Institution: University of Bath

Unit of Assessment: 9: Physics

a. Overview

We have used the time since our top five showing in RAE2008 to enrich the strength and diversity of our research portfolio, building new bridges to other disciplines. Key improvements to our research environment during the REF period include:

- Recruitment of top international quality young researchers to replace departing academics at the rate of two for one. The new positions were specifically targeted to fill gaps in our research portfolio, to ensure critical mass for our activities, to realise impact, and to help forge new intra- and inter-disciplinary collaborative links. All of the appointees were identified for their future leadership potential.
- Substantial investment in equipment and targeting of resources to secure and reinforce our ability to compete sustainably at the highest international level. We have positioned ourselves at the leading edge of exciting emergent fields such as graphene research.
- Strengthening group leadership to provide support for intra- and inter-disciplinary collaborative research and ideas generation, nurturing junior researchers, and funding acquisition. Group members profit from improved dynamism, enhanced communication channels, and a greater sense of identity and inclusion.

Our research is focused on the areas of condensed matter and optical physics. Activities in these areas cover a broad spectrum of experimental and theoretical work, and are organised as follows:

Photonics: The group is based in the Centre for Photonics & Photonic Materials (CPPM) and leads a major international effort in the field of linear and nonlinear photonics and optoelectronics, particularly in the context of novel and microstructured fibres. It benefits from an outstanding international reputation for its work on the optics of micro-structured materials, in particular the photonic crystal fibre (PCF) which was pioneered in Bath. Group members include Bird, Birks, Da Como, Gorbach, Knight, Mosley, Skryabin, Snow and Wadsworth.

Nanoscience: The group has an international reputation for the design and manipulation of novel functional materials on the nanoscale. Techniques embrace scanning probe microscopy, positron spectroscopy and neutron scattering, while facilities include the Graphene Centre and David Bullett Nanofabrication Laboratory. Research encompasses the structural, transport, magnetic and superconducting properties of condensed matter at the nanoscale, and covers the interactions between electrons and photons in semiconductor and metallic systems. Group members include Andrews, Bending, Coleman, Crampin, Da Como, Gordeev, Ilie, Mucha-Kruczynski, Nogaret, Salmon, Sloan, Snow, Takashina and Wolverson.

Condensed matter theory: The group is in vanguard of the international drive for computational and theoretical methods to bridge the behaviour of complex systems on multiple length and time scales. Research spans the condensed matter / optical physics spectrum and embraces the electronic and nanoscale properties of surfaces, photonic crystals, charge transport in optoelectronic devices, soft matter and biophysics, and network theory as applied to animal behaviour. Group members include Bird, Crampin, Jack, James, Mucha Kruczynski, Walker, Wells and Wilding.

b. Research strategy

Core strategy and vision. We achieve the critical mass necessary for internationally leading research by focussing activity in closely related fields that provide outstanding opportunities for cutting-edge, fundamental research and where ground-breaking applications and opportunities for interdisciplinary collaboration naturally emerge. By aligning our activities with key strategic themes at the national and international level we ensure access to sustained funding.

Our research groups provide a framework within which academics collaborate and an environment in which research staff and PhD students are supported in their scientific and career development. We invest in these groups through excellent academic appointments and with the provision of state-of-the-art facilities, and by supporting academics in their role as leaders of research, helping

them build their own research teams and obtain funding. In order to free up time for academics to pursue research, we employ a number of dedicated teaching fellows.

New directions. Pursuing this strategy has paid dividends in a number of areas. Since 2008 there has been a significant alignment of our research to take advantage of exciting new opportunities for funded research in functional materials. A prime example is the work of our Nanoscience group, which led to the establishment of the Centre for Graphene Science (joint with Exeter), which is supported by a £5M EPSRC Innovation award and a £1M Graphene Engineering award, and which aligns with the EPSRC grand challenge "Nanoscale Design of Functional Materials". Additionally CPPM has grown substantially in both size and areas of activity, with new areas such as speciality fibres for biomedical science, multicore fibres and devices for astronomical applications and applications in manufacturing metrology being developed during the REF period. These developments are designed to target impact and align with the EPSRC "Manufacturing the Future Challenge" and "Healthcare Technologies" themes. Similarly, Condensed Matter Theory has strengthened its activities in soft matter, diversifying into glass physics and self-assembly, which align with the EPSRC grand challenge "Emergence and Physics Far from Equilibrium".

Interdisciplinarity. Our core strategy has led to our research becoming considerably more interdisciplinary since 2008. 18 members of the UoA have active collaborations with academics outside of Physics departments. Within Bath alone, collaborations from members of CPPM span Chemical and Mechanical Engineering and Pharmacy and Pharmacology, while Nanoscience has collaborations with Chemistry, Pharmacy and Pharmacology, Chemical Engineering and Electrical Engineering. Similarly, Condensed Matter Theory has collaborations with Mathematics, Pharmacy and Pharmacology, Chemistry and Biology. Looking more widely, during the REF period 42% of our published papers have coauthors in non-physics departments (Engineering, Chemistry, Mathematics and Biology). Just two recent highlights of the successes of our interdisciplinary links are:

- Prof. Alison Walker collaborates closely with experimental Chemists in Bath on organic and dye-sensitized solar cells. Her world leading modelling methods for charge transport closely complement the experimental measurements. Indeed their 2008 paper in JACS has been cited over 330 times. This work has been recognised with a €4M Marie Curie ITN on Dye Sensitised Solar cells, coordinated by Walker, which involves 11 internationally leading research groups across 6 countries.
- Prof. Jonathan Knight has secured £1.1M funding (Bath's share of a £9m grant) for research into the use of optical fibres for medical endoscopy. Working with Chemists, Engineers, Computer Scientists, and medical practitioners from across the U.K., as well as three international healthcare technology and electronics companies, the work is creating a novel fibre-based probe that can readily be passed into the lungs of patients in intensive care units to enable early diagnosis of respiratory complications.

Growth. In recognition of the vitality and sustainability of our research and the strength of our undergraduate recruitment, the University has invested substantially in the department by replacing outgoing academics at the rate of two to one with top-flight young researchers. The University has recently signalled its further willingness to fund a *step change* in the size of our department, expanding by a further 4-5 FTEs in 2014.

Metrics. During the REF period, members of the department have maintained a record of publication in high quality journals. Over 500 papers have been published, attracting a total of over 3500 citations, equating to more than 130 citations per FTE. We have also filed 11 patents.

Strong group identity. In order to ensure that our research retains a clear identity and focus, each group elects a leader. During the REF period, this role has become more formally prescribed, with a mandate to promote a culture of collaboration and inclusion, nurture ECRs, identify funding opportunities and share best practice in grant applications. Leaders also manage the group meetings, which provide a forum for ideas generation alongside traditional seminars.

Strong research management. In 2010 the departmental research committee was reorganised, integrating it more closely into university structures and adopting a much more strategic role. Group leaders and the Knowledge Transfer champion sit on this committee, whose chair (Wilding) plays a key role in directing departmental research. Its remit is to identify new research and funding opportunities and to promote collaboration and interdisciplinary links. It also serves as an

information conduit linking individual research groups and the faculty executive. As an example of its activities, the research committee initiated a departmental research day (June 2013), which attracted researchers from a range of departments in Bath and across the south west universities to hear presentations on our research and to tour our facilities.

Enabling and recognising success. Since 2008, the department has had a research-oriented workload model within which staff can apply for additional time in order to prepare major grant proposals. The model ring-fences funded research time, reducing teaching and administration duties for those with higher levels of funding. It also provides all staff with an allocation of unfunded research time to allow them to explore new directions.

Vision for the future. We aim to consolidate and strengthen the vitality and sustainability of our research by recruiting and nurturing early career researchers in emerging areas who can help set the international research and funding agendas. This will be enabled by establishing internationally visible research structures which will be closely networked with partner organisations worldwide. Indeed the University has recently signed accords with a number of partner universities on four continents. Its International Strategic Fund provides support for academics to initiate international collaborations with these institutions. Under the scheme, five members of the department have made visits to China and Brazil to forge new research links.

Further strengthening of intra and interdisciplinary collaborations is expected to result from the GW4 partnership, a research alliance between Bath, Bristol, Cardiff and Exeter universities (established April 2013). It aims to ensure critical mass of research strength, facilitate infrastructure sharing and provide a framework for joint doctoral training and researcher development. Meetings are already occurring between research leaders to identify areas for links.

c. People, including:

i. Staffing strategy and staff development

Strategy: Our main aim, supported by the University, is one of sustainable expansion, and the 4.25 FTEs who have departed over the REF period have been replaced with 8 new FTEs. In order to fully capitalize on the opportunities provided by this expansion, we have sought to recruit internationally excellent young researchers who will:

- Fill gaps in our research portfolio and target emerging challenges
- Forge new intra- and inter-disciplinary collaborative links
- Ensure critical mass and sustainability of our activities

The new appointments have, we believe, realised these objectives across each of the three research groups. Da Como, Sloan, Takashina, Mucha-Kruczynski have joined the Nanoscience group, Mosley and Gorbach have joined the photonics group, while Jack and Wells have joined the Condensed Matter Theory group. The appointments replace Benabid (now at CNRS Limoges), Maier (now at Imperial), Russell (0.25 FTE in 2008, now Director Max Planck Institute for Science of Light), Davies and Kovalev who have left or retired. As examples of how these appointments have substantially strengthened each group and led to new directions and collaborations, we highlight the cases of Da Como, Jack and Mucha-Kruczynski.

- *Da Como* joined us from Uni. Munich in 2012 and was appointed as a reader. His interdisciplinary experimental work in molecular optoelectronics using laser spectroscopy complements that of the CPPM, the Graphene centre, Walker's theoretical work on organic solar cells as well as the experimental work of L. Peter (Chemistry). He also has multiple international collaborations and since 2008 has published in PRL and Nature Comms.
- *Jack* who joined us from Berkeley in 2008 is a top-flight soft matter theorist working mainly in the area of glasses and self-assembly. His appointment was targeted to strengthen the soft matter activity at Bath. Since arriving as a lecturer he has secured an EPSRC Career Acceleration Fellowship, been promoted to Reader, published in Science, PNAS and PRL and secured three further EPSRC grants across a variety of topics. He has also built up a strong network of international collaborations spanning Berkeley, New York, Stanford and Paris.
- *Mucha Kruczynski* joined us from Lancaster in early 2013 as a Bath Prize Fellow − a permanent academic position for ECRs of considerable promise, beginning with a two-year period of pure research. In Lancaster he worked with Falko on the theory of Graphene and

forged collaborations with Nobel Laureates Geim and Novoselov in Manchester, with whom he has publications in Science and Nature. His arrival at Bath will substantially strengthen the work of the Bath/Exeter Graphene centre and help forge new links with the Manchester group.

Staff development: Career development of researchers of all levels benefits from a strong network of support structures at both the departmental and institutional levels. These include dedicated support for ECRs, well resourced research support and staff development units, a flexible sabbatical leave scheme, clear promotion criteria, a robust workload model and an effective departmental staff development and performance review process.

Nurturing Early Career Researchers. The departmental strategy to focus recruitment on talented ECRs is backed up by continuing support for their research careers. Younger members of academic staff are prioritised in allocating University and DTA studentships and receive greatly reduced teaching and administrative duties during their first three years. They are also given detailed advice in preparing their EPSRC first grant proposal, and indeed all six such applications in the REF period have been successful.

The probationary process for new academics is carefully managed in order to accelerate their research careers. All probationers have formal quarterly meetings with the Head of Department at which progress with their funding, research, and publications are discussed. Mentoring arrangements are put in place for their first three years to help them to progress their careers, during which period they undertake the Bath Course in Enhancing Academic Practice. The research of ECRs is showcased annually to senior members of the academic community at the Vice Chancellor's Research Day and Jack and Sloan have both presented their work in this forum.

Nurturing research staff. The University's Code of Practice for the Employment of Research Staff aims to promote a supportive research culture that fosters high achievement. Research staff and managers are obliged to comply with the Code; it lists the responsibilities of the University and Principal Investigators, but also those of researchers themselves. The Research Staff Working Group ensures that best practice is disseminated in the area of supporting researchers and their career development. Wilding is a member of this group; he is also the Departmental Research Staff Coordinator, acting as the first point of support, information and advocacy for research staff at the department level and is responsible for ensuring implementation of the principles of the Concordat to Support the Career Development of Researchers. In recognition of its commitment to implementing the *Concordat,* the university was awarded the 'HR excellence in research' badge from the European Commission.

Supporting and strengthening our research portfolio. Forums for generating new ideas and interdisciplinary links range from short talks delivered to a faculty-wide audience (eg. Ignite event, June 2013), regional networking events such as the Physics research day (June 2013), and regular group meetings. Best practice in proposal writing is shared within the department through the strong research groupings, bespoke documentation to guide Physics ECRs through the grant application process, robust internal peer review processes, and a departmental Knowledge Transfer champion (Wadsworth). We work closely with the University Research Development and Support Office (RDSO) who provide support for all forms of research, innovation, and knowledge transfer. RDSO offer advice and support on funding opportunities, research proposal preparation, research project management, stimulating collaborations with other universities and business, KTPs, contracts, intellectual property management and commercialisation of research through consultancy, licenses and spin outs, supported by incubator facilities.

Developing our researchers. The Staff Development Unit provides a wide variety of leadership and generic skills training for academic staff, while the Researcher Development Unit provides development opportunities for doctoral students and research staff. These include workshops for doctoral students and researchers@bath − a development programme for research staff. The physics department runs a compulsory annual University-structured Staff Development and Performance Review (SDPR) scheme, including review of the past year and objectives setting for the year ahead.

Fellowships and sabbaticals. The department actively supports academics in applications for personal research fellowships. Fellowships have been held by Birks (Leverhulme, 2009/10) and Jack (EPSRC Career Acceleration Fellowship, 2010-2015). The University has a Sabbatical Leave Scheme, which aims to advance the pursuit of scholarship and research or teaching in the

University. The scheme is particularly aimed at those who wish to forge a new direction of interdisciplinary research. During the REF period, Andrews, Nogaret, Salmon, Skryabin, Walker and Wilding have all taken advantage of the scheme. As an example of its benefits, Nogaret's sabbatical at San Diego allowed him to strike out in a new interdisciplinary area. Specifically, he developed computational tools for extracting electrical parameters from biological neurons, allowing the prediction of the response of real neurons to arbitrary stimulation. As well as high-profile multidisciplinary publications, the sabbatical led to a patent (GB1209174.0), HEFCE market study funding (£16k) and facilitated a new collaboration with cardiologists at the Bristol Heart Institute (Prof Julian Paton), and research grant applications (Wellcome Trust, BHF, EU-FP7).

Equality and diversity. Our research community is multicultural with staff, postdocs and research students hailing from over 20 countries including China, Thailand, India, Saudi Arabia and Mexico. Monitoring of equality and diversity takes place under the auspices of the University Equality and Diversity Manager, Marlene Bertrand, and at the departmental level by Dr Adelina Ilie (Departmental Equality Coordinator) who actively promote equality and diversity issues. As an example of our commitment to diversity, we provided a private office to a researcher in order to accommodate their religious needs.

To instil an appreciation of the legal responsibilities of the Equality Act 2010, chairs of recruitment committees attend a course and take an online module and test. The department will be applying for a Bronze Athena Swan Award in November 2013 and has collected and analysed data on applications and success rates for postgraduate, postdoctoral and academic positions. Focus groups of female academic staff and postdocs have been held to help formulate our emerging action plan.

Recognising excellence – internal promotions to chairs:

In the REF period there has been a healthy throughput of promotions to personal chairs for Dmitry Skryabin (2011), Alison Walker (2008) and Nigel Wilding (2009).

ii. Research students

Enhancements to the environment for research students in the REF period include:

- Creation of the Graduate School in the Science Faculty. This has streamlined admissions and progress monitoring, which is now web-based. It has provided a focussed source of information for students, supervisors and directors of study, and has initiated interdisciplinary forums for students to present their work to a broad audience such as the faculty research afternoon held in June 2013.
- Establishment of the ONYX Graduate Training Alliance with the Physics Departments at Exeter and Bristol. Its aim is to provide enhanced doctoral training for students working in photonics, spintronics, electronics and other –onics, through shared training and one-off events. For example, a 3-day student-led conference was held in May 2012 in Bath and included a wide-range of transferable skills training. It was attended by 36 PhD students, 9 academics and 5 industrialists.
- Opening of a Graduate Centre, providing social and informal working and training space.

PGR recruitment is pursued through a variety of channels: PhD projects are advertised on departmental and faculty webpages, academic networks and mailing lists, and on find-a-PhD.com. Principal sources of studentships are University scholarships (2-3 per year), and DTA. These are complemented by a steady stream of self-funded overseas students. Recruitment (fulltime PG equivalent) over recent years was 9(2008/9), 7(2009/10), 11(2010/11), 9(2011/12), 11(2012/13).

Supervision and Training. All students have a supervisory team, consisting of a lead supervisor and at least one other. New academics are supported by their mentor, and the standard of all supervisors is monitored via the SDPR process and the Faculty Research Committee. The training needs of all PGR students are assessed annually by supervisors and each year students can draw on any of over 100 training sessions offered by the University PG Skills Programme that address all aspects of the Joint Statement of Skills Training. Departmental skills training includes a poster competition (in the form of a soiree, to which all members of the department are invited) and a postgraduate seminar programme attended by all PGs.

The Department research groups provide a supportive environment for PhD students, who are regarded as integral members of the research community. Indeed, *all* PGRs (who completed within

the REF period) have co-authored at least one peer reviewed publication, while several have co-authored as many as 20 papers. Regular seminars and topical meetings provide forums for presentation of their work and for learning about the wider context of their research. PGRs attend and present their work at national and international conferences and summer schools. As a snapshot, in 2012 conference prizes were won by Chauhan (Nanocon, Brno), Merchant (ECUA, Edinburgh), Curran (CRIMS, London) and Hari (ICM2012, Busan). In the same year, almost a half of our publications included student co-authors.

Progress monitoring. Student support is coordinated at the Departmental level by the postgraduate Director of Studies, who oversees supervisor and examiner appointments, confirmation for PhD after 12 months (on the basis of a substantial written report and viva by two independent assessors) and annual monitoring, all scrutinised at Faculty level. Students in difficulty at this stage are proactively supported in developing and delivering a plan for improvement.

d. Income, infrastructure and facilities

Income: UOA grant income has remained robust during the REF period. Our main funding source is EPSRC. Income was £2.74M (2008/09), £2.8M (2009/10), £2.1M (2010/11), £1.8M (2011/12). £2.1M (2012/13). Income in kind from use of STFC facilities amounted to £2.0M. Time was also allocated on non-STFC facilities to Salmon (4 days beam time on SPring-8, Japan and 1 day on the Advanced Photon Source, Argonne, worth together ~£60k) and to Nogaret and Takashina: (High Magnetic Field Facility, Grenoble, 148 days and 14 days respectively, funded directly by EU but estimated to be worth several hundred thousand Euro).

Grants are currently held as PI by Andrews (£700K), Bending (£2.0M), Birks (£150K), Coleman (£240k), Da Como (£120k), Gorbach (£52K), Jack (£860K), Knight (£1.5M), Mosley (£104K), Nogaret (£75K), Salmon (£468K), Skryabin (£150K), Sloan (£108K), Takashina (£100K), Wadsworth (£100k), Walker (£175K), Wilding (£307K), Wolverson (£401K).

Infrastructure and facilities:

The ***photonics group*** operates world-class photonic crystal fibre fabrication facilities and associated optical laboratories in a purpose-designed building that opened in 2005. The facility was upgraded in 2012 by the addition of a third custom fibre drawing tower (£140k) and new spectrometers and cameras (£90K) were acquired in 2008/2010. These investments were made possible, in part, because of the facility's mixed funding model, whereby it is supported by research grants as well as income from commercial partners. The latter streams include external research users paying commercial rates, contract work for external bodies, and profits from a premium Continuing Professional Development unit in fibre fabrication.

The ***condensed matter theory group*** makes extensive use of Bath's kilonode High Performance Computing cluster (managed by Computing Services). The University is currently in the process of making a major £1M upgrade to its high performance computing capabilities.

Activities in the ***nanoscience group*** are underpinned by access to a number of excellent key facilities including:-

- The David Bullett Nanofabrication Facility. Opened in 2003 this offers ~145m^2 of class 1000 cleanroom that houses photo- (Süss MJB3) and electron beam (Hitachi S-4300 SEM/Raith ELPHY Plus) lithography, thin film deposition (Edwards thermal and e-beam evaporators, PECVD, DIBS), wet and dry etching (Oxford ICP 80 & ICP 100), imaging (Hitachi SEM, Veeco Multimode AFM) as well as equipment for device characterisation and packaging. In the last two years the facility has been upgraded by the installation of a new load-locked dry etching system (Oxford ICP 100) and a direct-write maskless laser lithography system.
- The Graphene Centre, a new facility opened in May 2012 as part of the Bath-Exeter Centre for Graphene Science. It houses two state-of-the-art UHV Omicron scanning probe microscopes; a low temperature STM and a low temperature STM/QPlus AFM.
- Andrews's lab has nJ and mJ ultrafast lasers for terahertz time domain spectroscopy; Da Como's lab has a time-resolved infra-red spectrometer.
- Salmon's lab houses a high pressure press, and he and Nogaret also make extensive use of neutron, X-ray and high magnetic field facilities in Grenoble and at ISIS.
- Coleman's laboratory houses unique positron beam systems for characterisation of near-surface and interface defects.

The nanofabrication, fibre fabrication and high performance computing facilities underpin much of the research in the department and have been set up in a sustainable way as Small Research Facilities (SRFs) within the University. An SRF recoups all FEC costs from users on a unit charge basis to cover equipment operation, service/maintenance and consumables. Our academics have been successful in obtaining external funding to support (and enhance) them on research council and EU grants as well as from industrial facility users.

Shared equipment. Following a faculty reorganisation in 2008 we have much more ready access to equipment based in other departments. This is facilitated by an online equipment database that allows academics from Bath (as well as other universities and businesses) to search for, and request access to, large items of research equipment. In addition, many large research tools have been centralised in two major facilities that are being steadily expanded via funding bids and a rolling programme of University investment. The Microscopy and Analysis Suite provides access to electron microscopy, optical spectroscopy and scanning probe microscopes (AFM, STM, MFM, LFM etc). Similarly the Chemical Characterisation and Analysis Facility, provides access to mass spectrometry, NMR, X-ray diffraction.

Consultancies and professional services. Engaging with business is a core principle of our impact strategy. Within the REF period examples of such activities have included:-

- **Fianium Ltd** (Southampton) advises members of the CPPM (Knight, Wadsworth) on current interests of the community of supercontinuum users, on problems with existing supercontinuum sources, and of developments in state-of-the-art fibre-based pump laser sources. Fianium has also employed several CPPM members as consultants.
- **Mauna Kea Technologies** (Paris) informs CPPM members of the current state of endoscope fibres and products, and the direction in which the industry is moving.
- Prof. Nigel Cronin's role as Chief Scientist to **Microsulis Medical Ltd** (Denmead, Hants).
- The Nanofabrication Facility of the Physics department offers (via Bending) consultancy services to industrial companies and academics including: Support for the R&D work of **Nanogan** and **IQE PLC** (Cardiff) in the area of III-nitride optical emitters; Fabrication of prototype electro-optic modulators for **Gooch & Housego** (Illminster); Fabrication of Pb humidity sensors for **Birkbeck College** and **UCL**, used in a range of high profile conservation projects for historical organs and fine artwork around Europe; Development of hardware and Bi Hall effect sensors for mK scanning probe imaging in collaboration with **Attocube GmbH** (Munich); Fabrication of nanoscale III-V Hall effect scanning probe sensors for **Nanomagnetics Instruments Ltd (**Oxford).
- The fibre fabrication facility has supported external users from the University of Leeds, **DSTA** (Singapore), and has provided custom fibres to **NKT Photonics** (Denmark).

e. Collaboration or contribution to the discipline or research base

Bath Physicists are extremely outward looking, collaborating widely in both geographical and interdisciplinary terms. Since 2008:

- 51% of our papers include one or more international coauthors
- Collaborations span over 300 organisations worldwide
- 42% of our papers include a non-physics co-author and 6% include an industrial co-author.

Consortia and networks. We are proactive and successful in initiating and engaging in large national and international consortia and networks. For example: *Walker*: EPSRC Supersolar (6 partner organisations, £4m), EPSRC Supergen on Excitonic Solar Cells (20 partners, £3.3M), EU MODECOM on organic LEDs (coordinated by Walker, 13 partners, €1.3M); EU Destiny ITN on Dye-sensitized Solar Cells (coordinated by Walker, 12 partners, €4M); *Birks*: EU Opticon on Astrophotonics (24 partners, €8.5M); *Nogaret*: EU SPECTROSPIN Network on spectroscopy of spin excitations (coordinated by Nogaret, 3 partners, €44K); *Knight, Wadsworth, Birks*: EU CARS EXPLORER on Contrast Imaging (7 partners, €3.1M); *Jack, Wilding*: NetworkPlus-emergence and physics far from equilibrium (20 partners, £0.23M), Molecular Dynamics Network (14 partners, £78K); *Bending***:** EPSRC Superconductor Ferromagnet Metamaterials (5 partners, £2.7M), EPSRC Graphene Hub (2 partner organisations, £5M), EU COST NanoSC (24 partners, €150K); *Knight, Wadsworth*: EU nEUROPt on optical imaging of brain oxygenation (14 partners, €5.7M).

Worldwide collaborations. We collaborate with leading research groups and institutions

worldwide. Examples are Coleman with A. Knights (Ontario), Knight with F. Wise (Cornell), Jack with D. Chandler (Berkeley), Salmon with M. Wilson (Oxford), Wilding with K. Binder (Mainz), Skryabin with E. Cerda-Mendez (Berlin), Andrews with S. Maier (Imperial), Ilie with S. Bendal (Cambridge), Nogaret with D. Ritchie (Cambridge), Sloan with R. Palmer (Birmingham), Walker with C. Zannoni (Bologna), Mucha-Kruczynski with Geim and Novoselov (Manchester), Bending with V. Moshchalkov (Leuven), Da Como with Talapin (Chicago) and Scherf (Wuppertal).

Interdisciplinary collaborations and contacts: Prominent examples include CPPM's work with Bath's Dept of Mechanical Engineering to develop new methods for precision metrology; Coleman's work with Materials Engineers in Hangzhou to understand how the technologically-important electroluminescent properties of titania films are affected by oxygen-vacancy defects; Walker's work with members of Bath's Dept of Chemistry on combining physical and chemical descriptions of dye-sensitized solar cells to improve their efficiency and stability; Da Como's work on polymer electronics with Chemists in Wuppertal to design tailor-made materials with optimum electronic properties; Nogaret's work on Artificial Neurons with Bristol's Dept of Physiology and Pharmacology to understand the response of neurons to stimulation; Gordeev's collaboration with Bath's Dept of Pharmacy and Pharmacology on imaging of human skin to improve the efficacy of pharmaceutical creams; James's work with behavioural biologists in Oxford to understand the collective behaviour of social animals by application of network theory

Industrial collaborations: Our research activities are informed by strong collaborative and consultative links with industrial users. Prominent collaborations include Wadsworth and Knight with Fianium Ltd (see case study), Bending with Attocube GmbH, Nanomagnetics and Nanogan to develop magnetic sensors; Walker with Cambridge Display Technologies, Quantumwise, SAES Getters, and Merck to improve the efficiency of optoelectronic devices; Da Como with BASF, Konarka Technologies, GE Global research Europe and Novaled working on OLEDS and solar cells; Takashina with NTT Corporation, working on silicon quantum transport.

Contribution to the discipline

Prizes and honours: Skryabin won the 2009 Institute of Physics Maxwell Medal and Prize, The award is made for outstanding contributions to theoretical, mathematical or computational physics; Knight won the 2012 IOP Optics and Photonics Division Prize; Da Como won the Young Talent Total award (2011). An international workshop was held in Coleman's honour (2012).

Invited conference talks: Knight (16), Skryabin (15), Bending (11), Birks (10), Salmon (9), Walker (9), Wilding (8), Da Como (7), Wadsworth (6), Coleman (5), Ilie (3), Jack (3), Nogaret (3), Sloan (2), Gordeev (3), Snow (2), Wolverson (1), James (1).

Invited lectures/seminars: Including Salmon (17), Wilding (18), Knight (10), Da Como (14), Birks (9), Bending (7) Coleman(7), Walker (5), Wadsworth (4). Total of 72 talks at UK institutions and 30 talks abroad.

Editorships of international journals: Bending (3), Wilding (3), Birks (1), Salmon (1), Skryabin (2), Wadsworth (1), Ilie (1).

Visiting professorships and fellowships: Salmon: Yamagata, Montpelier II and Institute Laue-Langevin; Bending: Exeter; Da Como: JILA, Boulder.

Fellowships of Learned Societies: Optical Society of America: Knight (2011), Birks (2008), Skryabin (2012).

Conference and workshop organization: Coleman (8), Wadsworth (7), Knight (3), Birks (1), James (2), Nogaret (2), Salmon (4), Wilding (2), Jack (2), Bending (1), Da Como (2). 34 in total.

Visitors: The department has hosted scientific visits of over a month from 10 foreign scientists.

Leadership: *Bending*: EU COST Nano-superconductivity management committee; IOP superconductivity group (chair); steering committee for ESF research network programme; *Wilding*: EPS Liquids Board; *Salmon*: ISIS user committee, ESRF allocation panel, advisor to House of Lords Select Committee on science and technology, ILL instrument review committee, EPSRC roving panel member. *Bird***:** EPSRC Strategic Advisory Team on Infrastructure; prioritisation panel (2x as chair). *Coleman***:** International Committee on Positron Annihilation (chair), 2009-12; Scientific Consulting Board, European Intense Positron Beam Facility. *Nogaret*: IOP Nonlinear Physics group committee.