School of Physics and Astronomy: Strategic Plan 2021-2026

Aspiration - World Leading St Andrews

The School's core strategy is to excel in our chosen areas of strength, in order to deliver world-class research, impact and teaching. Our attainments in REF2014 (3rd equal in UK in GPA), repeated high rankings in university league tables and the National Student Survey, and our JUNO Champion and Athena SWAN silver awards stand witness to the successes in this strategy. We aspire to consolidate this position of strength by identifying opportunities for increasing our research impact, and our grant and teaching income. We will strengthen our core research areas in astrophysics, condensed matter and photonics, and further develop our research centres to meet the University's interdisciplinary priorities of *Materials for the Modern World, Health, Infectious Diseases and Wellbeing, Big Data, Sustainability, Evolution, Behaviour and Environment*, *Peace, Conflict and Security,* and *Cultural Understanding.* We aspire to create a globally visible School as a beacon for outstanding research and teaching in an inclusive environment promoting creativity, originality and the wellbeing of staff.

What distinguishes Physics and Astronomy at St Andrews

Our research and teaching strategy is designed to benefit from our relatively small size. The School of Physics and Astronomy is known for its world-leading research in its three priority areas, and remains one of the top places to study physics in the UK, offering students a unique and memorable experience. Our scientific outputs, and just as importantly our undergraduate and postgraduate students, are highly esteemed. Former students are primary in attaining visibility globally as they continue to promote St Andrews as a place of academic and scientific excellence throughout their careers. Recruiting and supporting the best staff ensures that we can continue to increase our global standing. Our continued investment in staff and students, as well as facilities, is essential for future success.

Excellence in Research: Building Centres of Excellence

We achieve high impact by concentrating on key research areas where we have or can attain international leadership. Building naturally on our priority areas of *Astrophysics (Ast), Condensed Matter (CM)* and *Photonics (Phot)*, and to facilitate world-leading research, maximize synergies and impact, our research activities have nucleated around seven interdisciplinary centres and institutes. They are

- The Centre of Magnetic Resonance (CM/Phot, Est 2009)
- The Organic Semiconductor Centre (*CM*, Est 2010)
- Institute for Data-Intensive Research (*Ast*, Est 2014)
- The Centre for Exoplanet Science (*Ast*, Est 2016)
- The Centre for Designer Quantum Materials (*CM*, Est 2019)
- The Centre of Biophotonics (*Phot*, Est 2019)
- The Mackenzie Institute for Early Diagnosis (*Phot*, Est 2019)

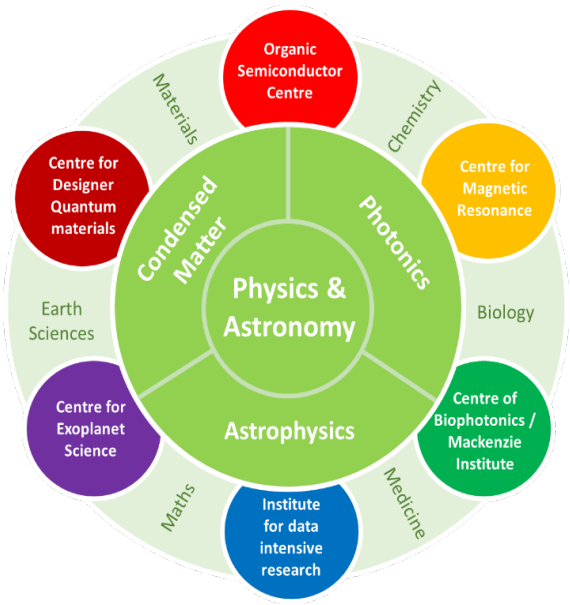

Figure 1: Interdisciplinary links of the Centres and Institutes in the School of Physics and Astronomy.

The centres profit from strong links with other Universities and research organizations, several of which are formalized, e.g. through the Scottish Universities Physics Alliance (SUPA), an International Max Planck Partnership (IMPP) and an International Max Planck Research School (IMPRS). These structures ensure that we are well-placed to contribute to and benefit from future Scottish pooling

initiatives which are likely to be interdisciplinary, but based on existing research strengths well represented in the School.

Research Strategy

At the heart of our research strategy is to identify areas in which we can develop combinations of research leaders and facilities that enable world-leading and agenda-setting research and impact whilst building critical mass. The School of Physics and Astronomy has invested heavily in infrastructure, with a focus on realizing unique capabilities and growing our global footprint in our strategic priority areas. These investments are connected with key recruitments that have enabled us to realize over the last years the full potential of new Ultra-Low Vibration laboratories, Cleanroom facilities, a dedicated biophotonics lab and our SUPAscopes. We have further enhanced this through a molecular beam epitaxy lab for the growth of designer oxide heterostructures, a spin-resolved angular resolved photoemission system and a materials-characterisation suite, a combination that is unique in the UK. Creating clusters of excellence is essential in bidding for prestigious collaborative grants.

Global St Andrews

Building on our strengths and in realizing our vision of creating a department with international visibility, leadership and diversity, we have in recent years consolidated collaborations with international peers. This is evidenced through:

- close collaboration with research groups at four Max Planck Institutes (MPI for the Chemical Physics of Solids, MPI for Physics of Complex Systems, MPI of Light, MPI of Solid State Physics) within the framework of an International Max Planck Partnership
- pan-European training programmes such as the International Max Planck Research School, with the School of Physics and Astronomy as a partner and a Marie-Curie ITN on exoplanets led by St Andrews
- an international research programme on new organic light emitting materials funded through a JSPS core-to-core programme with Kyushu University
- our key participation and leadership in international astronomy surveys SDSS-4 and SDSS-5
- a collaboration funded by the Human Frontiers Program to use techniques from biophotonics to image neurons with Harvard Medical School and University of Cambridge
- leadership in the recently launched CHEOPS exoplanet space mission.

Entrepreneurial St Andrews

Our Centres provide a framework for accelerating impact by bringing together researchers from the School of Physics and Astronomy with those from other disciplines, to translate new concepts and mechanisms developed by us towards applications in other research fields or directly to industry. Examples include applications of our research for (i) biomedical applications and diagnosis, (ii) for sensors for water quality monitoring, (iii) modelling of light-tissue interactions for COVID disinfection, and (iv) high performance, ultra-compact, space qualified antennas for satellites. Going forward, we will work to strengthen the impact for our condensed matter research, using our expertise and understanding to identify routes to application for quantum materials and new device concepts based on these. The Centre of Designer Quantum Materials is key to realizing this vision. We seek to strengthen this area through more activity in the design and engineering of prototype devices using advanced quantum materials to create new sensors, platforms for more energy-efficient information processing and novel concepts for energy harvesting.

We foresee exciting opportunities for new joint activities with Eden Campus coming online. These include the possibility for companies located at Eden Campus to profit from some of our unique research expertise and infrastructure in joint projects, as well as providing opportunities for joint projects to develop some of the results from our research to higher technology-readiness levels and to market. We are keen to contribute to shaping the vision for Eden Campus and we have several commercialisation projects which will benefit from the rapid prototyping facility planned there. The

School is already a leading participant of Engineering @ St Andrews, the initiative to consolidate the diverse engineering activity across the University.

The successes of our efforts in translating research to technology are evidenced in the large number of patents applied for by or granted to members of the department, with 78% of these being already licensed out. Our photonics research and teaching in particular interfaces in many ways with industry, for example through the Engineering Doctorate programme in Applied Photonics in which students spend 75% of their time working directly with a company and the sponsoring firm gains access to University laboratories and facilities.

Excellence in Teaching

We aim to provide undergraduate and postgraduate students with an education of the highest quality, providing them with the skills and knowledge for a successful career in industry, business and academia. The School of Physics and Astronomy has frequently achieved top ranks in national league tables for its teaching, making it the go-to place to study physics in the UK. We have achieved this position through a well organized and taught teaching programme, healthy student-staff interactions, and with strong links to our research activities. Teaching laboratories, small-group tutorials, and individual final year projects are important aspects of this programme. Suitable teaching spaces plus individual and group study areas in the School's building contribute to the student experience, not least by helping build a learning community that involves students and staff. We will continuously seek opportunities to use new technologies, evolving pedagogies, and developments in student expectations to ensure that we maintain the excellence of our teaching programme.

Our successful teaching programme is heavily oversubscribed with students having the highest grades. This offers an opportunity to organically and sustainably grow student numbers in the coming years, mindful of maintaining the quality of our teaching and the St Andrews experience for students. Such growth needs to be commensurate with growth in the numbers of teaching, research, support and administrative staff in the School, and increased teaching, laboratory and research facilities.

Diverse St Andrews

In striving to achieve and sustain leadership in teaching, research and impact, we are mindful of creating an inclusive and supportive environment. Promoting equality, diversity and inclusion is a School priority, reflected in our Juno Champion status, an Athena SWAN Silver award, and a sustained track-record of high staff satisfaction. We aim to enable access for and encourage students from disadvantaged backgrounds through the Gateway programme. Our successes in attracting a diverse student population are visible in a percentage of female undergraduate students well above the national average. Our academic staff gender ratios are higher than national averages and we look to increase these across all research areas, and at all staff levels.

Sustainability

Inspired by the ground-breaking work of St Andrews Professor John W. Allen who developed the first light-emitting diode (LED) lamps, our research is at the forefront of identifying underpinning physical mechanisms and advanced materials to enable the development of more energy efficient future technologies and new routes to energy harvesting. Research activities in this area span from the development of new materials for more energy efficient photovoltaic solar cells and lighting technologies, through indoor energy harvesting to new materials platforms for future quantum information processing. Our Astronomy research helps us to understand the impact of a wide range of atmospheric conditions for the possibility of life on other planets, providing invaluable input to managing the changing conditions on our own planet. Our teaching curriculum stresses the role of physics in achieving a sustainable society

On a more immediate level, the School strives to undertake its research in a sustainable fashion, evidenced, for example, by recuperation of 95% of the helium required for low temperature experiments using Scotland's only such liquefier. We strive to improve on the recovery rate by not only recovering helium from the School of Physics and Astronomy but also from other Schools. Future

routes to further improved energy efficiency of our research include recuperation of waste process heat for provision of heating.

How to realise our aspiration

In order to significantly increase our research impact globally, we need to invest in our research strengths while retaining flexibility and agility to react to newly emerging research directions.

Research Strategy

Over the next five years, we aim to grow the international visibility and global recognition of our science and of our interdisciplinary centres. We look to grow in areas which enable transformational advances and accelerate impact by exploiting the strengths of our Centres and synergies between them and through increased collaborations with other academic institutions and industry. The School has had a recent expansion in astronomy staff, re-establishing strong groups in galaxies and star formation that balance our work in exoplanets. Priority areas for expansion will include ones that can benefit from recent facility developments in our clean rooms, MBE, SARPES, biophotonics and ultra-low vibration labs. We will continue to reassess our advertising and hiring processes to ensure a maximally diverse pool of applicants, and ultimately an increase in our gender balance and diversity amongst academic staff across all research areas within the School.

Particular focus areas in which we foresee strategic hires and expansion are:

- Developing the science of ***advanced quantum materials*** and utilize their emergent properties to realize new technology. Casting these materials into prototype devices enables entirely new science, en-route to technology. This is a crucial approach that is expected to enable technologies beyond Moore's law, the importance of which has been recognised in the International Roadmap of the Semiconductor Industry, and where the unique growth and characterisation facilities available in St Andrews provide the necessary basis for transformational advances, contributing to a renaissance of engineering in St Andrews.
- Bridging between our theory group, condensed matter and photonics, an expert in ***materials prediction*** and computational physics would enable new insights and control of designer materials with applications in novel information technologies, photovoltaics, and energy storage. An expert in this area would be at the interface between photonics, condensed matter, and theory as well as related activities in Chemistry.
- Building expertise in biophysics by exploiting novel approaches in ***advanced Imaging*** by building on our world-leading expertise in photonics or magnetic resonance would complement ongoing work and create new opportunities for early diagnosis in the Mackenzie Institute.
- Using our expertise in **biophotonics** for applications in early diagnosis and treatment of diseases, strengthening our leading portfolio in biophotonics research. Approaches to diagnosis inspired by our photonics research can be developed further and lead to dramatic improvement of early detection of medical conditions with potentially life-changing implications for public health in developed and developing countries.
- Growth in ***Photonic Materials*** and their applications, building around our current strengths in nanophotonics, metamaterials and solution-processed semiconductor materials. We envision, e.g., attracting an expert in hybrid-perovskite solar cells, who would collaborate well with researchers in the Organic Semiconductor Centre, and complement an active field at the interface between Physics, Chemistry and Engineering. This is an area that underpins development at the Eden Campus, translating world-leading fundamental research into industrially successful IP.
- Bridging between photonics and condensed matter, utilizing light-matter interaction for energy harvesting and to control ***emergent phases of matter*** is a high impact area, currently underrepresented in P&A but building on existing expertise. Control of emergent phases of matter by light provides an alternative way to make the quantum materials we create and study be technologically useful for high-speed electronics, and therefore create a link from our fundamental research in quantum materials to applications.

- An area with possible links to several Schools and priority areas of the University is "***Physics of Sustainable Energy***", exploring viability and prospects of new concepts for energy harvesting, storage and conversion. This is an area that is set to benefit from increased funding levels in view of the Climate Emergency, and would link to research activity around energy materials, energy storage, photovoltaics and provide a strategic link to engineering activities and the Eden Campus.
- Observational (1) ***exoplanet*** characterisation, with projected retirement we envision a new hire to maintain international leadership in this topical area.

We will aim to grow these areas through staged targeted recruitment as well as attracting independent fellows and increasing our grant funding in these areas. The research councils have in past years moved towards awarding funding to larger collaborative consortia. We hope that through this increased critical mass we increase our international visibility and ability to bid for these large strategic grants and at the same time reduce our vulnerability to staff departures. It is critical that we have enough research staff that can help support our research and teaching activities. This is challenging if the number of PGR students decreases, so we will look to external grants that can support cohorts of PhD students, such as future EPSRC DTC calls or the Leverhulme Doctoral Training Centres and to University and development (e.g. PGT income) to support PGR stipends. We aim to ensure maintenance of our infrastructure through grant funding, and to provide an infrastructure account for resilience. We will plan for an upgrade to our helium liquefier, on which most of our condensed matter research relies, to ensure sustainability and expansion of our research activities.

Developing Entrepreneurship

The Eden Campus provides an opportunity to significantly increase our ongoing impact activities. We see many opportunities from within our current research activities across photonics and condensed matter, with potential in data intensive activities within the astrophysics research groups. Developing new technologies from our scientific advances will be an important aspect in our strategic hires detailed above.

Our ambition is to increase the amount of industry and government engagement with St Andrews academics, enabled by participating in relevant organisations in aerospace, security, and defence. We are setting up Framework Agreements to allow company sponsorships of projects in the School, and enabling us to be a key participant in a Strategic Partnership on Materials Technology.

Consolidating Excellence in Teaching

We view the small group teaching and teaching labs as key to the student experience, and we need to maintain the recognised high quality of our teaching programme as student numbers continue to grow. We therefore anticipate growth in the number of teaching fellows/associate lecturers, which are essential in delivering and further developing our teaching programme and provide the additional resources necessary in order to contribute to future summer programmes. We will ensure that education-focused staff have clear career progression strategies through their deployment across our teaching and admin programme. We would be keen for teaching staff to be given the opportunity for education-focussed sabbaticals to give them the opportunity to experience world-leading teaching at other institutions.

We will continually reassess our teaching programme to ensure it efficiently delivers a core physics and astronomy education at an internationally leading level and preserves the unique educational experience that distinguishes St Andrews as an excellent destination for university studies. We will also maintain the strong ties between our teaching programme and our world-leading research activities that ensure students are best trained and inspired for future careers in science and technology. We will continue to develop educational technology such as our visualisation tools for studying quantum mechanics, our online peer groups and assessments, and through our widespread educational research programme. We will also increase the resilience in our teaching programme by

developing expertise in the admin roles across a larger number of academic staff, and by ensuring resiliency strategies for individual core modules.

Equality, Diversity and Wellbeing

Student and staff wellbeing is a priority for the School. We will continue to evaluate teaching and admin workloads to ensure they are feasible for all staff and to foster research and teaching excellence within the School. The School's EDI committee will organise dedicated wellbeing events for staff and students as well as expanding the range of events by working more closely with Occupational Health and Student Services. We will identify possible events that will help the LGBTIQ+ community to continue to feel included within the School, as well investigate the possibility of applying to host a national undergraduate Women in Physics Conference (e.g., CUWiP). The appointment of a new Ogden Fellow (Jan 2020) is helping to build and develop stronger links with local primary and secondary Schools. This has the potential to promote greater female STEM participation within local Schools, as well as the possibility of promoting the diverse nature of the Physics student body at St Andrews.

Environment for Excellence

Our current excellence in research and in teaching relies on our highly beneficial infrastructure, including the current estate and equipment. Our School ethos is to have an integrated research and teaching environment, helping to build a community of students and staff that makes the experience of studying and undertaking research in St Andrews unique. We need to maintain this competitive advantage to attract, and maintain, internationally leading scientists as well as the excellent standing of our student body.