Institution: Aberystwyth University

Unit of Assessment: 9 Physics

a. Overview

The Department of Mathematics and Physics (DMAP) at Aberystwyth University has a research environment that encourages inter-disciplinarity, with very active cross-fertilisation between Physics and Mathematics. The research groups share a common research infrastructure incorporating laboratories, computing, electronic and mechanical workshops and support staff, all located in the same building. Each of the groups' researchers have distinct disciplinary backgrounds, leading to a vibrant and unique research culture

The **Materials Physics (MP)** group includes Evans, Finlayson, Flikkema, Greaves, Richards, Wilding, Zhou, Burgarth, Cox, Davies and Gough. The interests of these experimentalists and theoreticians cover liquids, foams, glasses, semiconductors and low-dimensional materials. Approaches include developing bespoke instrumentation, new computational methods and use of central facilities. Staff have membership of other groups (Wilding, Burgarth) and those undertaking primarily mathematical modelling (Cox, Davies) and the mathematics of quantum control (Gough) are submitted to Mathematical Sciences (UoA10).

The **Solar System Physics (SSP)** group includes Grande, Li, Morgan, Pryse, Taroyan, Wilding and Barnes. The interests of these researchers span processes in the Sun, the outflow and eruption of solar material into interplanetary space and the environment of the Earth and other planets. Approaches include High Performance Computing (HPC), instrument development and leadership of collaborative space projects. Staff share membership with the MP group (Wilding) and the Intelligent Robotics group in the Department of Computer Science (Barnes, submitted to UoA11).

The Aberystwyth **Quantum Structures, Information and Control (AQStIC)** group includes Burgarth, Gohm and Gough. They work in the area of quantum systems in interaction with their environment, and in particular the emergent field of quantum control engineering. Emphasising the close link between physics and mathematics in this group, Burgarth is submitted to UoA9, with Gohm and Gough submitted to UoA10; Burgarth and Gough share membership with MP, for example in low dimensional materials for spin physics and photonics.

All physics staff are engaged in international collaborative research. The Centre for Advanced Materials and Devices (CAFMaD) and the Wales Institute of Mathematical and Computational Sciences (WIMCS), both funded by HEFCW, have provided regional networks for materials, space and modelling research during the census period, and staff have engaged in their leadership, organisation and activities.

b. Research strategy

DMAP's strategy is to continue to grow and strengthen physics research groups by the following:

Aim1	Promoting high-quality research and growing income streams
Aim2	Supporting and training junior researchers
Aim3	Exploiting the interdisciplinary environment
Aim4	Expanding international collaboration

Aim1: Physics staff have published over 250 peer-reviewed papers in international journals during the census period. Through targeting journal titles in physics, astronomy and materials, the overall quality of our research output has improved since RAE2008. We have diversified research income streams with a larger number of projects involving UK and international industry. Across the department, research income (c. £1M per annum) has an increasing contribution from non-RCUK sources, notably a three-fold increase in EU funding since 2008. Access to UK and international central facilities accounts for a further £0.6M per annum.

We plan to increase research income using DMAP's experience with European funding schemes and with collaborative research projects that include industry, in particular SMEs. We will specifically target strategic areas in Horizon2020, aligning with priorities such as Space and Photonics. We will strengthen internal and external links in areas including quantum technology, mathematical modelling, functional materials, autonomous systems and space instrumentation.

Aim2: In DMAP, we aim to recruit and train junior researchers in strategic areas. We have made six new appointments (including three Early Career Researchers (ECR)), each appointed to his/her first full-time UK academic position. These appointments cover quantum physics (Burgarth), materials physics (Finlayson, Zhou, Richards) and space physics (Morgan, Taroyan).

Aim3: Internal funding support for seed corn research and travel is provided by the AU research fund and conference fund (that both prioritise ECRs and collaboration). In addition, DMAP makes available a Research and Impact travel fund that prioritises new collaborations, summer fellowships for distinguished visitors and PhD studentship funds, prioritising jointly funded projects.

From August 2013, DMAP will align more closely with the Department of Computer Science (DCS) within a new Institute of Mathematics, Physics and Computer Science (IMPACS), sharing central space on the main university campus. IMPACS will further enhance cross-fertilisation between the three disciplines and provide an integrated research infrastructure with shared buildings, facilities and support staff.

Aim4: We have developed new international partnerships centred on central facilities and space missions, and have organised and hosted international conferences and workshops. 85% of submitted physics papers are collaborative involving non-AU partners and 64% involve international collaborators. UK collaborators include Cambridge, Oxford and Imperial College.

These aims are described in a DMAP strategy document, which is updated frequently, and discussed at monthly meetings of the department's Research Committee (RC). The RC, chaired by the Director of Research, consists of physics and mathematics research group leaders and the Head of Department, with other staff co-opted at each meeting. Researchers from other departments and support staff are invited to discuss specific items, ensuring an easy route to the proposal of strategic inter-disciplinary projects, for example and the space-materials-robotics intersection. The RC assists research groups to develop research capacity and research of world-leading quality, to integrate the activities of physics and mathematics for mutual benefit and to address the strategic priorities of the Research Councils and other funding bodies, by appropriately emphasising academic, social and economic impacts of the research.

Delivery of the research strategy is monitored by the RC through data collected in the University's Current Research Information System (PURE) and bi-annual monitoring meetings between researchers, the Head of Department and the DMAP Director of Research. In these meetings, key indicators are identified and refined to monitor the performance of individuals and groups, including research outputs, grant income and research student supervision, paying particular attention to both the quantity and quality of such indicators. This information feeds into regular departmental monitoring meetings with the University Research Committee.

The University's Research Office has received further investment during the census period to provide an improved support service to researchers, including (particularly interdisciplinary) grant development and application, improved research finance processes, large research-intensive project management and coordination of REF and Research Monitoring. In July 2013 the Research Office merged with the University's Enterprise Office to create the Department of Research, Business & Innovation (DRBI). With a combined staff of fifty, the DRBI delivers integrated and proactive research and enterprise development services.

Strategic Objectives for Physics, progress in the current census period and future directions are summarised as follows:

The **MP** group's research strengths are developing new materials and new instruments through collaborative projects in mathematical modelling and experiments, at Aberystwyth and at central facilities. Physics successes include the discovery of perfect glass, supported by EPSRC, STFC and industry, coloured glass for calibration targets for planetary explorers, supported by ESA and STFC, recycled glass for new energy applications, in collaboration with a local SME, new methods for organic semiconductor growth and characterisation, funded by the Royal Society and the EU, and a new method for the fabrication of graphene on diamond, funded by EPSRC. New instruments, funded by EPSRC, STFC and HEFCW, include an aerodynamic levitator designed for contactless structural and viscosity studies of high temperature liquids using neutron and x-ray scattering and a hyperspectral microscope designed for parallel chemical and optical studies using synchrotron radiation.

Our strategy is to broaden and deepen the physical understanding and application of materials through new instruments and computational methods and new collaborative projects. Key materials areas are extreme materials (e.g. polyamorphic liquids), low dimensional materials (e.g. graphene), and organic materials (e.g. macromolecular polymers). Key instrumentation areas are commercialisation of design and services, and knowledge transfer (e.g. applications in climate science and heritage). Key computational areas are 3-d modelling and HPC, working closely with mathematicians and computer scientists. New collaborative projects include an EPSRC Centre for Doctoral Training in Diamond Science and Technology; a multi-disciplinary partnership with Warwick, Imperial, Oxford, Bristol, Cardiff, Newcastle and Strathclyde, starting in 2014.

The **SSP** group's core expertise in the observation and modelling of processes affecting the Sun and the planets is enabled by lead roles in space missions such as Chandrayaan-1, SMART-1 and access to spacecraft, satellite and radar data (Venus Express, Cassini, SuperDARN, Radiation Belt Storm Probes, EISCAT, LOFAR). Research is highly collaborative leading to new advances in areas such as solar tornados, coronal mass ejections, Venus ionosphere, lunar geophysics and space weather. ESA, STFC and UKSA funding has supported mathematical modelling, HPC, instrument development and data processing.

Our strategy is to lead projects in solar and planetary observation, modelling and exploration within missions such as BepiColombo, ExoMars and JUICE (Jupiter Icy Moons Radiation Environment) and in the future Marco Polo, and to develop new interdisciplinary collaboration in areas such as glaciology, radiation modelling, materials science, robotics and instrumentation.

The activities of the **AQStIC** group centre on the development of theoretical models for the application of control principles to quantum systems. This includes developing the theory of quantum feedback networks and the controllability of quantum spin chains. The group's research is highly interdisciplinary at the boundary of physics, mathematics and engineering, and incorporates classical and quantum probability, information and control methodologies.

Our strategy is to expand the mathematics – condensed matter physics interface, for example using spin structures based on diamond, graphene and ferromagnetic monolayers. This activity is a strategic growth area for physics and mathematics, exploiting the closeness of the disciplines within DMAP.

c. People, including:

i. Staffing strategy and staff development

DMAP's strategy is to retain and develop research staff and to further recruit researchers with a commitment to undertaking high quality research. We aim to make appointments that transcend disciplinary boundaries, particularly between mathematics, physics and computer science.

Six new appointments have been made across the physics research groups since 2008. Four are new university lectureships, strengthening the Mathematics – Physics boundary in AQStIC (Burgarth), solar modelling in SSP (Taroyan) and photonics in MP (Finlayson, Richards). The university and Coleg Cymraeg Cenedlaethol (CCC), the Welsh Federal College, jointly fund a further new SSP lectureship (Morgan). The sixth new researcher (Zhou) held a CAFMaD-funded

lectureship and subsequently progressed to a new research professorship in DMAP, held alongside a professorship at Shanghai University.

Two of the new lecturers (Burgarth and Finlayson) have participated in the Welsh Crucible, a programme of personal, professional and leadership development for future research leaders supported by HEFCW and the Welsh universities, with 30 participants competitively selected each year from promising early- to mid-career researchers across all disciplines in Wales.

In addition, DMAP hosts two retired but research-policy-active Fellows of the Royal Society, Prof. Sir John Houghton and Prof. Ken Walters. The department benefits from their advice and guidance on national and international initiatives, and on grant applications.

Since 2008, we have recruited international staff from China, Hungary and Germany. One ECR submitted in RAE2008 is now Deputy Director of Materials Physics in Space at German Aerospace (DLR), another has moved to a senior academic position at UCLAN. A third ECR has been awarded a lectureship at Aberystwyth following an RCUK fellowship. Former PDRAs now hold positions in Spain (ESA), China (Chinese Academy of Sciences and Shandong University), The Netherlands (ASTRON), and the UK (Aberystwyth Computer Science, Rutherford Appleton Laboratory, University of Glasgow and Nottingham Trent University).

All staff are expected to complete a programme of personal development/training each year, through an annual Staff Development and Performance Review (SDPR), including courses run locally (by AU's DRBI and the Centre for the Development of Staff and Academic Practice) or elsewhere. Early- and mid-career researchers are encouraged through SDPR to lead research projects and to take on leadership positions within the department, acquiring experience and expertise that will consolidate the sustainability of the research environment. Staff development includes research planning and monitoring meetings and peer advice on research proposals.

The DRBI runs a compulsory course on financial management of research grants. ECRs are each assigned a mentor from among the senior staff in their research group, who advise on grant application processes, university processes etc. during their 3-year probationary period. Applications for promotion are encouraged, making use of the University's new mentoring scheme for candidates for promotion to senior lecturer and reader.

Strategies for identifying research opportunities, developing applications and generating grant income involve support at both departmental level, using the expertise of senior staff and research groups for compulsory peer-review to target project ideas, and at a University level, through the DRBI. The latter offers resources including an internal library of successful grant applications, and facilitation of strategic bids for large research grants.

DMAP operates a research leave scheme for all academic staff, for one semester in eight, overseen by the Research Committee. Leave is subject to an appropriate research plan, enabling intense periods of research, the development of research grant applications, and writing of major pieces of work. The research leave policy also provides for buy-outs funded by external grant income. Successful use of research leave is monitored and informs future decisions on leave allocation.

DMAP is committed to implement the Concordat to Support the Career Development of Researchers, and the university received an HR excellence in research award in 2010 and 2012. Research staff are assigned mentors within their research groups, complete a probation agreement with targets for publications and conference presentations, and are encouraged to engage in internal and external professional development courses. Standards of research quality and integrity are articulated in the Aberystwyth University Policy on Safeguarding Good Research Practice. All staff receive equal opportunities training before serving on interview panels, and the University is currently applying for Athena Swan status.

ii. Research students

To enrich the department's research community and culture, we actively seek to increase the number of postgraduate research (PGR) students. Funding for graduated students since 2008 includes RCUK (STFC, EPSRC, NERC) and the EU in addition to competitively won university studentships (e.g. Doctoral Career Development Scholarships (DCDS)). Current students are funded by STFC, EPSRC, DCDS, EU (Structural Funds and FP7), and overseas (US, China) government and investors. In support of furthering opportunities for PGR students, DMAP has introduced new postgraduate scholarships (two per year) to attract outstanding international and home students, supplementing investment at university level in DCDS.

PhD students are assigned two supervisors and are provided with academic training including research seminars by external speakers, at research group meetings, and presentations to peers. Skills training provided by the University includes a compulsory first year 20-credit PG skills module in IT, IP, publishing and writing. Research students also develop their own training sessions, for example developing and delivering specialist computer programming courses. Students also engage with outreach activities (e.g. leading the Aberystwyth node of the Institute of Physics (IOP) Physics Buskers) and assist with Open Days, workshops and conferences hosted by the department).

PGR students are given financial support to present their work at leading international conferences and to organise their own meetings. For example, DMAP established an International Network for Young Scientists (INYS), with support from the British Council and in collaboration with NUS and NTU, holding workshops in Singapore (2009) and in Aberystwyth (2011) from which collaborations have ensued. Physics PhD students have been nominated and awarded prizes for presentations at international meetings such as ICMAT 2009, PSD 2011, MRS 2010, Diamond Conference 2011, MAXlab 2012, MRS 2013.

Student progress is monitored annually, including student reports, supervisor reports and departmental interviews. Satisfactory progress after the first year is a necessary pre-requisite for progression from MPhil to PhD. Reports are assessed by a board of academic staff, chaired by the Director of Research, who interview all students. Destinations of PhD students graduating within the REF census period include academic and research positions in the UK (Lancaster University, Rutherford Appleton Laboratory) and abroad (NTNU Trondheim, Norway, National Observatory of Athens, Greece, University of Otago, New Zealand, Hanoi University of Technology, Vietnam) and positions outside academia (Marketing Manager, Elmac Technologies Ltd, Senior Research Scientist, Element Six Ltd, Research Associate, National Library of Wales, Publishing Editor, IOP).

d. Income, infrastructure and facilities

The main research income streams for physics research at Aberystwyth are RCUK, the EU and industry (£3.7M), supplemented by access to UK and international central facilities for x-ray science, neutron science, radio science and planetary science (£3.5M). Additional infrastructure funding from the university and HEFCW (£0.5M) has supported materials laboratories, workshops and computing. This income is supplemented by consultancies and contracts with industrial partners. The research expertise of staff is available in AU's directory of expertise, leading to (i) commercial contracts e.g. in metal alloys, diamond science and technology and optical instrumentation, (ii) collaborative academia-industry grants, e.g. EU-funded knowledge exchange studentships with SMEs in glass science (Ten Green Bottles) and in vacuum instrumentation (Scanwel); (iii) non-disclosure agreements and materials transfer agreements with companies in areas such as polymer electronics and photovoltaics.

Specialist materials facilities, supported by the university, RCUK and HEFCW, include bespoke instrumentation such as imaging ellipsometry, luminescence and Raman for multi-phase materials, in-situ x-ray and neutron scattering at high temperature for liquids and glasses and real-time, in-situ photoemission for thin films and coatings, in addition to standard fabrication, spectroscopy, microscopy and diffraction facilities.

The Planetary Analogue Terrain Laboratory provides a unique test location for camera and calibration targets developed in collaboration between MP and SSP physicists and computer scientists, supported by STFC, ESA, UKSA and HEFCW.

DMAP hosts a 128-node Beowulf HPC cluster, accessible to all staff and students for modelling and simulation, paralleling the provision by HPC Wales. Further investment has centred on improved backup and storage facilities in 2013. This is complemented by ten 3D stereo desktop PCs distributed between offices, a dedicate computer laboratory and a 3D stereo "wall" with infiniband connection to the compute cluster, supported by EU funding.

Support for all IT facilities, research laboratories, mechanical and electronic workshops is integrated in a team of ten staff under the leadership of the Director of Infrastructure. Research laboratories are supported directly by postgraduate-level technicians, trained in instrumentation and characterisation.

Continuing this integration, a £0.5M HEFCW-funded infrastructure investment was secured in 2012 by DMAP and the Department of Computer Science to co-locate all technical and research facilities for both departments on the main university campus.

Research income from research grants is supplemented by awards for access to central facilities (including the Diamond Light Source, SRS, ISIS, and the ILL for the MP group and EISCAT and ESA for the SSP group). In addition to UK facilities, the following access time to international facilities has been awarded, with an estimated total value of £1M:

Facility	*Time awarded*
BESSY, Germany	36 days
MAXlab, Sweden	29 days
ASTRID, Denmark	7 days
APS, USA	29 days
SNS, USA	15 days

e. Collaboration or contribution to the discipline or research base

Collaboration is a very important feature of all research in DMAP with all research groups active in national and international partnerships. Physics researchers have established new collaborations in China, Germany, Japan, USA, New Zealand, Norway, Sweden and the Netherlands, through research projects, fellowships and joint publications.

MP researchers collaborate on materials, instruments and facilities, including leading projects such as a new soft x-ray photoemission facility at the Diamond Light Source, bringing together 70 researchers from academia and industry addressing issues in catalysis, biomaterials, photonic materials, environment and atmospheric sciences, space science and heritage science.

SSP researchers collaborate internationally to build instruments, acquire and interpret data; this includes PI roles in Chandrayann-1 X-ray Spectrometer (C1XS) (Grande), the European Space Agency SMART-1 (D-CIXS) (Grande), with CoPI or CoI in BepiColombo (Grande), Cluster (Grande), JUICE (Grande), Cassini (Grande), Venus and Mars Express (Grande), (JAXA) SELENE (Grande), and the Solar Dynamics Observatory's Feature Finding Team (Morgan) and strong collaboration in LOFAR, EISCAT, Van Allen Storm Probes and STEREO HI.

National initiatives such as the HEFCW-funded networks, CAFMaD and WIMCS have funded collaboration in materials, devices and mathematics, and in 2010 the three Welsh Physics Departments made a £10M bid to HEFCW to create a joint Institute for Advanced Study with the aim of establishing the environment for a step-change in investment for physics in Wales. Whilst this vision has yet to come to fruition, cooperation between the Departments has enhanced significantly and further joint initiatives are underway. In High Performance Computing, we engage

with HPC Wales to develop projects and training for project students. A new collaborative network in quantum theory, www.qymru.org, was launched in 2012. Researchers are increasingly exploiting the growth of social media, for example through international online Q+ hangouts seminars (with 2600 followers on Google Plus), www.quantiki.org (the main portal to quantum physics world wide).

Our national and international visibility has been enhanced by advisory board and panel membership, including STFC Science Board (Greaves), STFC Physical and Life Sciences Committee (Greaves), IOP Council (Greaves), COSPAR (Committee on Space Research of the International Council for Science) Council (Grande). Researchers have had leading roles on panels and committees, including EGU Planetary President (Grande), COSPAR Vice Chair for space weather (Grande), Chair of B07 working group at the Diamond Light Source (Evans), Chair of IOP Wales (Grande), Chair of the Welsh Optoelectronics Forum (Evans). Wider panel membership and active involvement includes NASA Low Cost Access to Space (Morgan), NASA Small Explorer Mission (Grande), IOP External Engagement (Grande), HPC Wales Board (Grande), as well as various STFC, EPSRC and central facilities panels.

Visibility as a research institution has been enhanced by the organisation and hosting of workshops and conferences in Aberystwyth, including Entropy in Glass 3 (2009), Remote Sensing of the Inner Heliosphere Workshops (2009, 2011), Position Sensitive Detectors 9 (2011), QuICC Summer school (2012), Europlanet/ESA workshop on the future of radiation modelling (2012), LMS Conference on Open System Identification (2013), Cynhadledd Wyddonol y Coleg Cymraeg Cenedlaethol (2013).

Organisation of international conferences elsewhere include the initiation and Chair of the Executive Committee and Science Organising Committee of the European Planetary Science Congress (EPSC), now the largest Planetary Science conference in Europe (Grande), the initiation and Chair of the International Conferences on Light and Particle Beams in Materials Science (2008, 2010, 2013) (Greaves) and Division IV Chair of the International Association of Geomagnetism and Aeronomy (IAGA) (Li). Researchers have been members of International Advisory Committees, including the International Conference on the Physics of Non-Crystalline Solids (PNCS) (Greaves), and have organised and convened sessions at conferences such as the European Geosciences Union (EGU) in 2009 (Li), RAS Specialist Discussion Meeting in May 2011 (Taroyan), the Asia Oceania Geosciences Society (AOGS) in 2012 and 2013 (Li), and at the UK National Astronomy Meetings (Li, Morgan).

Invited presentations at international meetings include: KITP Program: Control of Complex Quantum Systems, Eclipse on the Coral Sea, EPSC, EGU, CLEO/PHAST 2008, ICFSI 2009, Diamond Conference 2009, IGC 2010, IUGG 2011, SPIE Photonics West 2011, ICMAT 2011, NCM 2010, SRMS 2010, 8th Pacific Rim Conference on Ceramic & Glass Technology, 6th International Discussion Meeting on Relaxations in Complex Systems, AOGS 2012, IDMRCS 2013, LPBMS 2013, AOGS 2013, IAGA 2013.

Physics researchers have been editors or associate editors of international journals including Current Opinion in Solid State and Materials Science (Greaves), Journal of Non-crystalline Solids (Greaves), Diamond and Related Materials (Evans), Eos: Transactions of the American Geophysical Union (Grande) and Earth Moon and Planets (Grande); Pryse is the chair of the editorial board of Gwerddon.

Greaves received the 2011 George W Morey Award from the American Ceramic Society, for major contributions to the field of glass science. With honorary professorships at UCL, Cambridge and Shanghai, he was appointed as a Strategic Scientist at Wuhan Institute of Technology in 2013. Li holds a visiting professorship at Shandong University, China. Morgan has foreign collaborator status at the Institute for Astronomy, University of Hawaii. In 2011, Evans was awarded an Erskine Fellowship at the University of Canterbury, New Zealand. Grande was visiting Chair at the Open University (to 2010), and a Visiting (Carte Rouge) Professor at the Institute of Radiation and Planetary Science, Paul Sabatier University, Toulouse (2012).