REF period, members have given 65 keynote/plenary/review lectures at international conferences, contributed >300 invited talks, and served on organising committees of 46 international conferences. Our staff have also set up new annual conference series: Anders set up the Quantum Thermodynamics

series, which has been running yearly since 2014, while Bertollotti has set up a biennial "Complex Photonics Science Camp" (2015, 2017, and 2019). Hibbins and Sambles have also organised and chaired two prestigious Rank Prize conferences. To increase our international recognition, by bringing international physicists to Exeter, conference hosting has been a focus. Supported by our Director for International Relations and University events team, this resulted in a strong programme of home-hosted international conferences and workshops – Table 6.

- Our Director for International Relations has introduced International Research Summer Schools (6-10 weeks) combining English with physics sessions, targeting international students. We also support international PGRs with a programme to act as Exeter ambassadors abroad, where they are encouraged to give talks while visiting home countries/schools/universities.

Other Esteem Factors

- During the REF cycle, Stone has been appointed Honorary Consultant Scientist for both Gloucestershire and Exeter NHS Foundation Trusts (2014-20). Hibbins was appointed to the EPSRC SAT for physical sciences (2019,20), and >50% of our staff have sat on funding prioritisation panels, seven times as panel chair. Sambles has been particularly prolific in participating in and chairing important review panels for the MoD (5 times since 2015) and reviews, 7 times since 2016, for physics programmes across many highly ranked institutions including Cambridge (2016) and the University of Hong Kong (2018).
- Many of our researchers are respected leaders in their fields, corroborated by an exceptional series of international awards since 2014:

Staff member	Award	Year
Vukusic(EMAG)	IOP Bragg Medal	2014
Chabrier(ASTRO)	Ampere Prize	2014
Anders(EMAG)	IOP Bates Prize	2015
Bertolotti(EMAG)	IOP Moseley Medal	2016
Sambles(EMAG)	IOP Honorary Fellowship	2018
Barnes(EMAG)	IOP Young Medal	2019
Chabrier(ASTRO)	IOP Hoyle Medal	2019
Brunt(ASTRO)	Harry Otten Prize	2019
Baraffe(ASTRO)	Viktor Ambartsumian Prize	2020
Stone (BIO)	IPEM Academic Gold Medal	2020

Table 7: *Prizes and awards.*

- Several staff members filled editorial roles at international journals: Russo (Scientific Reports and Nanomaterials MDPI), Palombo (Biomedical Optics Express), Srivastava (Nanomaterials), Hibbins (Scientific Reports), Portnoi (SPIE Journal of Nanophotonics), Baraffe (Computational Astrophysics), Stone (Translational Biophotonics, Clinical Spectroscopy and RSC - Analyst), Barnes (Journal of Modern Optics), Anders (New Journal of Physics).
- For many years, Prof Roy Sambles has been a pivotal member of our staff, recognised throughout the world for his pioneering work in photonics. During the REF period, Sambles was appointed the IOP president (2015-17), and his celebrated career rewarded with a Knighthood in 2020 for services to scientific research and outreach.

Future Outlook

Beyond 2021, further income growth/FTE of 5 to 10% per annum is built into our business model. To meet this, we look to enhance industry interaction in core areas, and to develop future interdisciplinary partners for large grant bids. We plan to:

- Supported by IIB, further develop impact of QSN research via their entrepreneurial activities in graphene composites.
- Expand our recently formed Centre for Metamaterials and Innovation. Building on our strengths in fundamental materials, this will provide a focus for the exploitation and extension

of industrial links as well as allowing us to fully capitalize on government industrial strategy funding.

- Depending on the outcome of the financial reassessment for project North Park (due 2021), relocate ASTRO to a new building. The colocation of Astrophysics with the Global Systems Institute and the Institute of Data Science and Artificial Intelligence will enhance cross-disciplinary collaboration, and promises exciting new developments in climate physics, exoplanet atmospheres, and data science and machine learning.
- Strengthen existing links with the LSI, Medical School and hospitals. Following the metamaterials model, we will form a Centre for Advanced Healthcare Technologies. Working across disciplines, this will enhance external recognition and help maintain critical mass, allowing us to more easily respond to research council and Innovate UK calls. This will ensure that our fundamental research in BIO translates from benchside to bedside.