Science and Technology Facilities Council

ASTeC Highlights 2020–21

Accelerators in a New Light

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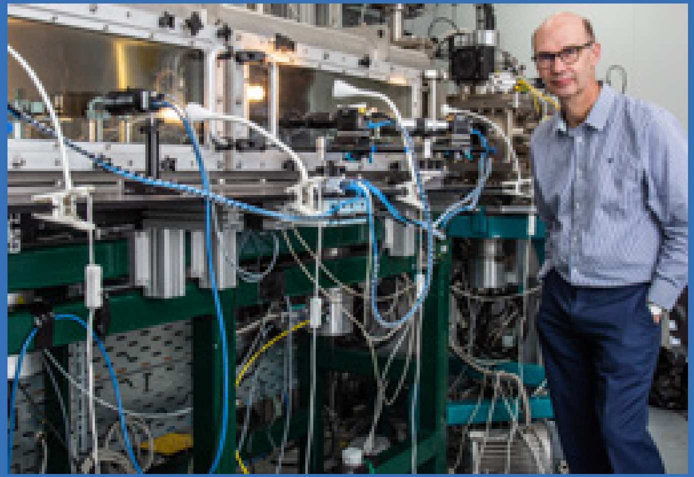
Foreword

The activities in this report were all carried out during the first year of the COVID-19 pandemic. Despite the many additional challenges that this brought, ASTeC continued to function effectively and productively, with our major hands-on projects at Daresbury Laboratory able to continue apace after careful but swift risk mitigations were established, as described in this report. All of our staff were flexible in their approach and worked very hard to make the best of a difficult and challenging situation. This included rapidly switching the major Linac2020 conference to a virtual event and similarly running our outreach activities fully online. These experiences were extremely successful and highlighted some of the positive impacts of being virtual, especially in being able to reach many more people and people from different audiences. Our design and simulation activities were also largely carried out by staff working from home. Again this proved to be very successful, a particular highlight being the complex design of the FEBE user area being completed and then reviewed by an external panel.

For several years ASTeC has worked on a number of different accelerator technology areas which have a focus on reduction in energy usage and so this year we have formally brought these activities under one programme, called Sustainable Accelerators. The aim of this programme is to increase the visibility and impact of our activities in a wider global context. In addition we have started a new activity to look holistically at particle accelerators from a NetZero angle to identify where we should further target our resources to have the greatest impact in this high priority area. These exciting developments are reported here and will grow in the future.



Professor Jim Clarke

Designing New Accelerators

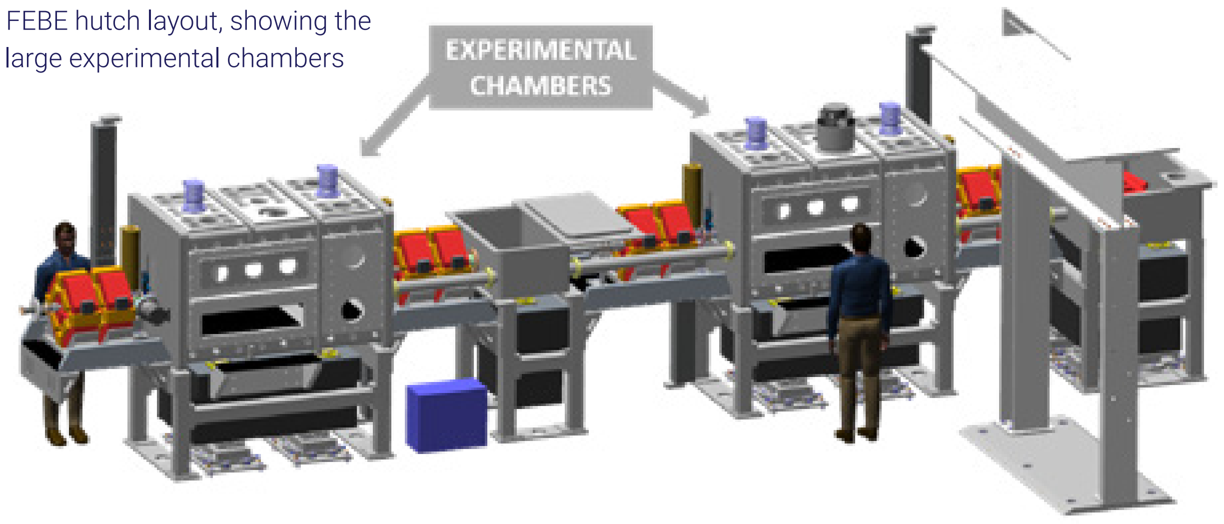
ASTeC's mission is to 'Make a Brighter Future through Advanced Accelerators'. To do this ASTeC scientists and engineers design new accelerators and accelerator upgrades for varied applications. Three examples are given here – an upgrade to CLARA, the test accelerator at Daresbury, to enable research into novel methods for accelerating charged particles, a program to design robust accelerator-based radiotherapy machines for treating cancer in Low and Middle Income Countries in Africa, and another step towards an X-Ray Free-Electron Laser for the UK.

FEBE: A Full Energy Beam Exploitation user area for CLARA

By 2024 the CLARA accelerator test facility at Daresbury will be delivering ultrabright 250 MeV electron bunches to the Full Energy Beam Exploitation (FEBE) user area. The unique properties of the beam have attracted significant interest from scientists in UK academia and industry who want to use it for R&D in varied fields, from electron therapy to plasma physics.

ASTeC has worked closely with national and international partners to inform the FEBE concept and provide real value and relevance to future users. The design was finalised in 2020 and then successfully reviewed by an international panel. Procurement and construction is now underway so that FEBE will be ready for first experiments in 2023. FEBE is unique because it has a separate shielded enclosure, or 'hutch', inside which the electron beam passes through two large experimental chambers. The hutch can be accessed by users without having to turn CLARA off at source. This allows users to install experiments in the hutch while ASTeC scientists operate the accelerator for other purposes. Flexibility is at the heart of the hutch design. The two experimental chambers are nominally empty, providing users with lots of space to install their experiments. The chamber doors, which provide a variety of optical and electrical interfaces, are designed to be replaceable and can be customised by the user.

The FEBE hutch layout, showing the two large experimental chambers



The chambers themselves can even be removed to leave space for larger and more complex experiments.

FEBE has another interesting feature - the CLARA electron bunches can be used in combined experiments with a high intensity (over 100 TW) laser which will live in a specialised laboratory directly above the hutch. This capability enables exciting research in a number of 'novel acceleration' setups in which the CLARA electrons can be accelerated from 250 MeV to energies approaching 1 GeV (and beyond!) in a range of dielectric and plasma structures.

The ASTeC FEBE team and the CLARA user community worked closely with each other to design the FEBE beam line and hutch. This continuing spirit of cooperation will give FEBE the best chance to deliver some really exciting future science and showcase the value of CLARA at Daresbury Laboratory.

ITAR: Improved Radiotherapy Access for Africa

It is estimated that by 2040 there will be 27.5 million new cancer cases worldwide annually, leading to more than 13 million deaths. Up to 70 per cent of these will occur in low and middle-income countries (LMICs), including those in Africa which have an acute shortage of radiotherapy machines used for life-saving treatment. There are currently 385 radiotherapy machines in Africa, but most of these are located in South Africa, Egypt and Morocco. A recent report published by the Lancet Oncology Commission estimated that by 2035 at least 5,000 additional radiotherapy machines will be needed to meet demand in African LMICs.

Since 2017, ASTeC has worked with collaborators to address the current shortfall. Project ITAR (Innovative Technologies towards building Affordable and equitable global Radiotherapy capacity) now brings together a multi-disciplinary and international team of experts from the ICEC, CERN, Lancaster and Oxford Universities, the Cockcroft Institute, ASTeC, the John Adams Institute, Swansea University, King's College London, National Hospital Abuja, Botswana-UPENN Partnership and Princess Marina Hospital. The aim is to realise a new type of linac based radiotherapy machine that is affordable and robust enough to be used in more challenging environments. During this year long project, the ITAR team has defined the persistent shortfalls in basic infrastructure, equipment and specialist workforce and has developed new solutions leading to a detailed specification and conceptual design which has been reviewed by international experts in accelerator and medical fields. The plan is to build a prototype at Daresbury Laboratory to test some of the unique aspects of the design. ITAR is a crucial component of a bigger project called STELLA – Smart Technology to Extend Lives with Linear Accelerators (STELLA). This is a multi-disciplinary collaboration aiming to produce effective radiotherapy machines as well as provide access to relevant training and mentoring. The project STELLA will be built on the technology developed by the ITAR project.

Dr. Taofeeq Ige (National Hospital Abuja, Nigeria) in front of one of the hospital's radiotherapy LINACs.

UKXFEL: A World-Leading X-Ray Free-Electron Laser for the UK moves one step closer

In 2020, ASTeC was a key contributor as UK scientists set out the case for a major new accelerator facility – an X-ray Free-Electron Laser (XFEL). XFELs produce ultra-short and ultra-bright pulses of X-rays, which are used to make discoveries through revealing the dynamics of various scientific processes. XFELs are still a relatively new technology, with five operating worldwide (in the USA, Japan, Germany, Switzerland and South Korea). New techniques are continually being developed and major new projects or upgrades are underway in China and the USA respectively.

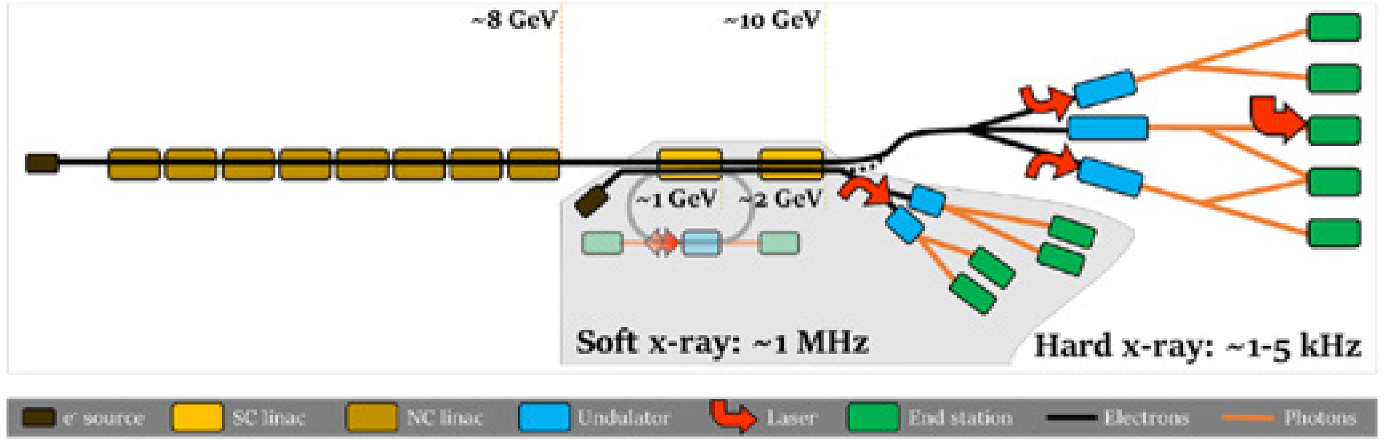
There has been a long-standing ambition within the UK science community for a world-leading XFEL facility. Efforts intensified recently when STFC commissioned the Science Case project, led by Prof. Jon Marangos of Imperial College. The project was launched at the Royal Society in July 2019, and following a series of enthusiastically-attended community meetings, the Science Case was published in July 2020. After further community consultation, it was updated for review by an independent panel of international experts in October 2020.

Front Cover of the UK XFEL Science Case

ASTeC scientists and engineers, with their colleagues in the Central Laser Facility (CLF), have been central to the Science Case project, liaising with the Science Case team to develop a vision for a next-generation XFEL. Each of the different science areas have their own requirements but there are many overlapping themes. There is a strong desire for increased control of the X-Ray pulse properties, e.g. attosecond pulses or very narrow bandwidth, with excellent stability and a desire to reach new frontiers of photon energy and intensity.

The need for various combinations of sources is a key feature – multiple X-ray pulses, high-power lasers, THz and electrons. In the era of 'Big Data', it is essential to maximise the data acquisition rate, placing demands not only on the accelerator technology but also on sample delivery, detectors, lasers and computing.

ASTeC contributed substantial sections of the Science Case document, including three technical options for the facility outline. The international review panel concluded that a clear case had been made from a scientific "mission need" perspective and recommended that the project proceed to the next phase – a Conceptual Design. The case's focus on the combination of multiple sources and on fully coherent sources was praised as being particularly compelling and it was recommended that the CLARA test facility be used to tackle more of the key UK XFEL R&D challenges. The proposal has subsequently entered UKRI's Infrastructure Fund process.



The 'hybrid' option for a future UX XFEL, which combines a MHz repetition rate superconducting linac with a kHz repetition rate normal conducting linac.

Publications With Impact

Every year ASTeC scientists and engineers publish their work in high-impact, peer-reviewed scientific journals. Two examples are highlighted here – a Nature paper describing groundbreaking radiotherapy research on the CLARA test accelerator, and a Physical Review paper presenting a new design for a powerful source of X-rays and gamma-rays.

Groundbreaking Radiotherapy Research

ASTeC's test accelerator CLARA, at STFC's Daresbury Laboratory, is designed to develop, test and advance new accelerator technologies and their applications. One important application is cancer therapy and a UK-first experiment at CLARA has now opened the door to an alternative form of radiotherapy.

The research, which was led by the University of Manchester and the Christie NHS Foundation Trust, with guidance from ASTeC accelerator scientists, studied the effectiveness of using Very High-Energy Electron (VHEE) beams as an alternative form of radiotherapy for treating deep tumours that are hard to reach. Radiotherapy uses particles or waves to destroy or damage cancer cells by damaging their DNA so that they stop dividing or die. Scientists believe that radiotherapy using VHEE beams, at energies up to 250 MeV, could be significantly cheaper and more effective at treating tumours than existing forms of radiotherapy.

First promising results from this research were published in Nature's Scientific Reports. The paper explains that VHEE beams are as effective at damaging DNA in cancer cells as conventional X-Rays and proton beams, and more effective at accurately targeting tumours deep within the body whilst minimising damage to the surrounding tissue. As a result, this technique could also lead to a reduction in the number of follow-up radiotherapy treatments needed by the patient.

The experiment at CLARA was the first in the UK. It involved firing short electron bunches, of energy up to 40 MeV, into water phantoms which represent the human body, and into specially prepared DNA samples. The idea was to precisely measure any DNA damage. This was followed by similar experiments carried out at a higher beam energy at the CLEAR facility at CERN in Switzerland. The planned FEBE beamline on CLARA will provide access to higher energy electrons, up to 250 MeV, making this a unique UK facility to carry out future in-depth research in VHEE radiotherapy.

This paper represents a significant step in verifying the potential of Very High Energy Electron beams to treat cancer. It relies on a seamless collaboration between The University of Manchester's Department of Physics and Astronomy, The Division of Cancer Sciences, ASTeC, CERN, and The Christie NHS Foundation Trust.

The paper can be read here: https://www.nature.com/articles/s41598-021-82772-6

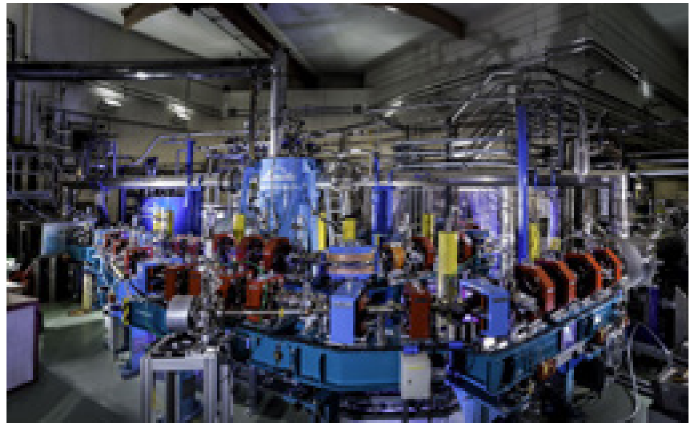
James Jones, from the ASTeC accelerator physics group, carrying a purpose-built sample holder and helping to set-up the CLARA experiment.

Towards Gamma-beams

Energy Recovery Linacs (ERLs) combine the best features of storage rings with those of single pass linacs. In a storage ring, an electron bunch is produced in an electron gun, accelerated once to GeV scale energy, and used millions of times as it circulates in a ring, generating X-ray synchrotron radiation for experiments on each pass as it goes round. In a single pass linac, an electron bunch is produced in an electron gun, accelerated, and then used only once. This means that to provide the same electron bunch repetition rate for X-ray production as a storage ring requires millions of times more energy. The Energy Recovery Linac employs a clever trick to get round this – after the bunch has been accelerated and then used it is decelerated in the same linac and thrown away. But, because the linac is superconducting, there are no energy losses inside, and the energy extracted from the decelerated bunch can be used to accelerate a fresh bunch. The ERL therefore powers itself, and can provide the same bunch repetition rate as a storage ring.

However, compared to a storage ring, the ERL can deliver bunches with a higher 'brightness' - which means the electrons in the bunch can be more tightly compressed together in space and time and energy, and the bunch is therefore more usable for experiments – it will produce more powerful synchrotron radiation, for example. This is because as bunches circulate in a storage ring they lose the memory of their initial properties and decay to a stable equilibrium state where the brightness is reduced. In an ERL however, the bunch only circulates one, so if a bunch enters the linac with high brightness this is retained. The ERL therefore combines the high bunch repetition rate, or high average beam power, of the storage ring with the high brightness of the single pass linac.

The ERL opens the way to exciting new applications, both in high energy particle physics and at lower energy for EUV, X-ray and gamma ray production. ASTeC pioneered the development of ERLs in Europe, with Daresbury hosting the ALICE ERL-based Free-Electron Laser user facility until 2016. Since the closure of ALICE, ASTeC have continued

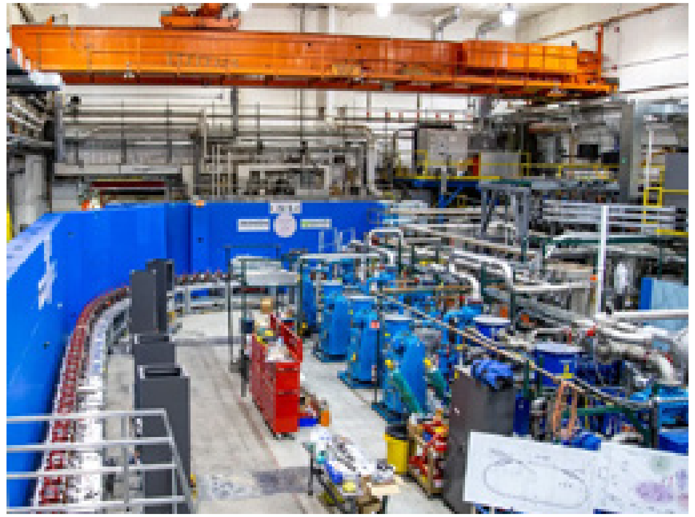


The ALICE ERL at Daresbury Laboratory. This was the first Energy Recovery Linac in Europe

ERL research in collaboration with overseas facilities with a view to incorporating an ERL in a future UK facility such as a UK-XFEL.

One potentially revolutionary application of ERLs is to produce X-rays via Inverse Compton Scattering. Here a high power laser is collided with a high brightness electron bunch and the laser photons scatter off the electrons while having their energy amplified, or their wavelength reduced, by orders of magnitude, producing X-rays or even gamma rays. The attractions of the scheme are that compared to a storage ring the electron bunches have higher brightness, so they scatter more of the laser photons, and the electron bunch energy can be much lower than that of a storage ring that produces photons of the same wavelength from synchrotron radiation. Early research on this idea was carried out on ALICE in 2009. Now ASTeC and Manchester University physicists and US collaborators at Cornell University, Old Dominion University and Jefferson Laboratory have published a design for such a source on the CBETA ERL at Cornell University. The paper shows that ERL driven Compton sources can produce more X-ray photons per second than the largest synchrotron radiation facilities even though the accelerator is much smaller and cheaper. The paper was selected by Physical Review – Accelerators and Beams as an Editor's Suggestion. This paves the way for production of even higher energy gamma rays, having far-reaching implications for nuclear physics, security, nuclear decommissioning and medical isotope production. This is because Compton produced gamma rays can be nearly monochromatic. Such a 'gamma beam' would be able to reveal and exploit resonances in nuclear structure, leading to a new field termed nuclear photonics. ASTeC are building collaborations with both UK and international partners to develop this new capability.

The paper can be read here: https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.24.050701

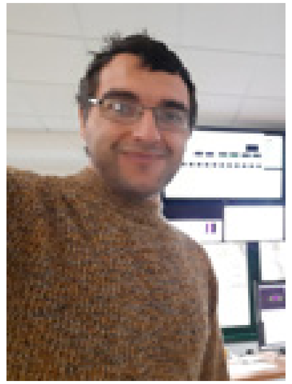


The CBETA ERL accelerator at Cornell University

ASTeC People

ASTeC employs more than 90 staff and students who work on a variety of fascinating projects, from developing technical systems in-house to contributing to international design studies of future particle physics colliders. In this section some ASTeC staff tell their individual stories and we highlight the successes of some of our many PhD students.

ASTeC People



Alex Brynes

'For the past four years I have been studying for a part-time PhD with the University of Liverpool while working full-time at ASTeC. This work was the result of a fruitful collaboration between ASTeC, the Cockcroft Institute, Elettra-Sincrotrone Trieste, Pulsar Physics and ASML, with the goal of studying the collective interactions between particles in a high-brightness electron accelerator. These interactions can degrade the quality of the electron beam, and have a significant effect on the operation of, for example, a free-electron laser (FEL).

All of the experimental data required for the thesis was collected during a week at FERMI (the FEL facility based at Elettra in Trieste, Italy) in early 2017, while the data analysis took up the remaining years of the PhD. There were three sets of experimental data taken during this week, each of which was designed to help us understand two collective effects which can affect the FEL performance: coherent synchrotron radiation (CSR) and the microbunching instability (MBI). Both of these effects arise due to the fields produced by large numbers of charged particles propagating through an accelerator, although finding a correspondence between the theory and experimental measurements is really difficult.

I developed new methods to analyse the experimental data and did rigorous simulations to compare with the experiments. I also helped improve the theoretical analysis. The end result was that I developed a deeper understanding of the collective effects. My thesis concluded by suggesting further optimisations for future iterations of the FERMI FEL.

Studying for a PhD while working full-time at ASTeC was challenging, but ultimately it proved to be a fantastic learning experience, both at a personal level and in terms of improving the understanding of collective effects for ASTeC - the lessons learned from this study could prove to be important for future developments of ASTeC's test accelerator CLARA and it's novel acceleration beamline FEBE, and could suggest novel experiments that can be performed on these machines.'

Valentina Malconi

'I am a Year in Industry Student at ASTeC. When I started my first task was to implement a CO_2 monitoring system as part of the strategy for managing COVID-19 on site at Daresbury Laboratory. The monitors had to be set up on a stand so that they could be moved around and placed where most needed, so my role was to design a 3D printable plastic bracket to hold the monitors. It was a fun project to start with as I already had experience with additive manufacturing, so after quickly familiarising myself with the design software, which was new to me, I could design and test a couple of prototypes right away.

Now that my Year in Industry is coming to an end, I can reflect on my experience as a whole and what I learned. The relaxed and supportive environment is definitely among the things I enjoyed the most, together with the occasions to network (despite COVID), and also the people - everybody is so friendly and down for a chat, but also willing to help.

I also really liked that I could choose what to work on and the opportunities to take part in varied projects from other groups - this is something I ended up doing and really enjoyed. In terms of technical skills, I have learnt to use multiple software packages for electrical circuit design and simulation prior to building testing and improving prototypes. I also learned to program in Python, a new language for me. In terms of non-technical skills, I feel more confident with my in-person communication skills as I've had the opportunity to interact with so many people. Finally, one of the most important lessons was to not be afraid of being proactive. For example, I found a project I was interested in and asked to become involved - this work will now now be part of my Final Year Project at University.

To conclude, I have been pleasantly surprised by the number of interesting science and engineering topics that ASTeC undertakes, and I am very happy to say that I have been offered a graduate position in the Diagnostics Group. I am very excited that after my degree I will be returning to explore all the different opportunities that ASTeC offers. '

PHD Successes

Despite the challenges of the past 18 months, this year has been a bumper year for ASTeC's PhD students. All the students, supervisors and support staff who worked hard to find ways to complete their projects in challenging times deserve many congratulations.

Pavel Juarez-Lopez (Liverpool University) completed his experimental PhD working on photocathode development, working through several lockdowns with the particular support of his ASTeC supervisor Lee Jones and Carsten Welsch at Liverpool University. Pavel how has a postdoctoral position at DESY in Germany working on cathodes for the European XFEL.

Victor Chang (Imperial College) completed his PhD work on photocathode emission theory, under the supervision of Tim Noakes and Elaine Seddon from ASTeC and Nick Harrison at Imperial College.

Kay Dewhurst (Manchester University) successfully defended her thesis on the design of capture and transport of Laser Wakefield Accelerator electron bunches for short-pulse light sources, supervised by Bruno Muratori of ASTeC. A recent paper in Nature Scientific Reports on short-pulse coherent emission has already been published using work from her thesis.

Ewa Oponowicz (Manchester University) was one of several EU-funded OMA Fellows, studying superconducting gantries for particle therapy under supervision of ASTeC's Hywel Owen. She successfully defended her thesis and now continues work on that topic as a CERN Fellow working with the Cockcroft Institute.

Ruta Sirvinskaite (Loughborough University) completed her thesis on Non-Evaporable Getter (NEG) coatings for vacuum vessels under the supervision of Oleg Malyshev from ASTeC and Mike Cropper from Loughborough. She has gone on to work for DESY in Germany, applying her skills in NEG technology to Petra IV, a collaboration which ASTeC are excited to be involved with.

Green Beams

As a publicly-funded organisation ASTeC has a clear mandate to improve sustainability in all its activities. This includes a commitment to reduce carbon emissions to net zero by 2040, ahead of the UK's ambitions. One important ASTeC initiative is setting up a Sustainable Accelerators Task Force which will consider how to reduce the carbon footprint of major facilities. ASTeC are also developing greener technical solutions for accelerator subsystems such as the tunable ZEPTO accelerator magnets, which require no electric current, and superconducting thin films for making accelerator cavities more efficient.

The Sustainable Accelerators Task Force

STFC operates large accelerator facilities which have substantial energy footprints. A typical facility will consume several megawatts of electricity. Diamond Light Source, a medium-energy storage ring, uses 6-7 MW of electrical power. Larger collider facilities use much more - during Run 2, the Large Hadron Collider at CERN used an average of 86 MW, the same as a medium-sized city! So the accelerator community has a responsibility to reduce the climate impact of its operations. ASTeC have therefore formed a Sustainable Accelerators Task Force with members from all specialist groups.

The Task Force will analyse ASTeC's accelerator R&D activities and look for ways to reduce carbon emissions. It will also find opportunities to use ASTeC research to tackle climate goals. The Task Force plans to do a review, called "Green Beams", which will look at the carbon emissions of accelerators. It will use a new accelerator facility called RUEDI as a case study, but will consider the wider implications for accelerators in general. The first step is investigate all the major subsystems of accelerators - for example RF cavities, lasers, magnets, radiation shielding and thermal stabilisation – and for each one calculate the emissions produced across the whole life cycle, from manufacture through to operation, maintenance, and finally decommissioning. The second step is to find innovative and practical ways to reduce these emissions. The Task Force will also look at R&D into emissions-mitigation schemes at other accelerator laboratories around the world, and how ASTeC might learn from them.

This is the beginning of a major new initiative for ASTeC. The ambition is to become a world-leading centre for sustainable accelerator R&D. Accelerators play a vital part in many areas of climate research - in turn ASTeC will help ensure that they are designed, built and operated in the most environmentally sustainable way.

A new solar farm at Daresbury Laboratory, an example of STFC's drive towards sustainability

A ZEPTO Magnet for Diamond Light Source

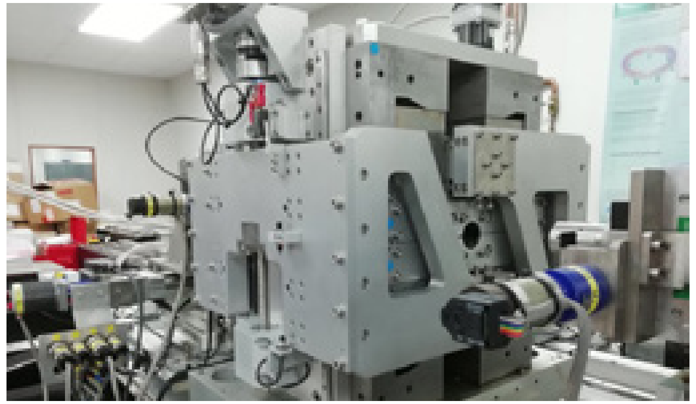
Since 2011 ASTeC has been collaborating with CERN to develop energy saving magnet solutions for future particle accelerators. This gave rise to the Zero Power Tuneable Optics (ZEPTO) project. The idea is to replace power-hungry electromagnets, in which the magnetic field is created by passing high electric currents through copper coils surrounding the steel magnet poles which shape the field, with alternatives in which blocks of permanent magnet material create the field. The key feature of the ZEPTO designs is the ability to change the field strength, but not its shape, by moving the permanent magnets.

ASTeC is now investigating how its technology can be commercialized. The next step, before a worldwide launch, is a real-world demonstration in which an electromagnet on the Diamond Light Source is being replaced by a new ZEPTO prototype. The new prototype features a unique modular construction of the permanent magnet blocks – this will make it easier and cheaper to assemble, or replace if it gets damaged.

The two permanent magnet blocks can also be independently controlled so that any imbalances that cause the centre of the magnetic field to move can be corrected.

The most challenging part of the design was making it splittable straight down the middle so that it can be installed around an existing beam pipe without breaking the vacuum. This is an essential feature because the required level of vacuum may take days of pumping to restore once the machine has been opened up to atmosphere. The design challenge comes from the magnetic forces - during assembly the steel components pull towards the magnet blocks with an equivalent of a metric ton of force on each side!

This prototype has now been constructed and is being measured to ensure the field quality is good enough. It will be operated on Diamond for a year to demonstrate that a ZEPTO magnet can be as good and reliable as the electromagnet it replaces.

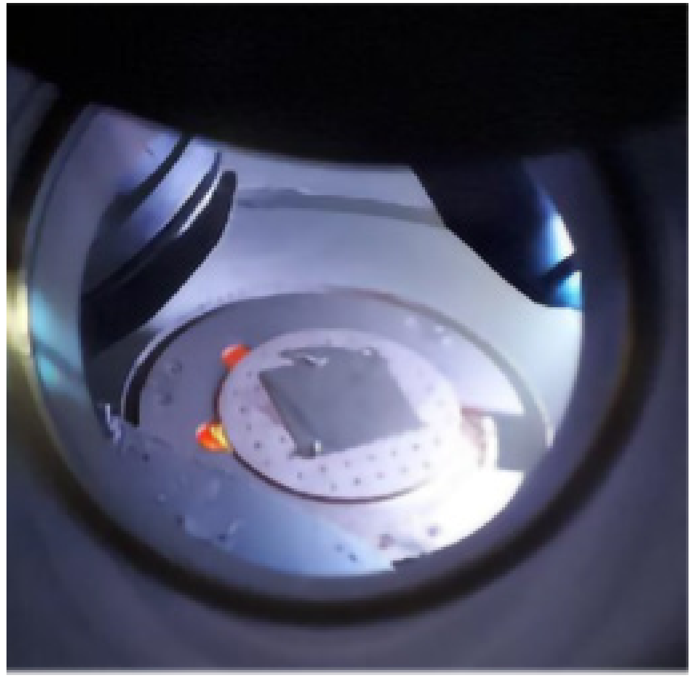


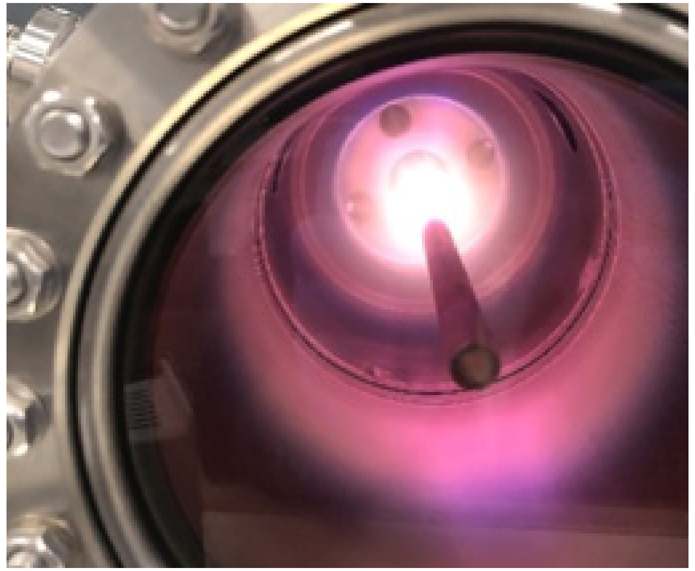
The Diamond Light Source ZEPTO quadrupole fully assembled and in position for testing

Superconducting Thin Films for High Efficiency Linacs

Modern particle accelerators require Radiofrequency (RF) linear accelerators (linacs) with large acceleration gradients and low power losses. Linacs made of superconducting materials such as niobium are, at the moment, the best solution. However, they are expensive to build and must be cooled with liquid helium to below -271°C. The dominant electricity demand is for the cryo-plant that cools and liquefies the helium. To significantly reduce this demand a suitable alternative to niobium is needed.

Operating at a slightly higher temperature of -269°C could actually halve the electricity demand, and if lower loss materials were used the amount of heat to be extracted would be reduced. The idea is to take advantage of the fact that the penetration depth of the RF fields into the linac internal surface is very shallow – superconductivity is really only a surface effect - so it might be possible to replace the expensive bulky niobium with thin superconducting films deposited on a cheaper base material.

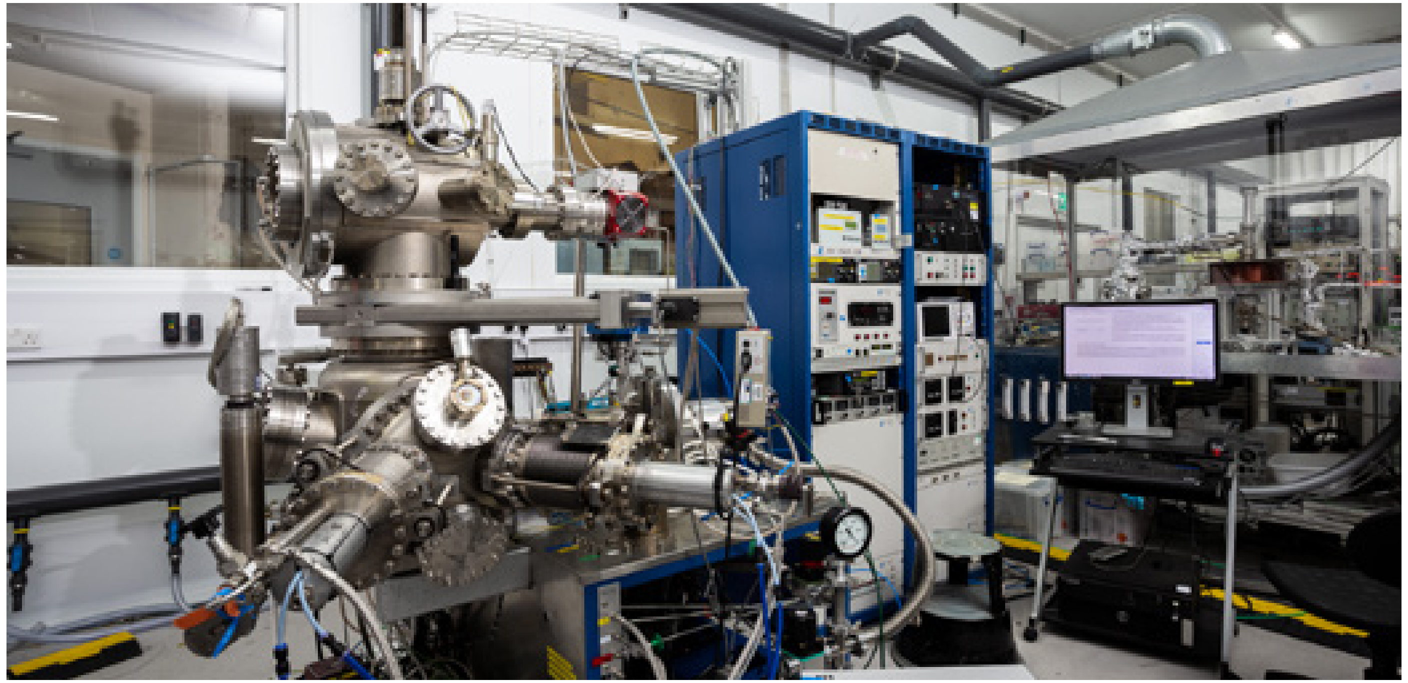




Superconducting thin film deposition facilities in ASTeC's VISTA laboratory for planar surfaces (left) and accelerator cavities(right).

ASTeC scientists are developing such a superconducting thin film technology. This could be used in future UK particle accelerators, such as an upgrade to the ISIS neutron source or a UK X-Ray Free-Electron Laser, and also in international projects with UK participation, such as the International Linear Collider, the Future Circular Collider or the European Spallation Source. The ultimate performance of the thin film coatings depends on how the material is deposited onto the base material and, most importantly, the properties of the base material surface. The ongoing R&D aims to understand and optimise the processes and to employ appropriate techniques to tailor the surface for best performance. ASTEC works in partnership with Liverpool and Lancaster Universities and is also coordinating large scale international collaborations such as ARIES and IFAST.

A part of the VISTA Laboratory



Challenges of the COVID-19 Pandemic

The COVID-19 pandemic, and resulting lockdowns, affected ASTeC staff both personally and professionally, but everyone worked together to overcome the challenges of this unprecedented time. Scientists and engineers are used to mitigating and managing risks in their work - this experience was applied during lockdowns. Everyone adapted quickly to both remote working and new on-site safe systems of work. As a result, progress in ASTeC's projects and programmes continued apace.

Site-wide changes

The Daresbury Laboratory site-wide strategy focussed on staff safety while maintaining research-critical activities. Specific controls were developed - for example mandatory face coverings in communal areas, social distancing via one- and two-way systems, increased cleaning of high frequency touch points, monitoring of air quality in shared work areas and improved ventilation in work spaces. The number of staff on site was limited and everyone quickly adapted to working from home where possible.

Contractors, visitors and staff all had their temperatures checked regularly and if COVID cases were reported, targeted testing was deployed.

ASTeC staff were central to the administration of these controls. They developed IT systems to track activities and ensure compliance with building occupancy thresholds, and they carried out incident investigations when there was suspected on-site transmission of COVID-19.

European Spallation Source Progress

The European Spallation Source (ESS) High-Beta Cavity (HBC) project is supplying 84 superconducting radiofrequency cavities for the high-energy section of the ESS accelerator. Before delivery to CEA in France, where the cavities are installed into the cryomodules (which cool the cavities with liquid helium so they become superconducting) the cavities are tested in the SuRF Lab. This facility was still being commissioned when the COVID-19 pandemic started. The challenging work was complicated by the new COVID-19 safe working practices. A workflow was developed so that each process could be performed in isolation before the cavity was passed to the next workstation. Equipment and work stations were cleaned between each process, and wherepossible tasks were altered so they could be done by only one person. Many systems were changed to allow remote operation and monitoring, reducing the number of people needed on site at any one time. Although these changes were introduced very suddenly, SuRF-Lab is now fully commissioned and operational, with the first cavities delivered to CEA.

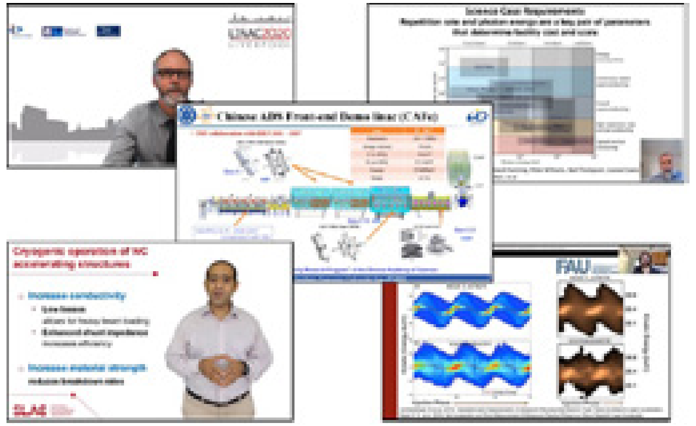
SuRF Lab

Linac2020 Conference Goes Virtual

The International Linear Accelerator Conference is hosted bi-annually, and typically attracts more than 400 linac specialists from around the world. Linac2020 was scheduled to take place in Liverpool during early September 2020, but as global pandemic restrictions escalated it became obvious to the UK conference organisers (STFC Daresbury Laboratory, the Cockcroft Institute and John Adams Institute) that a physical event was not going to be viable. Alternative solutions had to be sought.

It was decided to delay the original event by two years to 2022, but to also host a smaller virtual event to present the considerable linear accelerator R&D undertaken since Linac2018 in Beijing. Linac2020 was thereby hosted as a virtual conference for the first time in its almost 60-year history. Astonishingly, the event attracted 710 live international participants from about 30 countries, with 800 registered to access the offline videos. The timing of the sessions was tailored to ensure speakers from all regions could deliver their talks at a convenient local time.

A new element was a live Women In Science and Engineering session which focussed on retention and advancement. This session comprised distinguished panellists who reviewed the challenges of being attracted to science and engineering in the first place and then maintaining motivation to stay within the field. The panellists shared their personal career experiences and answered questions from the online audience. The UK coordinators are now looking forward to hosting the physical Linac2022 Conference as originally planned in Liverpool in 2022.



Reaching Out Online

Traditionally ASTeC reaches out to the public by inviting visitors to the Daresbury site, such as for the popular annual Accelerator and Particle Physics Masterclass (APPMC), or by going out to festivals, such as the Big Bang. The last event on site was the 2020 APPMC, just two weeks before the first national lockdown. The next planned events were the 2020 Summer Work Experience Programme and the Laboratory Open Week which both had to be cancelled despite all the work that had gone into getting them ready.

With traditional outreach now impossible, ASTeC adapted, and delivered an online programme. This was an amazing success and reached a larger audience than ever before. To avoid disappointing all the eager students who had applied for work experience, they were all invited to an online series of interactive seminars. There were several sessions aimed at GCSE and A-level students, covering topics ranging from electromagnetism to machine learning. The final fun session was an 'ask us anything' panel Q&A. There was even a live tour of the CLARA test accelerator, achieved through Zoom and a phone camera! Each session was attended by around 90 students, far more than would have been involved in person. The students were so engaged that two additional hour-long videos had to be filmed to answer all the questions.

The annual APPMC was the greatest outreach challenge of lockdown, but also the biggest success. An established programme of onsite activities was converted into one that could be delivered online. This happened over 2 afternoons. ASTeC welcomed more than 200 students from all over North West England, as well as Berkshire, Northampton, Nottingham and Leeds. Despite the challenges, and the unusual format, the APPMC had among the highest feedback ratings ever for an event hosted by DL!

Still from a video of a vacuum demonstration prepared for the 2021 APPMC

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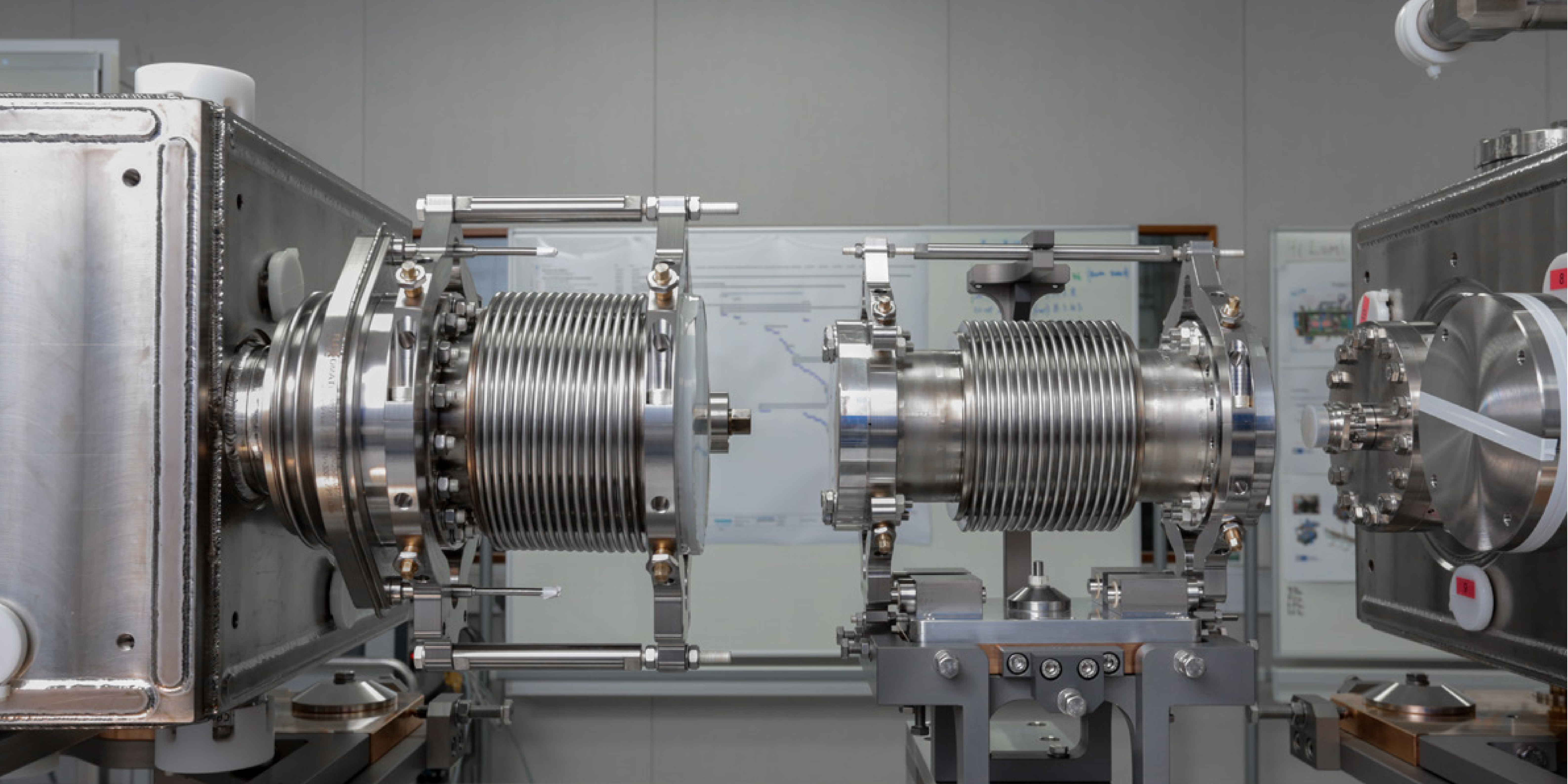

Science and Technology Facilities Council
Polaris House
Swindon
SN2 1FL

stfc.ukri.org