Institution: King's College London (KCL)

Unit of Assessment: 9 (Physics)

a. Overview

The Department of Physics at King's College London has evolved and grown significantly in recent years, with 27 staff submitted to REF2014 compared with 17 to RAE2008. The Department forms the core of a wider integrated physics research activity across the College, with ties to the Department of Mathematics and to physics research programmes embedded in interdisciplinary research divisions within the Health Schools of King's College London. The Department is grouped into three research areas:

The research focus of the **Theoretical Particle Physics & Cosmology (TPPC)** Group is on tests of new models of particle physics beyond the Standard Model, including supersymmetry, large extra dimensions and strings. These tests include collider experiments, indirect and direct dark matter searches, and the particle physics of the early universe ranging from inflation to theoretical models of quantum gravity. In combination with the *Theoretical Physics Group* in King's Mathematics (UoA10), the Group forms part of a significant activity in Theoretical Particle Physics in King's College London, with the two groups offering distinct methodological approaches.

The **Theory & Simulation of Condensed Matter (TSCM)** Group employs a wide range of theoretical and computational techniques to study phenomena in condensed matter and molecular systems. The Group develops new approaches to study a diverse collection of elementary electronic excitations through the electronic structure, with expertise including bridging length and time scales to enable the study of properties at the mesoscopic scale, and the theory of quantum open systems using methods of non-equilibrium statistical mechanics. Applications range from topics in materials science such as fracture and stress-corrosion, to nanotechnology, to biological materials, to correlated electronic systems. Within King's, the Group is linked to complementary activities in biophysics in the School of Biomedical Sciences of King's (UoA5), and in statistical physics approaches in the *Disordered Systems Group* of the Department of Maths (UoA10).

The **Experimental Biophysics & Nanotechnology (EBN)** Group adopts an interdisciplinary approach around the linked themes of nano- and bio-photonics, functional nanoparticles, and cell and single molecule biophysics, combining expertise in nanofabrication, advanced imaging techniques and modelling. It is a leading centre in nanophotonics and plasmonics. The Group also has a strong activity at the physics-life sciences interface and has developed a close collaboration with the Randall Division of Cell and Molecular Biophysics (the "Randall", UoA5); as a result the Department has added two joint academic appointments in biophysics (Garcia-Manyes and *Owen* (UoA5)). The Group leads the Centre for Biophotonics unifying research activity in optical bioimaging across the College, including physics research activity within the Randall (UoA5), the Dental Institute (UoA3) and the Division of Imaging Sciences and Biomedical Engineering (UoA15).

b. Research strategy

A core principle underpinning the Department's strategy has been to develop a high level of excellence in focussed areas of research, identified in RAE2008:

- Three Research Groups have been defined to ensure a capability to build critical mass activity within each, within the size and shape of the Department.
- Research group profiles were developed with intrinsic capacity both to enable the Department to provide undergraduate physics teaching with strong cover across all major sub-disciplines, and to provide capability to address new important challenges in physics and associated disciplines, allowing the Department to be responsive in its research strategy to new breakthroughs.

Since 2008 research activity has been enhanced by implementing the following strategies:

- We have consolidated each Group with new appointments to enable it to reach a critical mass and enhance its existing research base, and made judicious joint appointments to facilitate permanent ties within King's and in London.
- We have appointed leading researchers as new Heads of the Research Groups, to provide each with strong leadership.

- We have provided a focus on interdisciplinary research, to ensure capability to respond to emerging research challenges which increasingly straddle traditional disciplinary boundaries.
- We have built on our central location in London in the College's Strand campus, to develop strong partnerships with complementary world-class activities in other London institutions as well as within King's, to ensure a world-leading local research environment.
- We have managed the size and shape of the Department to ensure that the cross-group interaction of academic staff, integration of researchers at all levels, and the active and informal interface with the undergraduate population have all been maintained as an important and distinctive defining feature of its environment.
- We have enhanced our infrastructure for research support with: substantial investment in experimental and computational facilities to enable world-class research; funding of interdisciplinary Centres and activities; improvement of our research support base by encouraging and facilitating staff grant writing activities.

Key strands of this have been:

- A founding partner of the London Thomas Young Centre for the Theory & Simulation of Materials (KCL, Imperial, QMUL, UCL, NPL) and the CECAM JC Maxwell node (KCL, Cambridge, Oxford, Imperial, UCL).
- Establishment of the Department as a centre for particle phenomenology in London, including: leadership of the London Centre for Terauniverse studies (providing strong links to CERN and the two key experimental particle physics groups in Imperial and UCL); partnership of the London Institute for Cosmology (KCL, Imperial, UCL, QMUL); its role as Physics Co-ordinator for the LHC MoEDAL experiment; a founding partner of the London Institute of Field Theory and Particle Physics LIFTAPP (KCL, Imperial, UCL) now being established.
- Establishment of KCL as a major centre for the theoretical particle physics, with the parallel development of the TPPC Group and the growth from 6 to 11 staff of the Theoretical Physics Group in KCL Mathematics (UoA10); the two groups share an STFC Consolidated Grant.
- An increasingly close relationship with the London Centre for Nanotechnology (LCN) alongside the establishment of a leading activity in nanophotonics (leading an EPSRC Programme Grant) and in the application of nanotechnology in biomedical science.
- Development of research at the physics/life science interface with strong links, through joint appointments and funding, to biomedical research in KCL, one of the strongest in the UK: the College is one of the three academic partners (KCL, Imperial, UCL) of the Francis Crick Institute, while King's Health Partners is one of five accredited UK Academic Health Science Centres.
- The presence of senior academic visitors and organisation of workshops and high profile lectures to promote a vibrant research culture.

This balance of clearly-defined groups has proved successful in managing staff and research within the Department, and administering decisions related to funding, teaching and the intake of postgraduate students. Departmental research strategy is developed by the Departmental Strategy Group, comprising the Head of Department and Heads of Group. Resulting actions are initiated by the Head of Department in consultation with the Head of the School of Natural & Mathematical Sciences, and the Vice-Principals for Arts & Sciences and Research & Innovation, as appropriate.

The **Theoretical Particle Physics & Cosmology Group** is well placed to respond to important new experimental and observational data sets to emerge over the next 5 to 10 years. A focus of the Group in RAE2008 was the particle physics of the early universe, and this remains an important strength. The recent and future development of TPPC as a centre of excellence for research in particle physics and related areas of cosmology and astrophysics meets the need for strong theoretical activity to underpin and test the plethora of experimental and observational data set to emerge over the coming years. In particular, expansion of the TPPC Group during the REF period has ensured closure of a gap within London in collider phenomenology, linking to CERN and the two large experimental particle physics groups in Imperial (LHC CMS) and UCL (LHC ATLAS), and including the Group's role as Physics coordinator for the LHC MoEDAL experiment, and a future priority is to ensure this position is both held and strengthened further.

The **Theory & Simulation in Condensed Matter** Group was identified as particularly strong in RAE2008. During this REF period it has expanded its activities from an atomistic modelling (and more specifically Density Functional Theory) focus to a broader theoretical condensed matter activity including, with new members, the physics of many kinds of dynamical phenomena in correlated electron systems, and also research that bridges longer length and time-scales. This has led to the creation of a research activity with sufficient breadth of expertise to be able to respond easily to new challenges in condensed matter research as they emerge. Within London and the Thomas Young Centre the Group also now provides real strength in the development of new methods in condensed matter theory, providing a launch-pad for the study of a wide range of materials phenomena and materials systems. The development of the Group has led to the establishment of strong ties with complementary research in non-equilibrium systems and statistical physics in the Department of Mathematics, and in biomolecular modelling and biophysics in the King's School of Biomedical Sciences, providing the basis for future growth.

The **Experimental Biophysics & Nanotechnology** Group provides core strengths in nanotechnology, photonics and biophysics:

- During the REF period the EBN Group has significantly increased its activity in nanophotonics, plasmonics and metamaterials, supported by an EPSRC Programme Grant, an ERC Advanced Investigator Award, and significant College investment in new academic staff and research infrastructure. The research area addresses many priorities in information and communication technologies and in biological and chemical sensing.
- The development of nanophotonics research also underpins further cross-College strength in advanced photonics within the Centre for Biophotonics. Optical imaging is likely to play a key role in the achieving the central aims of post-genomic biomedical research and is a College-wide strategic priority, with: joint appointment between Physics and the Randall, with further senior appointment planned; establishment through a Wolfson Award of a Microscopy Methods Development Laboratory; the creation of one of Nikon Instrument's prestigious worldwide Imaging Centres at KCL (in turn providing a valuable lever for recruitment of research leaders in this area).
- The Group has also developed further strength in the application of scanning probe and related techniques to address major challenges in soft nanotechnology and biology. This has led to the establishment of an activity in single molecule force spectroscopy, again strongly linked to biomedical sciences in KCL through joint appointment with the Randall. Further development of such single molecule biophysics is an important element of the Department's future strategy.

Future development priorities for the Department are:

- Further growth to consolidate the strong research environment that has been established in the Department, and ensure sufficient scale to respond to new challenges.
- Further development of the TPPC Group as a leading centre for particle phenomenology to meet the need for such research with the flow of data from the LHC, the Planck satellite and many astroparticle experiments now underway.
- Restructuring of the present EBN Group, and new appointments, leading to the creation of two new groups: *Nanophotonics & Metamaterials*, to provide a focus for this growing research area, with future development including meeting new challenges in quantum nano-optics and strengthening capability in theoretical nano-optics; *Biophysics & Soft Matter*, with joint appointment of staff from TSCM, to build on strengths in molecular simulation, biophotonics, nanoparticles and single-molecule mechanobiology. This will provide a strong interdisciplinary focus and connection to biomedical sciences in the College and the Francis Crick Institute, for which a key role of the university partners is to provide underpinning strength in physical sciences.

c. People, including:

i. Staffing strategy and staff development

Strategy and Appointments has been informed by the Department's Research Strategy, with:

- Growth of King's Physics with the appointment of **15 new academic staff** across all 3 Research Groups, to ensure critical mass for both teaching and research;
- Recruitment of senior staff to take leadership of the three Research Groups, act as mentors for junior staff, and define and implement future research strategies for the Groups.

In **TPPC** John Ellis was appointed from CERN in 2010 as Head of Group and Clerk Maxwell Professor of Theoretical Physics, strengthening the Department's links with CERN and with experimental particle physics in Imperial and UCL through an ERC Advanced Grant he was subsequently awarded. The appointment of Acharya further strengthened the Group's expertise in collider phenomenology and experiment (through his membership of ATLAS), while the appointment of Lim strengthened the Group's activities in theoretical cosmology.

In **TSCM** Mark van Schilfgaarde was appointed from Arizona State University as Head of Group, bringing new electronic structure theory expertise to London. In particular, his appointment provided the Group with a bridgehead to expand beyond atomistic simulation into new areas of correlated electrons. With the appointment of four new lecturers (Bhaseen, Bonini, Kozik, Weber) this has resulted in a strong balanced portfolio of expertise across condensed matter theory and simulation, supported through investment in computational facilities (section d), salaries and studentships. During the REF period Mainwood retired and two group members left the Department to take up another academic appointment: Miodownik as Professor of Materials & Society in UCL Engineering, and Doltsinis as Chair of Functional Nanomaterials in Münster.

In **EBN** Anatoly Zayats was appointed from Queen's University Belfast as Head of Group, building on College strength in photonics with the establishment of a leading activity in plasmonics, supported through three new lecturerships (Dickson, Sapienza, Wurtz). Additional lectureships in single molecule biophysics (Garcia-Manyes, Owen (UoA5)), made jointly with the Randall, have strengthened the links to biomedical sciences within KCL. The development of EBN has been supported by investment in new laboratory space equipment (section d), salaries and studentships, and access to nanofabrication facilities at the LCN. During the REF period Davies retired, Michette died in post, and Green transferred to the Division of Imaging Sciences and Biomedical Engineering in the School of Medicine (while retaining a laboratory and collaboration with Physics).

Essential requirements of all new academic appointments have been: (i) an outstanding research track record (the h-index of all new starting lecturers has been between 7 and 18 on appointment, with a median of 11) and strong independent research vision; (ii) a good fit with the research priorities of the Groups.

International Staff. Of those 15 academic staff appointed during the REF period, 8 have been recruited from outside the UK: Ellis (CERN, faculty), van Schilfgaarde (ASU, faculty), Acharya (ICTP, faculty), Garcia-Manyes (Columbia University, Beatriu de Pinós Fellow), Kozik (Ecole Polytechnique, SNF Fellow), Owen (University of New South Wales), Sapienza (ICFO Barcelona, Ramon y Cajal Research Fellow), Wurtz (University of Northern Florida, faculty). 3 further staff had moved to the UK less than two years from appointment at King's: Lim (Cambridge, faculty, from Columbia), Weber (Cambridge from Rutgers), Bonini (Oxford from MIT). 9 of the new academic appointments obtained their PhDs outside the UK.

An important element of the Department's research environment is the presence of senior academic visitors. During the REF period this has included: Carl Bender (Wilfred R. and Ann Lee Konneker Distinguished Professor of Physics, Washington University in St. Louis), 2011–present and as a Leverhulme Visiting Professor 2011/12; Jim Pinfold (Alberta), 2006–present and as a Leverhulme Visiting Professor (2008/9); Jose Grifols Gras (Barcelona) 2008–11; Robert Latour (McQueen-Quattlebaum Professor of Bioengineering, Clemson) 2012–13 as a Marie Curie International Incoming Fellow; Michele Parrinello ForMemRS (ETH) 2011–present. The Department also hosts every year a number of visiting postdoctoral research fellows and PhD students, in particular through the Thomas Young Centre Visiting Fellowship scheme. The Department has an international agreement for staff and student exchange with ICTP.

Academic Staff Support & Career Development. A basic criterion for the appointment of all new academic staff is that they have the potential to be an international research leader, and a priority for the Department is to take steps to ensure that this can happen. All new academic staff are provided with start-up funding to enable them to establish a strong independent research programme. This has included for all new staff at lecturer level the core equipment required, dedicated newly refurbished laboratory space for experimentalists, and a College-funded PhD student. Additional support has been provided where there has existed a specific need (such as provision to Garcia-Manyes of a dedicated molecular biology technician for polyprotein fabrication).

All new academic appointments have a protected teaching and administration load during their probation, which is three years (or less in cases of prior appropriate experience or rapid advancement). Every new member of staff is supported formally through mentoring, while experienced staff across Groups spending considerable amounts of time advising and helping new colleagues. Indeed, KCL Physics is committed to assisting *all* staff in establishing their careers. This means, firstly, providing good facilities, and supporting staff through annual appraisal, providing a clear opportunity for advice on career development to be sought and given.

Postdoctoral Career Development. With increasing research funding, the Department has seen a growth in the number of postdoctoral research associates (PDRAs), currently **24**. The project supervisor has principle responsibility for the management of the PDRA, and his/her career development including appraisal, with oversight by the Head of Research Group. All PDRAs are expected to present their work in internal Group seminars, as well as workshops and conferences. A bi-annual forum provides the opportunity for all PDRAs to raise any concerns and be informed of developments within the Department. There is also a PDRA representative on the Department Research Committee. The Researcher Development Unit (RDU) in the College's Graduate School has responsibility for central training and development for PDRAs, as well as PhD students and supervisors. This includes a programme of over 300 workshops per year for researchers, a Careers Adviser, e-learning provision and one-to-one coaching. The RDU leads the College on implementing the Concordat for the Career Development of Research Staff and obtaining the HR Excellence in Research badging from the European Commission. The RDU also hosts the Vitae London Hub and is therefore directly involved in shaping national policy on researcher development. Since 2012, 5 PDRAs have secured academic posts (UK, Hong Kong, USA).

Equality & Diversity. KCL recognises that equality of opportunity and the recognition and promotion of diversity are integral to its academic and economic strengths, and the College is committed to providing and promoting equality of opportunity in all areas of its work and activity. The College holds an Athena Swan Award while the Department of Physics is in the process of preparing an application for Project Juno Practitioner status supported by the Department's Juno Committee, comprising representatives from postgraduates, postdoctoral, technical and academic staff. The College's Career Break Fund aims to increase the retention of academic staff working in STEMM disciplines on returning from a career break (for maternity, paternity or adoption leave), with grants of up to £20k to be spent over a year on anything that will support them in their work.

ii. Research students

The number of PhD students in the Department has risen steadily in the REF period: **42** in 2008/9, **45** in 2009/10, **47** in 2010/11, **48** in 2011/12, **57** in 2012/13 and **67** in 2013/14. With the exception of early withdrawals (5) and 1 for health reasons, **all** students successfully submitted their PhD thesis within 4 years and were awarded a PhD. With 30% of staff within 3 years of their first academic appointment, and senior staff recruited from outside the UK still in the process of building their research team, we can expect an on-going rise in the PGR student-staff ratio as new academic staff establish their research programmes. A high proportion of the Department's PGR population is international (2012/13: 65%, with 30% from outside the EU), reflecting the very high quality of applications we receive from overseas.

Selection and Funding. The quality of overseas applicants has meant, e.g., that the Department has been successful in securing competitive College-funded studentships. The development of a Graduate Teaching Assistant scheme has also provided a funding route for suitable UK and EU students; these involve up to 4 years' PhD study balanced with tutorial responsibilities, and are backed up by the King's Learning Institute. The Department has a number of self-funded students, the majority with overseas government-funded scholarships. In common with other Physics Departments, the majority of PhD applicants require funding, and so the strong increase in EPSRC research income over the REF period has led to a corresponding increase in the EPSRC Doctoral Training Grant with an associated rise in UK PGR numbers. Assignment of PhD studentships is guided not only by student quality but also by strategic need, with studentships targeted to new funded research projects, to promote collaborative projects between staff, both within the Department and elsewhere in KCL, to kick-start new initiatives, and to ensure continuity in the research teams of staff. A PhD studentship is provided in the start-up package of all new staff.

Training and monitoring. To broaden their research horizons, students attend the weekly 'Physics at the Nanoscale' Research Seminar for the EBN and TSCM Groups, a weekly 'Theoretical Particle Physics & Cosmology' Seminar for the TPPC Group, and the weekly 'Maxwell Society' (general) lectures. The Department also hosts a number of conferences, workshops, one-day events and high profile lectures, supported through dedicated funding. TPPC students can also attend the regular 'London Triangle' seminars and London Cosmology Discussion Meetings. For TSCM students the Thomas Young Centre supports a wide range of activities including highlight seminars, soirees, workshops and student days, which alternate between the partner institutions including KCL. In biophotonics KCL is one of the host partners of the regular Leica Scientifc Forum of prestigious lectures. Our location in central London enables students and staff to easily attend events at other London Colleges, the Royal Society, the Institute of Physics, the London Centre for Nanotechnology etc.

The College employs the Vitae Researcher Development Framework to help identify the needs of PhD students, and to set up tailored training programmes, with a comprehensive suite of programmes provided by the Researcher Development Unit (RDU, see (c)(i) above) of the Graduate School. The Department places great emphasis on providing opportunities for, and training students in, the presentation of their work, which ranges from the provision of dedicated outreach training to the student-organised postgraduate seminar series. Research groups hold regular group meetings at which PGRs and PDRAs regularly present their work, while an annual research day for the School of Natural & Mathematical Sciences provides students with an opportunity to present their work to a wider audience than that of their particular specialism. All students are expected, and funded, to present work and attend research conferences.

Each PhD student has a first and second supervisor. Progress is monitored formally through six-monthly review with both supervisors, which are then assessed by the Departmental Postgraduate Tutor. All students are assessed at the end of the first year through a report and viva examination before transfer from MPhil to PhD registration. There is a PhD representative on the Department Research Committee, while a bi-annual forum, chaired by the Postgraduate Tutor, provides the opportunity for all students to raise any concerns and be informed by the Head of Department of developments within the College.

d. Income, infrastructure and facilities

Infrastructure & Facilities. Since 2008 the College has provided **£2.3M** investment in research infrastructure and facilities, in support of its expansion of Physics at KCL providing the resources required for both existing and newly appointed staff to pursue world-class research; this has included a **£955k** refurbishment programme for the creation of state-of-the-art research laboratories, and **£1.1M** for new experimental research equipment and computational resources. A further **£1M** has been committed by the College for postdocs and studentships for staff appointed in this period. In addition, in 2008 the Physics Department relocated its offices to newly refurbished **£5.3M** space.

A project for the refurbishment of an additional 250 m^2 of laboratory space is scheduled to provide new facilities to allow for decant from remaining activity in the Strand Quad Building (scheduled for rebuild), for the expanding experimental profile of the Department of Physics, and for restructuring of the existing mechanical workshop provision.

Computational research is supported through dedicated high performance computing facilities, housed in a purpose-built data-centre managed by a server manager with a PhD in computational electronic structure theory. The largest system of 480 processing cores presently provides HPC support to the whole TSCM group, with additional smaller clusters configured, to meet the specific needs of researchers in the TSCM and TPPC groups. The College has committed **£420k** for the purchase of a new HPC facility for the School of Natural & Mathematical Sciences (the TSCM Group being the principal user).

Core experimental facilities are brought together with the Physics Experimental Small Research Facility under the management of a facilities technician and overseen by a departmental steering committee, including AFM, FEG-SEM, UV-Vis and FTIR spectroscopy, ellipsometry and thermal evaporation. Additional facilities within the EBN Group Laboratories include confocal and multi-photon microscopy, nonlinear, time-resolved, fluorescence and Raman spectroscopy, SNOM and

dynamic light scattering. Extensive College facilities exist for electron microscopy in the Centre for Ultrastructural Imaging and for a wide-range of state-of-the-art optical imaging modalities in the Nikon Imaging Centre, both supported by dedicated technical teams. An agreement with UCL provides access to the LCN clean-room and FIB. KCL is a partner with UCL and Imperial of a successful EPSRC strategic equipment bid (£1.7M) for a new Neon FIB at the LCN.

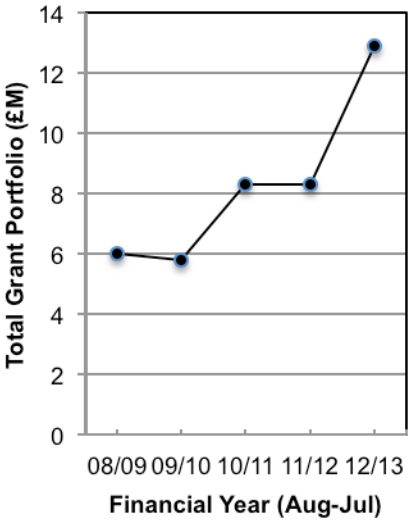
With commercial partner Nikon, a UK Bioimaging Centre has been established at KCL, supported through a College investment of **£1.4M** and further substantial investment from Nikon, to provide an extensive suite of advanced microscope systems to be made available to the ca. 600 PIs in the biological and health sciences sections of the College. A Wolfson Foundation/ Royal Society award to the Department of Physics, matched by College Funding, has enabled the establishment of a **£620k** Microscopy Methods Development Laboratory adjacent to the Nikon Imaging Centre, to foster innovation, proof of concept, development and collaborative application of novel optical imaging technology, and to provide a physical focus to the Centre for Biophotonics.

External Facilities. Usage within the assessment period of high performance computing (HPC) facilities not supported by the Research Councils, awarded to KCL Physics staff after competitive review, is indicated in the table below. The table also summarises all HPC time *awarded* through international competitive review *since July 2012*, with an estimated total value of ca. **£7M**, reflecting a very significant increase in HPC awards in support of the recent development of computational physics research within the Department.

HPC Facility	Core-Hours (kH)	AU 10^6	Cost (k£)[1]
Non-RCUK HPC time used Jan 2008 – Jul 2013			
Marenostrum	1557	9.7	241
NSCCS	80	0.8	5
Argonne	500	1.7	31
HPC time competitively awarded since Jul 2012			
HECToR[2]	70069	280	1615
Hartree Blue Joule	5000	50	150
COSMOS[2]	550		17.5
Marenostrum	1000	19	110
Argonne[2]	85333	927	5350

[1] Costs calculated using HECToR pricing at the time of the award.

[2] Allocations have been awarded to consortia; the values indicated correspond to the allocations for KCL staff.



Research Income has increased substantially since 2008, reflected also through an increasing ratio of postdoctoral research associates and fellows to staff. Important elements in this have been an EPSRC Programme Grant (with another recently awarded), an STFC Consolidated Grant, and two ERC Advanced Investigator Awards (Ellis and Zayats). The total value of the Department's portfolio of external research grants during each financial year in the REF period is indicated in the above figure. *50% of the submitted staff have been appointed to their first academic position within the UK since 2010*, while a high proportion have been in their first permanent academic job during the REF period. Many of these new staff have already successfully secured their first research funding and so, *as these staff become established within the UK funding system, the Department's research grant portfolio can be expected to continue to grow significantly*.

e. Collaboration or contribution to the discipline or research base

1. Research collaborations, both national and international, form the basis of the majority of research in the Department:

• Its central location in London means in particular that it enjoys strong local collaborations with other London partners, including: wide-raging collaborative activity under the aegis of the Thomas Young Centre for Theory & Simulation of Materials; the ERC 'Terauniverse' project; the EPSRC 'Active Plasmonics' project; collaborative use of facilities within the LCN; collaborations with NPL.

• TPPC is linked to a number of international experiments: the LHC through 'Terauniverse' and as

Physics co-ordinator of MoEDAL; the Euclid Consortium; the Virgo-EGO Scientific Forum; the Cerenkov Telescope Array project.

• During the REF period the Department has been involved with a number of national and international consortia grants. National consortia include an EPRSC Critical Mass Grant Toucan on Catalytic properties of nanoalloys, EPSRC Basic Technology Grants on supramolecular self-assembly and on 'smart X-ray optics', EPSRC Programme Grants 'Active Plasmonics', and 'Hydrogen Embrittlement in Steel', and the UK Car-Parrinello consortium, while various EPSRC projects have supported national collaborations in EBN and TSCM. The Department's participation in a number of FP7 consortia, PICO-Inside, ADGLASS, MultiHy, PLAISIR and BONAS, has enabled collaborations with leading European universities and research-centres in materials modelling and in plasmonic enhanced photonic devices. Membership of FP7 Marie Curie RTN Universenet, ITN ACRITAS, Erasmus Mundus EXTATIC, and a number of COST Actions have all fostered collaboration. Non-UK funding (NSF, US Army, Argonne National Lab) have supported further bilateral collaborations, in addition to a number of Royal Society partner grants.

Interdisciplinary research lies at the heart of much of the Department's activities. Research in biophotonics concerned with the development of new optical imaging techniques is in collaboration with biomedical scientists working in translational research divisions in KCL. This is underpinned by the College-wide Centre for Biophotonics, the Nikon Imaging Centre, an MRC/EPSRC/BBSRC Next Generation Optical Microscopy Programme, a Wellcome/EPSRC medical imaging centre and a CRUK/EPSRC Comprehensive Cancer Imaging Centre. Single molecule force spectroscopy underpins projects in the King's British Heart Foundation (BHF) Centre of Research Excellence. Condensed matter simulation also involves collaborations with researchers in chemistry, biology and engineering to address important new challenges such as catalysis, fracture, metallurgy, photovoltaics, thermoelectrics, sensing and cell and molecular biology. Research in TPPC includes activity at the Maths/Physics interface, including mathematical physics and geometry.

Interaction with research end-users plays a pivotal role in the development of research strategy. Industry needs for improvement of LEDs (OSRAM) and photo-detectors in the near-IR (Sagem) and mid-IR (Xenics, Vigo) have led to the development of a new direction of research for plasmon-enhanced photonic devices. Similarly, requirements for nanoscale optical interconnects (Intel, Silios) and nanoscale light sources for high-density magnetic storage (Seagate) provided the impetus for the development plasmonic-waveguide based approaches in these areas (with PhD studentships funded by Seagate and Intel). A programme in chemo-mechanical modelling of rock fracture has led from the need of a major multinational mining corporation (Rio Tinto) to inform its operations in rock crushing and block caving, as well as safety considerations, while the need of BP in fuel and lubricant technology has led to research in fluids/surface interaction modelling.

The development of new software resources forms an important activity in the TSCM Group. Van Schilfgaarde is primary author of the *LM Suite* of electronic structure software based on the LMTO method, including the first implementation of the Quasiparticle Self-Consistent *GW* approximation developed by van Schilfgaarde, now considered as a gold standard in the electronic structure community. Kantorovich has developed and maintains the *TETR/LEV00* software suite for DFT simulations. Bonini was a contributor to *Quantum Expresso* electronic structure software package and Lorenz to the *LAMMPS* molecular dynamics simulation package.

2. Leadership. Department members have actively contributed to shaping national and international landscape of the field during the REF assessment period through:

(i) Advisory board and committee membership. During the assessment period **Ellis** has been a member of Advisory Committees to major physics institutions in 11 countries including, e.g., Institut Lagrange (Paris), Universe Excellence Cluster (Munich), Higgs Centre for Theoretical Physics (Edinburgh). He was advisor to National Research Foundation on CERN-related physics (Norway) and a member of the Quality Assurance Review of Dutch Physics and the Scientific and Technical Advisory Committee, Cerenkov Telescope Array. Ellis is a member of CERN Steering and Project Committees for Compact Linear Collider (2006–), TLEP (2012–) and Future Circular Colliders (2013–), and was Advisor to the CERN Director-General for relations with Non-Member States (1999-2011). **Mavromatos** was a member of the CERN-Greece committee advisory board (2005-11) and is Physics co-ordinator for the LHC MoEDAL experiment (2011–). **Sakellariadou** was a member of the External Advisory Board of the DFG Research Training Group "Models of Gravity"

(Germany, 2012–), and Vice-President of the Hellenic Society on Relativity, Gravitation and Cosmology (2010-). **Zayats** sat on the International Review Panel for the A*STAR (Singapore) Metamaterials Programme (2011), Nanophotonics Europe Foresight Panel (2010-11), European Nanophotonics Roadmap Merging Optics and Nanotechnologies (2006-09). **Wurtz** chaired the User Group for the Center of Nanoscale Materials at Argonne National Laboratory (2011-13). **De Vita** was a member of the HPC Wales Advisory Board for EU-funded high performance computing (2012–). A number of staff have sat on COST Action Management Committees: **Baletto** (MP0903), **Michette (**Chair MP0601, MP1203), **Kantorovich** (MP1303), **Zayats** (MP0803).

In support of the national discipline: **Ellis** was a member of the STFC Science Board (2007-10); 5 staff are currently EPSRC College members; **Richards** is Chair of the UK Standing Conference of Physics Professors (2013–) and was a member of the IOP Membership and Qualifications Board (2008-12); **Fairbairn** was a member of the IOP Astroparticle Physics (2008-13) and High Energy Particle Physics Committees (2010-2013); **Sakellariadou** is a member of the UK Cosmology Committee (2008–); **Molteni** was a member of the IOP Women in Physics (2005-11) and Theory of Condensed Matter (2006-09) Committees. KCL is a principal actor in establishing and running the London-wide Thomas Young Centre, with **De Vita** co-founder, Deputy Director (2006–2010) and Chair (2011–), while **Kantorovich** and **van Schilfgaarde** sit on the executive board. **De Vita** was also co-founder and Node Authority (2012) of the JCMaxwell CECAM Node (with Imperial, UCL, Oxford and Cambridge).

(ii) Conference organisation. Important contributions to scientific community also include wide-ranging membership of programme committees and co-organisation of international conferences, workshops and schools. Appointment of staff as conference programme chairs in major international conferences has included those of **Zayats** as General Chair (2012) and Programme Chair (2011) of the OSA Integrated Photonics Research Conference, General and Programme Chair of the Nanophotonics and Metamaterials conference, EOS General Assembly (2010, 2012). **Acharya** and **Ellis** co-founded and chaired the biennial African School for Fundamental Physics and its Applications (SA 2010, Ghana 2012, Senegal 2014), the only one of its kind in Africa, fully funding > 50 students from all over Africa. Among staff recently appointed to their first academic position, **Lim** was Chair of Numerical Cosmology 2012 (Cambridge) and **Sapienza** was Chair of Complex Nano-Photonics (Cumberland Lodge 2013).

(iii) Invited lectures. The international standing of the Department is evident from *numerous* invited, plenary and keynote lectures at major international conferences. Examples of important keynote and plenary lectures include those given by **Ellis** at the Royal Society, Hadron Collider Physics Conference and the Nobel Symposium on Particle Physics, **Mavromatos** at DISCRETE '08, 12 and **Zayats** at META-10,-12, SPIE Defence & Security 2012, SPIE Optics and Photonics Congresses 2010, 2011. In particular, staff appointed to their first academic post since 2007 gave numerous invited talks at international conferences and workshops, with examples including: keynote by **Baletto** at TOFA2012; **Bhaseen** at Arnold Sommerfeld School 13 and APS March Meeting 13; **Bonini** at Ψk 2010; keynote by **Dickson** at NFO-10; plenaries by **Fairbairn** at IOP HEPP 2010, TeV Particle Astrophysics 2010 and COSMO 2013; **Garcia-Manyes** at the Gordon Research Conference Single Molecule Approaches to Biology 2013, **Lorenz** at SoftMatter 2008; keynote by **Sapienza** at TNT 2013; keynote by **Wurtz** at SPIE Optics and Photonics 2012.

(iv) Fellowships and Awards. During the REF period **Ellis** was appointed Commander of the British Empire (CBE) for services to science and technology and was awarded 4 honorary doctorates. He was awarded an ERC Advanced Investigator Award (2011–16). **Acharya** was Leverhulme Visiting Professor at the University of Nottingham, prior to appointment at KCL. **Garcia-Manyes** was awarded the 2012 (first) Annual Prize of the Spanish Biophysical Society, and an EPSRC Early Career Fellowship (2013-18). **Ginzburg** was awarded a Newton Fellowship (2011) and an EPSRC Postdoctoral Fellowship (2013-16). **Owen** (UoA5) was awarded an ERC Starting Investigator Award (2013–18). **Sapienza** was awarded a Ramon y Cajal Fellowship (2009-12). **Weber** (2009-12) and **Kozik** (2011-13) were awarded Swiss National Foundation for Science Postdoctoral Fellowships for Advanced Researchers. **Zayats** was awarded an ERC Advanced Investigator Award (2012–17) and a Royal Society Wolfson Merit Award (from 2014).