Science Highlights 2010 - 2011

Accelerator Science and Technology Centre

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ASTeC

Accelerator Science and Technology Centre

Science Highlights
2010 – 2011

This report covers the work accomplished by the
Accelerator Science & Technology Centre
(ASTeC) for the financial year 2010 – 2011

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Foreword

I replaced Mike Poole as Director of ASTeC at the end of June 2010. Given Mike's renowned passion and commitment to the development of free electron lasers (FEL) internationally, it is fitting that in this year we achieved lasing in the ALICE FEL, the first energy recovery linac (ERL) driven FEL in Europe.

FEL lasing was a major highlight in a very diverse programme of research delivered through the efforts and innovation of the ASTeC staff and their collaborators. I would like to congratulate the staff involved for the professional delivery of this programme which both underpins the development of a range of future accelerator facilities and applies their skills and expertise to applications in areas such as health, energy and security.

A second major highlight this year was the commissioning of EMMA, the World's first non-scaling fixed field alternating gradient (FFAG) accelerator. This technology is at the heart of plans for future particle accelerators for science. It also has the potential for application to cancer therapy and energy production. This programme was successfully delivered through the intensive effort of ASTeC and Technology Department staff in partnership with national and international collaborators.

International collaborations are a fundamental part of ASTeC's programmes. We have well established programmes with CERN and other institutes in Europe, America and Asia. This year, our expertise on light source design has been in demand. ASteC has worked under contract on the MAX IV injector design and consolidated a collaborative programme with Berkley National Laboratory on advanced FEL physics. In addition we are now finalising several work packages that we will lead for the SwissFEL project.

Accelerator test facilities such as ALICE and the Front End Test Stand are fundamental to technology and skills development within the UK. The need to go beyond the state of the art in order to satisfy the demanding requirement of future facility users pushes and directs our evolving programmes. For instance we are now looking at technologies to follow those exploited on ALICE which could be fundamental in enabling the delivery of an advanced free electron laser capable of producing atto-second pulses.

Finally, collaborative research with industry is important to ensure the exploitation of our unique skill base in this fundamentally important technology. This year ASTeC has deliberately increased our proactive approach and was the lead organisation of a highly successful industry showcase event, strengthening the engagement of industry with ASTeC and the Cockcroft Institute. Developing such interactions will ensure that the UK gains the maximum impact from its investment in ASTeC not only through its fundamental role of delivering science but in other arenas by supporting growth and the economy in a more direct manner.

All of this has not been easy within current financial constraints but ASTeC is preparing for the challenges ahead and we are looking forward to delivering accelerator R&D next year which will enable great science in future years.

Director Susan Smith

Contents

ALICE 4
Development of Photon Beamlines on ALICE 7
EMMA....8
EMMA Induction Acceleration 12
The Synchrotron Radiation Source - a Lasting Legacy 14
Photocathode R&D 16
CLIC Spoilers 18
CLIC Drive Beam Quadrupoles....20
MAX IV Injector....21
SRF Cavity Fabrication with Industry....22
Vertical Orbit Excursion FFAGs....24
Beamline Design of a Soft X-ray FEL 26
Development of Free Electron Lasers 28
MICE....31
Optical Clock Distribution System....33
Superconducting Undulators 34
Electron Stimulated Desorption Study 35
NEG Coatings Development....36
Hydrodynamic Approach to the Free Electron Laser Instability 37
Outreach 38
Cryogenics Training....40

Workshops and Visits:
Accelerator Technology Showcase 41
ICFA Beam Dynamics Mini-Workshop on Deflecting
Crabbing Cavity Applications in Accelerators....42
EUCARD Meeting 43
Mike Poole Fest....44
X-Band Workshop....45
IOP Particle Accelerators and Beams Group Workshop and
ASTeC Future Vision of Electron Test Accelerators....46
European Synchrotron Light Sources Workshop XVIII,
Trieste and FERMI@Elettra Commissioning 47
Beam Measurements Course at the Jefferson Laboratory
Free Electron Laser 48
LBNL Visit....49

Publications....50
Financial Summary 55

ALICE

ASTeC's largest experimental facility, ALICE is a multi-purpose test bed for advanced accelerator technologies.

Realisation of the original concept of ALICE was achieved with the first-lasing of an infra-red free electron laser (FEL). In 2010/11 this huge achievement represents a first not just for ALICE but indeed for national accelerator physics. It is the first demonstration of a 4th generation light source in the UK.

ALICE is a unique machine in both the UK and Europe. It is an energy recovery electron accelerator, a prototype for extremely high power, high brilliance light sources which would consume too much energy with conventional accelerator technologies to be viable. In the energy recovery method the accelerated electron beam is de-accelerated by a superconducting RF cavity and its power is extracted, resulting in a much lower overall energy demand. ALICE incorporates the UK's first superconducting linac, a technology choice for many of the leading accelerator facilities around the world.

The achievements of ALICE this year are the pinnacle of several years of hard work and other major successes such as first demonstration of energy recovery in Europe and operation of a Compton backscattering x-ray source. In October 2011 first clear lasing was observed, following months of machine measurement, optimisation and tuning. Alongside this major success, ALICE has continued to serve as a terahertz source with exciting new experiments involving effects of this type of light source on living tissue.

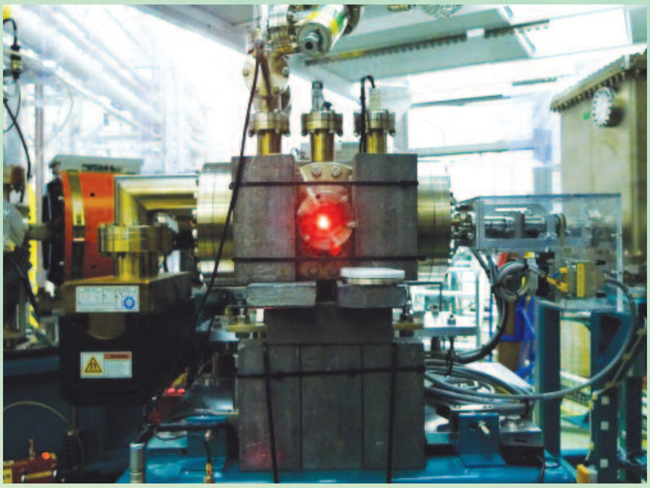
The capabilities of ALICE are made possible by detailed knowledge of the beam dynamics built up by ASTeC staff over the previous months and years. Considerable effort has been put into transporting beams of higher quality and higher peak power through the accelerator, to meet the extremely stringent conditions required for operation of the FEL.

New measurements this year progressed the understanding of the machine to allow the capability to provide high charge, highly compressed beam bunches, with low energy spread. This involved careful characterisation of the beam phase space with different configurations. This year a novel "electro-optic" (EO) diagnostic technique was used to determine the beam qualities at the crucial location. The EO diagnostic provides an ultra-fast measurement of the electron bunch temporal profile that is of utmost importance for ALICE performance.

Modification of the electron pulse set up enabled stable operation at significantly higher charges to be obtained. This was achieved by a reconfiguration of the drive photoinjector laser system, and was the final step in reaching the necessary beam quality for lasing of the FEL. This step has also provided powerful flexibility in beam conditions for the other ALICE applications.

ALICE also serves as the injector for EMMA, which this year achieved a world first when electrons were accelerated in this novel type of accelerator.

ALICE FEL – A Triple First



The ALICE FEL undulator

A significant ALICE milestone was achieved this year – the first lasing of the infra-red FEL. The achievement of this milestone was also the first demonstration in the UK of a FEL of this type and the first demonstration in Europe of a FEL driven by an energy recovery linac accelerator.

A free electron laser is a fourth generation light source with a unique combination of properties; it is easily tuneable over a broad wavelength range, has a high pulse repetition rate and generates extremely short pulses of light, which are more than a million times brighter than those produced by third generation light sources such as the Diamond Light Source in Oxfordshire. FELs are becoming increasingly significant worldwide, with facilities like FLASH (in Germany) and LCLS (in the USA) now enabling researchers to do experiments probing previously unexplored physical regimes. The successful operation of the ALICE FEL has now moved the UK one step closer to having its own national FEL facility by demonstrating the skills and technological insight necessary to design, build and operate a fourth generation light source.

The ALICE FEL is built around a 1m long undulator; an array of dipole magnets of alternating polarity that cause the electron bunch produced by the ALICE accelerator to wiggle from side to side as it passes through, which causes the electron bunch to emit a small amount of infra-red light, so called 'spontaneous emission'. This light was first detected in early 2010, and measurements of its spectrum proved an extremely useful diagnostic. The spectral width confirmed that the energy spread within the electron bunch was sufficiently small for lasing, and by steering the electron bunch at the entrance to the undulator to minimise both the peak wavelength and line width of the emission, the optimum electron beam trajectory was found. Reassuringly, this was precisely on the reference axis to which the undulator had been aligned when installed.

The ALICE FEL undulator

To achieve lasing, the infra-red spontaneous emission is contained within a 9 m long optical resonator built around the undulator. The length of this resonator is carefully set so that the round trip time of the infra-red pulse within the resonator is precisely matched to the interval between electron bunches. When this happens the circulating infra-red pulse emitted by one electron bunch overlaps with the next electron bunch passing through the undulator (at close to the speed of light) and through the FEL mechanism 'stimulates' this bunch to emit more radiation than the first bunch. This radiation circulates in the resonator and stimulates the next electron bunch to emit even more, and so on. In this way the radiation intensity is amplified over just a few millionths of a second, from a few Watts initially to more than ten Million Watts (MW) when the FEL reaches saturation. A fraction (a few percent, or a few MW) of the radiation is extracted through a hole in one of the mirrors so that its properties can be measured and ultimately be used for scientific experiments.

This process was started in early summer 2010. The work was time consuming because in order to achieve lasing it was expected that the resonator length would have to be correct to within 20 μm, or 1/5th the width of a human hair. However, and disappointingly, only a very small enhancement in the infra-red intensity was seen by scanning the resonator length. From analysis of the results it was concluded that the amount of light being extracted though the hole in the mirror was too great compared to the amount of light being emitted by each electron bunch, which meant the light was being extracted from the resonator faster than it was being generated. To fix the problem a number of improvements were made to the FEL set up. First, the resonator mirror was replaced by one with a smaller hole. Second, the configuration of the ALICE photoinjector laser was altered so that the amount of charge in each electron bunch could be doubled to the original design value of 80 pC. This meant that each bunch emitted more spontaneous emission and more effectively amplified the radiation already circulating in the resonator.

Members of the ALICE team celebrating first lasing of the FEL on 23rd October 2010 in the Control Room

With these changes made, lasing was quickly achieved at a wavelength of 8 µm on 23rd October 2010. The first measurements of the variation of FEL power as the resonator length was changed were in very good agreement with the earlier predictions from simulations. The range of resonator length over which lasing was sustained was close to the expected 20 µm and the highest peak power in the FEL pulses recorded to date is 3 MW in a pulse of duration 1 ps. With further optimisation a factor of three increase in output power is expected.

Further progress was made in 2011. Firstly the continuous tunability of the FEL was demonstrated. While lasing at 8 µm the gap between the magnetic arrays in the undulator was gradually and smoothly increased. This smoothly changed the FEL wavelength over the range 8 - 5.7 µm while maintaining lasing. This is one of the unique features of the FEL which makes it the scientific instrument of choice for many types of experiment. Later in the year the FEL radiation was successfully transported out of the ALICE accelerator hall along a beamline to the dedicated photon diagnostics room where further characterisation at different wavelengths could be performed with greater ease. Measurements of the transverse profile of the FEL beam have been characterised in the beamline using an infra-red sensitive camera.

The FEL now operates routinely and is undergoing full characterisation in preparation for use in a small number of targeted scientific experiments, which can exploit the characteristics of this unique UK light source, helping to develop the techniques and technology for future generations of light sources.

ALICE Terahertz Applications

Since its inception ALICE was envisaged as a powerful source of terahertz (THz) radiation for several different applications. The THz power produced from the process of "coherent synchrotron radiation" in ALICE is many, many times higher than that achievable from other sources, and indeed there are few such sources available worldwide. This makes ALICE a unique and valuable facility for photon science applications where light in the THz region is required.

Researchers from Liverpool University have been performing exciting new experiments with biological systems using the ALICE THz source. A particularly useful feature of the ALICE THz source for these systems is that very high power is delivered in very short pulses, which means the radiation does not heat up the material that it hits. The fact that the light is also emitted over a broad spectrum of wavelengths is also an advantage. The intense shots of power are at least a thousand times more powerful than sources based in the laboratory or at conventional accelerators. This type of research into biological effects of THz may help to understand the mechanism of biological organisation and has potential in the diagnosis of cancers.

Once again careful and detailed machine tuning was required to provide the optimum THz conditions for the biological experiments, and at the beginning of the year the first exposures of living cells (retinal, corneal, and stem cells) were carried out, building a dedicated beamline to transport the radiation to a shielded in-situ incubator very close to the accelerator, to maximise the power dose to the samples. The preliminary results from these novel experiments will help to guide more controlled and sophisticated experiments in future, when THz radiation is transported to the dedicated tissue culture laboratory which is part of the ALICE facility.

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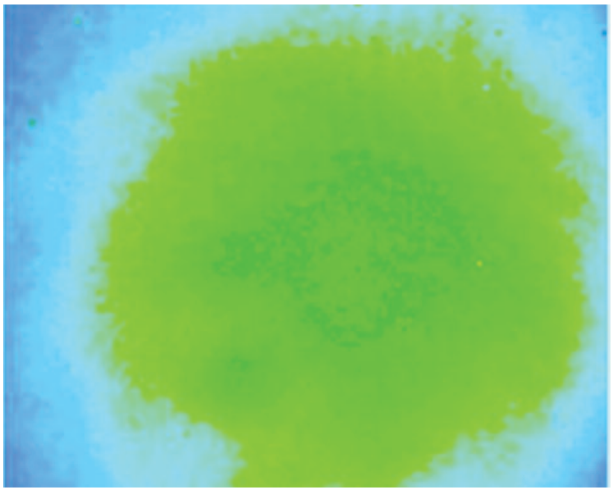
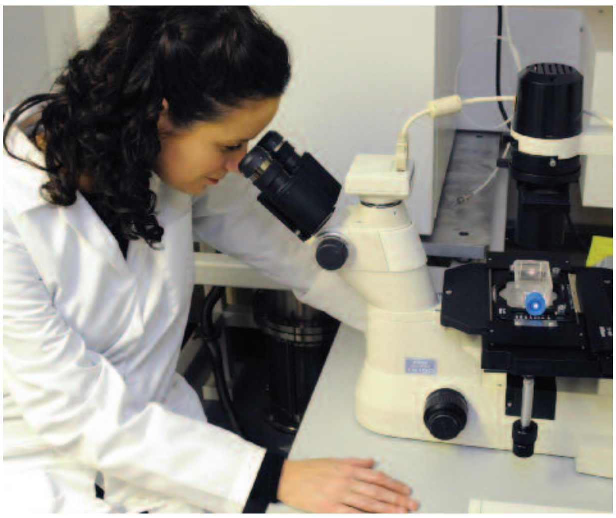


The profile of the FEL beam as recorded on an infra-red camera



Liverpool University Staff member in ALICE's Tissue Culture Laboratory

Development of Photon Beamlines on ALICE

The ALICE accelerator provides two novel sources of radiation for experimental uses. By temporally compressing the electron bunch in a chicane, it generates intense, broad band radiation in the terahertz (THz) region of the electromagnetic spectrum. Following the chicane, the electrons pass through an undulator in the centre of an optical cavity which acts as a Free Electron Laser (FEL), emitting intense, pulsed photon beams in the mid-infrared (IR) region. The Photonics group in ASTeC has been instrumental this year in commissioning the beamlines carrying the photon beams produced into areas in which they can be utilised for a variety of scientific studies. The group has also been heavily engaged in providing the diagnostics and photon expertise in order to develop the sources themselves.

Highlights this year included the successful operation of the IR-FEL in an energy recovery linac system, making it the first of its kind in Europe. This included the demonstration of continuous wavelength tuning at fixed machine energy.

Optical metrology expertise was used to determine the precise radius of curvature of the FEL cavity mirrors, a crucial parameter in ensuring that the FEL yields the high optical gain needed for high power lasing. The use of an IR spectrometer proved invaluable in measuring the spectral output of the spontaneous emission from the IR-FEL, allowing the electron beam to be steered co-axially with the optical axis of the FEL cavity – another requirement for lasing. The Photonics group have recently completed the commissioning of the IR-FEL beamline through from the accelerator hall and into the adjoining diagnostics room, where they are collaborating with the University of Liverpool and the Cockcroft Institute to exploit the intense mid-IR radiation for high resolution biological imaging with a scanning near-field optical microscope.

The group has also ensured success in the transport of high intensity THz radiation into a dedicated tissue culture laboratory for experiments on living cells. This science programme is lead by Peter Weightman from University of Liverpool physics department working with clinical scientists from the faculty of medicine. They are also collaborating with a team from the University of Manchester lead by Wendy Flavell who are using the unique time structure of the ALICE accelerator and the ability to synchronise it with optical laser systems to study the behaviour of novel photovoltaic systems.

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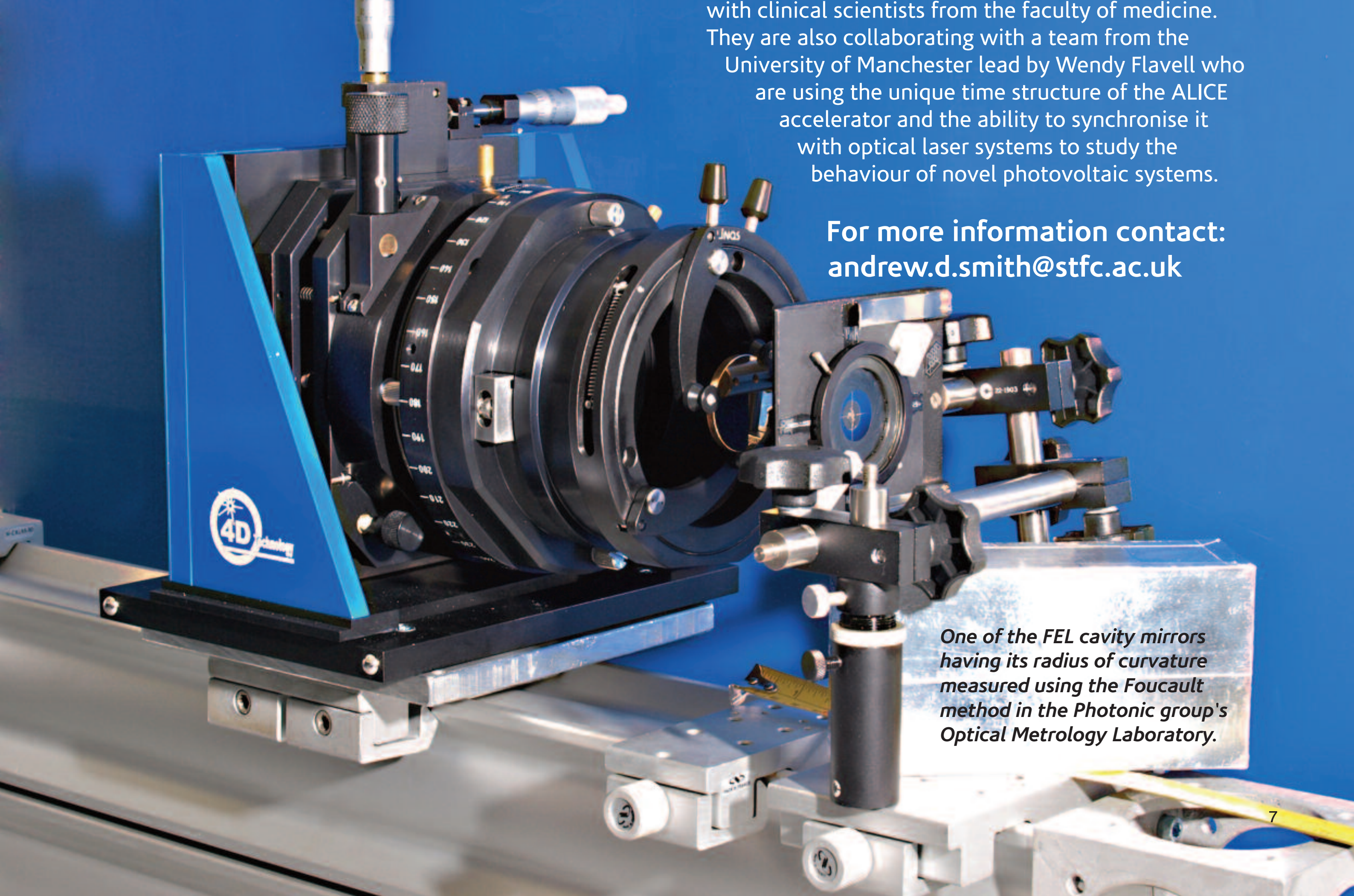
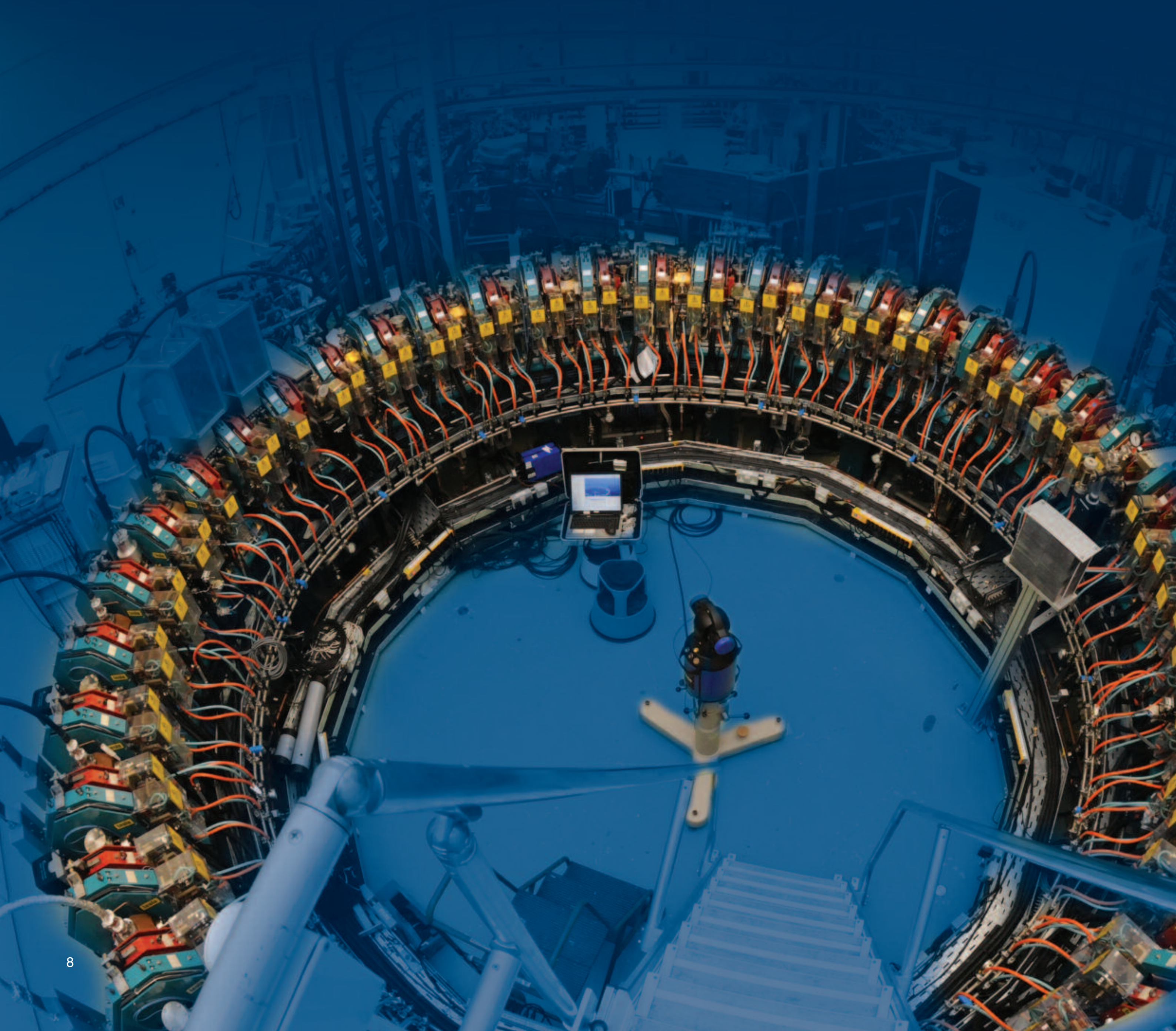


One of the FEL cavity mirrors having its radius of curvature measured using the Foucault method in the Photonic group's Optical Metrology Laboratory.

EMMA

Non-scaling Fixed-Field Alternating Gradients (FFAGs) have a variety of applications from hadron therapy, Accelerator Driven Systems (ADS) to the rapid acceleration of muons for a Neutrino Factory or a muon collider. A proof of principle machine for this new accelerator concept has been built over the last few years and is being commissioned at the STFC Daresbury Laboratory in the UK. This proof of principle machine is called EMMA or the Electron Model for Many Applications.



EMMA has been funded as part of BASROC – British Accelerator Science and Radiation Oncology Consortium. Included with this funding are the design of a non-scaling FFAG (PAMELA) for the acceleration of carbon ions and protons for the treatment of cancer and the study of other potential applications of this technology.

EMMA has been designed to demonstrate and study in detail all the features of non-scaling FFAGs. To do this, while keeping costs down, it was decided it should accelerate electrons from 10 to 20 MeV. In addition, the machine has been designed to be very flexible and it has numerous diagnostic devices to allow detailed measurements of the beam parameters to be performed. It is built from 42 magnetic cells, each about 40 cm long, making the circumference 16.5 m. Each of these cells has two ring magnets and almost every other cell has an RF cavity. The cells in between have vacuum pumps or diagnostic devices. There is also a dedicated injection line where as much as possible of the full 6-dimensional phase space of the incoming electron bunch is measured. Additionally, there is a diagnostics line, the purpose of which is to enable as precise as possible a determination of the effect of a non-scaling FFAG on an electron bunch.

EMMA Commissioning

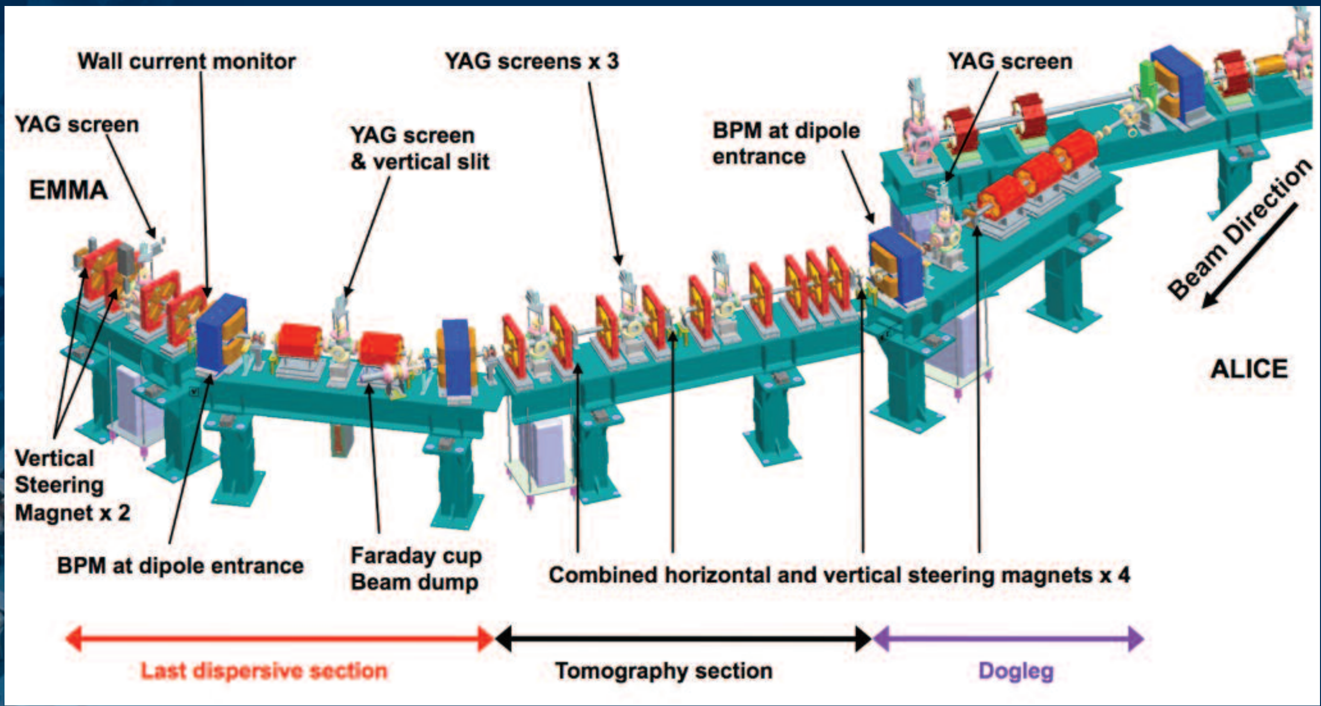
EMMA commissioning has been in progress for just under a year. During this time a lot has been learnt about the world's first non-scaling FFAG. The main steps and milestones achieved, as far as commissioning is concerned, have been as follows:

Injection Line Commissioning

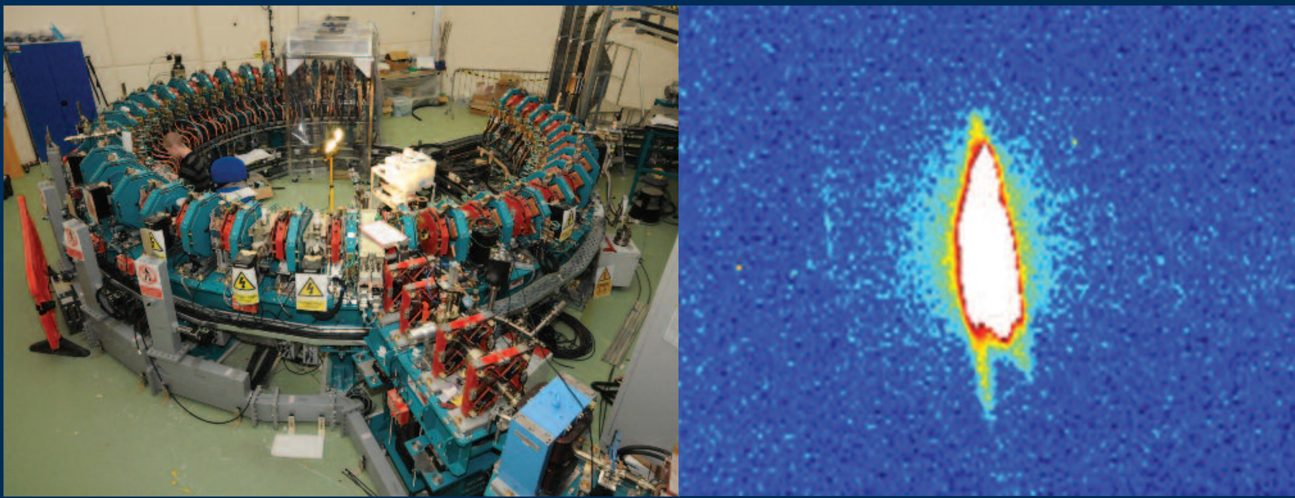
The EMMA injection line has been in place since the 10th March 2010 and commissioning started later that month. Commissioning of the injection line has been ongoing and the tomography section analysis has resulted in several publications with more planned. A combination of tomography and quadrupole scans has been used to fully characterise the transverse properties of the beam before it is injected into the EMMA ring. As well as a characterisation of the beam, there was an optimisation of the various parameters and an improved design of the line which allows space charge to be taken into account. In particular, it was found that the energy spread could be minimised to 7 keV beam for a 15 MeV, or, equivalently, 0.05 %. The injection line is shown below, together with all the relevant sections labelled.

Four Sector Commissioning

Before the full ring was in place, the opportunity was taken to commission four out of the seven sectors of EMMA – this started on 20th June 2010. This gave the opportunity to study the beam in the first part of the ring only without circulation and, therefore, to look at the application of non-scaling FFAG cells for use in medical gantries for therapy. A picture of the four sector gantry style commissioning is shown, together with the first beam seen on the last screen on 22nd June 2010.



ALICE to EMMA injection line



4 sector or gantry style EMMA commissioning and beam at exit.

EMMA Ring Commissioning

Commissioning of the complete EMMA ring started on 13th August 2010 and very good progress was made within days with circulation of more than 1000 turns without RF routinely achieved. The entrance and exit angles of the injection septum were measured each time. This information was used, along with the relevant modelling and the dedicated software, the injection into EMMA was optimised using the septum and the two kickers to ensure the beam was placed on the correct, energy dependent, trajectory. Subsequently, the RF and the novel LIBERA synchronisation system from Instrumentation Technologies were commissioned, with the assistance of engineers from the company. Using the custom beam position monitors (BPMs) and electronics developed especially for EMMA to read and store the position data over multiple turns, it was possible to correct and stabilise the orbit. The BPM system, which instruments 53 out of the possible 89 in the ring and injection/extraction lines, detects button signals that are multiplexed in pairs (horizontal and vertical) by a locally mounted front end module. The custom designed Versa Module Eurocard (VME) based detectors, de-multiplex and digitise these signals and store the position data for post processing and analysis. A number of technical faults with the firmware have been addressed during commissioning, and the first 4 BPMs on the injection line have been instrumented and tested successfully. Further work to eliminate some ambient kicker and RF noise from these low level signals is continuing. However, the system was significant in demonstrating that the set up of the RF cavities were at the correct accelerating crest points, both individually and globally, and on 29th March 2011, first acceleration was achieved.

Diagnostics Beamline Commissioning

The full diagnostics beamline was installed during the ALICE winter shutdown and was available for use from 28th January 2011. Together with the commissioning of EMMA for acceleration, the diagnostics beamline was utilised and on 7th March 2011 the first extraction from EMMA was achieved. This was very easy to do in the first instance, however, extracting beyond the first dipole of the diagnostic beamline proved slightly more difficult to optimise. Nevertheless, when this was achieved, it was then possible to routinely extract the accelerated beam from EMMA to the end of the line. The diagnostics beamline design is shown here.

First complete extraction, with acceleration in the diagnostics beamline was eventually achieved along with consistant extracted energy measurements. The beam images shown are taken on the first and fourth YAG (yttrium aluminium garnet) screens in the beamline, with and without RF. The first two images show the beam without RF and the second two, the beam with RF, on YAG (yttrium aluminium garnet) screens 1 and 4, respectively. This shows that the electron beam in EMMA was accelerated by a factor of 1.68 and went from
12.5 (+/- 0.1) MeV/c momentum at injection to
21.0 (+/- 1) MeV/c at extraction.

Kicker and BPM shielding

During the commissioning of EMMA noise from the RF and kicker switching units severely hampered the operation of the BPMs. Thus a programme of work was undertaken to improve the BPM performance by reducing the noise level and for this two approaches were taken.

The first improvement was to add a 3 mm aluminium RF shielded box around the BPM front end cards that are located under each of the 7 EMMA girders. All shielding units have been delivered and 110 out of the 180 units have been fitted, which include the units used regularly during commissioning. It is planned to fit the remaining 70 units in July.

The second improvement has been to design and construct a more substantial shielded box around each of the 4 kicker switching units. Two units for the injection system have been installed and the remaining 2 units for the extraction system will be fitted in July.

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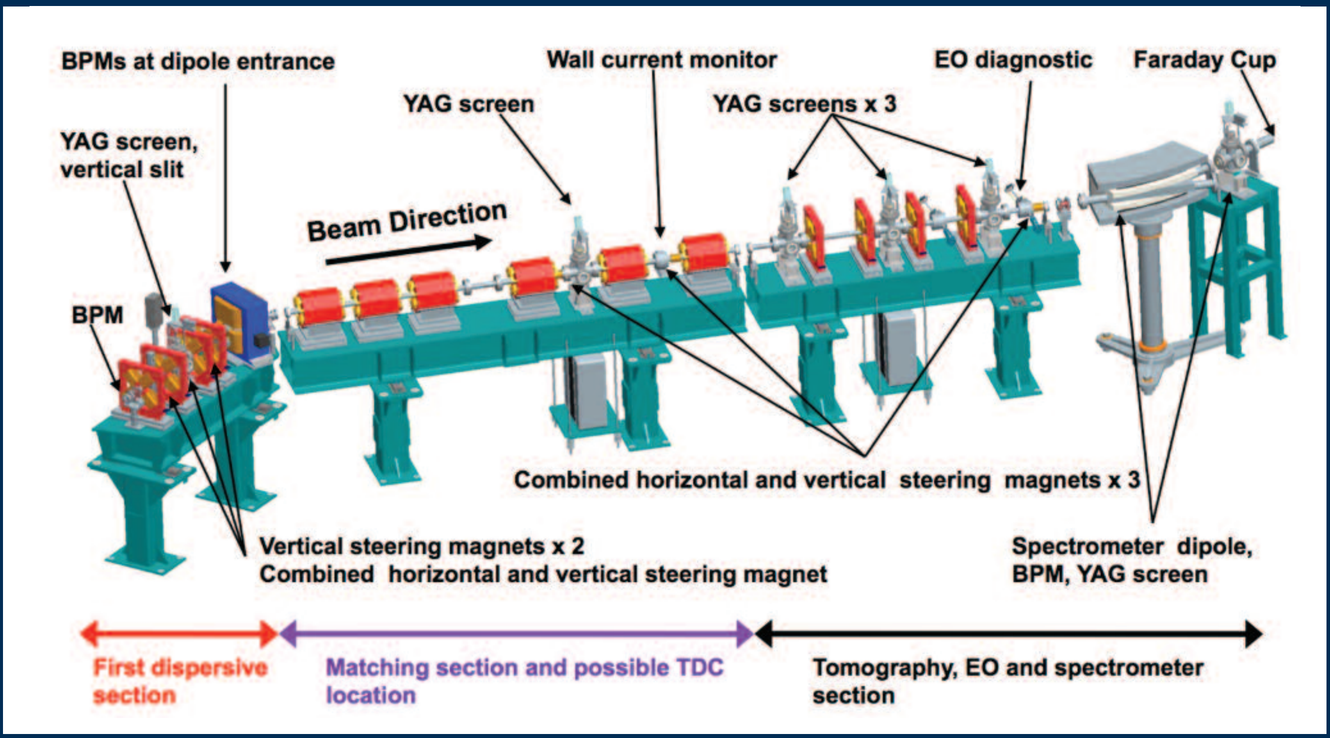
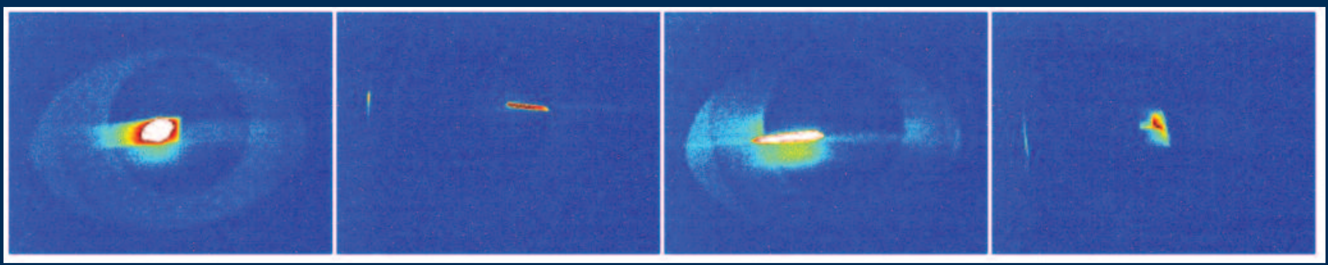


EMMA extraction and diagnostic beamline



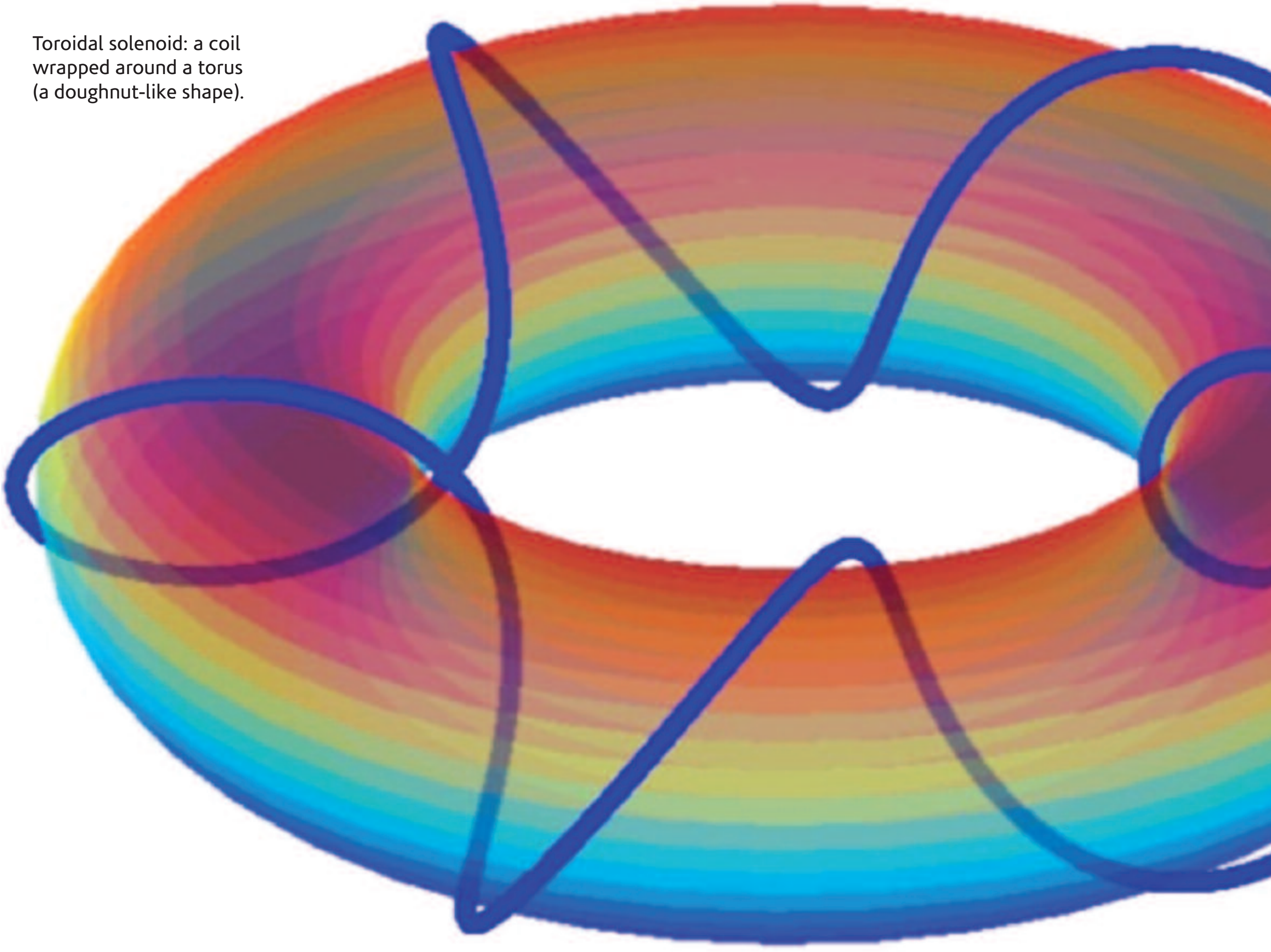
YAG screen images in the extraction line with and without acceleration.

EMMA Induction Acceleration

Toroidal solenoids have been known, and used, in various applications for quite some time. Certain aspects of their electromagnetic behaviour have been studied by Maxwell. Toroidal solenoids are now widespread in the form of toroidal transformers and inductors. Despite their ubiquity toroidal coils have a number of intriguing properties that are not fully understood at present. Consider a time dependent current flowing along the windings of a toroidal inductor with the current strength being constant along the wire (quasi-static regime), the leading order multipole moment of the system is the magnetic dipole moment, originating from the azimuthal current component flowing around the rotation axis of the torus. Existing theoretical work suggests that the next order multipole moment is the so-called toroidal dipole moment. In much the same way in which a magnetic dipole moment can be visualized as a current loop and an electric dipole moment, as a pair of equal-in-magnitude electric charges of opposite signs, a toroidal dipole moment can be seen as surface current flowing along the meridians of a torus (poloidal current).

Alternatively, a toroidal moment can be obtained by bending a cylindrical permanent magnet into a torus, bringing its south and north poles in contact with each other. Static toroidal moments (poloidal currents) do not generate magnetic fields outside their own volumes. However, despite the absence of magnetic field, a non-trivial vector potential is nevertheless present outside the torus. It cannot be removed by a gauge transformation and can actually be measured (the Aharonov–Bohm effect).

Toroidal solenoid: a coil wrapped around a torus (a doughnut-like shape).



An additional property of the poloidal currents is that the strength of the current depends linearly on time and the resulting magnetic field changes linearly with time whilst remaining confined to the inside of the torus.

The electromagnetic field generated by a poloidal current depending linearly on time are shown. The resulting electric field is static (time-independent). The magnetic field is non-zero only inside the torus and depends linearly on time. The z-axis is the axis of rotation symmetry.

The electric field exists both inside and outside the torus, and is time-independent. Such a field configuration has a number of advantages for induction acceleration; the beam is not disturbed by stray magnetic field generated by the accelerating transformer and no electromagnetic waves are radiated by the system (i.e. no electromagnetic interference). Clearly, generating currents that depend linearly on time is not possible in practice and alternating the signs of the time-derivative of the current will be necessary. This means that higher order derivatives will be inevitably present during particular time intervals and this will generate short bursts of radiation. Investigating such a system could result in improving the existing designs of accelerating transformers and it is planned to investigate this further over the next year.

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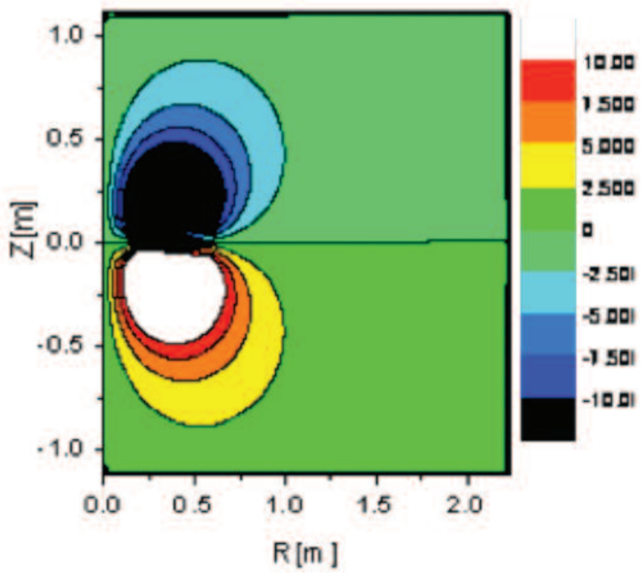
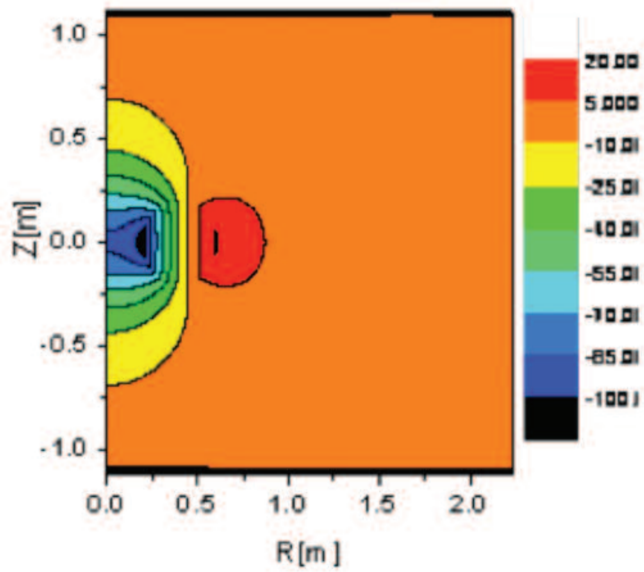
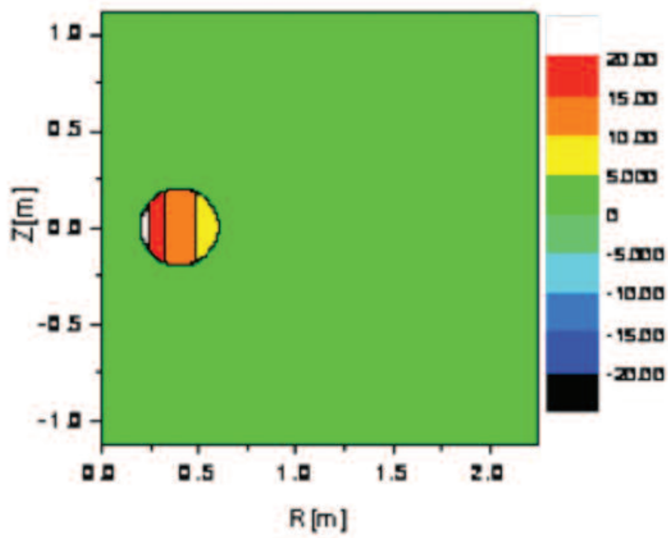


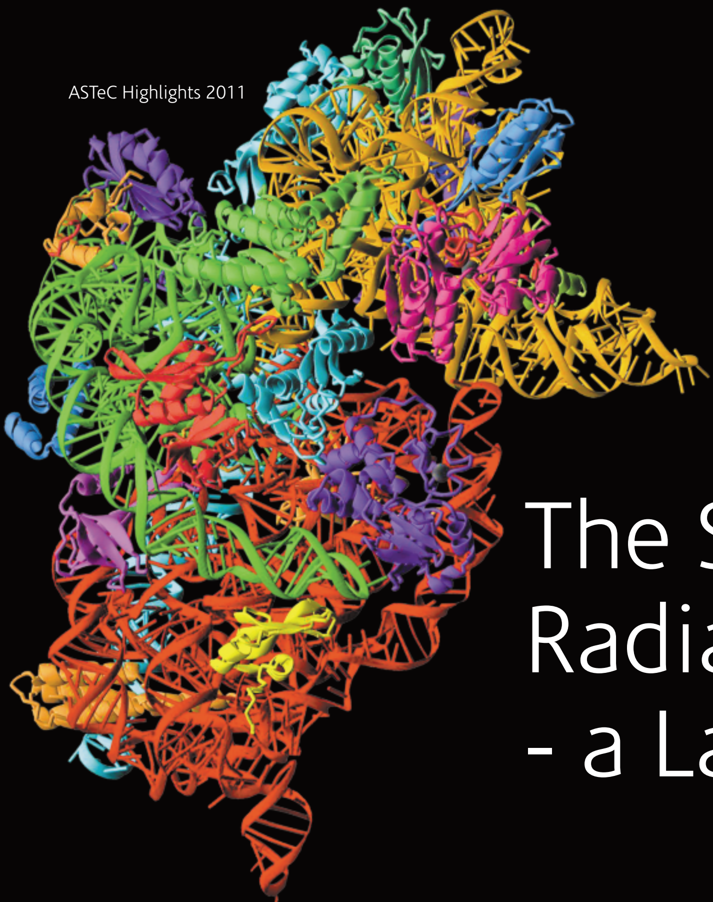
Radial electric field component E_r.



Axial field component E_z.



Azimuthal magnetic field component H_Φ.



The Synchrotron Radiation Source - a Lasting Legacy

The Synchrotron Radiation Source (SRS) lifetime came to an end in August 2008. The Decommissioning Project then started, utilising a large number of specialist STFC staff in the project team. Several members of ASTeC's Photonics Group were heavily involved in the asset management and physical decommissioning of the facility.

Construction of Dipolehenge

Since its conception the internationally renowned SRS, the world's first dedicated source of synchrotron light had been pushing back the frontiers of knowledge for almost 30 years. During its operation, UK and international scientists conducted thousands of scientific experiments on the SRS. The facility operated 24/7 and up to 40 experiments could be carried out simultaneously. Two-and-a-half thousand scientists used the facility every year for their cutting edge research. As it was a world first, the SRS required a wide range of advanced technologies to be developed by Daresbury scientists and engineers. High power magnet and radio-frequency systems steered and accelerated the electron beam that generated the synchrotron light. Complex mirror systems relayed the light to the experiments. Detectors and electronic control systems were developed to collect the data. This pioneering work led to synchrotron light becoming one of the most powerful and versatile research tools in science. It is now invaluable in a wide range of investigations in medicine, biology, physics, chemistry, geology and environmental and archaeological science.

The SRS had a large amount of sophisticated equipment still in place at its closure and the Decommissioning Team made a very important contribution to its lasting legacy. Large sections of the newest beamlines were carefully dismantled and shipped to other synchrotron sources such as Diamond, ANKA, SESAME, Australian Synchrotron Light Source and INFN to return to active service. Many other components were also rescued and have already been put to good use elsewhere at Daresbury Laboratory, such as on ALICE and EMMA, and other items of equipment are being stored for new applications in due course. This required a careful approach to valuation and asset management to maximise the return on the earlier investment of public funds.

Equally important was the requirement to preserve important documents and properly record the existence and impact made by the facility over its lifetime. A significant effort went into sorting through a huge volume of papers and log books and finding a suitable permanent home in which to store them.

Documents, photographs and other archival information have been donated and have been officially accepted by MOSI (Museum of Science and Industry, Manchester) to accompany its science collection. The collection is accompanied by equipment including beamline 2.3 on display in the Revolution Manchester Gallery which showcases Manchester's greatest innovations. Beamline 16.5 is in the Manchester Science Gallery and assembly of the unit is expected to commence in the near future. In addition one of the wiggler and quadruple magnets will also be on display outside in the museum grounds. A testament to the importance of the SRS was the award of the Nobel Prize in Chemistry to Professor John Walker in 1997. His work on solving the structure of adenosine triphosphate (ATP) synthase relied on data measured at the SRS. This enzyme is of crucial importance in almost all living things since it generates the molecules used to drive biochemistry. The SRS also played a part in a second Nobel Prize awarded in 2009 for revealing the structure of the ribosome, the part of the cell which makes proteins. The SRS was the inspiration for more than 70 facilities around the world. During its lifetime, the SRS at Daresbury collaborated with almost every country active in scientific research. It hosted over 11,000 users from academia, government laboratories and industry worldwide, which led to the publication of more than 5,000 research papers in leading journals. It resulted in numerous patents and solved over 1,200 protein structures.

The exhibition at the Manchester Museum of Science and Industry and the recently erected "Dipolehenge" in the grounds at Daresbury Laboratory acts as a constant accolade to the heritage of the SRS and the importance of its international achievements.

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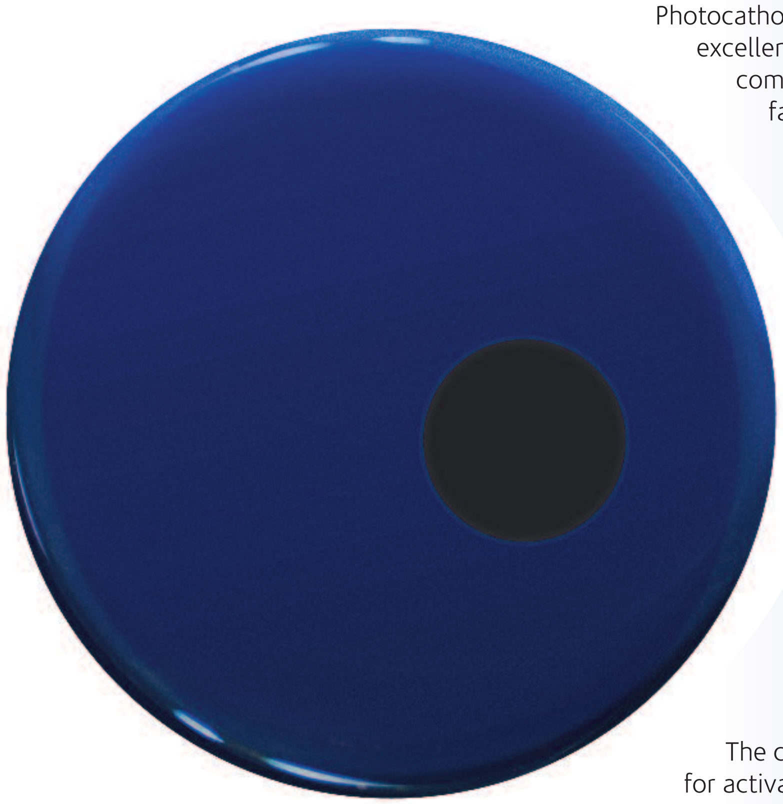
Photocathode R&D



An anodised ALICE photocathode. The photocathode is 31.4 mm Ø, and the anodising process leaves a purple/blue sheen. The preserved area which will later be used as an electron source is clearly visible.

The photocathode is a key component of an electron accelerator as it is the electron source, and the properties of the electrons emitted by the photocathode affect the ultimate performance of the accelerator. These properties include such things as the quantum efficiency (QE) of the cathode which is a measure of how efficiently the cathode emits electrons, the electron bunch length (i.e. the 'pulse' length), energy spread, transverse size and divergence. Understanding the underlying photocathode physics and controlling the properties of the emitted electrons remains a key area of particle accelerator research and development.

The lifetime of photocathodes activated to high levels of quantum efficiency (QE) has been studied using the ALICE Photocathode Preparation Facility (PPF). The PPF is an excellent system to carry out these studies as it combines a state-of-the-art cathode preparation facility with the ability to continuously monitor quantum efficiency (QE) (and hence lifetime) while the activated cathode is progressively poisoned. A range of gas species normally found in the residual gas spectrum of a photoinjector vacuum system were used to poison cathodes, and photocathode lifetime was measured as a function of the pollutant gas dose for cathodes activated with both oxygen and nitrogen triflouride (NF_3) as an oxidant. The results summarised opposite show that Gallium arsenide (GaAs) photocathodes are highly sensitive to oxygen containing species, and that cathodes activated with NF_3 are more resilient to contamination, exhibiting better lifetime.

The consistency of the performance level achieved for activated photocathodes has been investigated in terms of the ultimate quantum efficiency (QE) achieved. This involved making a comparison between the achieved QE levels for photocathodes activated using either caesium-oxygen (Cs-O) and caesium-nitrogen triflouride (Cs-NF_3). While higher initial levels of quantum efficiency (QE) were achieved using the Cs-O recipe, a much more consistent level of performance was seen using the Cs-NF_3 recipe, as shown opposite.

ASTeC has developed a procedure for anodising the ALICE photocathode. Anodising uses a dilute acid solution to create a thick oxide layer on the surface of the cathode which prevents subsequent activation. By using a masking jig which uses an o-ring to protect a specific area of the cathode surface from the acid, we can preserve a small area of the cathode surface for later activation, as shown opposite. Minimising the active area of the cathode reduces spontaneous emission of electrons (known as field emission) during operation. It is anticipated that an anodised photocathode will be installed for the first time in the ALICE photoinjector during the last quarter of 2011.

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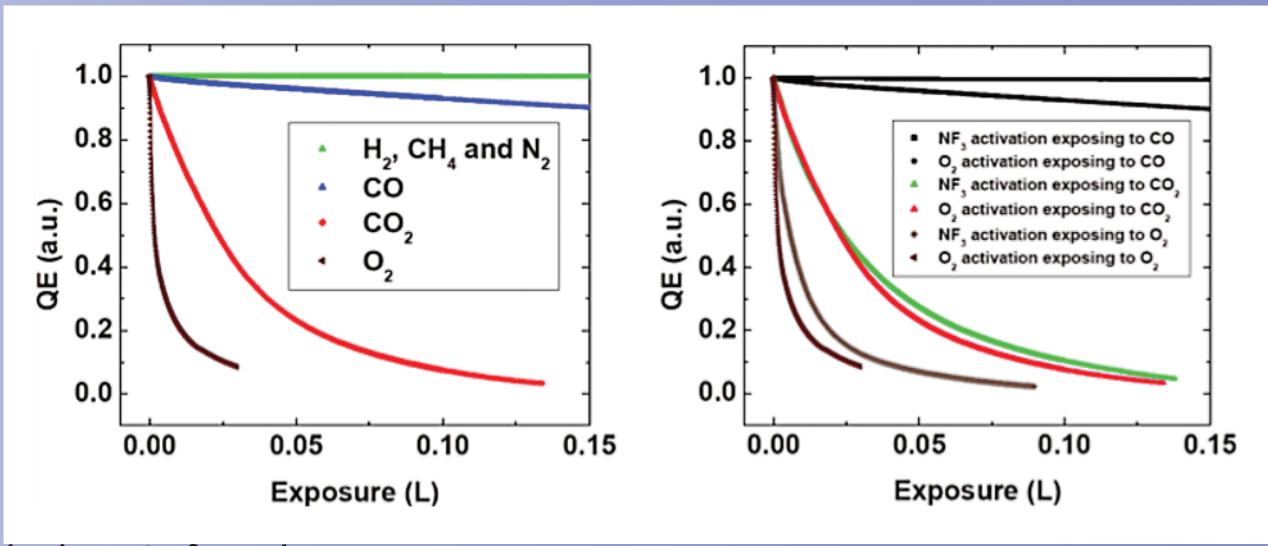

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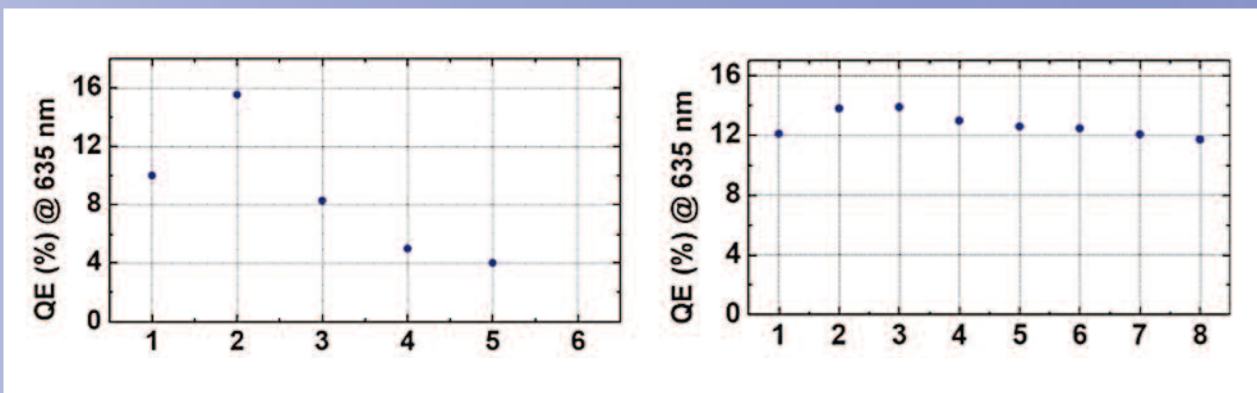
Summary of the lifetime measurement results for photocathodes activated using Cs-O (left) and Cs-NF_3 (right), then exposed to various gaseous species.



Plots showing the ultimate QE achieved when activating with Cs-O (left) and Cs-NF_3 (right) as a function of the number of cleaning/activation cycles for the photocathode

CLIC Spoilers

The electron and positron bunch trains in the Compact Linear Collider (CLIC) have a high transverse energy density (of the order of GJ/mm^2) and therefore, in the case of errant or mis-steered beams, their potential to cause damage to accelerator components is severe. In CLIC a post-linac energy collimation system is dedicated to intercept these mis-steered beams. This collimation system consists of a thin spoiler and a thick absorber downstream. The purpose of the spoiler is to increase the angular divergence of an incident beam via Multi Coulomb Scattering, which increases the beam size at the downstream absorber thereby reducing the risk of damaging it. However, the spoiler design has to survive the impact of the full train and needs to be made of a material that will not reach any dangerous temperature that could fracture or melt.

ASTeC has investigated different material and geometrical options using the FLUKA Monte Carlo code to simulate the energy deposited by an impinging CLIC bunch train together with ANSYS Finite Element Analysis to calculate the stresses generated in the spoiler body. Beryllium arises as the best candidate material for a long tapered design collimator. Its high electrical and thermal conductivity will avoid generating high wakefields, which might degrade the orbit stability and dilute the beam emittance and together with its large radiation length compared to other metals makes it an optimal candidate as, in the case of the beam impacting the collimator, temperature rises will not be sufficient enough to melt the metal.

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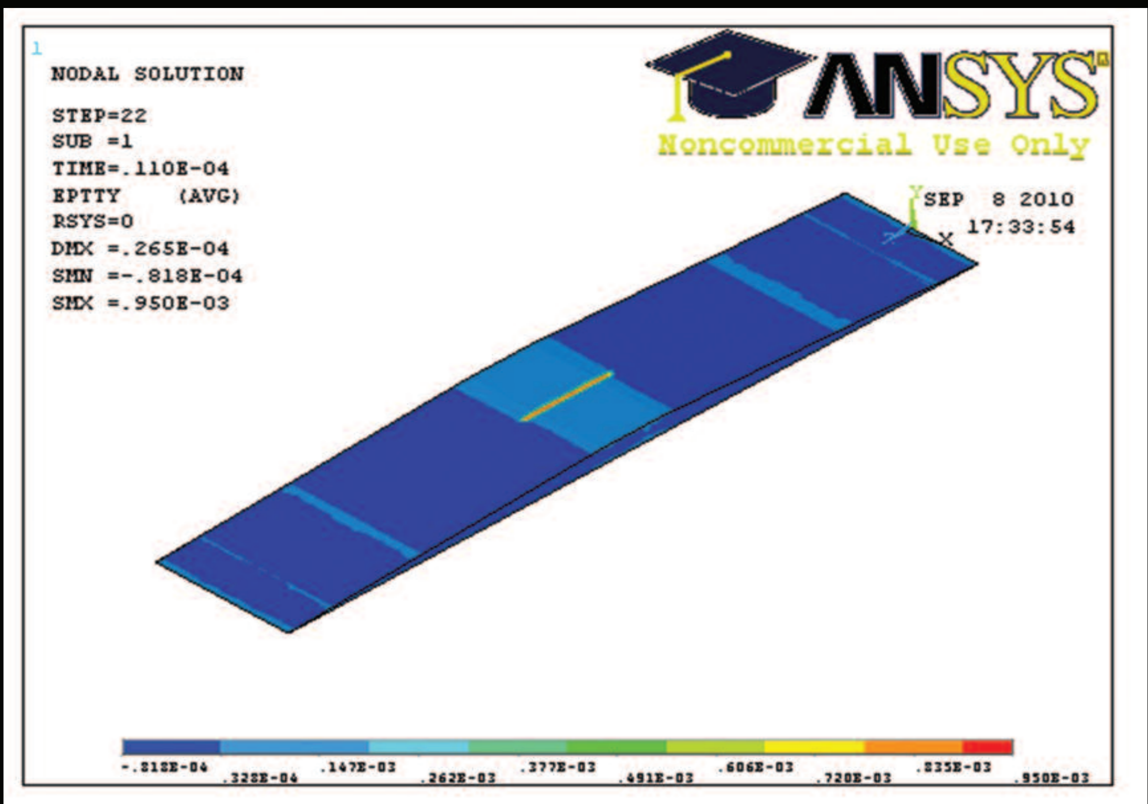
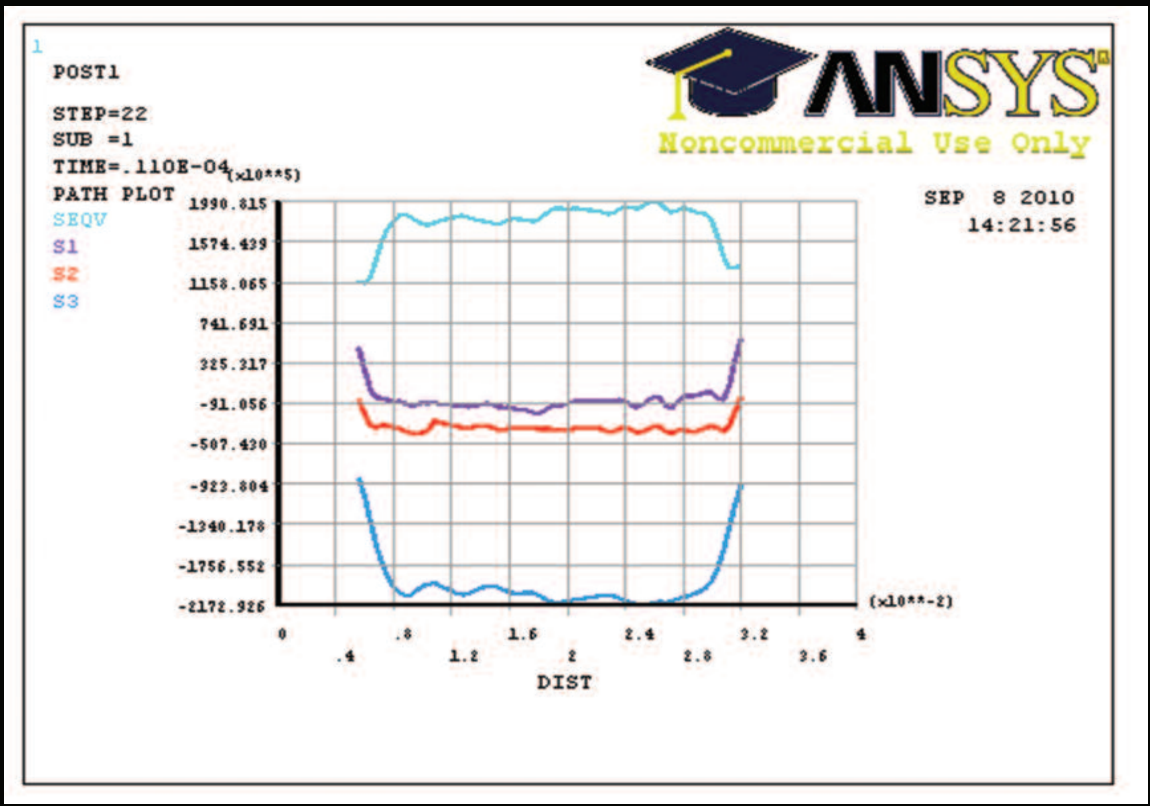
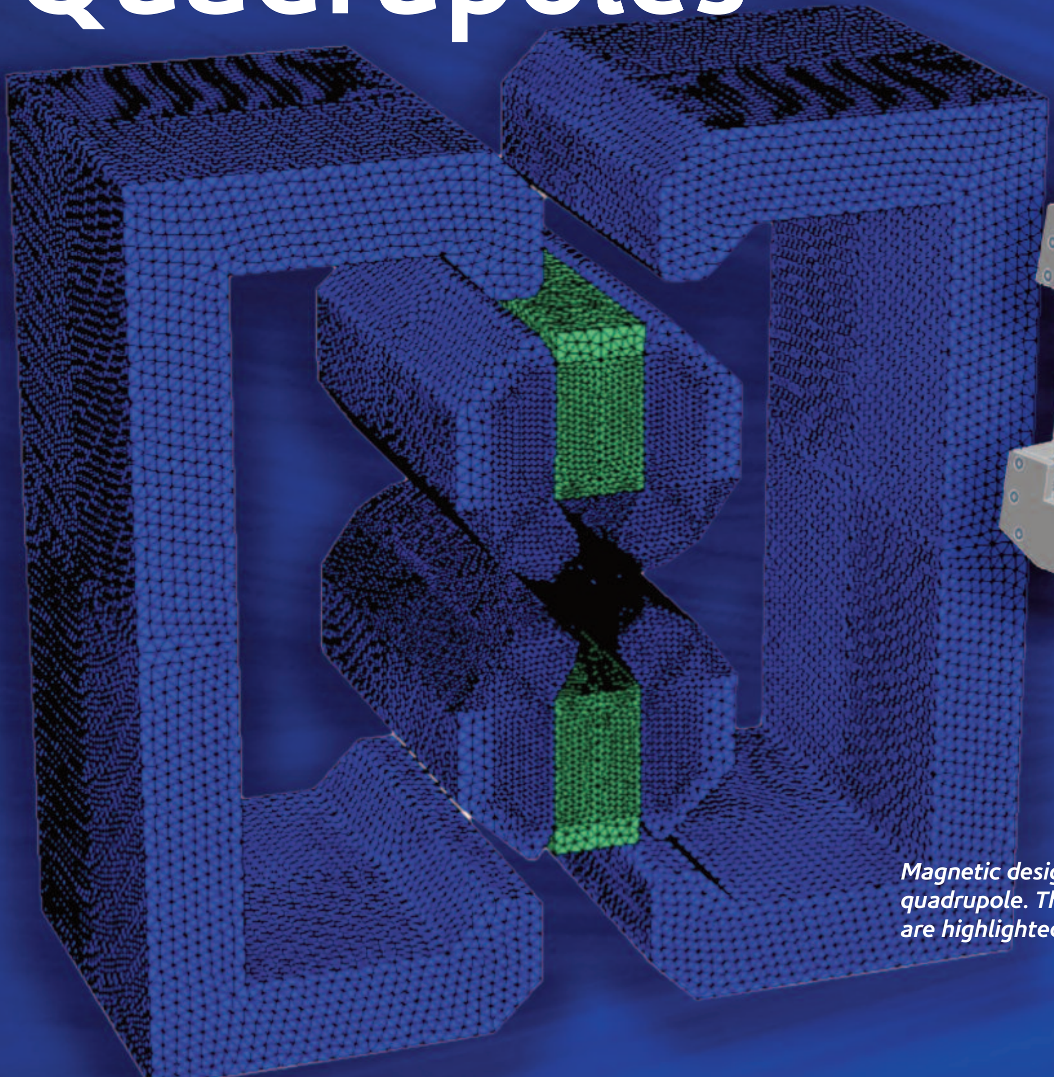


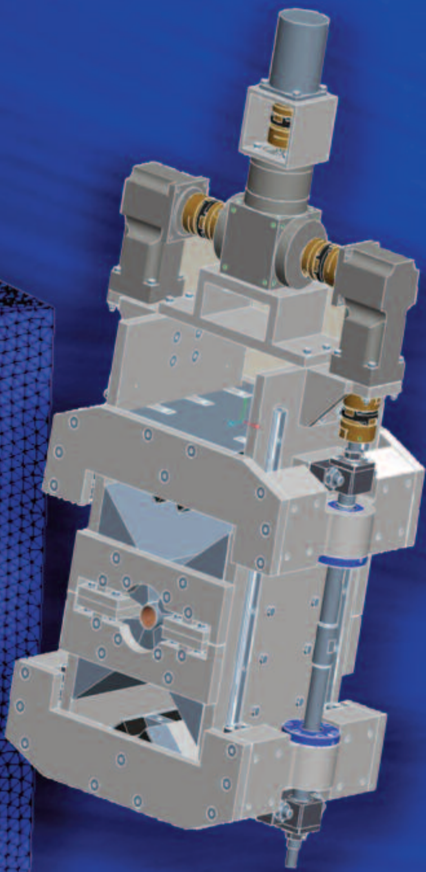
Von Misses stress (in Pa) in the spoiler body 11 μs after the CLIC bunch train hit.



Von Misses stress (upper curve in the plot) and the three components of stress in the Cartesian coordinate system (in Pa) along the spoiler body 11 μs after the CLIC bunch train hit. The negative value of the three components of stress indicates a compressive stress.

CLIC Drive Beam Quadrupoles





The engineered design for the high strength quadrupole.

Magnetic design of the low strength quadrupole. The permanent magnets are highlighted in green.

ASTeC's MaRS group, together with the Technology Department at Daresbury Laboratory, have been collaborating closely with CERN on a design for quadrupole magnets for the Compact Linear Collider (CLIC) Drive Beam Decelerator. There are two drive beam decelerator lines each 21 km in length which require over 40,000 quadrupoles to keep the beams focussed. There are stringent limitations on the size and power consumption of these magnets and ASTeC has been investigating the possibility of a design based on permanent magnets, which require no power to produce a magnetic field.

ASTeC have now produced two designs for adjustable permanent magnet quadrupoles, with a novel 'undulator-like' adjustment mechanism which moves the permanent magnets away from the beam axis to reduce the influence of the field on the beam. These two designs (high and low strength) will cover the entire length of the drive beam decelerator, from 2.4 GeV to 240 MeV. An engineered design for the high strength version is almost complete and a prototype is in the early stages of procurement, for assembly at Daresbury in late 2011. Magnetic design of the low strength magnet is complete and a full mechanical design will be produced later in the year, with a prototype being constructed in 2012.

These innovative designs for an adjustable permanent magnet quadrupole have proved very successful in the CLIC study, and could easily be adapted for other accelerators and other types of magnet. ASTeC has filed a patent covering these ideas.

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MAX IV Injector

The decision of the Swedish government to fund the construction of MAX-IV is the latest major European investment in light sources. The facility, based in Lund in the south of the country, will consist of a 3 GeV low emittance storage ring and full energy injection linac. Whilst the ring design is well advanced, the design for the linac is less so. ASTeC has a long history of fruitful collaboration with Max-lab, which in this reporting year was further developed. ASTeC staff: Deepa Angal-Kalinin, Julian McKenzie, Boris Militsyn and Peter Williams were invited by the MAX IV Laboratory (Max-lab) to carry out injector linac design work under contract. Contributions were made in the areas of photoinjector simulations, linac optics, longitudinal dynamics tuning studies, and magnet tolerance calculations. This work was included in the MAX-IV detailed design report, and has helped define the component specifications required by Max-lab for the manufacturers bidding to supply the project.

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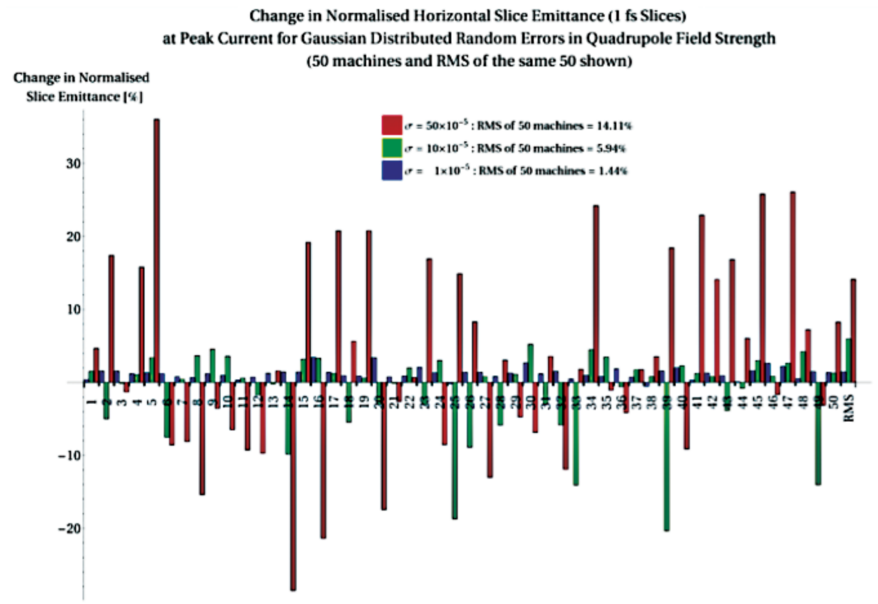
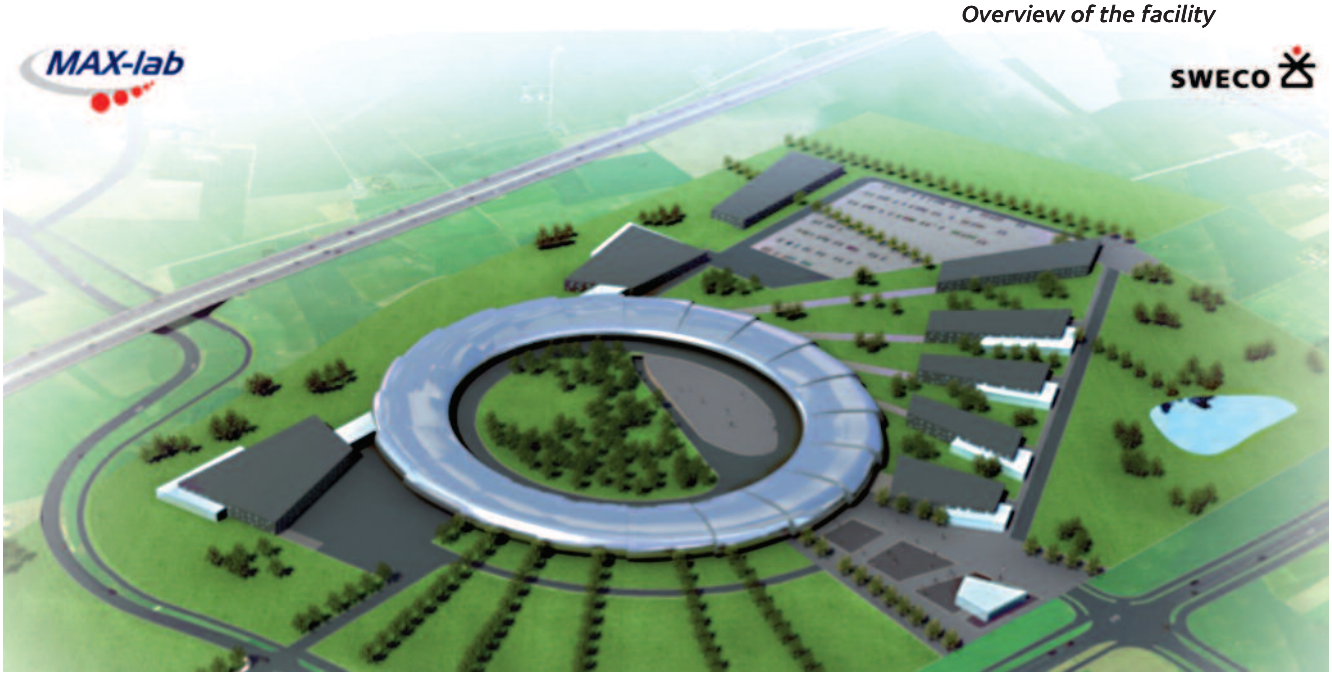
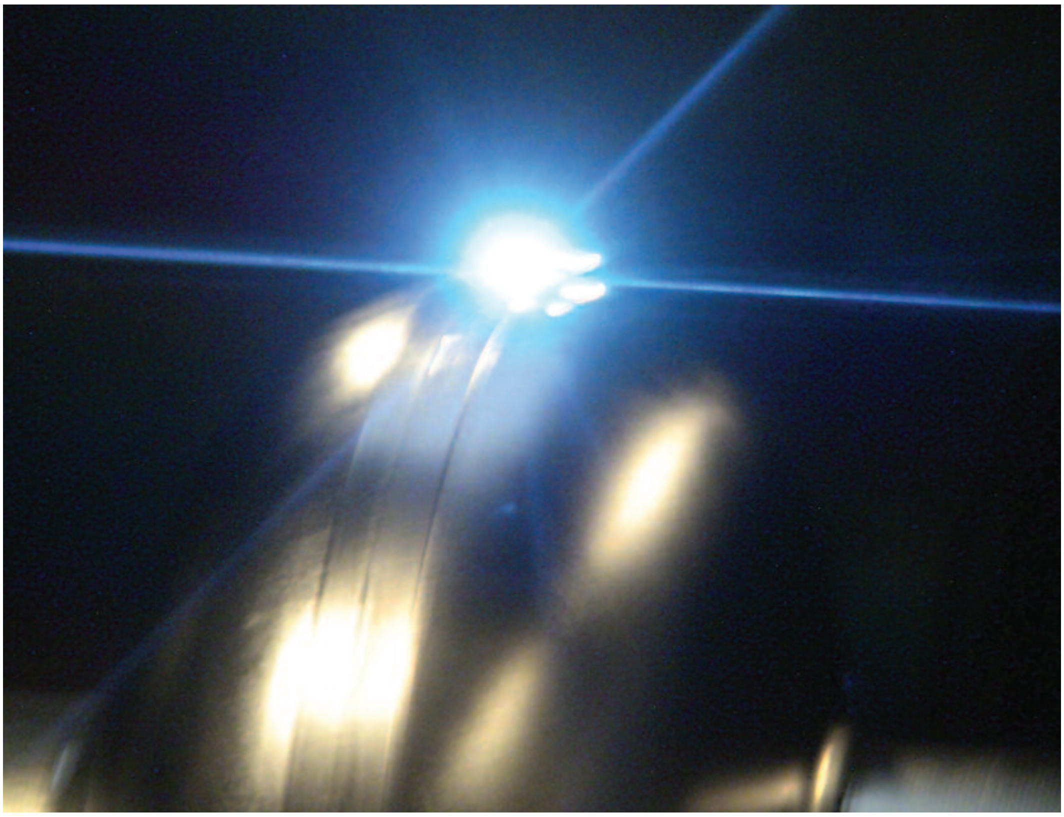


Example tolerance study of quadrupole field errors

Overview of the facility



SRF Cavity Fabrication with Industry



Equator electron beam welding

Testing of the first two Superconducting RF (SRF) cavities manufactured within the UK has been completed as part of an STFC Innovations funded Mini-PIPSS collaboration project, jointly undertaken by ASTeC and Shakespeare Engineering Ltd (UK) and in collaboration with Jefferson Laboratory (JLab) in the USA. The overall objective of the programme was to develop the capability within UK industry to demonstrate fabrication of SRF cavities for the very first time, and the first stage of this project was to design, manufacture, process, and high power test a 1.3 GHz single-cell SRF structure.

Three single-cell, 1.3 GHz niobium SRF cavities, the design of which utilises the standard TESLA geometry, have been fabricated by Shakespeare Engineering Ltd. The cavity half-cells were pressed from high purity (RRR = 300) sheet niobium after successful trials had initially been performed with copper sheets, which have similar malleability properties to niobium. The cavity beam-pipes were also spun from sheet material, thus eliminating the need for performing an electron beam (EB) weld along the seam of a rolled sheet of niobium, as is typically performed, which produced minimal loss of material thickness.

Members of the project team visited JLab to witness the welding and processing of the cavities, along with post processing and testing of the first fabricated cavity (S/N 01). The cavities were welded at JLab on a 6-axis EB welder and prior to each welding operation, an ultrasonic degrease and light buffered chemical polish (BCP) etch was performed on each of the weld preparation areas, to minimise the likelihood of contamination. No issues were encountered in the EB welding of the first cavity, until the final equator weld for the second cavity, where there was a lot of debris seen flying from the joint as the cavity was rotated around its horizontal axis, which culminated in a big 'flash' as the weld came to an end. It is suspected that contamination was trapped between the two interfaces at the equator surface which was then pushed around the weld joint by the electron beam. A visual examination of the weld indicated that the weld appeared to be leak tight. To minimise this risk, future geometry designs will avoid step interfaces and incorporate preferentially butt joints, though greater care and attention with regards to component alignment will be required.

In order to ensure that there are no impurities or inclusions on the internal surfaces of the cavity, which potentially could have been formed during the machining and welding processes, a conventional BCP etch was performed using a 1:1:1 acid mixture of HF (49%), HNO_3 (65%), H_3PO_4 (85%). This process was performed on the first cavity at JLab, where it was then tested in their vertical test facility (VTF), during which the cavity reached its target specification of an accelerating gradient of greater than 15 MV/m at an unloaded quality factor, Q_o of 1 x 10^{10} at 2 K. However, multipactor was experienced at gradients just above 15 MV/m. The cavity was re-processed a further 3 times in an attempt to improve the accelerating gradient and to resolve the multipactor issue. An accelerating gradient of 22.94 MV/m with a Q_o of 1.06 x 10^{10} at 2K was achieved during the final tests, and a maximum gradient achieved of 28.05 MV/m with a Q_o of 2.93 x 10^9. However, multipactor was still present at around 16 MV/m, which could be quickly overcome.

The second cavity (S/N 02) was BCP etched at Daresbury Laboratory in a dedicated fume cupboard, which was modified specifically to perform the process. Testing of the cavity was then performed in a VTF which had been re-located, due to radiation shielding issues to allow for high gradient tests to be performed. The results obtained from this preliminary test were poor, with strong 'Q-disease' and low field Q_o performance which limited the achieved gradient to less than 4 MV/m. It is believed that the 'Q-disease' is most probably caused by a combination of excessive hydrogen being embedded in the bulk material of the cavity surface, due to poor temperature control during the BCP process and because insufficient material may have been removed. Further preparations to re-process the cavity are currently underway, to enable additional testing which is hoped to replicate or even exceed levels reached by the S/N 01 cavity tested at JLab.

Tests performed to date demonstrate that UK industry has the capability to fabricate SRF components to the required standards. The first cavity tested at JLab, exceeded the required success criterion and further testing is to be performed on the second cavity at Daresbury Laboratory along with tighter process control. Overall a large amount of experience has been gained on the fabrication, processing and testing of SRF structures in a relatively short period of time. Further funding has been requested to enhance this programme of work in order to further develop the knowledge and capability of UK industry, in collaboration with ASTeC in this critical field of accelerator technology.

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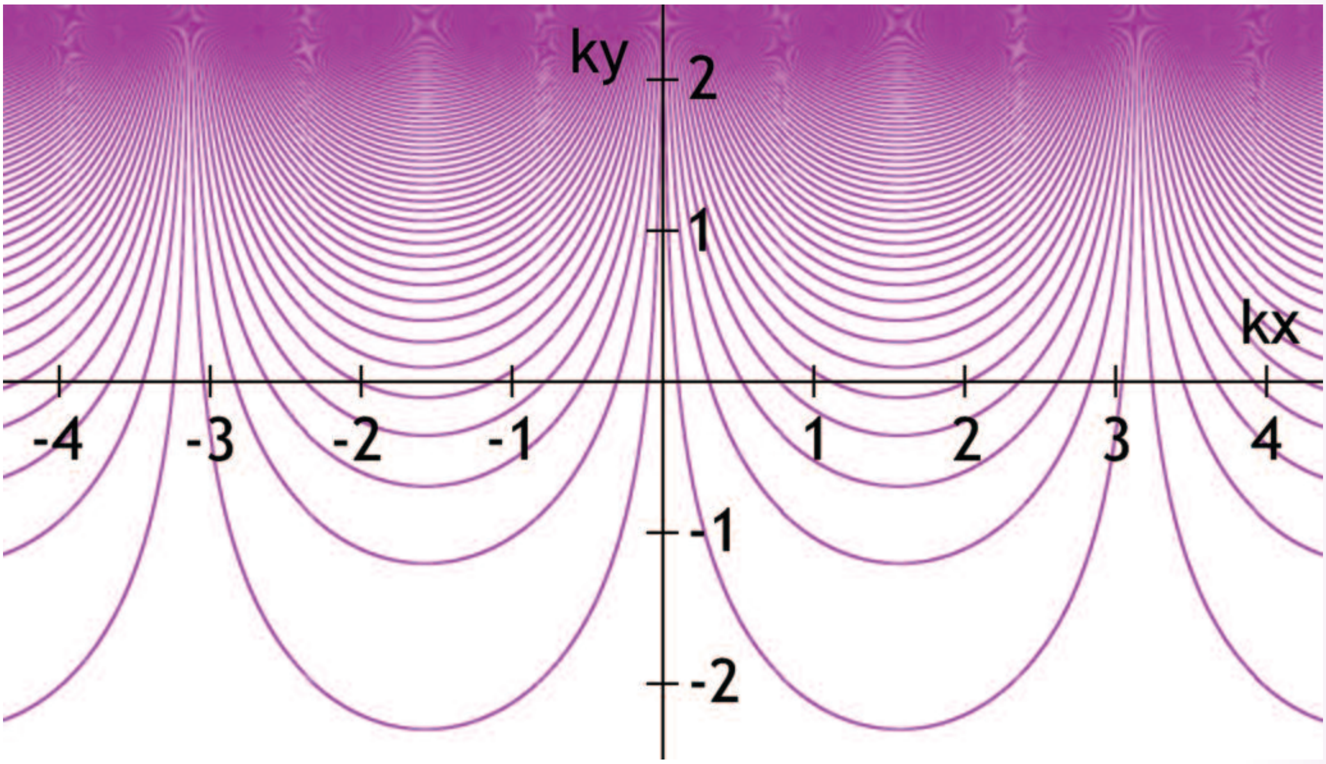
Vertical Orbit Excursion FFAGs



$$B_y = B_0 e^{ky} \cos kx \qquad B_x = -B_0 e^{ky} \sin kx$$

The 80 years since the development of the first cyclotron would seem ample time to find the ideal magnetic field arrangement for a circular accelerator, but the journey has not been without surprises. The synchrotron massively increased the energy range accessible without having to build magnets the width of the entire accelerator, while the invention of alternating gradient focussing allowed magnet costs to be further reduced by reducing the beam size. The time-varying fields used in synchrotrons dominated accelerator technology for the late 20th century. However, the emergence of superconducting technology is now calling for our assumptions to be re-examined.

Superconducting magnets as they exist today are unable to ramp dozens of times per second, which would be required of magnets in a modern high power synchrotron. The first fruit of reassessing circular accelerators in this light was the rediscovery of the FFAG (Fixed Field, Alternating Gradient) machine, originally proposed in the 1950s when it lacked an obvious advantage over the synchrotron. Now, however, the ability to accelerate a synchrotron-like energy range with fixed-field magnets much narrower than a cyclotron's is a good fit to superconducting magnet technology. The FFAG magnets work this magic by having large quadrupole gradients in their "dipole" magnets, providing a wide range of magnetic field strengths to bend beams of different energies.

The ASTeC Intense Beams Group's work on the Vertical Orbit-Excursion FFAG (VFFAG) questions another assumption of accepted accelerator wisdom: why does the beam orbit have to move horizontally (i.e. with increasing radius from the machine centre) as the energy increases? The beam's "closed orbit" in the machine is an equilibrium phenomenon, so in theory it could move in any direction provided the correct bending fields to close the orbit are present.

The magnetic field shown is an example of a field in which the bending force on the beam increases as the beam moves vertically. It also includes a (skew) focussing quadrupole component that can be used to focus a beam in a FODO-style (focussing, defocussing magnets) alternating gradient arrangement. In fact, with the field equation given, the tune of the machine is even constant with energy (something that is true of synchrotrons but only "scaling" FFAGs), which is very important to avoid losing particles via resonances, especially in high power beams with a large amount of space charge.

The advantage of this field arrangement relates again to superconducting magnet technology. In normal conducting magnets, the field is usually shaped by iron pole pieces and the field lines travel from the north pole to the south pole, so a magnet with a horizontally slotted aperture and a pole above and below it produces a strong vertical field (horizontal bending) in the aperture. However, superconducting magnets operate at fields beyond the saturation of iron and without iron pole pieces. The field produced by superconducting magnets is shaped by the current carrying coils only. It is thus strongest near the coils themselves, and produces a field at right-angles to the current direction. Horizontal bending in a horizontal slot magnet now becomes much harder to achieve because coils placed immediately above and below the slot will produce primarily horizontal fields, not the vertical required. On the other hand, horizontal bending in a vertically slotted magnet becomes easier because the field direction can be parallel to the slot direction with coils placed near the beam. This is illustrated below.

A possible practical application of such a machine was presented by ASTeC at the Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2010) conference for an upgrade ring for the ISIS accelerator. The fixed field both reduces the superconducting magnets' energised volumes and coil thicknesses as well as allowing the accelerating RF to be on for the full 50 Hz cycle rather than half of it as in the current ISIS synchrotron (in ISIS the magnetic fields are falling for half the cycle). This style of magnet could also find applications in medical hadron therapy machines because it retains the advantages of the FFAG while allowing the magnet to be shrunk to fit the beam in the horizontal direction. In these medical machines the beam tends to be small, so this could be a significant cost saving.

Finally, it should be mentioned that the VFFAG, like the FFAG, is not strictly a new idea. It was mentioned in a theoretical context in a 1960 paper by A.T. Fateev in the Russian journal Atomnaya Energiya, where it was called the "ring cyclotron" (a term that now means something else). The physics has not changed in the 50 years since, but our technology has.

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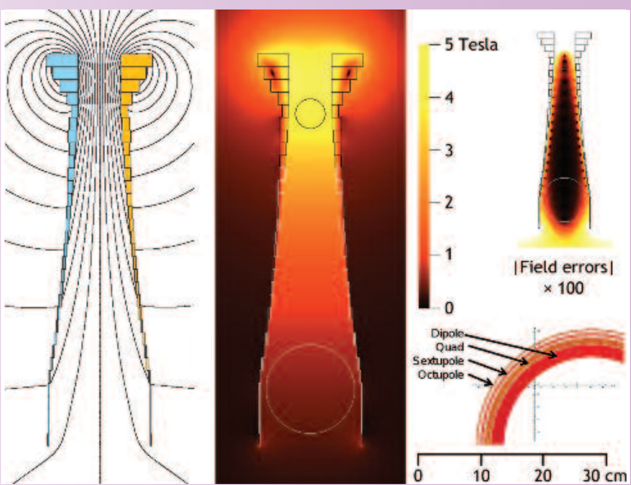
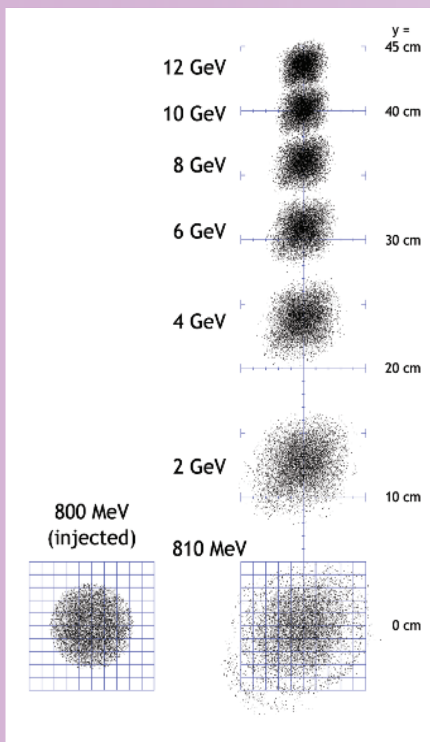
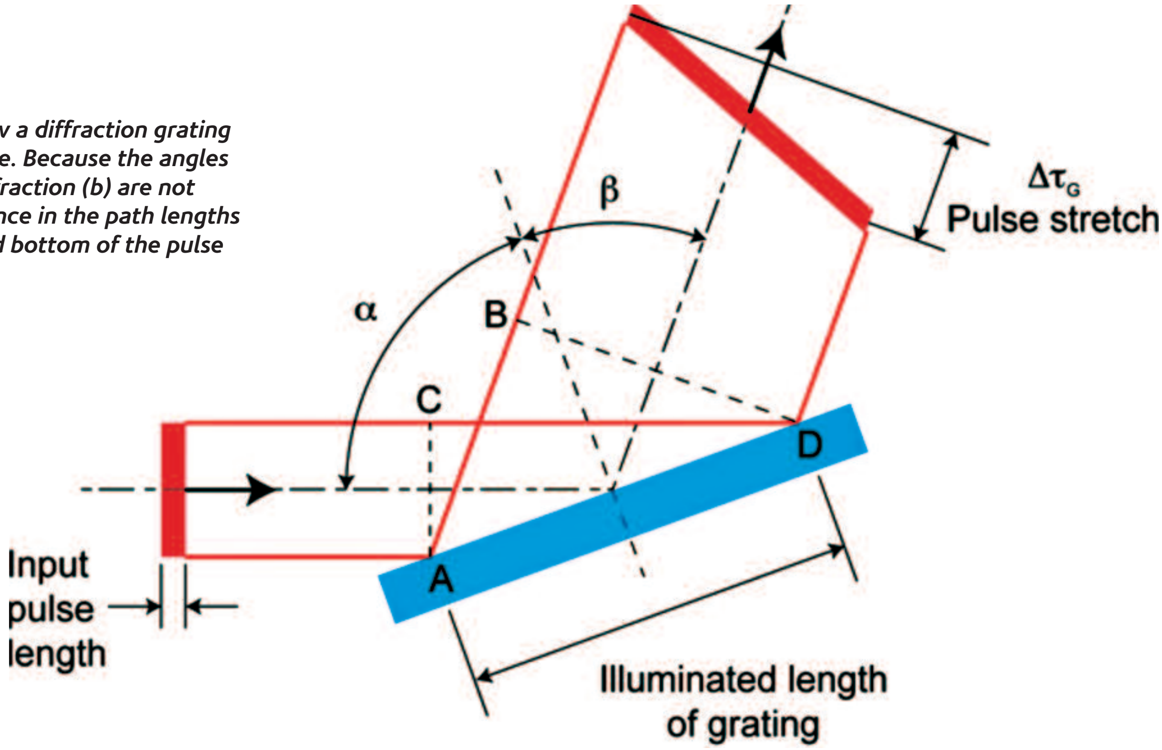


A superconducting VFFAG magnet designed for an 800MeV-12GeV proton ring taking the ISIS output beam as input.



Simulation of a proton beam, of the size produced by ISIS, being accelerated in the VFFAG machine to 15 times its original energy. Simulations such as these make sure the non-linearities in the VFFAG magnets do not make the usable aperture of the machine too small.

Beamline Design of a **Soft X-ray FEL**

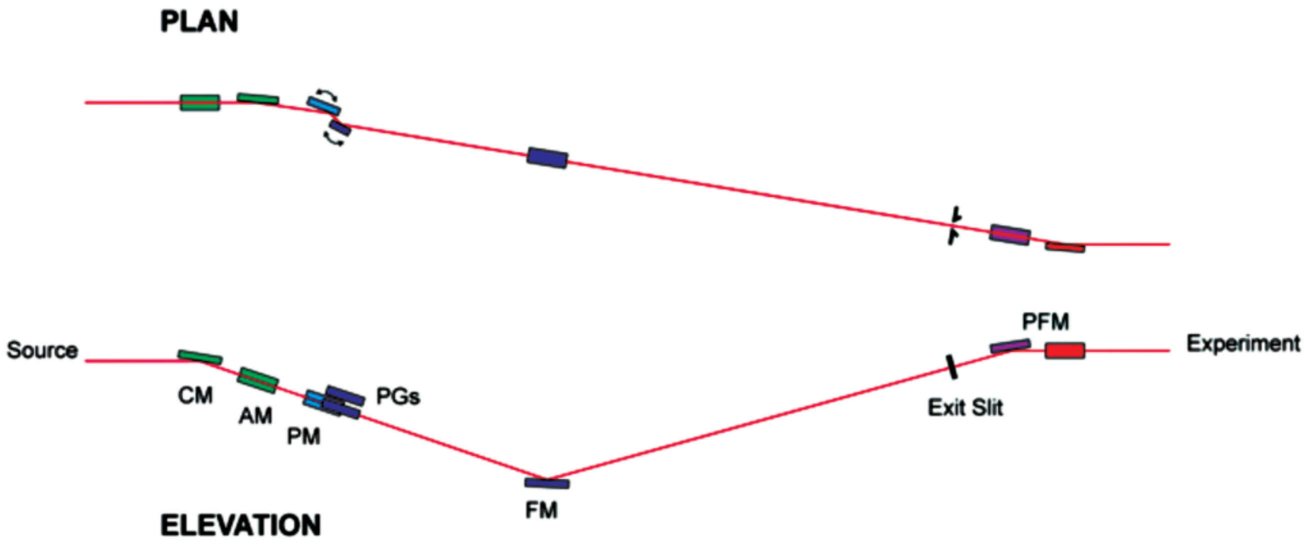


This diagram shows how a diffraction grating stretches a photon pulse. Because the angles of incidence (a) and diffraction (b) are not equal, there is a difference in the path lengths travelled by the top and bottom of the pulse (CD vs AB).

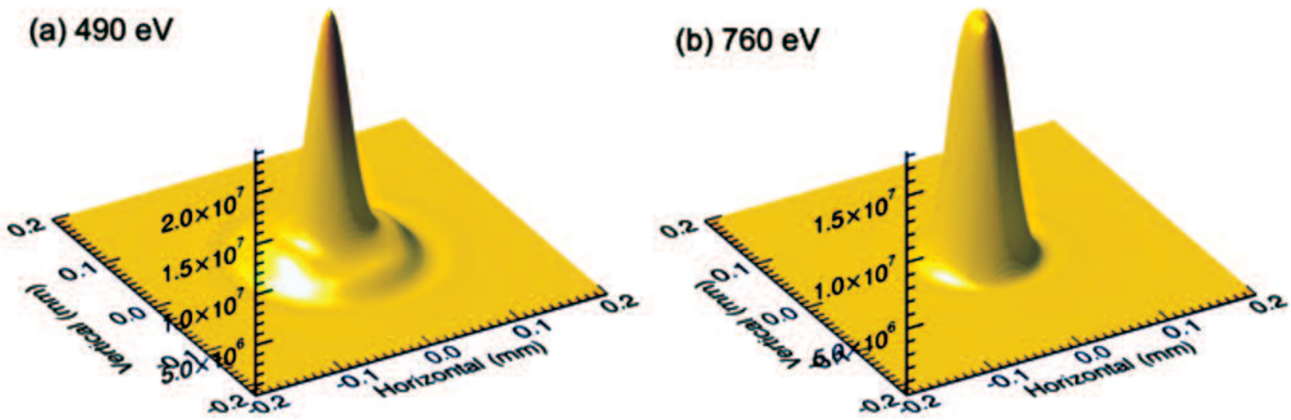
A seeded soft x-ray Free Electron Laser (FEL) can produce highly intense pulses with durations in the femtosecond range and bandwidths close to the transform limit. In an ideal world, spectral filtering would not be required, and would in fact be undesirable as it would stretch the pulse temporally. However, the reality is that the FEL output will be contaminated with radiation outside the spectral bandwidth of the main pulse. This could come from self amplified spontaneous emission (SASE) radiation from the unseeded part of the electron bunch or from harmonics of the radiation fundamental. For some experiments it will be necessary to remove these components but without substantially changing the temporal character of the main pulse.

The problem in the soft x-ray region is that the standard spectral filter, i.e. a monochromator, uses diffraction gratings to separate the different spectral components of the radiation before selecting those that are required. By the nature of the way a grating works, it adds a longitudinal shear to the pulse, which gives a temporal stretch equal to the radiation wavelength divided by the speed of light and multiplied by the number of illuminated grooves on the grating surface. This stretch, which is in addition to any stretch from the transform limit, can easily exceed the picosecond level.
The challenge of eliminating or minimizing the amount of pulse stretch can be tackled in several ways. A second grating can be added to reverse the shear of the first and thus give no overall pulse stretch. However, the penalty is very low transport efficiency since diffraction efficiencies in the soft x-ray are never very high. The grating can be oriented so that the grooves are almost parallel to the incoming light, but such an arrangement is difficult to implement on a FEL source.

An output of the work done for the NLS CDR (New Light Source Conceptual Design Review), a novel scheme for a monochromator beamline that gives an accurately controlled and limited stretch to the pulse whilst maintaining high transport efficiency has been developed. The scheme uses the established SX700 monochromator design working in collimated light. With this monochromator, the included angle at the grating can be freely chosen. Thus the radiation footprint and hence number of illuminated grooves can be defined, giving control over that amount of temporal stretch added to the pulse. A simple formula was derived for determining the correct operating angle of the grating. A key part of the design process was to understand the spatial properties of the FEL source and this was achieved by using the Daresbury wavefront propagation code FOCUS to propagate the output of FEL simulations from the code Genesis. Thus, the position, size and quality factor (M^2) of the source could be determined over the tuning range of the FEL. Without these codes proper design of beamlines for FEL source is not possible.



Layout of the soft x-ray monochromator beamline for a FEL source. The collimating mirror (CM) and adjustable mirror (AM) work together to collimate the light at the diffraction grating in the dispersive direction whilst focussing it at the exit slit in the non-dispersive direction. The plane mirror (PM) is used to vary the include angle at the plane grating (PG) so that the number of illuminated grooves is defined. The focussing mirror (FM) focusses the dispersed light at the exit slit, which blocks the unwanted spectral components. After the slit, a post focussing mirror (PFM) system refocusses the light at the experiment. The overall length of the beamline from source to experiment is 91 m.



Wavefront propagation with the FOCUS code is used to determine the source properties from the Genesis simulations. These are the results of reverse propagation of the simulated output at 490 and 760 eV photon energy used to the deduced source position. At the lower photon energy, the source is much less Gaussian-like due to wings of the electron beam approaching saturation.

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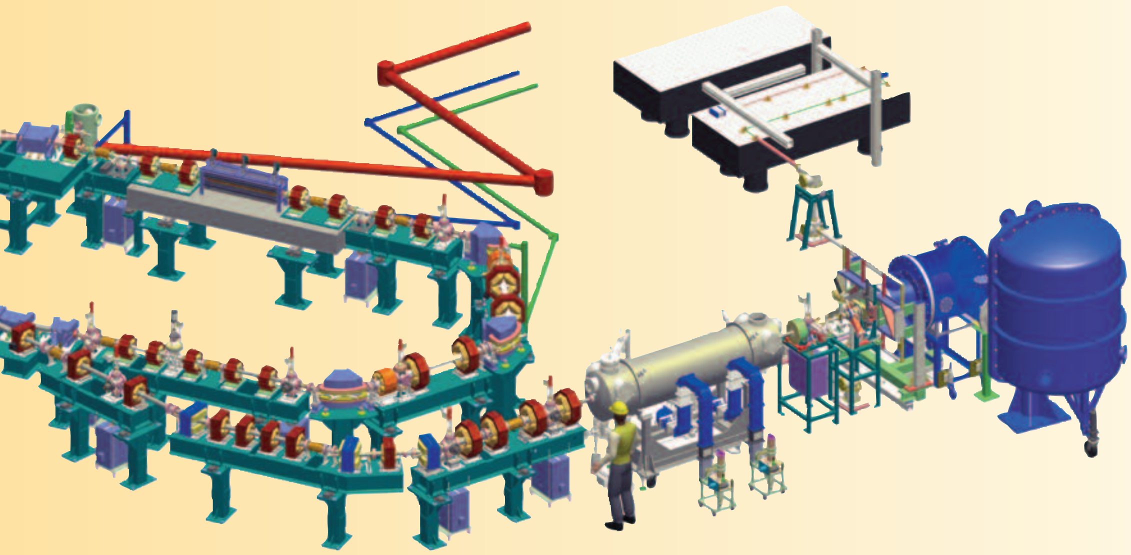
Development of Free Electron Lasers

The aim of the IRUVX-PP project, funded by the European Commission, was to undertake the preparations necessary to establish a consortium of free electron laser light sources in Europe, called EuroFEL. This consortium would also incorporate other advanced accelerator based facilities capable of delivering short pulses of light for a wide range of experiments. Coherent light beams of tuneable wavelength from terahertz (THz) through infrared, the visible spectrum, ultra violet and all the way to x-rays, delivered in femtosecond flashes of light can act as a stroboscope in a multitude of experiments to investigate dynamic effects in matter such as the processes involved in chemical reactions. These studies will complement the results obtained using table top lasers and synchrotron radiation facilities, but, unlike these now well established sources, they are very expensive and cannot support simultaneous multiple beamline operation. Furthermore, there are significant technological challenges that each country simply cannot afford to tackle independently. The importance of EuroFEL is demonstrated by its inclusion in the European Strategy Forum on Research Infrastructures (ESFRI) roadmap. Among the projected benefits is the coordination of collaborations for developing the technologies that will provide the infrastructure, world-class instruments and support services much needed by the research community to undertake their novel experiments.

The countries engaged in the project have been represented by a variety of public research organisations and institutes with existing or planned Free Electron Lasers (FEL) or accelerator based pulsed light facilities, and include Germany (DESY and HZB), Italy (Elettra and INFN), Sweden (MAX-lab), Switzerland (PSI), and the UK (STFC). STFC staff who worked on the project over the past three years mainly came from the Central Laser Facility (CLF), Swindon Office and ASTeC.

Other than the project management, STFC contributed to the output of every IRUVX-PP work package (WP) and ASTeC staff played a significant part in this work. One work package, WP3, led by staff in the CLF, sought to understand what type of technical developments would be required and how best to share ideas for working together in expert groups to achieve them. ASTeC took part in several very constructive workshops and initiatives which led to a mutual understanding of the current state-of-the-art. Future proposals to collaborate in key areas to overcome known difficulties and initiate joint technical developments were identified. Two technical work packages WP7 and WP8, were concerned with evaluating current limitations to experiments, such as beam jitter and intensity variations, and how to overcome them, as well as the fabrication of novel adaptive optics. Key to these advanced light sources is the ability to synchronise laser pulses to drive the accelerators and in measurements such as pump probe experiments where the intense FEL output is required to excite a transient state of matter and another photon source is used to characterise it. Latest developments in modelling wavefront propagation were shared to understand better the potential for optical components to degrade the light pulse quality (pulse duration, intensity, wavelength spread etc.) which is essential for designing beamlines that will meet the experimenters' needs. This culminated in a substantial report by the experts – "A compendium on beam transport and beam diagnostic methods for Free Electron Lasers". A number of investigations were undertaken, such as on aging and reliability of optical components in particular their deterioration when exposed to unprecedented intensity of light, and equipment was developed to advance diagnostics including electro-optical prototypes installed on ALICE with associated fast read-out electronics.

A clear demonstration of collaboration would be provided by a joint approach to satisfying the needs of users when they apply to various FEL sources. Understanding these needs and providing an appropriate level of guidance, particularly for first time users, as well as proposing solutions for avoiding duplicated effort when applying for beam time formed the business of WP2. Again, ASTeC staff helped to make significant progress in agreeing the basic principles needed for a unified access policy and in designing a prototype web-based portal for user access – a FEL user interface. WP4 focussed on a number of related human resource issues and considered how to overcome the key problem of limited expertise in this rapidly developing area and how to ensure mobility of workers for knowledge exchange unhindered by bureaucracy and employment constraints. The all important communications aspects were discussed by WP5, which also had the responsibility of producing newsletters and publicity material for the project. The outcome of this work is again a prototype website that will keep the communities in each member country well informed. A key element in seeking and receiving funding for these facilities is the potential to impact a nation's wellbeing whether this arises through improvements in health or from economic benefits and WP6 specifically focussed on how best to engage industry to achieve these aims. This work package was led by staff in Swindon Office and delivered proposals for identifying the important sectors of industry that will need to be grown to construct FEL facilities, the procurement, knowledge and technology exchange policies under which the consortium would operate, and the means of protecting intellectual property in technology developed in partnership.



Draft statutes and internal regulations developed by WP1 are now available to take EuroFEL forward as a European Research Infrastructure Consortium. However, it will require further debate and refinement of the encapsulated principles before they can be fully implemented. In the meantime, collaborations are being pursued through a much simplified memorandum of understanding on which agreement is eagerly awaited.

The final phase of this project came to an end on 31st March 2011, shortly after the 3rd Annual Meeting hosted by HZB. Once again, ASTeC and STFC were well represented and contributed to the lively discussions and proposals for continuing the successful work of the project.

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Partners of IRUVX-PP – the preparatory phase of EuroFEL

EuroFEL
FREE ELECTRON LASERS OF EUROPE

Science and Technology Facilities Council

The UK Science and Technology Facilities Council (STFC) is one of Europe's largest multidisciplinary research organisations supporting research, innovation and skills in particle physics, astronomy, nuclear physics and space science through UK universities and participation in major international collaborations. The Council designs, builds, operates and exploits world-leading, large-scale facilities in the UK including the ISIS neutron facility and the Central Laser Facility, and is a major stakeholder in the Diamond Light Source. It also provides access to international facilities. (For further information please visit: http://www.stfc.ac.uk/) STFC's Accelerator Science and Technology Centre (ASTeC) studies all aspects of the science and technology of charged particle accelerators, ranging from large scale international and national research facilities through to specialised industrial and medical applications. It is also a partner in the Cockcroft Institute with the Universities of Lancaster, Liverpool and Manchester. Additional collaborations include the John Adams Institute, other universities and international laboratories.

New Light Source (NLS) and ALICE FEL

In 2008, the UK Science and Technology Facilities Council (STFC) embarked on a project to examine the case for a New Light Source facility (NLS). To achieve the scientific goals, ultra-short pulses of intense, coherent X-rays at a high repetition rate, tightly synchronised to sources spanning THz to Vacuum-UV, were envisaged. A Conceptual Design Report was produced in May 2010, however, as a result of STFC's Science Programme Prioritisation it was decided not to proceed with the project at this time but to review the scientific priorities again in 3-5 years.

A broad range of accelerator physics R&D continues within ASTeC, including the development of an energy recovery linac prototype called ALICE (Accelerators and Lasers In Combined Experiments). Originally conceived as a test bed for a fourth generation light source, ALICE uses a superconducting RF booster and linac and incorporates an infrared Free Electron Laser (FEL). Electron bunches are transported through the FEL and back to the linac with the correct RF phase to decelerate them such that the energy is recovered and given to new bunches.

The ALICE FEL was commissioned in October 2010 and, once established, lased for several hours at a wavelength of about 8 microns. Lasing appeared quite tolerant to the machine settings and a scan of output power versus cavity length showed the expected behaviour. This is the first such FEL to lase within the UK and is the only energy recovery driven FEL to operate within Europe. Full characterisation of FEL performance and output properties is in progress. For further details see: http://alice.stfc.ac.uk/accelerator/index.html.

The production of short-pulse X-rays was successfully demonstrated using Compton Back Scattering prior to the installation of the FEL and THz radiation is being used for experiments as well as a diagnostic tool, e.g. confirming bunch compression. The FEL IR beamline is currently under construction. ALICE also acts as the injector for a 19-cavity non-scaling Fixed Field Alternating Gradient (FFAG) ring known as EMMA (Electron Machine with Many Applications). In this type of accelerator the bending magnets have a radial magnetic field gradient whose strength is constant during acceleration requiring the orbit to vary considerably as the particle beam momentum increases and resonances are rapidly crossed. Commissioning of EMMA is also underway.

ALICE FEL parameters

Parameter	Design Value	Achieved so far
Energy (MeV)	35.0	27.5
Bunch Charge (pC)	80	40-60
Normalised Emittance (mm-mrad)	10	~12
Bunch Length, FWHM (ps)	1.4	~1.5
Energy Spread, FWHM (%)	0.25	~0.7
Max. Train Length (µs)	100	100
Bunch Repetition Rate (MHz)	81.25	16.25
Max Number of Bunches per Train	8125	1625
Cavity Length (m)	9.224	9.224
Cavity Mirror ROC (m)	4.85	4.85
Single Pass Gain (%)	66	~25

MICE

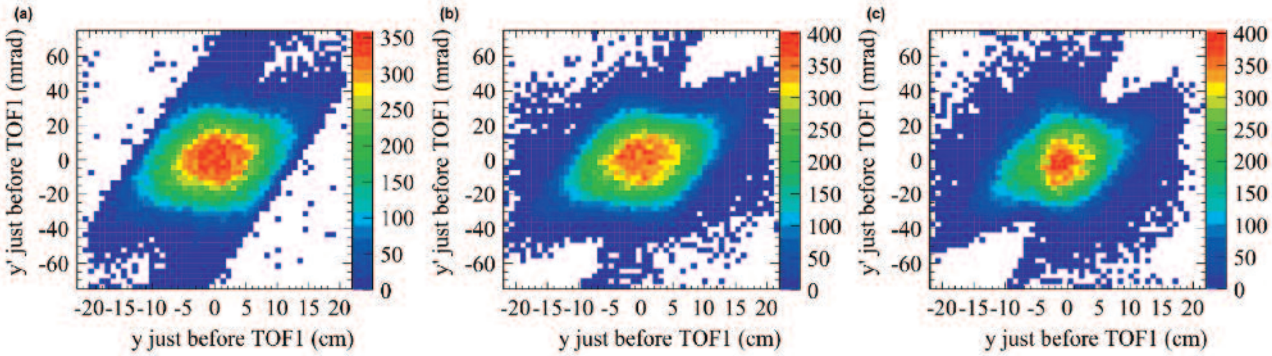
The international Muon Ionization Cooling Experiment (MICE), which is under development at the Rutherford Appleton Laboratory (RAL), will provide the proof-of-principle of the novel technique proposed to cool muon beams at the Neutrino Factory and the Muon Collider. The short muon lifetime (2.2 s at rest) makes it essential that cooling is carried out quickly. Traditional techniques are too slow, taking many lifetimes to cool the beam. Ionization cooling, a single-pass process in which the muon beam is passed through a series of liquid hydrogen absorbers interspersed with accelerating RF cavities, is fast. Successfully demonstrating ionization cooling with MICE will be a critical step on the road to making intense high energy muon beams a new tool for particle physics.

The Experiment

The MICE experiment comprises three 20 l volumes of liquid hydrogen and two four-cavity linac modules. Beam transport is achieved using a number of solenoids: the "focus coils" that surround the liquid hydrogen absorbers and the "coupling coils" that surround the linac modules. The MICE cooling channel is expected to reduce the emittance of the beam by 10%. The change in emittance will be determined with a relative precision of ±1% using two solenoidal tracking spectrometers that sandwich the cooling channel. Each spectrometer solenoid is instrumented with a scintillating fibre tracking detector. A particle identification system (scintillator time-of-flight hodoscopes and threshold Cherenkov counters) upstream of the cooling channel allows a pure muon beam to be selected. Downstream of the cooling channel, a final hodoscope and a calorimeter system allow muon decays to be identified and rejected. The calorimeter is composed of a lead scintillator section (known as the "KL") followed by a fully active scintillator detector in which the muons are brought to rest (the Electron Muon Ranger, EMR).

Characterising the MICE Muon Beam

The first major milestone in the MICE experimental programme has been passed with the demonstration that the MICE muon beam on ISIS is capable of delivering a beam of the required purity over the range of momentum and emittance necessary to investigate ionisation cooling. This has been established through the analysis of the data collected during the highly successful running period in the summer of 2010. The time-of-flight hodoscopes were used to measure the position of the particles in the beam and a transport matrix approach was used to estimate the beam momentum



and emittance. An example of the results that have been obtained is shown below. The purity of the beam was established using the time-of-flight measurement together with the Cherenkov counters and the KL. The data is now being prepared for publication.

This summer, a prototype of the final piece of the instrumentation for MICE, the EMR was installed and commissioned successfully. This significant step towards the completion of the instrumentation for the experiment paves the way for the completion of the EMR. The completed device will be shipped to RAL early in 2012.

Delivering the Infrastructure

The infrastructure that supports the experiment is as important to its success as the components of the cooling channel and the instrumentation. Over the past year, the UK teams many of whom are drawn from the Daresbury and Rutherford Appleton Laboratories, have made strides in delivering the systems that present the greatest technical risks. Since a full description of all the contributions is beyond the scope of this short article, an outline of three of the highlights of the excellent progress is defined below.

Three liquid hydrogen delivery systems are required to service the three absorber modules. An excellent collaboration between Daresbury Laboratory (DL) and RAL staff has delivered the first system. To date, the test absorber has been filled with 20 l of liquid helium; a stringent test of the cryostat and cooling circuit. The team is now completing the safety case that is required before the system can be operated with hydrogen.

The two linac modules in MICE require a total of 8 MW of RF power at 201 MHz. Four high power amplifiers based on the Thales 116 triode will provide this power and DL staff have completed and commissioned the first system. Using tubes recovered from the supplies that serve the ISIS injector linac, the amplifier has delivered an output power of 1 MW. The successful re-commissioning of the first amplifier is an important step towards the completion of the RF system for MICE.

To serve the experiment when the cooling channel is in place requires the upgrade of the control electronics for the MICE target. The photograph below shows the completed target controller electronics. The bespoke system has been commissioned and is operating flawlessly in the MICE target test rig at RAL.

The Way Forward

Next year will be equally exciting for MICE. Over the course of the year, both spectrometers will have been installed and commissioned. The focus coil, presently under construction at TESLA Engineering, together with the first hydrogen absorber will be installed. This equipment will allow the first investigation of multiple cooling scattering with MICE. The two linac modules and the two remaining absorber/focus coil modules will then be added as the experiment progresses to the first ever demonstration of ionization cooling. This will be a landmark, perhaps marking intense, high energy muon beams, the Neutrino Factory and the Muon Collider an option for the field.

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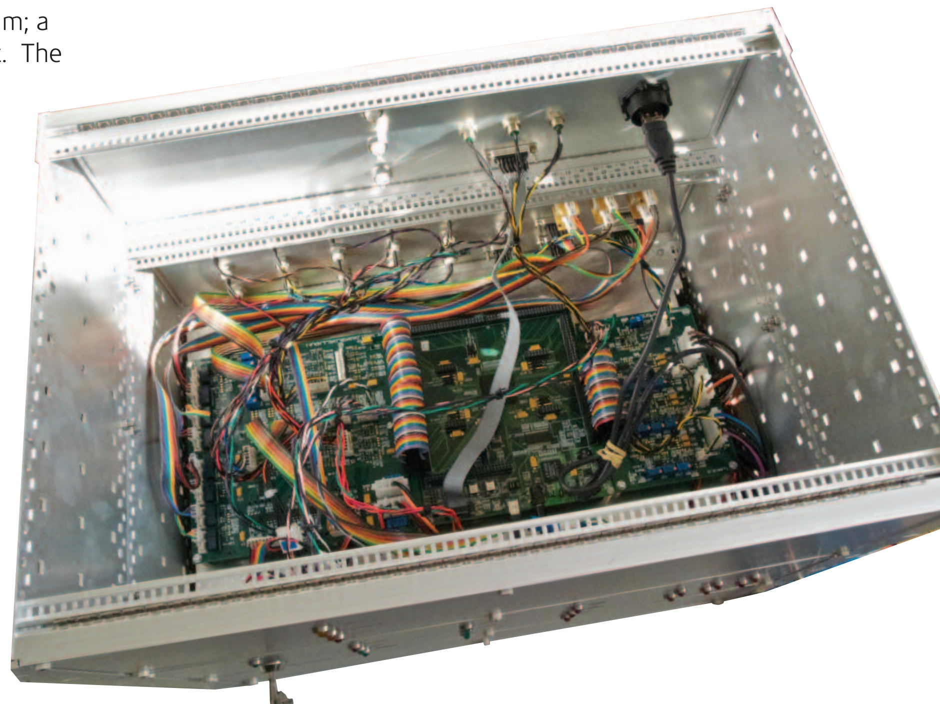

Optical Clock **Distribution System**

Highly stable clock distribution across large scale facilities is important for the synchronisation of beam generation, beam manipulation components and end station experiments. The aim of the project is to develop an optical clock distribution system which can be stabilised to sub-10 fs arrival time stability.

In the past year a prototype of an optical clock distribution system has been installed on ALICE. The system incorporates optical fibre links to deliver femtosecond optical pulses to the required sites. The femtosecond pulses act as both the delivered clock signal to use with synchronisation diagnostics and also as the error signal to detect optical path length changes in the fibre links. This enables the optical propagation path to be actively compensated thus providing the required arrival time stability.

The installed link is novel in its delivery of sub-100 fs pulses to clock sites, providing improved resolution to synchronisation diagnostics, as well as its exclusion of bi-directional amplifiers means that there is improved passive stability of the link. Characterisation of the installed link has shown that it has enough stability to provide beam arrival information with greater resolution than can currently be obtained on ALICE and a beam arrival monitor has been installed to exploit this improvement. Developments are now underway to use non-linear crystals to optically lock the fibre link down to within the target level. In addition, novel locking schemes making use of the optical carrier itself are under development which could further increase the resolution of the path length detection while preserving its range.

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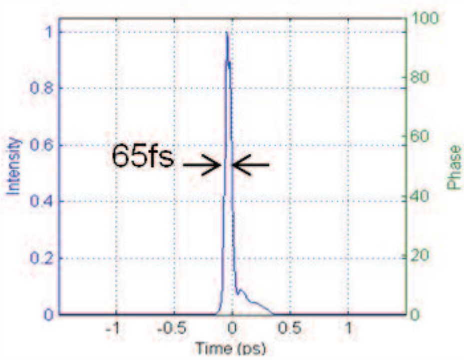

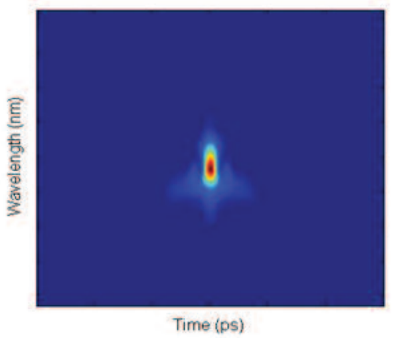

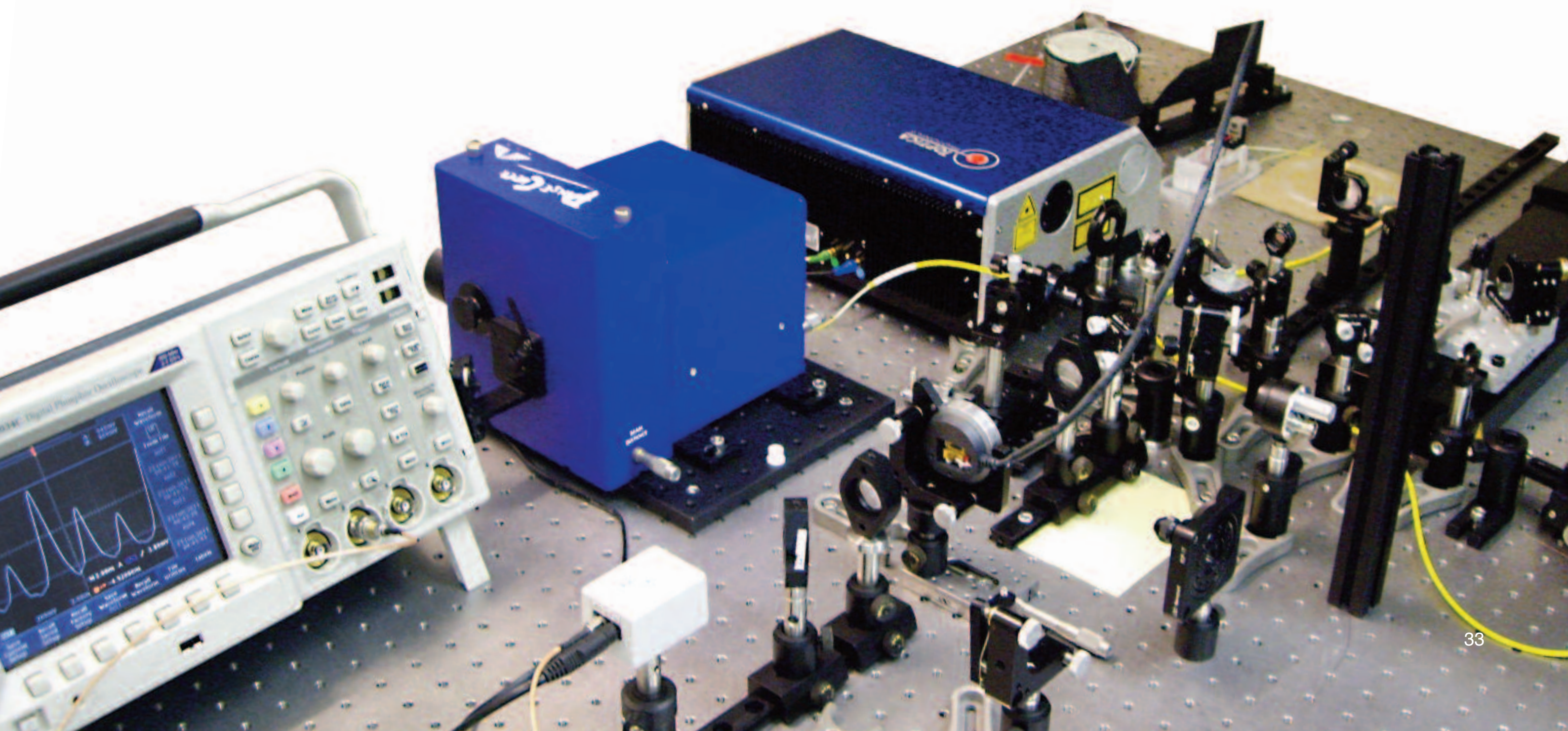

Superconducting **Undulators**

Undulators are special periodic magnets that are used to generate synchrotron radiation in third (e.g. Diamond Light Source) and fourth (e.g. ALICE free electron laser) generation light sources. They are conventionally built using strong permanent magnet blocks, but for applications requiring the very highest magnetic field strengths it is essential to use superconducting magnet technology instead. ASTeC has been working with Technology Department for a number of years now on developing superconducting undulators, primarily for the International Linear Collider positron source. This has culminated in the fabrication and successful testing of a 4 m long helical undulator that has been specially designed to generate circular polarisation.

Recently the team has taken on the new challenge of building a superconducting undulator suitable for the Diamond Light Source. This is actually in many ways more difficult than the helical magnet as the magnetic field quality requirements are much more stringent and this in turn is reflected in the engineering tolerances that must be achieved. Nevertheless the team has made impressive progress with the design and are now very much in the R&D phase of this project. A key feature of the design is that the undulator is required to operate at 1.8 K, rather than the usual atmospheric liquid helium temperature of 4.2 K. A novel cryogenic scheme has had to be developed and this will be proven in isolation prior to full magnet fabrication in late 2011. In parallel, a short (30 cm) test undulator will be constructed and tested to prove the engineering concept is able to achieve the required tolerances. It is anticipated that the complete 2 m long undulator will be installed in Diamond Light Source in 2014 and if it achieves the required specification it will be the most advanced undulator ever built.

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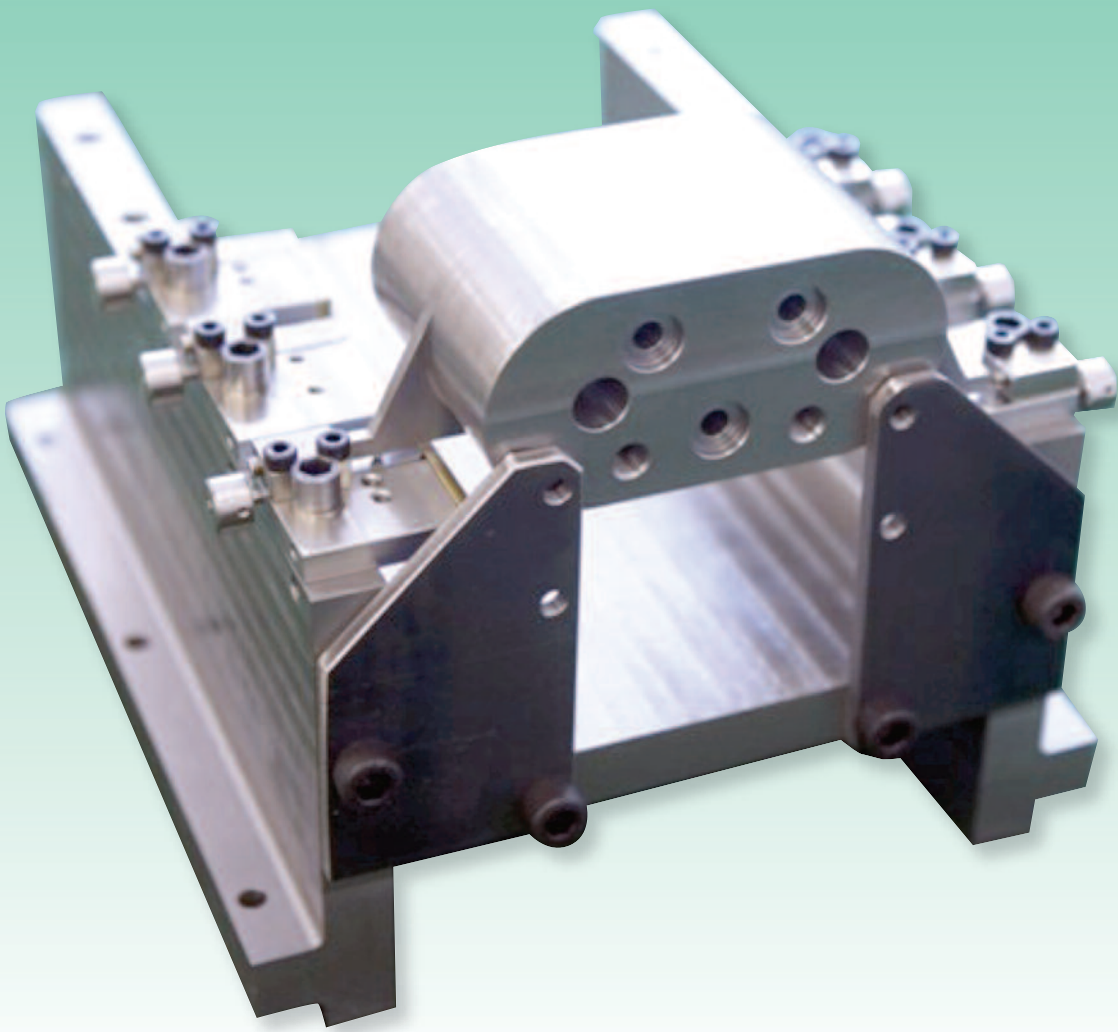
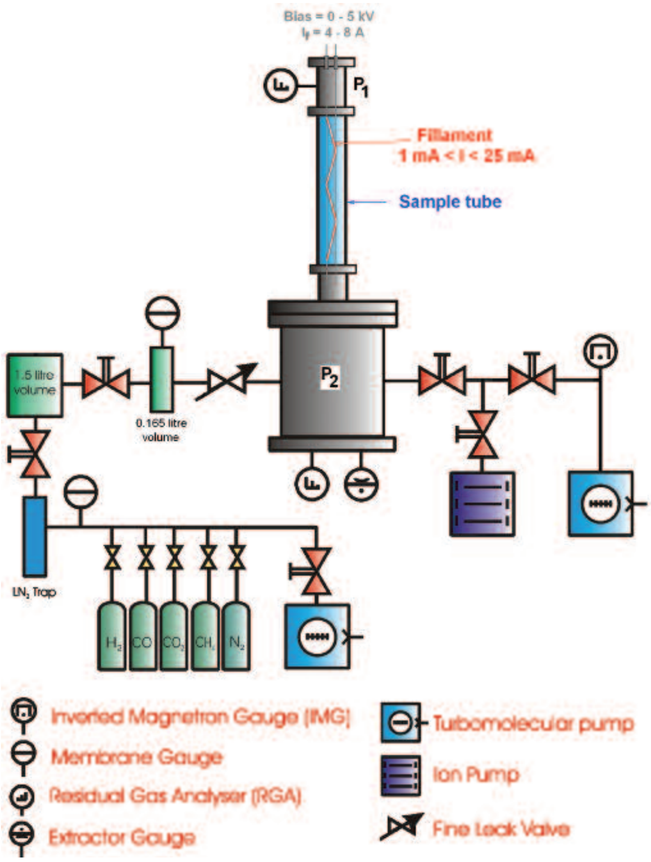
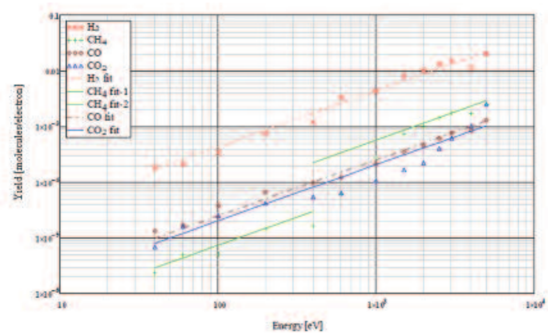


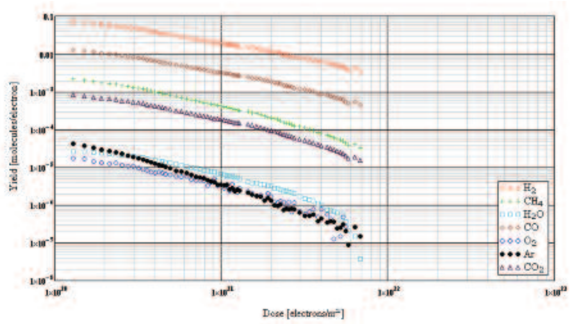
Electron Stimulated Desorption Study



Layout for electron stimulated desorption measurements from tubular samples.



ESD yield as a function of electron dose for stainless steel sample baked at 250 °C for 24 hours.



ESD yield as a function of electron energy for stainless steel sample baked at 250 °C for 24 hours.

To design any new accelerator one needs desorption yield data for different materials prepared and treated under different conditions. The focus of the work was on developing the method for electron stimulated desorption (ESD) measurements from tubular samples, improving the existing set up, analysing the results and creating a database with studied materials for future accelerator vacuum design. The ESD from stainless steel, copper and aluminium samples was studied as a function of many parameters such as electron dose, energy of electrons, bake-out temperature, pumping before the bombardment starts, etc. The results were presented at the European Vacuum Conference (Salamanca) in September 2010 and published in a paper in Vacuum.

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NEG Coatings Development

The ongoing collaboration between ASTeC and Manchester Metropolitan University (MMU) aimed to study and further develop the novel vacuum technology of non-evaporable getter (NEG) coatings. This technology, originated at CERN, allows coating of the entire beam vacuum chambers of the particle accelerator to reduce gas desorption and provide distributed pumping speed at lower cost.

The work performed by ASTeC this year has focussed on two things:

- Engineering the NEG film with required pumping properties, understanding the role of each metal in the film, influence of deposition conditions, advantages of alloy target.

- Studying the NEG coating under particle bombardment (photons, electrons, ions, etc.). The aim is to optimise the NEG coating for the best performance (lower pressure and high lifetime) under particle bombardment.

The best pumping properties were achieved with physical vapour deposition (PVD) coating using a new TiZrHfV alloy target instead of four twisted filaments, the performance of this new coating is even better. This NEG coating can provide the necessary pumping properties after NEG activation at 140°C for 24 hours, 40°C lower than one made with three twisted filaments. This is very useful for accelerator design and allows a reduction in the cost of bake-out and permitting the use of materials for components of the vacuum chamber that it is not possible to bake at high temperatures.

The electron stimulated desorption from NEG coated samples was studied as a function of many parameters such as electron dose, energy of electrons, NEG coating activation temperature and procedure, and NEG saturation with different gases. It was found that NEG coating allows lower pressure to be reached even when non-activated compared to the baked stainless steel sample. NEG coating can be activated by an electron bombardment, i.e. in some cases the NEG activation by heating to 140-180°C for 24 hours can be avoided. The desorption yields of activated NEG reduces with an accumulated electron dose. The desorption yields are linearly proportional to the energy of electrons in the range of 30 to 5000 eV.

These results were presented in invited talks at the Applied Physics and Technology Division Conference of the Institute of Physics in Manchester in April 2010, at the European Vacuum Conference (Salamanca) and 63rd IUVSTA Workshop (Avila) in September 2010 and at the Symposium on Vacuum Based Science and Technology (Kaiserslautern) in October 2010 and published in three journal papers.

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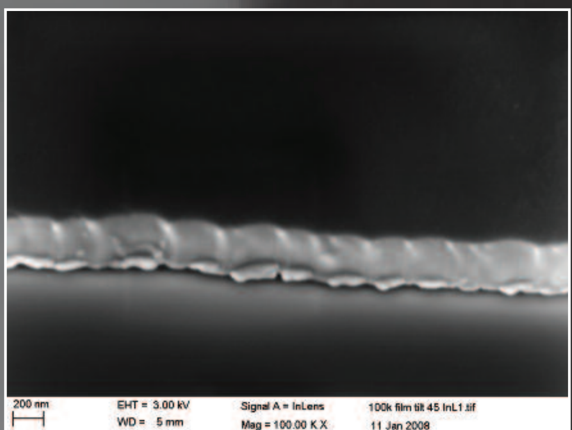

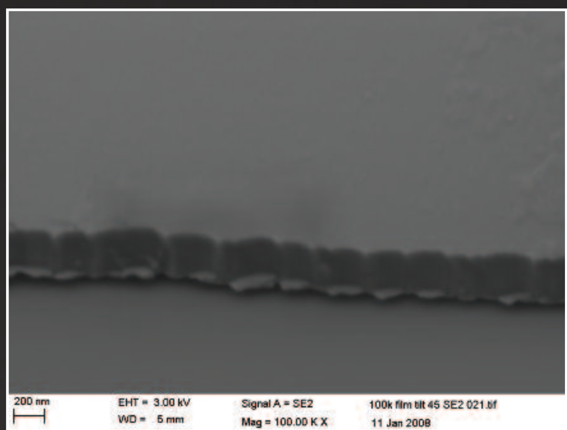

X-section SEM micrograph of a TiZrVHf film deposited on stainless steel using a quaternary alloy wire.

Hydrodynamic Approach to the Free Electron Laser Instability

Free electron lasers (FELs) are tuneable sources of coherent radiation and a number of FELs are currently operated around the world. A large number of studies dedicated on the subject exist nowadays and FEL theory is both well-advanced and well-understood. At the same time exotic new ideas such as solitons in FELs have been considered as well.

A complete, rigorous approach to FEL modelling could potentially uncover new physics and lead to new applications. Such an approach is the self-consistent solution of the kinetic (Vlasov) equation and the Maxwell equations. Vlasov's equation describes particle balance in the phase space and implies conservation of the total number of particles. In exactly the same way the continuity equation (in fluid dynamics or in electrodynamics) states that the total amount of fluid or charge is conserved. Clearly, in the absence of ionisation or recombination the rate at which the number of particles occupying a given volume of phase space (known as the particle distribution function) changes is equal to the net particle flux through the walls surrounding that volume. The flux in turn is determined by the forces acting on the particles through the electromagnetic field. The latter is described by the Maxwell's equations and its source terms are determined by the ensemble of particles itself. This mutual coupling of the electromagnetic field and the charged particles dynamics is known as self-consistency.

Unfortunately finding solutions to this system of equations in its original form is not an easy task. Therefore, a natural question to ask is if it is possible to replace the kinetic equation with an equivalent set of equations, which is both easier to work with and, in the same time, retains (most of) the original physics. A common approach in plasma physics is to work with the moments of the kinetic equation rather than with the equation itself. These moments are obtained by multiplying the kinetic equation by the momentum, momentum squared and so on and then performing integration in the momentum space. The result is a hierarchy of hydrodynamic equations: the continuity equation, the macroscopic momentum balance equation and the energy balance equation are the three lowest-order members of the set.

In the present work it is shown that by using a specific assumption for the particle distribution function the resulting set of hydrodynamic equations is finite: only the two lowest-order members of the hierarchy are present and they are coupled to the Maxwell's equations. Note, that space-charge effects are naturally present in this formulation. In addition the relatively simple set of hydrodynamic equations (compared to the original kinetic equation) means that a much more efficient numerical modelling is now possible. To examine the consequences of the newly derived system its linear stability properties have been studied as well. This results in determining the small-signal gain of the laser and the figure below shows the normalized small signal gain as a function of the normalized radiation frequency for various beam energies. Satisfactory agreement with previously reported results based on the exact solutions to the linearised Vlasov equation has been also found.

The new approach is now being applied to FELs and it is anticipated that this could potentially lead to new insights (e.g. the possibility of soliton generation) as well as a more complete and computationally efficient model of the FEL process.

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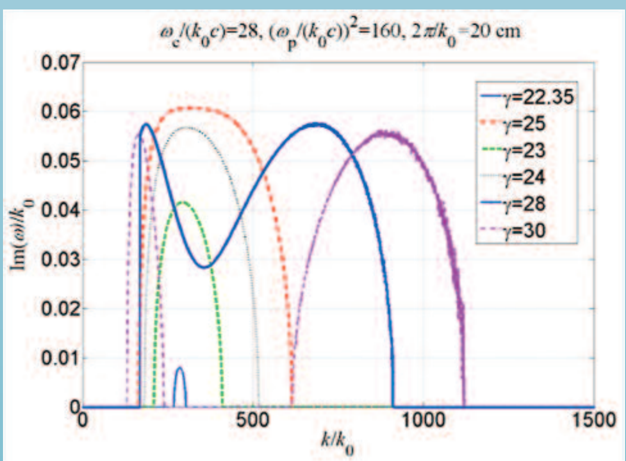

Dependence of the normalised small signal gain on the radiation wavenumber, k for various energies where ω_c and ω_p are the cyclotron and plasma frequencies, respectively, $k_0=2\pi/l$, (l is the undulator period length).

Outreach

"Masterclass with a twist ?" The Institute of Physics created the particle physics masterclass programme which sees annual events run all over the country aimed at giving A-level students an insight into particle physics as a pre-cursor to undergraduate study.

Accelerator Masterclass

Daresbury Laboratory have run a masterclass for many years, but this year, in recognition of the fact that Daresbury is in a unique position to offer an insight into the tool which underpins particle physics (the particle accelerator itself), the Daresbury class was re-branded as an accelerator physics masterclass.

This complementary event was run for the first time at Daresbury in March 2011, with ASTeC staff working closely with University colleagues to run the masterclass on behalf of the Cockcroft Institute.

The masterclass programme contained various talks and demonstrations intended to give a basic knowledge of particle accelerator systems, and included a 3D flythrough of the ALICE and EMMA accelerators in advance of a hands-on experiment to estimate the ALICE injector beam energy. There were additional new tasks investigating the physics of electron bunch compression which is needed to effectively drive the ALICE free-electron laser, and a design exercise centred on the Diamond Light Source in which the headline design parameters for the accelerator was estimated. Feedback received from participants was overwhelmingly positive, with one student immediately registering for a summer placement.

Mini Science Festival

In October, Daresbury Laboratory ran its annual British Science Association mini festival which was well-attended, despite damp weather. The Cockcroft Institute stand contained a number of eye-catching and involved demonstrations, including a fine electron beam tube which is essentially a miniature particle accelerator, but by far the greatest interest was in the Van de Graaff generator. There was a continuous queue of children waiting to 'connect' with the generator and enjoy a hair-raising experience. The generator worked very hard that day, and succeeded in raising hair, despite the dampness of the day.

School Visits

There have been six large group visits to ALICE and EMMA over the course of the year, mainly from schools. The impact of these visits is very high as the ALICE and EMMA accelerators are small enough to view and comprehend easily, yet complex and ground-breaking enough to fire the imagination! These visits have lead to requests for further visits, and some local schools now consider their visit to be an annual event which gives their students a key insight into 'real' science.

Links with Altrincham Grammar have been strengthened further through ASTeC's presence at their annual careers fair. The fair is open to several other schools in the Altrincham locality, and proved to be a great opportunity to tell people about STFC, the Cockcroft Institute and particle accelerator activities at Daresbury, and tempt them into a career in science and engineering.

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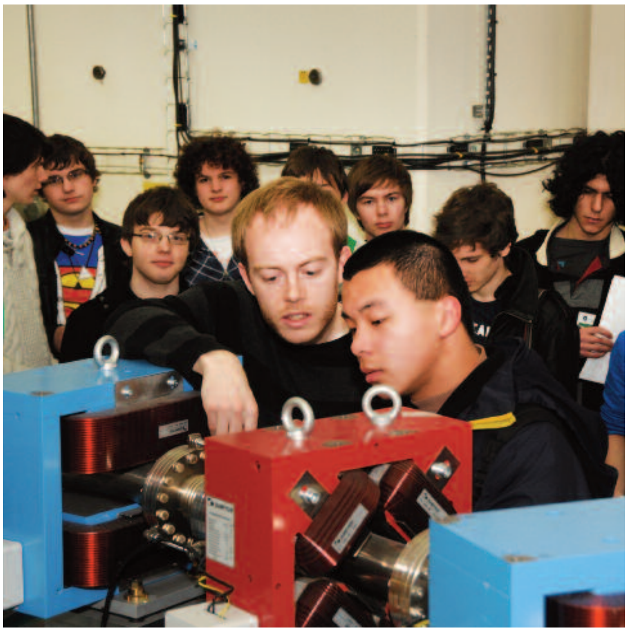

Cryogenics Training

A one day training course on cryogenics was held at the Cockcroft Institute, Daresbury Laboratory on 20th April 2010. This was the third in the series of the Cryogenics Training programme organised by ASTeC. The first two courses were conducted at Rutherford Appleton Laboratory (RAL) in June and October 2009. A total of 35 participants from diverse fields such as RF engineering, accelerator physics, detectors, and engineering design, as well as a number of the students from the Cockcroft Institute participated in this course.

Rob Done (RAL) opened the proceedings with a talk on the 'Introduction to Cryogenics' which explained how to translate the laws of thermodynamics to design some of the real low temperature systems.

This was followed by a presentation by Adam Woodcraft (ROE) who described the behavior of material properties at low temperatures, explaining how the data available in the literature could be misleading and gave some practical advice to extract useful information from various sources.

Additional talks were provided by Tom Bradshaw (RAL) and Shrikant Pattalwar. Tom's talk described the technology of 'Closed Cycle Refrigerators' and their applications in some of the space programmes. Included within this subject was the important topic of multi-layer insulation, a critical component in any cryogenic system. Shrikant's presentation provided an introduction to 'Large Scale Cryogenics', highlighting some of the challenges in developing cryogenic systems for modern particle accelerators.

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Workshops and Visits

Accelerator Technology Showcase

On Friday 22nd October, Peter McIntosh chaired an Accelerating Science: Accelerating Business showcase event which highlighted the fundamental areas of accelerator science and technology, to an invited audience of 30 selected industrial companies, whose product portfolio is synergetic with these specialist areas of research and development. Many of the invited companies did not have strong links at all with any previous or current accelerator activities on the Daresbury site. The remit for the event was to try and strengthen industry engagement with ASTeC and Cockcroft Institute accelerator programmes and to identify potential funding opportunities which could support such collaborations. The event included a series of presentations from leading accelerator scientists and technologists from ASTeC and the Cockcroft Institute highlighting the key accelerator technology R&D areas across a wide range of technical disciplines which included RF, vacuum science and advanced laser systems. This was then followed by a tour of Daresbury's ALICE and EMMA accelerators as well as the new Engineering Technology Centre. The event ended with case study presentations from two cutting edge businesses that have benefitted from successful collaboration with STFC and ASTeC.

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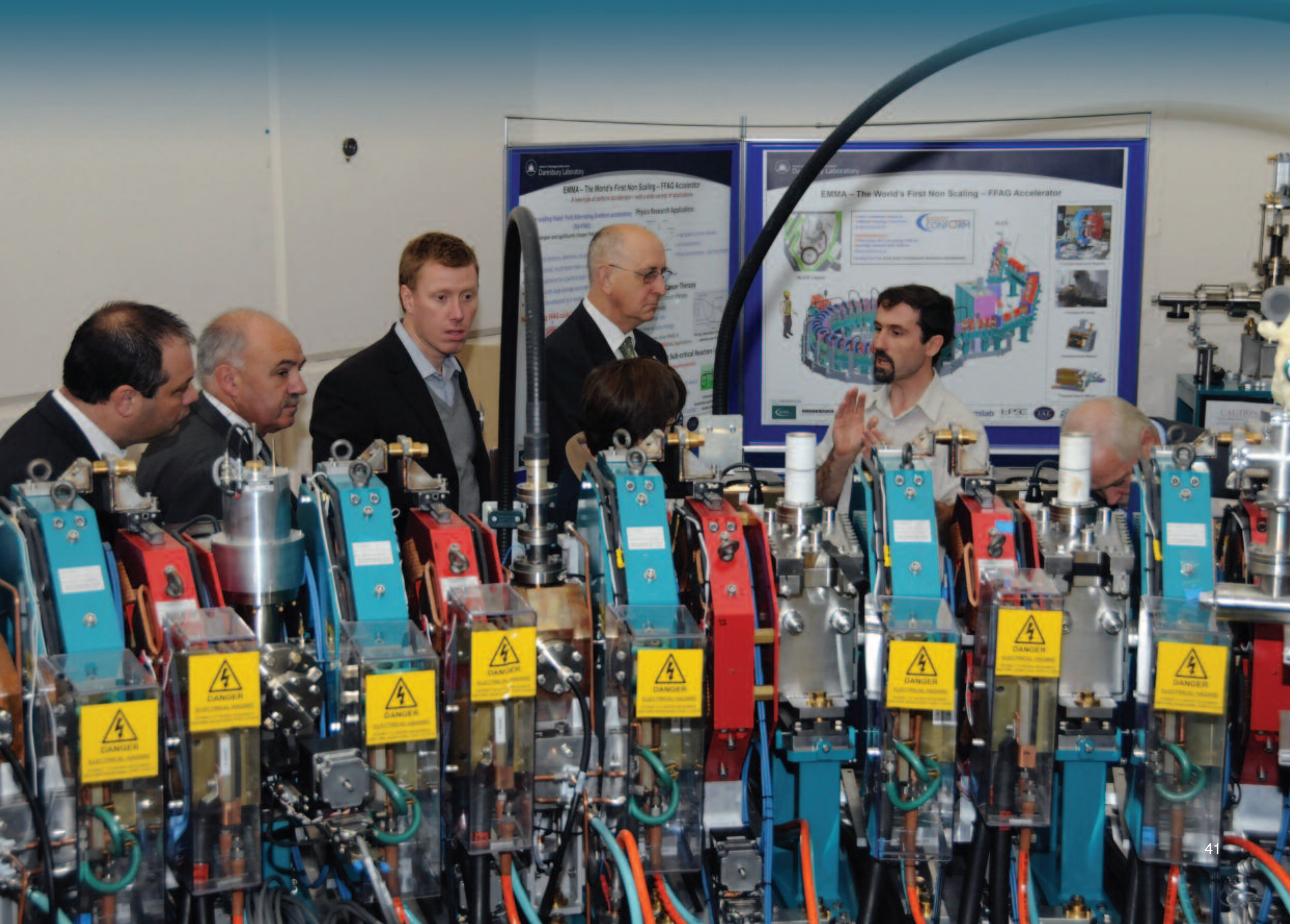

Workshops and Visits

ICFA Beam Dynamics Mini-Workshop on Deflecting Crabbing Cavity Applications in Accelerators

Originally organised for 21st – 23rd April 2010, which then had to be cancelled at short notice due to the Icelandic volcanic ash cloud, the 2nd ICFA Beam Dynamics Mini-Workshop on Crabbing/Deflecting Cavity Applications in Accelerators was rescheduled and hosted at the Cockcroft Institute from 1st – 3rd September 2010 and chaired by Peter McIntosh from ASTeC. A total of 42 delegates participated, including Shakespeare Engineering and Tech-X (UK) as industrial sponsors, who were able to witness the tremendous growth in application of these systems for beam manipulation and precision diagnostic purposes for both storage rings and linacs. A number of new application areas were highlighted, which included CLIC, Project-X, SPX@ANL, CEBAF Upgrade and XFEL, as well as updated R&D progress on LHC and Spring8. The fundamental scientific benefits of such short pulse x-rays, developed using these systems were also reviewed.

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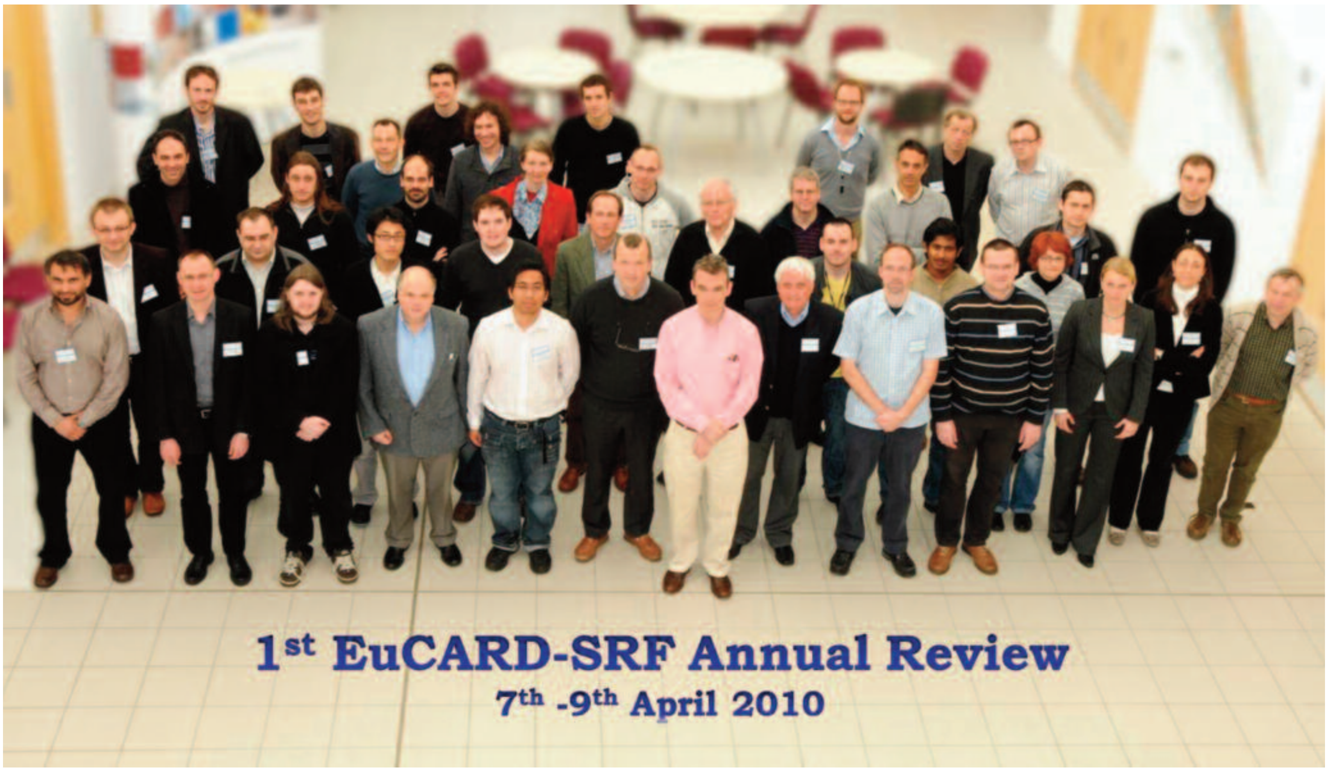
Workshops and Visits

EUCARD Meeting



The 1st EUCARD Superconducting RF (SRF) Annual Review was hosted at the Cockcroft Institute from 7th – 9th April 2010. During which, a total of 15 leading European Institutes participated in reviewing progress in many different fields of SRF technology as part of a collaborative EUCARD work-package programme, areas of research which include:

- SRF gun and photo cathode development,
- Innovative SRF structure design and optimisation,
- Higher Order Mode (HOM) diagnostics,
- Thin film technologies,
- Improved processing facilities,
- Precision RF control systems.

The participants also had the opportunity to see the ALICE and EMMA accelerator facilities, as well as gaining an overview of the SRF programmes the Cockcroft Institute has ongoing at present, such as the International Cryomodule Collaboration project, where Cockcroft is leading the design for a new highly optimised Energy Recovery Linac (ERL) cryomodule and the International Liner Collider (ILC) crab cavity system project. For the latter project two SRF dipole-mode cavities have been synchronised in a vertical cryostat to phase control tolerances which exceed the requirements for ILC.

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Workshops and Visits

Mike Poole Fest

At the end of June 2010 Mike Poole retired from Daresbury Laboratory after more than 43 years of continuous service. During his career Mike made a tremendous impact, both nationally and internationally, on the field of particle accelerators. In order to recognise this immense contribution a special symposium, "The Mike Poole Fest", was held at Daresbury Laboratory on the 29th June 2010.

The fest was attended by more than 150 of Mike's colleagues (past and present) as well as senior STFC staff. Mike was also supported on the day by his wife, his four children and his brother.

Mike received many gifts including a presentation from the Daresbury Laboratory Table Tennis Team and a photograph collection bound into a hardback book signed by many of his colleagues and those present on the day.

Workshops and Visits

X-Band Workshop

ASTeC and the Cockcroft Institute hosted "XB-10", an International Workshop on X-Band RF Structures, Beam Dynamics and Sources from 30th November to 3rd December 2010 at the Cockcroft Institute.

The purpose of the workshop was to pool common areas of interest and to explore the physics and technology of RF X-band accelerators. In order to achieve high accelerating gradients room temperature X-band structures are a natural choice. As an example of this, CLIC, is now aiming at an accelerating gradient of 100 MV/m at 12 GHz. Other accelerators are already in use commercially at X-band for medical cancer treatment and for cargo scanning.

The workshop incorporated talks both on relatively conventional accelerators, through to linacs exploring radically different structures. The workshop was attended by 80 scientists, engineers and students from around the world, all participated in XB-10 to study a range of RF and beam dynamics issues associated with X-band accelerators. The workshop proceedings will be published as a special issue of "Nuclear Instruments and Methods (Accelerators).

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Workshops and Visits

IOP Particle Accelerators and Beams Group Workshop

On Friday 25th February 2011 the IOP PAB (Institute of Physics Particle Accelerator and Beams) group hosted a half day workshop at the Rutherford Appleton Laboratory, "The Status and Challenges of Simulation and Computing for Accelerators". ASTeC staff were well represented with Chris Prior, Chris Rogers, Julian McKenzie and Peter Williams all giving talks. Other contributors came from ISIS and the Cockcroft and John Adams Institutes. The keynote speaker was the author of the General Particle Tracer code, Bas van der Geer of Pulsar Physics, Netherlands.

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ASTeC Future Vision of Electron Test Accelerators

As part of a fundamental reassessment of ASTeC's strategy in 2010 it was decided to evaluate the priorities for electron test accelerators in order to generate a five to ten year vision for how existing test accelerators should be developed and exploited. Also it was necessary to assess what the longer term requirements are in order to maintain and enhance ASTeC's position as a leading centre for accelerator R&D. Proposals were solicited and the top priorities were presented and debated at an open meeting at the Cockcroft Institute on 7th December 2010. The achievements and future plans for both ALICE and EMMA were presented as these existing test facilities form a key part of the strategic vision. In addition, ideas were proposed for new facilities focussing on areas such as laser plasma wakefield acceleration and also single pass, high gain, free electron lasers. The meeting fully supported the assertion that experimental test accelerators are a vital tool for every vibrant particle accelerator research team engaged in cutting edge R&D. It was emphasised that they enable the development of new technologies, new acceleration schemes, benchmarking of simulation codes, and allow innovative new techniques to be tested. In addition, they play a key role in developing the skills and expertise of the team in new areas which can subsequently be applied to large scale national and international facilities.

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Workshops and Visits

European Synchrotron Light Sources Workshop XVIII, Trieste

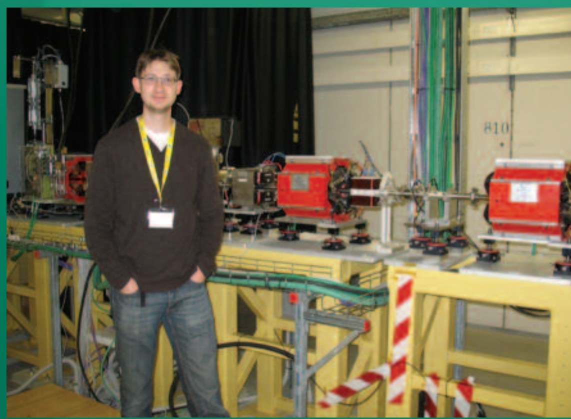
Peter Williams & Alan Wheelhouse attended the XVIII[th] European Synchrotron Light Sources Workshop held in Trieste, Italy on the 25[th] to 26[th] November 2010. This long standing meeting aims to foster information sharing and collaboration among Europe's operating and proposed light source facilities. Peter presented the recent achievements of ALICE, including Free Electron Laser lasing and terehertz operation and Alan presented IOT operational experience on ALICE and EMMA, information invaluable to other facilities when making procurement decisions. Major European developments presented included the commissioning of the ALBA synchrotron in Barcelona, and the FERMI@Elettra seeded free electron laser in Trieste.

For further information contact: peter.williams@stfc.ac.uk and alan.wheelhouse@stfc.ac.uk

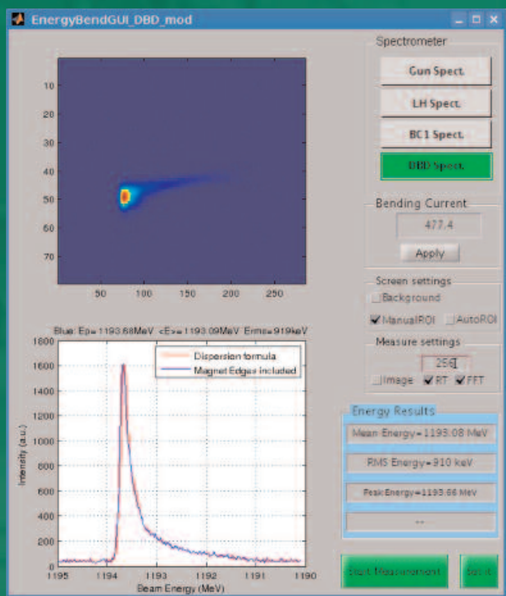
FERMI@Elettra Commissioning

Following on from the European Synchrotron Light Sources Workshop Peter Williams remained at the Elettra Laboratory in Trieste, Italy to take part in the commissioning of Europe's first seeded free-electron laser (FEL) user facility, FERMI@Elettra. Peter was able to gain hands-on experience in tuning and characterising the beam in this multi-GeV linac based FEL, and share experience from the commissioning of our own ALICE machine.

For further information contact: peter.williams@stfc.ac.uk



The seed laser injection section of FERMI FEL-1



Synoptic showing beam to FEL

Energy measurement with beam dump spectrometer

Workshops and Visits

Beam Measurements Course at the Jefferson Laboratory Free Electron Laser

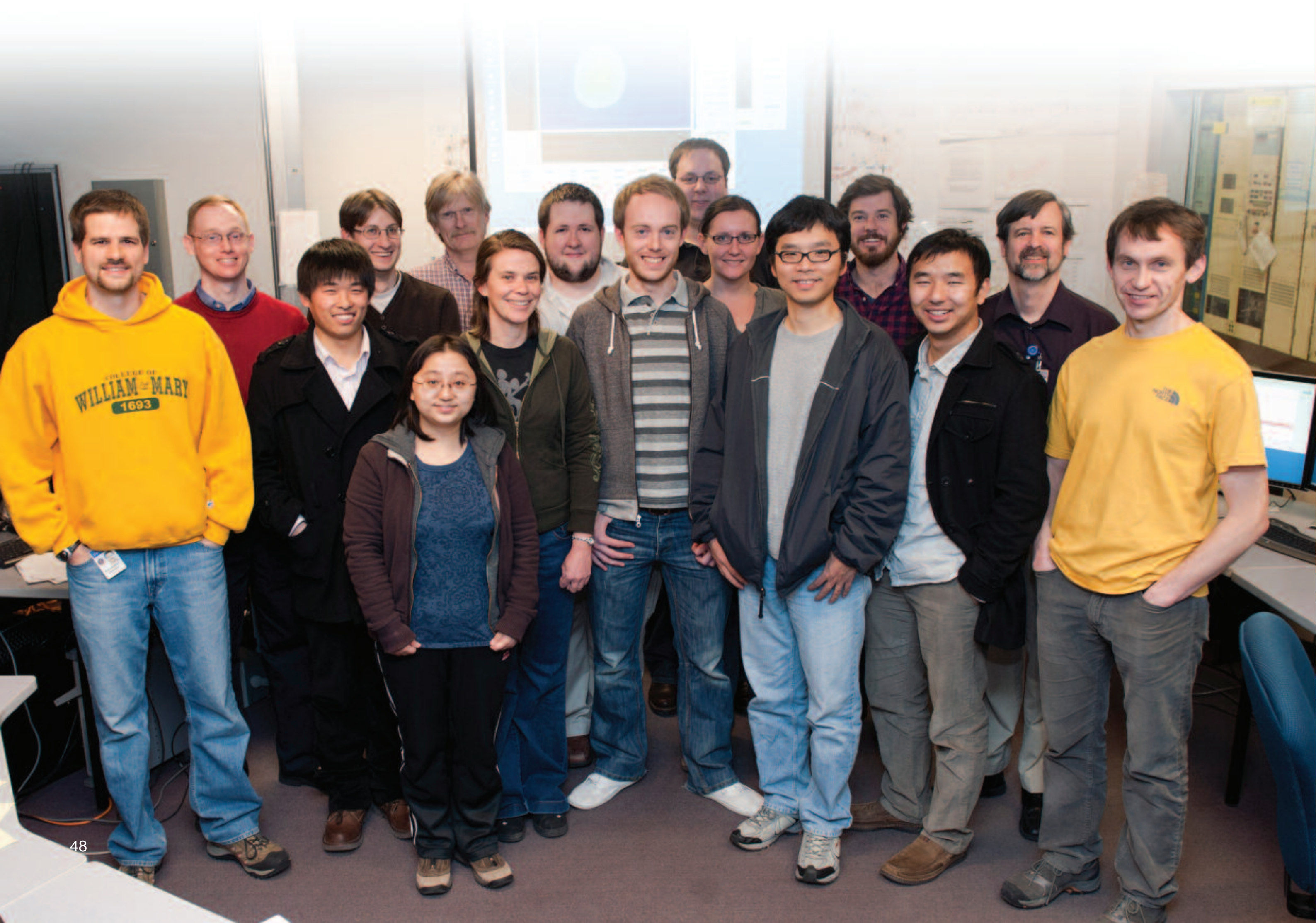
ASTeC staff David Dunning and Peter Williams visited the Thomas Jefferson National Accelerator Facility (JLab), Virginia, to attend a United States Particle Accelerator School (USPAS) course in which they gained extensive experience operating the JLab Free Electron Laser facility.

The two week course was titled "Beam Measurements, Manipulation and Instrumentation at an Energy Recovery Linac (ERL) Free Electron Laser (FEL) Driver", and was intensive and highly practical. Limited to only 12 students from around the world, much of the tuition from world leading accelerator experts was one-to-one. Support from JLab's operational team enabled extensive hands on experience of the JLab FEL with beam. Over the course of the two weeks, David and Peter learnt how to optimise the electron beam and establish lasing on the ultra-violet FEL.

In order to better understand the measurements being taken from the control room, the students were also able to make use of JLab's laboratory facilities to carry out off line characterisation of the beam diagnostic equipment, such as interferometers and beam position monitors.

Daresbury's longstanding links with JLab and the common aspects of the JLab FEL and ASTeC's own ALICE machine made this course a uniquely fruitful experience for David and Peter.

For further information contact: david.dunning@stfc.ac.uk and peter.williams@stfc.ac.uk



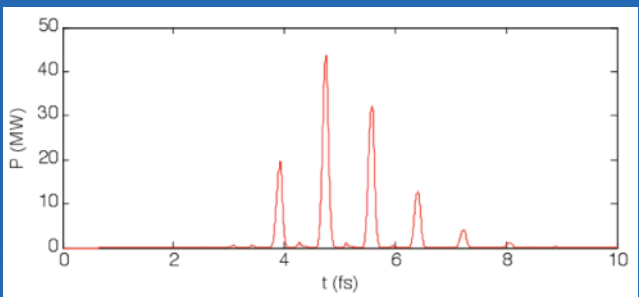
Workshops and Visits

LBNL Visit

ASTeC physicist Neil Thompson spent five weeks working at the Lawrence Berkeley National Laboratory (LBNL) near San Francisco, USA. He was invited over as a summer visitor to work with staff at LBNL on the design of a proposed high repetition rate soft x-ray Free Electron Laser (FEL) facility on the LBNL site. Neil developed conceptual designs for two different types of FEL, based on the expected parameters of the new accelerator. One was a seeded FEL with similarities to the FELs proposed for the UK's New Light Source (NLS) project. The other was an extension of previous research done within ASTeC on a new idea to create pulses of radiation from FELs that are orders of magnitude shorter than those currently available. An example of the predicted output from this scheme is shown below.

The visit was a great success, with a great deal being gained from the visit on both sides, with LBNL staff benefitting from seeing some of the research which is done at ASTeC that can be applied to their own proposed facility, thus helping to strengthen the collaboration between ASTeC and Berkeley.

For further information contact: neil.thompson@stfc.ac.uk



Predicted output from the short pulse FEL scheme. The wavelength of the emission is in the soft x-ray, at 1nm, and the duration of the individual spikes is less than 125 attoseconds.

Looking down from Lawrence Berkeley National Laboratory towards the Pacific Ocean.

Publications

ASTeC Publications 01 Apr 2010 – 31 Mar 2011

Journal Publications

ASTeC staff major contributors to all chapters in Part III Conceptual Design
NLS: conceptual design report

Bambade P, Pons MA, Angal-Kalinin D, et al.
Present status and first results of the final focus beam line at the KEK Accelerator Test Facility
Phys Rev Special Topics **13** (4) (2010) [doi:10.1103/PhysRevSTAB.13.042801]

Brooks SJ
Muon capture schemes for the neutrino factory
DPhil, Oxford University (sub-department of Particle Physics) (2010)

Bustamante N, Campillo NE, Diakun GP et al.
A lysozyme encoded by a pneumococcal bacteriophage with a novel cell wall-binding motif.
J Biological Chemistry Vol 285, 33184-33196 2010.

Chalupský J, Krzywinski, J, Gleeson A, et al.
Spot size characterization of focused non-Gaussian X-ray laser beams
Optics Express, Vol. 18 Issue 26, pp.27836-27845 (2010)

Clarke JA, et al.
The International Linear Collider: The Positron Source.
ICFA Beam Dynamics Newsletter No. 51, Apr 2010

Díaz M, Bailey P, Noakes TCQ, et al.
Compositional and structural Medium Energy Ion Scattering study of the temperature mediated diffusion determination at the Co/V interface in Co/V/MgO(100).
Surface Science. 604 (2010) 2177-2183

Eames C, Noakes T C Q, Bailey P, et al.
Phase selection in rare earth silicides.
Phys. Rev. B 82 174112 (2010)

Edgecock R, Kelliher D, Machida S, et al.
EMMA - The world's first non-scaling FFAG
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **624** (1) 1-19 (2010) [doi:10.1016/j.nima.2010.08.109]

Farahani S, Chalupsky J, Gleeson A, et al.
Damage threshold of amorphous carbon mirror for 177 eV FEL radiation
Nuclear Instruments and Methods in Physics Research A 635 (2011) S39–S42

Gentile M, Bailey P, Noakes TCQ
Influence of grain orientation on zinc enrichment and surface morphology of an Al-Zn alloy
Surface and Interface Analysis, 42 (4): 287-292 Suppl. SI APR 2010

Gutiérrez PC, Pradell T, Smith AD, et al.
Color and golden shine of silver Islamic luster
J.Am.Ceram.Soc. 93 pp.2320–2328 (2010) doi:10.1111/j.1551-2916.2010.03741.x

Haire AR, Noakes TCQ, Bailey P, et al.
Influence of preparation conditions on the depth-dependent composition of AuPd nanoparticles grown on planar oxide surfaces
Surface Science 605 (2011) 214

Hock KM, Ibison MG, Muratori BD, et al.
Beam Tomography in Normalised Phase Space
Nucl. Instr. and Meth. A (2011).

Holland DMP, Potts AW, Karlsson L, et al.
An experimental and theoretical study of the valence shell photoelectron spectrum of bromochlorofluoromethane.
J. Phys. B43, 135101 (2010).

Howe CJ, Bailey P, Noakes TCQ
Stacking faults in ultra-thin films of silver on Al (111) investigated by medium energy ion scattering
Surface Science, 604 (19-20): 1658-1665 SEP 2010

Jamison SP
X-ray science: X-ray FEL shines brightly
Nature Photonics **4** (9) 589-591 (2010) [doi:10.1038/nphoton.2010.210]

Jamison SP, Berden G, Phillips PJ, et al.
Upconversion of a relativistic Coulomb field terahertz pulse to the near infrared
Appl Phys Lett **96** (23) (2010) [doi:10.1063/1.3449132]

Jones RL, Thrall M, Henderson CMB
Complex impedance spectroscopy and Ionic transport properties of natural leucite ($K_{0.90}Na_{0.08}[Al_{0.98}Si_{2.02}]O_6$) as a function of temperature and pressure.
Mineralogical Society Vol 74 (3) 507-519(2010)

Long K, et al.
Neutrino Factory design report
Submitted to the ECFA neutrino panel

Lyapin A, Schreiber HJ, Jackson F, et al.
Results from a prototype chicane-based energy spectrometer for a Linear Collider
Journal of Instrumentation **6** P02002 (2011) [doi:10.1088/1748-0221/6/02/P02002]

Machida S, Fenning R
Beam transport line with scaling fixed field alternating gradient type magnets
Phys Rev Special Topics **13** (8) 084001 (2010) [doi:10.1103/PhysRevSTAB.13.084001]

Malyshev OB, Smith AP, Valizadeh R, Hannah A
Electron stimulated desorption from bare and nonevaporable getter coated
J Vac Sci Technol A **28** (5) 1215-1225 (2010) [doi:10.1116/1.3478672]

Malyshev OB, Zajec B, Haase A, et al.
Ar beam induced desorption from different materials at TSL
Vacuum **85** (2) 338-343 (2010) [doi:10.1016/j.vacuum.2010.07.007]

Marinov KB, Tzenov SI
Nonlinear density waves in the single-wave model
Phys. Plasmas 18, 032305 (2011)

McNeil BWJ, Thompson NR
X-ray free-electron lasers
Nature Photonics 4 (12) 814-821 (2010) [doi:10.1038/nphoton.2010.239]

McNeil BWJ, Thompson NR, Dunning DJ, Sheehy B
High harmonic attosecond pulse train amplification in a free electron laser
J Phys B **44** (6) 065404 (2011) [doi:10.1088/0953-4075/44/6/065404]

Militsyn BL, Burrows I, Cash RJ, et al.
High Voltage DC Photoinjector Development at Daresbury Laboratory.
ICFA Beam Dynamics Newsletter No. 51 (01/04/2010)

Milosaljevic M, Wong L, Valizadeh R, et al.
Correlation of Structural and Optical Properties of Sputtered FeSi2 Thin Films
JJAP 49 August 2010

Montgomery W, Tuff J, Kohn SC, Jones RL
Reactions between organic acids motmorillonite clay under Earth-Forming conditions.
J. Chemical Geology (2011)

Nettikaden VC, Bailey P, Noakes TCQ, et al.
Formation of barrier-type anodic films on sputter-deposited Al-Ti alloys.
Corros sci 52, 11 (2010) 3717-3724

Noakes TCQ, Bailey P, McConville C F, et al.
Two- and three-dimensional growth of Bi on i-Al-Pd-Mn studied using medium-energy ion scattering.
Phys. Rev. B 82 (195418 (2010)

Pattalwar S, Bate R
Cool-it a heat exchanger system to provide gaseous helium at intermediate temperatures for SRF linac
In Advances in Cryogenics Engineering, Vols 55A and 55B, eds. AIP Conference Proceedings, vol. 1218, ISBN 9780735407619, p595-600 (2010)

Pawley AR, Welch M, Lennie AR, Jones RL
Volume behaviour of the 10 Å phase at high pressures and temperatures, with implications for H2O content
American Mineralogist, Volume 95, pages 1671–1678, (2010)

Prior CR, et al.
Neutrino Factory Studies
ICFA Beam Dynamics Newsletter 51, August 2010.

Rogers CT
Design for a Muon Front End with Magnetically Shielded RF Cavities
in Neutrino Factories, Superbeams, and Beta Beams, eds. Goodman, MC and Kaplan, DM and Sullivan, Z, AIP Conference Proceedings, vol. 1222, ISBN 978-0-7354-0, p298-302 (2010)

Rogers CT
The Muon Ionisation Cooling Experiment MICE
ICFA Beam Dynamics Letter 51, 2010.

Roper MD
Matching a variable-included-angle grating monochromator to the properties of a soft X-ray FEL source to achieve a controlled temporal stretch
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **635** (1) S80-S87 (2010) [doi:10.1016/j.nima.2010.09.017]

Schofield PF, Smith AD, Quinn PD, et al.
X-ray Spectromicroscopy of Mineral Intergrowths in the Santa Catharina Meteorite
Geostandards and Geoanalytical Research 34 145–159 (2010)

Sheehy SL, Kelliher DJ, Machida S, et al.
Fixed field alternating gradient accelerator with small orbit shift and tune excursion
Phys Rev Special Topics **13** (4) 040101 (2010) [doi:10.1103/PhysRevSTAB.13.040101]

Sheppard DC, Bailey P, Noakes TCQ, et al.
Surface relaxation in Cu(410)-O: A medium energy ion scattering study.
Surface Science 604 (2010) 788-796

Sheppard DC, Bailey P, Noakes TCQ, et al.
Medium Energy Ion Scattering Investigation of Methylthiolate-induced Modification of the Au(111)
Surface Science 605 1-2 (2011) 138-145

Sheppard DC, Noakes TCQ, Bailey P, et al.
Thiolate-induced lateral distortion of the Cu(100) surface.
Surface Science 604 (2010) 1727-1732

Sobierajski R, Bruijn S, Gleeson A, et al.
Damage mechanisms of MoN/SiN multilayer optics for next-generation pulsed XUV light sources
Optics Express, Vol. 19 Issue 1, pp.193-205 (2011)

Walker M, Noakes TCQ, Bailey P, et al.
Structural analysis of the Cu(100)-p(2 x 2)-Sn surface using low and medium energy ion scattering spectroscopies
Physical Review B, 83 (8): Art. No. 085424 FEB 25 2011

Window AJ, Noakes TCQ, Bailey P, et al.
Silver sulphide growth on Ag(111): A medium energy ion scattering study.
Surface Science 604 (2010) 1254-1260

Valizadeh R, Malyshev OB, Colligon JS, et al.
Comparison of Ti-Zr-V nonevaporable getter films deposited using alloy or twisted wire sputter-targets
J Vac Sci Technol A **28** (6) 1404-1412 (2010) [doi:10.1116/1.3504600]

Conference Proceedings

Alekou A, Neuffer D, Rogers CT, et al.
Alternative Muon Front-End for the International Design Study.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Alekou A, Pasternak J, Rogers CT
Cooling Dynamics Comparison between the Bucked Coils and the FS2A Lattice.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Alekou A, Pasternak J, Rogers CT
Muon Cooling Performance in Various Neutrino Factory Cooling Cell Configurations using G4MICE.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Anania MP, Poole MW, Clarke JA et al.
The ALPHA-X Beam Line: towards a Compact FEL.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Angal-Kalinin D, Fernandez HL, Jackson F, et al.
The CLIC BDS towards the Conceptual Design Report.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Angal-Kalinin D, Jackson F, Jamison SP, et al.
Design of a post LINAC beam transport for the UK new light source project
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Asova G, Holder DJ, Muratori BD, et al.
Status of the Photo Injector Test Facility at DESY, Zeuthen Site
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Bailey IR, Clarke JA, Scott DJ, et al.
Eddy Current Studies From the Undulator-based Positron Source Target Wheel Prototype.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Bartolini R, Angal-Kalinin D, Dunning DJ, et al.
Beam dynamics for the NLS superconducting linac
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Berg JS, Giboudot Y, Kelliher DJ, et al.
Recent developments on the EMMA on-line commissioning software
Proc. 1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010

Brooks SJ
Optimising pion production target shapes for the neutrino factory
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Brooks SJ
Vertical orbit excursion FFAGs
46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2010), Morschach, Switzerland

Chanlek N, Jones RM, Herbert JD, et al.
Gallium arsenide preparation and QE lifetime studies using the ALICE photocathode preparation facility.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Clarke JA, Dunning DJ, Leonard S, et al.
Status of the ALICE IR-FEL
Proc. *32nd International Free Electron Laser Conference (FEL 10), Malmo, Sweden, 23-27 Aug 2010*

D'Arcy RTP, Holder DJ, Muratori BD et al.
Modelling of the EMMA ns-FFAG Injection Line using GPT.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Doel P, Atkins C, Smith AD, et al.
Active X-ray optics for high resolution space telescopes
Proc. International Conference on Space Optics, ICSO2010, Rhodes, Greece. (2010).

Dunning DJ, Thompson NR, McNeil BWJ
Long-scale modulation of electron beam energy in free electron lasers
Proc. *32nd International Free Electron Laser Conference (FEL 10), Malmo, Sweden, 23-27 Aug 2010*

Dunning DJ, Thompson NR, McNeil BWJ, et al.
Optimisation of an HHG-seeded harmonic cascade FEL design for the NLS project
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Edgecock TR, et al.
The EMMA Non-scaling FFAG
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Feldman C, Willingale R, Smith AD, et al.
The performance of thin shell adaptive optics for high angular resolution X-ray telescopes
SPIE 7803 78030N (2010) doi:10.1117/12.85882.

Fernandez-Hernando JL, Angal-Kalinin D
Beam dump and collimation design studies for NLS: thermal and structural behaviour
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Fernandez-Hernando JL, Resta-Lopez J
Thermal and mechanical effects of a CLIC bunch train hitting a Beryllium collimator
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Garland J, Owen HL, Muratori BD, McKenzie JW
Characterisation of the ALICE Accelerator as an Injector for the EMMA NS-FFAG
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Geng H, Dunning DJ, Thompson NR et al.
Polarization analysis for seeded FELs in a crossed-planar undulator
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Gerstl S, Clarke JA, Scott DJ, et al.
Status of COLDDIAG : a cold vacuum chamber for diagnostics
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Goulden AR, Bate R, Buckley R, et al.
Cryogenic Refrigeration Equipment for the New Light Source (NLS) Superconducting LINAC.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Gronberg J, Abbott R, Clarke JA, et al.
Design of a Pulsed Flux Concentrator for the ILC Positron Source.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Henderson J, McNeil BWJ, Dunning DJ
Beam quality and transport stability simulations in echo enabled harmonic generation
Proc. *32nd International Free Electron Laser Conference (FEL 10), Malmo, Sweden, 23-27 Aug 2010*

Jones JK, Angal-Kalinin D
Beam Delivery System Dogleg Design and Integration for the International Linear Collider.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Jones LB, McKenzie JW, Middleman KJ, et al.
The ALICE Energy Recovery Linac – Project overview and injector performance.
Proceedings of PESP 2010, Bonn, Germany 21st September 2010

Kelliher DJ, Machida S
Error study of a novel non-linear, nonscaling FFAG
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Kelliher DJ, Machida S, Sheehy SL
Orbit correction in a non-scaling FFAG
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Korostelev M, Thorley A, Malyshev OB, et al.
Impedance and single-bunch instabilities in the ILC damping rings.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Laundy D
Detector dead time in particle counting detectors.
Proc. Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XII, California, USA, 2 August XII 7805 (1) 780516 2010

Lyapin A, Schreiber HJ, Jackson F, et al.
Results from a Prototype Chicane-Based Energy Spectrometer for a Linear Collider.
SLAC PUB-14255. Nov 2010.

Machida S
FFAG Lattice with Superperiod Structure
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Malyshev OB
Ion induced pressure instability in the ILC positron DR
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Malyshev OB, Collomb NA, Wolski A, et al.
Mechanical and Vacuum Design of the Wiggler Section of the ILC Damping Rings
Proc. 1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010

Marinov KB, Muratori BD, Tzenov SI
Injection and extraction for the EMMA NS_FFAG,
Proceedings of HB2010, Morschah, Switzerland 2010,

Martin I, Bartolini R, Dunning DJ, Thompson NR
Short pulse options for the UK's New Light Source project
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

McIntosh PA, Goulden AR, Moss AJ, et al.
SRF linac development for the new light source project in the UK
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

McKenzie JW, Militsyn BL
Design of a VHF Photoinjector Option for the UK's New Light Source Project
Proc. *1st International Particle Accelerator Conference (IPAC10), Kyoto, Japan, 23-28 May 2010*

McKenzie JW, Militsyn BL
Initial Design of a Superconducting RF Photoinjector Option for the UK's New Light Source Project
Proc. *1st International Particle Accelerator Conference (IPAC10), Kyoto, Japan, 23-28 May 2010*

McNeil BWJ, Thompson NR
Mode Locked Optical Klystron Configuration in an FEL Cavity Resonator
Proc. 32nd International Free Electron Laser Conference (FEL 10), Malmo, Sweden, 23-27 Aug 2010

Militsyn BL, Burrows I, Cash RJ, et al.
First Results from III-V Photocathode Preparation Facility for the ALICE ERL Photoinjector
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Militsyn BL, Burrows I, Cash RJ, et al.
Development of high brightness, high repetition rate photoelectron injectors at STFC Daresbury Laboratory.
Proceedings of PESP 2010, Bonn, Germany. 21st September 2010

Molson J, Owen HL, Toader A, Barlow R
Advances With Merlin - a beam tracking code
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Moss AJ, Jamison SP, Wheelhouse AE, et al.
The EMMA LLRF system and its synchronisation with ALICE.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Moss AJ, Orrett J, McIntosh PA, et al.
Progress on the MICE RF system.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Moss AJ
EMMA RF commissioning and stabilization.
Libera Workshop (ITECH)

Moss AJ
RF status' report.
MICE collaboration meeting CM29

Muratori B, Jones J, Kalinin A, et al.
Preparation for EMMA commissioning
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Neuffer D, Martini M, Rogers CT, et al.
Muon Capture in the Front End of the IDS Neutrino Factory.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Pasternak J, Kelliher DJ, Machida S, et al.
Injection/extraction system of the Muon FFAG for the Neutrino Factory
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Pasternak J, Muratori BD, Smith SL, et al.
Accelerator and Particle Physics Research for the Next Generation Muon to Electron Conversion Experiment – the PRISM Task Force
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Pattalwar S, Bate R, Buckley R, et al.
Development of a Cryogenic System for the Proposed New Light Source (NLS).
ICEC 23, July 2010, Wroclaw, Poland

Pattalwar SP, Bate R, Goulden AR, et al.
SRF Cryomodule and Cryogenics Developments for the New Light Source.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Peach K, Sheehy SL, Kelliher DJ, et al.
PAMELA : overview and status
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Pivi MTF, Wang L, Malyshev OB, et al.
Recommendation for the feasibility of more compact LC damping rings.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Plostinar C
Design Optimisation of the Re-bunching Cavities for the Front End Test Stand at RAL
25th International Linear Accelerator Conference, LINAC10, Tsukuba, Japan, 12-17 September 2010

Plostinar C
MEBT Design for the RAL Front End Test Stand
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Pozimski JK, Aslaninejad M, Machida S, et al.
Investigation of Beam Loading Effects for the Neutrino Factory Muon Accelerator
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Priebe G, Laundy D, Phillips PJ, et al.
First results from the Daresbury Compton backscattering x-ray source (COBALD)
Proc. *Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XII, San Diego, California, USA, 2nd August 2010*, Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XII **7805** (1) 780513 (2010) [doi:10.1117/12.859671]

Prior CR
Overview of High Intensity Accelerator Projects
Proc. ICFA Beam Dynamics workshop on High Brightness Hadron Beams, HB2010, Morsasch, Switzerland, September 2010.

Rees GH, Kelliher DJ
New, high power, scaling, FFAG driver ring designs
Proc. *46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2010), Morschach, Switzerland, 27 Sep - 01 Oct 2010*

Resta-L´opez J, Angal-Kalinin D, Fernandez JL, et al.
Optimization of the CLIC Baseline Collimation System.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Rodriquez-Sanmartin D, Zhang D, Smith AD, et al.
Development of net-shape piezoelectric actuators for large X-ray optics
SPIE 7803 78030M (2010) doi:10.1117/12.860435.

Rodriquez-Sanmartin D, Zhang D, Smith AD, et al.
Development of spider micro-structured optical arrays for X-ray optics
SPIE 7803 780306 (2010) doi:10.1117/12.860420.

Rogers CT
Design for a Muon Front End with Magnetically Shielded RF Cavities
NEUTRINO FACTORIES, SUPERBEAMS, AND BETA BEAMS: 11th International Workshop on Neutrino Factories, Superbeams and Beta Beams-NuFact09. AIP Conference Proceedings, Volume 1222, pp. 298-302 (2010).

Rogers CT, Snopok P, Coney L, Jansson A
Wedge Absorber Design for the Muon Ionisation Cooling Experiment.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Rogers CT, Neuffer D, Snopok P
Front End Energy Deposition and Collimation Studies for IDS-NF
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Rogers CT, Snopok P, Coney L, Hanson G
Wedge Absorber Design and Simulation for MICE Step IV
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Saveliev YM, Smith SL, Bate R, et al.
Recent developments on ALICE (Accelerators and Lasers in Combined Experiments) at Daresbury Laboratory
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Sheehy SL
The EMMA accelerator and implications for hadron non-scaling FFAGs
46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2010), 27 Sep - 01 Oct 2010

Sheehy SL, Kelliher DJ, Machida S, et al.
PAMELA: Lattice Solution for a Medical C6+ Therapy Facility
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Smith PJ, Booth CN, Shepherd BJ, et al.
The MICE Target
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Thomason JWG, Prior CR, Rees GH, et al.
Injection Upgrades for the ISIS Synchrotron.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Thompson NR, Dunning DJ, McNeil BWJ
Improved temporal coherence in SASE FELs
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Thorin S, Angal-Kalinin D, McKenzie JW, et al.
Bunch compression by linearising achromats for the MAX IV Injector
Proc. *32nd International Free Electron Laser Conference (FEL 10), Malmo, Sweden, 23-27 Aug 2010*

Tzenov SI, Jones JK, Muratori BD, et al.
Setting the Beam onto the Reference Orbit in Non Scaling FFAG Accelerators.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Walker RP, Angal-Kalinin D, Clarke JA, et al.
Progress with the design of the UK's New Light Source facility
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Wheelhouse AE, Buckley R, Goudket P, et al.
Progress of the RF System for EMMA at Daresbury Laboratory.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Wheelhouse AE, Davies PR, Fernández-Hernando JL, et al.
Daresbury international cryomodule coupler progress.
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

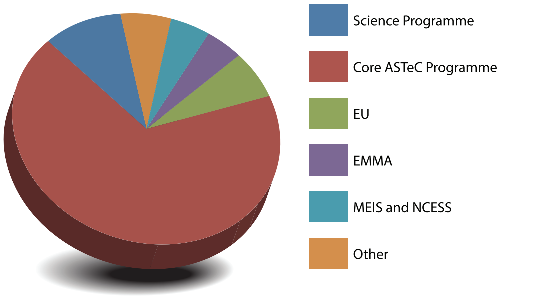
Williams PH, Angal-Kalinin D, Jones JK, et al.
Design of the recirculating Linac option for the UK New Light Source
Proc. *1st International Particle Accelerator Conference (IPAC 10), Kyoto, Japan, 24-28 May 2010*

Wolski A, Panagiotidis K, Malyshev OB, et al.
ILC Damping Ring Design Studies at the Cockcroft Institute.
ILC-NOTE-2010-057. 15-Nov-2010.

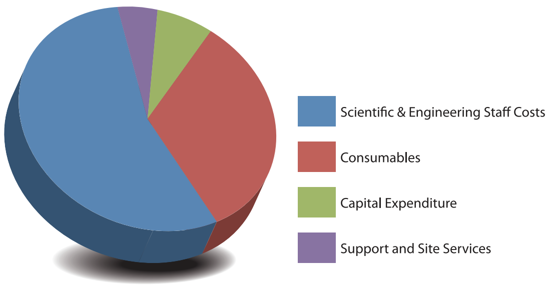
Financial Summary

ASTeC Activities 10/11

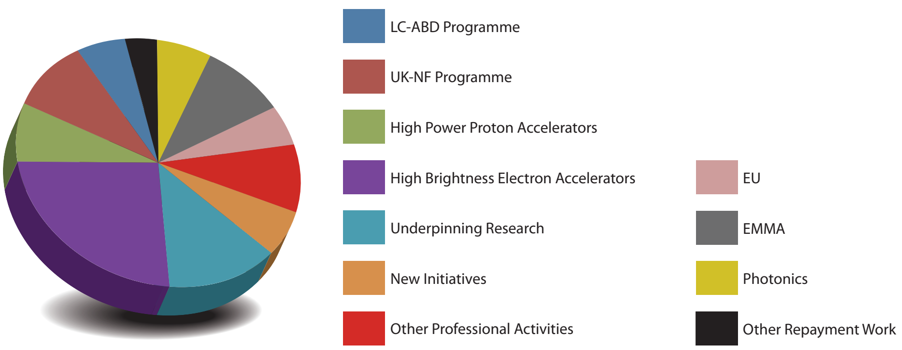
INCOME SOURCES 10/11	£K
SCIENCE PROGRAMME	892
CORE ASTeC PROGRAMME	6170
EU	577
EMMA	400
MEIS and NCESS	423
OTHER	565
	9027



EXPENDITURE 10/11	£K
SCIENTIFIC & ENGINEERING STAFF COSTS	4988
CONSUMABLES	2954
CAPITAL EXPENDITURE	611
SUPPORT AND SITE SERVICES	474
	9027



EXPENDITURE BY PROGRAMME 10/11	£K
LC-ABD PROGRAMME	523
UK-NF PROGRAMME	902
HIGH POWER PROTON ACCELERATORS	683
HIGH BRIGHTNESS ELECTRON ACCELERATORS	2167
UNDERPINNING RESEARCH	1194
NEW INITIATIVES	593
OTHER PROFESSIONAL ACTIVITIES	795
EU	448
EMMA	831
PHOTONICS	556
OTHER REPAYMENT WORK	335
	9027



Notes