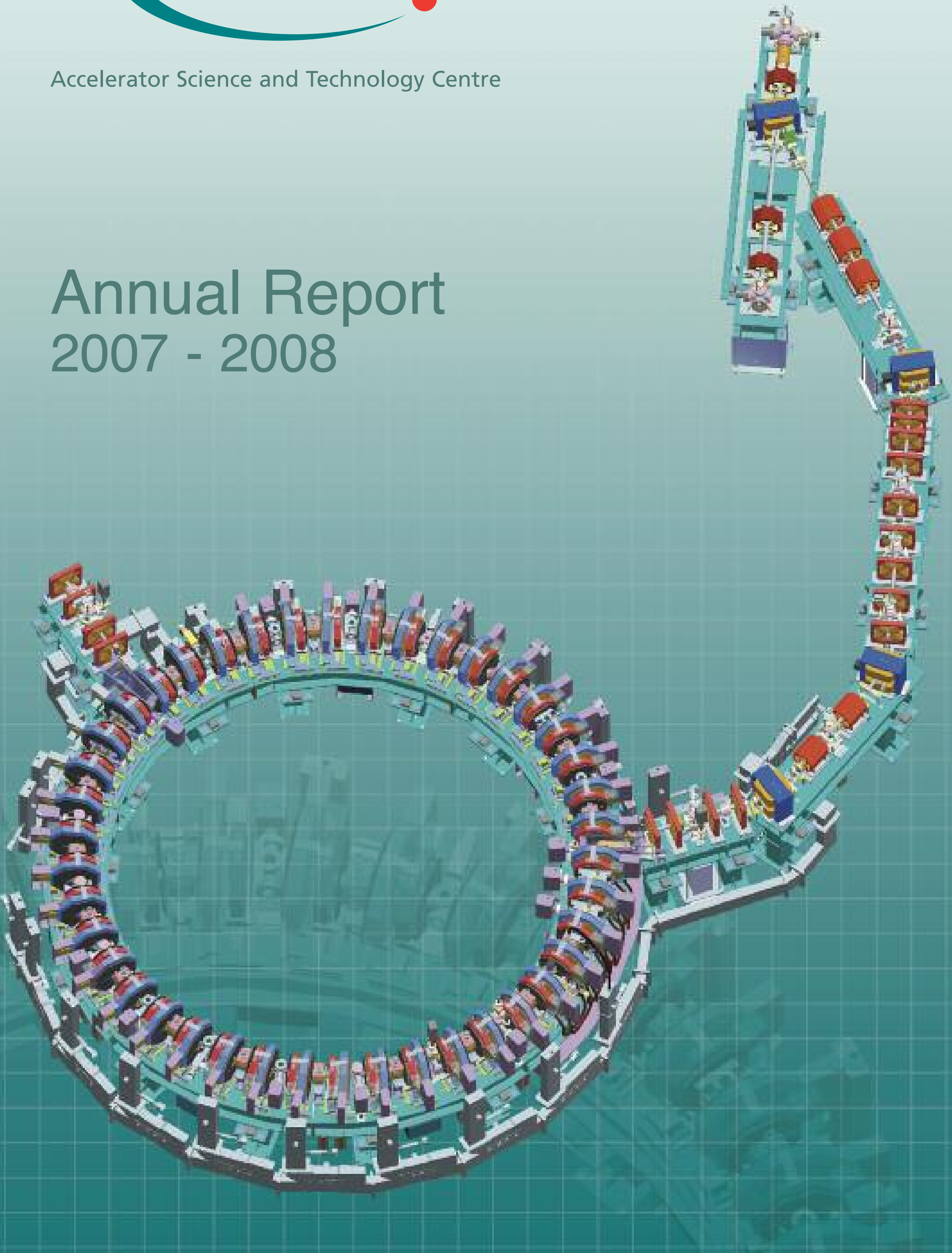
ASTeC

Accelerator Science and Technology Centre

Annual Report
2007 - 2008



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Accelerator Science and Technology Centre

Annual Report
2007 – 2008

This report covers the work accomplished by the Accelerator Science & Technology Centre (ASTeC) for the financial year 2007 – 2008.

Editors: Deepa Angal-Kalinin & Sue Waller.
Designed & produced by: Media Services, Daresbury Laboratory.

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Foreword

This Annual Report describes another very successful year for ASTeC and its staff. Amongst many highlights was the progress on the ERLP photo-gun commissioning, culminating in its detailed experimental characterisation. Other major parts of the ERLP were also brought on stream, including much of the superconducting linac hardware with its complex cryogenics infrastructure. Early in 2008 the overall experiment was renamed ALICE (Accelerators and Lasers in Combined Experiments), an important change to reflect the evolving nature of a project that underpins wide ranging physics and technology developments of relevance to a variety of future advanced accelerator applications, not restricted only to energy recovery demonstration but covering more generic aspects of next generation light sources too. Furthermore with the success of the EMMA funding bid ALICE also became a vital element in delivery of this innovative accelerator architecture. It is clear that this test facility is crucial to ASTeC's future R&D plans and it was therefore a relief that it emerged from the STFC funding crisis with a clear commitment to its programmes.

Although the long term involvement of ASTeC staff in the 4GLS project terminated during the period of this Report, the extensive skills learned over the previous five years did not, and as evidence of this team members rapidly contributed to alternative next generation design proposals that finally led to the initiation of the NLS (New Light Source) project feasibility studies in 2008. The ability to deliver such formal Design Studies is one of the most important reasons for a Centre such as ASTeC to exist.

Similar remarks can be made about the ASTeC contributions to the international design studies in which it participates, in particular its leading role on both the International Linear Collider and Neutrino Factory programmes. This recognition from outside the UK is an important metric of our activities and has been growing appreciably. Such programmes also highlight the crucial role of effective collaborations, both on the international level and with other national players, especially the UK university sector. The most important of the latter has undoubtedly been with the Cockcroft Institute under its new Director, Professor Swapan Chattopadhyay, and this relationship goes from strength to strength.

As already mentioned, ASTeC needs access to modern test facilities and in addition to the electron beam ones at Daresbury it has supported two such important programmes at RAL: the Front End Test Stand and the MICE experiment. In addition, a programme of underpinning accelerator technology development has continued, including advancements in magnetics, superconducting RF systems, diagnostics and vacuum science.

Although the reporting year ended under something of a financial cloud for STFC, ASTeC was able to defend its programmes robustly and with considerable success. However adaptability has also been required, for example in the response to major reductions in the ILC programme and the need to assume increased responsibility for ALICE funding.

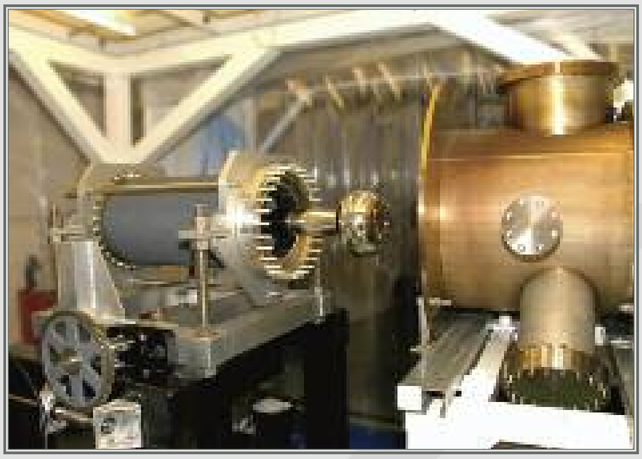
I am confident that our high staff skills and levels of commitment, together with our selected portfolio of diverse programmes, will sustain ASTeC through difficult times in the UK and also lead to new emerging opportunities for us all. I thank all of our staff and stakeholders for their ongoing support.

Mike Poole
Director

Contents

ALICE High Voltage DC Photoemission Gun: Electron Beam Characterisation

The ALICE (Accelerators and Lasers in Combined Experiments) experimental facility (known formerly as ERLP) is an Energy Recovery Linac (ERL) with a high voltage DC photoemission electron gun. The gun has been recently commissioned and the beam was fully characterised at various bunch charges.

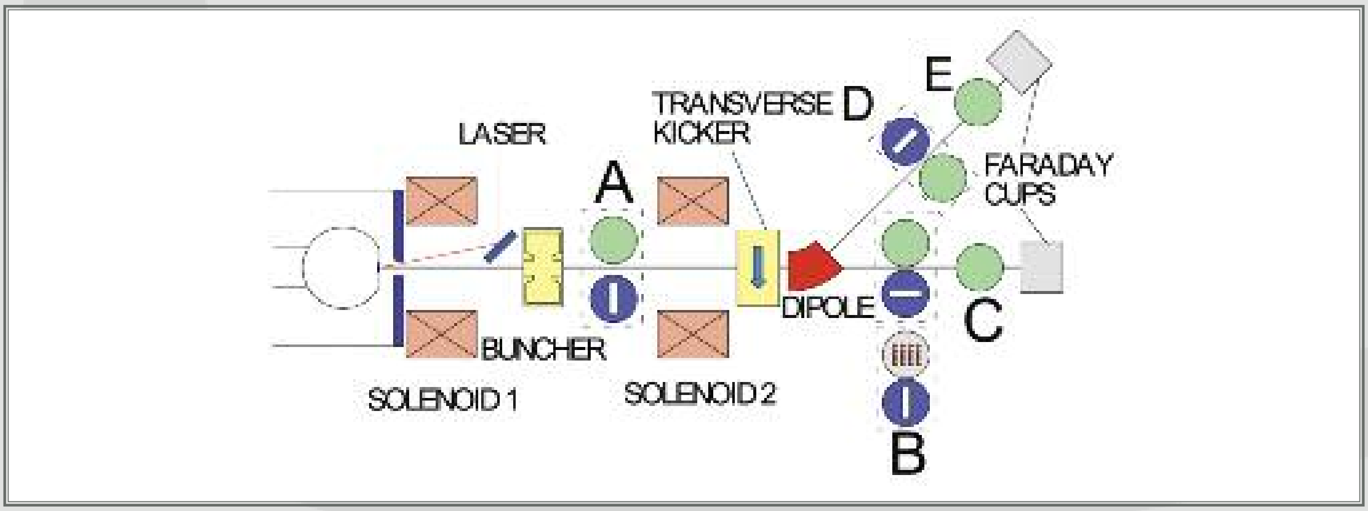


ALICE Photogun during assembly

The ALICE accelerator incorporates all the features of a 4th generation light source albeit at smaller scale. The machine aims to produce high brightness electron beams with up to 80pC of bunch charge and the electron energy up to 35MeV. An ERL is not restricted by the dynamic properties of storage rings and, therefore, can attain an unprecedented electron beam brightness limited only by the electron gun. Energy recovery also allows a significant increase in an average power of the light source (without building a dedicated power station nearby!).

The ability to produce ultra-short electron bunches well below 1pico-second and an availability of several light sources of different "colour" open up numerous possibilities for conducting investigations of fast processes on a femto-second scale in molecular and solid state physics to name just a few.

The gun is a replica of the Jefferson Lab design and operates at a nominal voltage of 350kV. Electrons are generated from the Negative Electron Affinity (NEA) GaAs cathode by green light from a Nd:YVO_4 mode-locked laser, frequency-doubled to generate a 532nm beam. Despite a few similar guns in operation or under construction, very limited experimental data is available on beam characteristics from this type of DC photoinjector. The ALICE gun has been recently commissioned and the beam was fully characterised at various bunch charges. Electron bunch properties from the ALICE DC photogun were investigated with a dedicated diagnostic beamline. It includes two solenoids used for transverse beam focusing and emittance compensation and an RF buncher operating at a fundamental frequency of 1.3GHz. A 1.3GHz transverse RF kicker allows the investigation of the longitudinal profiles of the electron bunches and measurement of the bunch length. The energy spectrometer, apart from measuring energy spectra, was also used for bunch characterisation, calibration and phase setting as well as for bunch length measurements.



Schematic diagram of the diagnostic beamline (not to scale).
Green circles represent YAG screens and blue circles represent slits.

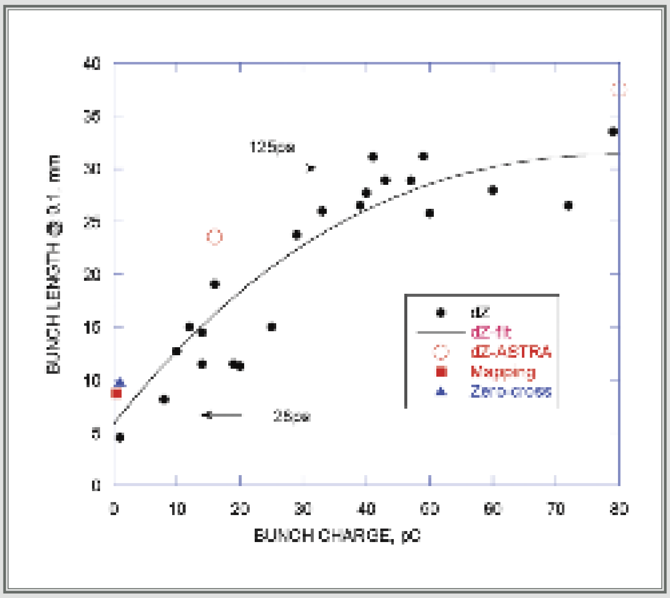
The gun is routinely high-voltage conditioned to 450kV after a bakeout to operate at a nominal 350kV for electron beam generation. The quantum efficiency of a freshly activated photocathode is normally above 3% which is sufficient for achieving bunch charges well above the required 80pC. The cathode lifetime remains to be an issue which will be addressed in the future gun development.

The electron beam was fully characterised at various bunch charges from approximately 1pC up to 80pC. The beam transverse emittance, longitudinal bunch profiles and their dynamics during bunching, beam energy spread, correlated and uncorrelated, were measured at each bunch charge and compared with the predictions from the ASTRA computer simulations. There was a good agreement between the two for most of the beam parameters, which ensures that the gun will deliver the required parameters and that the future gun development based on computer simulations will ensure reliable results.

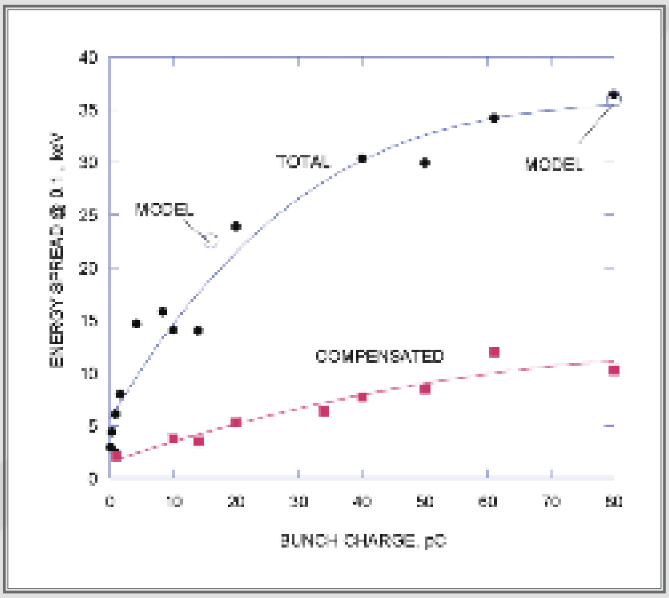
The transverse emittance however was found to be significantly larger at 80pC compared to the predicted model. This could be due to the fact that the model did not take several factors into account (e.g. the initial thermal emittance) and due to non-ideal experimental conditions (presence of field emission, sub-optimal magnetic field settings, non-uniform quantum efficiency map). In the future ALICE operation, a sizeable decrease of the transverse emittance is expected once these adverse factors are eliminated.

Upon completion of the gun commissioning phase, the diagnostic beamline was disassembled to provide space for the installation of the cryogenic module with the superconducting booster linac. During this phase of the ALICE commissioning, usefulness of the diagnostics in the gun beamline was fully appreciated. Based on this experience, an option is being considered to re-install these diagnostics and evaluate the compromise between the benefits that will be brought by this and a somewhat unavoidable deterioration in beam quality due to a longer distance between the gun and the booster linac.

Another significant development will be a gun upgrade with the installation of the load-lock system (next article in this report) that will ensure better quality of the activated photocathodes, higher quantum efficiency, longer cathode lifetime and a huge reduction in ALICE shutdown time for cathode changes.



Bunch length at 10% of the peak value as a function of bunch charge. Data was obtained with the RF transverse kicker (full circles), "energy mapping method" (square) and zero-crossing method (triangle). Open circles are the results from the ASTRA model.



Total and tilt-compensated energy spread at 10% of the peak value as a function of the bunch charge. Open circles indicate the results from the ASTRA model.

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ALICE: Photoinjector Load-Lock Upgrade

As particle accelerators become more sophisticated they require ever more complex electron sources which push the boundaries of performance. ASTeC scientists have been working on an upgrade to the ALICE photoinjector electron source, developing systems which may eventually be used on a next generation Light Source.

A photoinjector exploits laser-stimulated electron emission from an activated photocathode to deliver an electron beam with a high average current, high brightness and low emittance. Presently, the ALICE photoinjector gun can accommodate only a single photocathode, and requires disassembly and venting of the vacuum system to facilitate photocathode replacement.

In order to achieve the extreme vacuum needed for good photocathode lifetime, the system requires baking for up to 3 weeks.

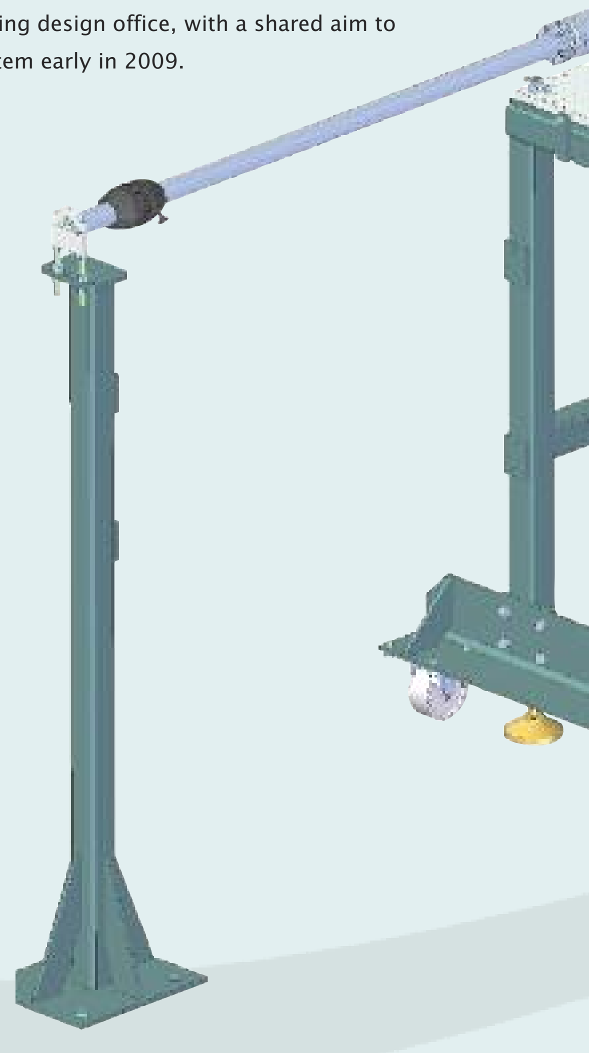
The key component of the upgrade is the integration of a three-stage extreme high vacuum (XHV) 'load-lock' system with the ALICE photoinjector. The load-lock system has become a standard extension to a photoinjector, and typically comprises:

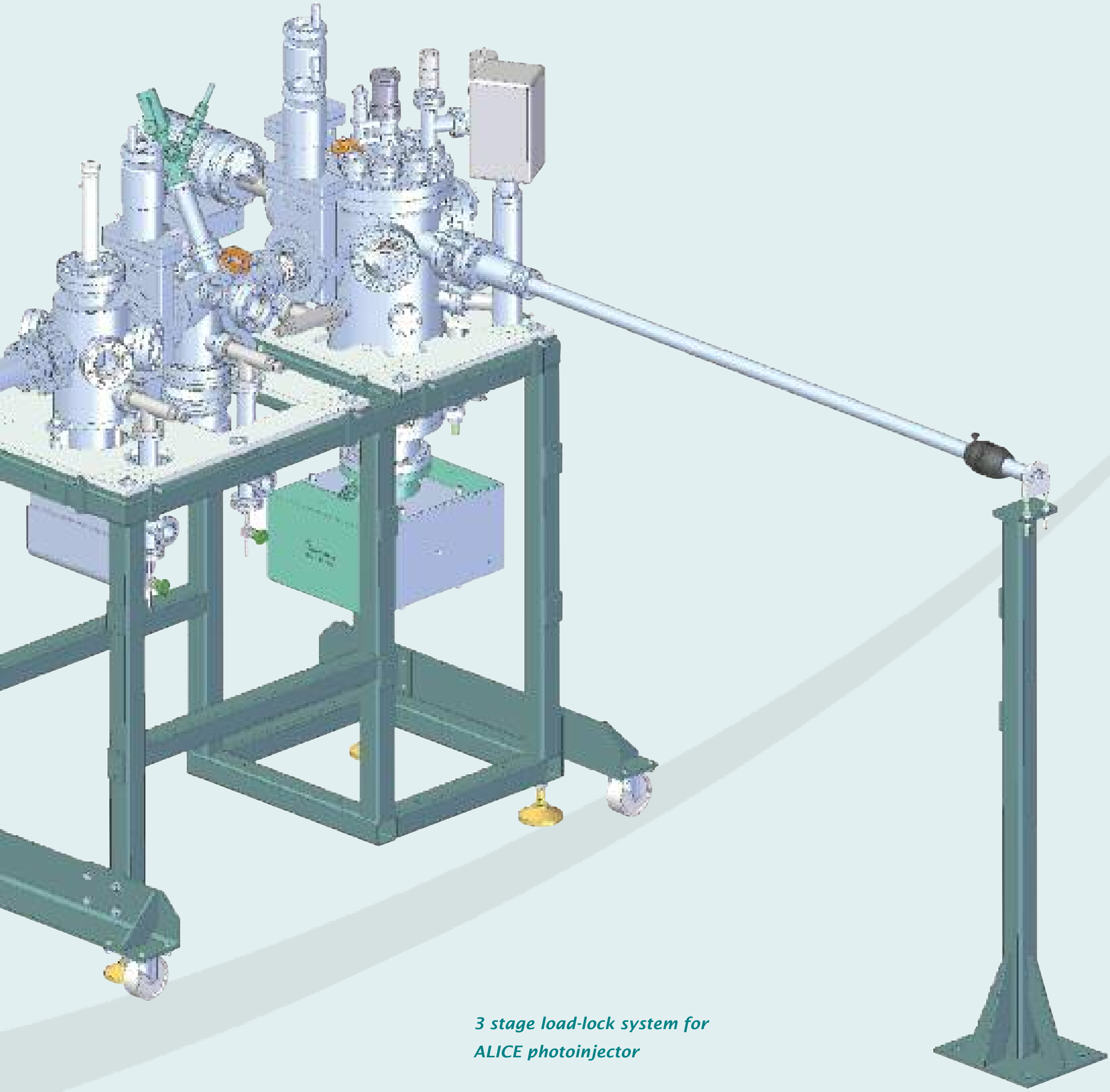
1) Loading chamber into which new photocathodes are introduced
2) Cleaning chamber for atomic hydrogen cleaning of the photocathodes
3) Preparation chamber where photocathodes are activated prior to use

The ALICE load-lock system will allow rapid transfer of photocathodes between the load-lock system and the photoinjector itself. Maintaining the integrity of the XHV vacuum system increases photocathode dark lifetime, and removing the apparatus of photocathode activation from the gun itself will greatly improve its high voltage stability and operational performance. Photocathode activation in a dedicated preparation facility also permits improved monitoring and control over key activation parameters, and should facilitate improved quantum efficiency and reproducibility.

Integration of the load-lock chamber with the existing photoinjector gun requires a re-design of the vacuum chamber and cathode ball. The new vacuum chamber will improve performance by addressing some of the vacuum-related issues which ALICE has encountered in the last 2 years. Additionally, the cathode ball must be modified to permit the transfer of cathodes to and from the external load-lock chamber.

A significant amount of work and planning has taken place over the past year in a productive collaboration between ASTeC's accelerator physics and vacuum groups, and a team from the engineering design office, with a shared aim to assemble this system early in 2009.

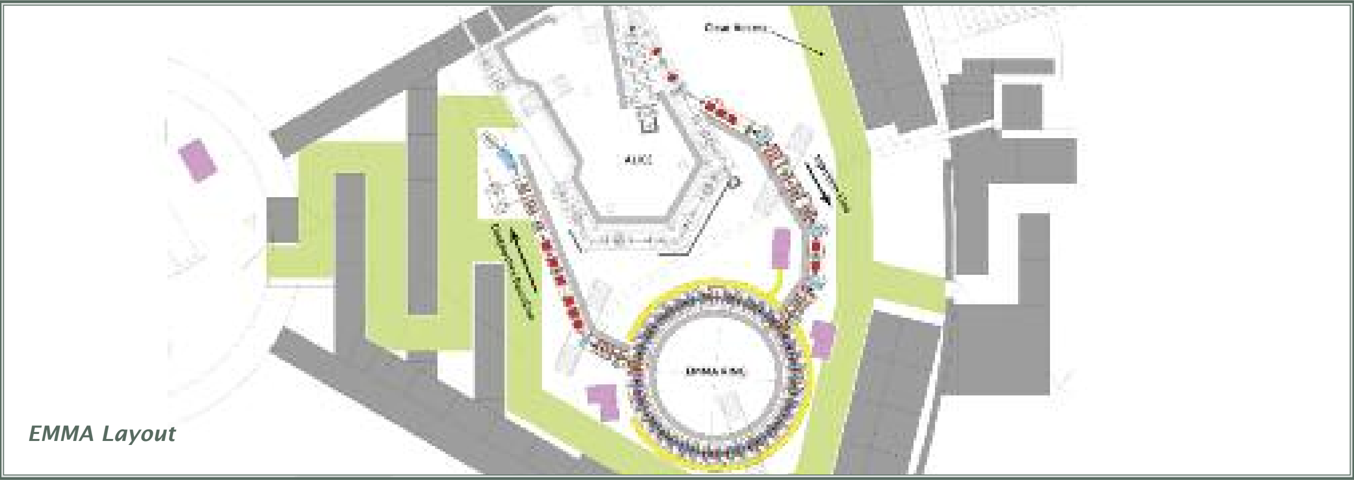




3 stage load-lock system for ALICE photoinjector

EMMA

The Electron Machine for Many Applications (EMMA) is a prototype for a non-scaling Fixed Field Alternating Gradient (ns-FFAG) accelerator. It will be the world's first ns-FFAG and will be installed at Daresbury Laboratory in 2009. Non-scaling FFAGs have potential applications as simple and compact proton accelerators for cancer therapy, as well as being an ideal machine to accelerate muons for a neutrino factory.



EMMA Layout

BEAM TRANSPORT

The novelty of ns-FFAGs requires full characterisation of the beam. In order to provide this, the injection line from ALICE to EMMA has been designed to incorporate a tomography section, which will fully characterise the beam before entering into the EMMA ring. A similar set of diagnostics has also been projected for the EMMA extraction line. These diagnostics will provide a complete knowledge of the ns-FFAGs beam dynamics effects on an injected beam.

The beam dynamics simulations are particularly challenging in EMMA due to the intrinsic non-linearities and the non-existence of a conventional reference orbit. A unique computer code developed by ASTeC staff implements the basic features of the synchro-betatron formalism suitably modified to study ns-FFAGs. The code calculates all beam properties at all intermediate energies from the injection to the extraction. In order to inject/extract beam into/from the EMMA ring, an injection/extraction septum is required along with two kicker magnets each at injection and at extraction to steer the beam. The code has also been an essential tool to simulate the injection and extraction beam trajectories over the energy range to determine the septum and kicker specifications.

MAGNET DESIGN

The magnet design for EMMA presented a challenging problem in many respects. The beam in EMMA will move radially outwards through the magnets during the acceleration cycle, so the aperture and the good field region must be very wide. The magnets must provide bending around the ring as well as focusing, and these two field components must be independently adjustable. This is achieved by displacing standard quadrupoles mounted on movable slides. The magnets are very thin in the longitudinal direction compared to normal accelerator magnets, so the field profile is dominated by 'end effects', and complex 3D modelling is essential.

To verify the modelling prior to full scale production a contract was placed with Tesla Engineering to complete the engineering design, manufacture and magnetic measurement of an F and D quadrupole prototype. The prototype D magnet field quality was improved further by making some minor changes to the pole shape as suggested by the ASTeC experts.

The contract for the 84 production magnets was awarded to Tesla Engineering following a competitive tender exercise. Construction of the magnets is well under way, and they will be delivered to Daresbury Laboratory in batches from November 2008 to February 2009.

Two other magnet types that offer major design challenges within EMMA are the septa and kickers. The septum bending angle needs to be very large (65° for injection and 70° for extraction) and, the space available for these magnets is severely limited. A MATLAB code was written that calculates the magnet position for each injection/extraction scenario that is of interest from an accelerator physics point of view. All the clearances between the beam, the magnet and magnet vacuum vessel were monitored to ensure that their values are acceptable. Following this stage, a detailed, time-varying, three-dimensional, finite-element magnet model of the magnet was built taking into account eddy current losses, magnetic nonlinearity and material anisotropy.

The EMMA kickers have to switch on and off in less than one turn around the ring (about 50 ns). Given the EMMA kicker switching speed and the short magnet length the inductive type of magnet was chosen. The C-shaped core is chosen for its ease of manufacturing and is made of a high quality ferrite. A coaxial line feedthrough is chosen to connect the magnet to its power supply due to its compactness and relatively small stray inductance.

RF SYSTEM

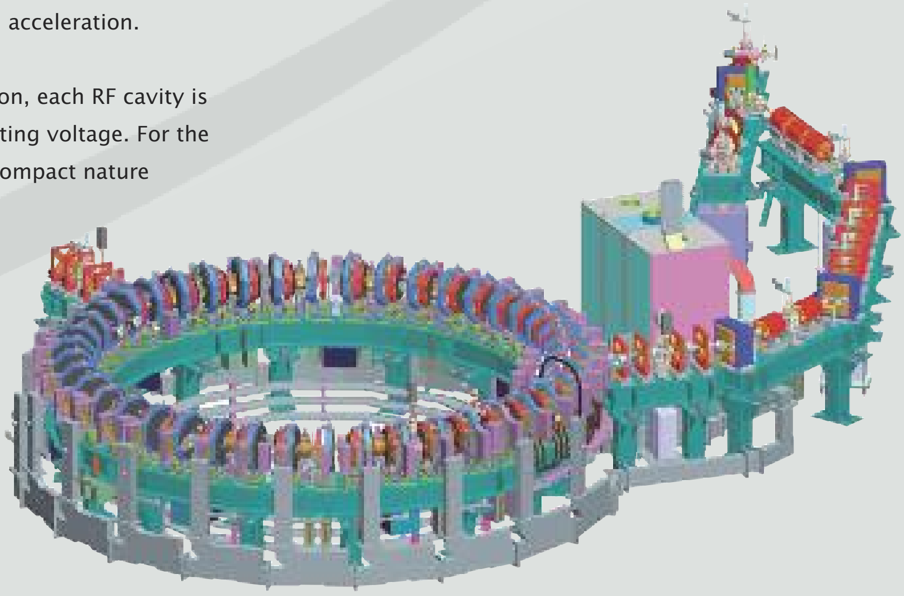
Due to the fast acceleration required in this 42-cell machine, 19 RF cavities are located in alternate cells, omitting 2 cavities to leave space for beam injection and extraction. Since this is a demonstrator machine, the RF system has to be flexible in order to test the whole parameter space, which includes varying the RF frequency and the rate of acceleration. Initially an acceleration of 2.3 MV/turn is required, with the potential to upgrade to a maximum of 3.4 MV/turn. The frequency range for operation is 5.5 MHz, and precise RF phase and amplitude control is required to ensure stable beam acceleration.

In order to provide the needed acceleration, each RF cavity is required to deliver up to 180 kV accelerating voltage. For the cavity design optimisation process, the compact nature of the EMMA ring imposes significant geometrical constraints which potentially reduce the cavity performance. This therefore impacts on the achievable efficiency for a normal conducting cavity, and so a design with the highest possible Q was developed. An aluminium model cavity was fabricated to confirm the predicted RF simulations and then a high power prototype cavity was built to confirm the required accelerating gradient could be achieved.

In order to distribute equal amounts of RF power to each of the RF cavities, a robust RF distribution system has been proposed. Since there are constraints due to size and the need to have crane access to the machine, numerous schemes have been considered. A cascaded system has been found to be the most suitable, whereby sufficient RF power is tapped off the distribution network around the circumference of the ring, requiring increasing levels of coupling towards the end of the waveguide or coaxial lines.

The total peak power required for the EMMA RF system (including 30% overhead), at a duty factor of 3.2% (1.6 ms, 20 Hz) is 90 kW, or 4.7 kW for each of the 19 cavities. To deliver this amount of power (excluding parasitic losses), a number of options have been evaluated at 1.3 GHz.

An RF tender exercise has been performed to secure cost effective solutions for both the RF distribution system and the high power RF amplifier (including associated power supplies and controls). The result of this tender is that a single high power IOT will be utilised, with its RF power distributed via a network of hybrid couplers to each accelerating cavity. The complete EMMA RF system is expected for delivery in Q2 2009.



Proposed EMMA RF System Layout

Next Generation Light Source Studies

The technical studies for the proposed 4GLS provided a timely input to the UK Light Source Review. The review concluded that a new project to develop the science and technology case for a next generation Light Source facility was required.

Technical studies for the proposed energy recovery light source facility 4GLS were pursued through most of 2007. These studies included the development of the advanced physics, with enhanced start to end simulations of the complex accelerator systems and a detailed analysis of beam loss and collimation requirements. In parallel to these physics studies, engineering and other technical system studies were carried out in support of a major costing exercise and a 4GLS science landscapes document[1] was produced defining the scientific potential of the facility.

These studies provided a timely input to the UK Light Source Review, the Science and Technology Facilities Council's (STFC) root and branch review of the UK`s Light Source strategy[2] . The review concluded that a new project to develop the science and technology case for a new light source facility was required. The New Light Source (NLS) project was set up combining the scientific expertise and technology capability within ASTeC and Daresbury Laboratory with the Rutherford Appleton Laboratory, and Diamond Light Source Limited, along with input from university teams nationwide.

[1] http://www.4gls.ac.uk/Documents/4GLS_Landscapes.pdf
[2] http://www.stfc.ac.uk/resources/pdf/UKLSRReport.pdf
[3] http://www.stfc.ac.uk/SciProg/Photon/photonsci.aspx

A timescale for the project was announced[3] in February 2008:

1. Project launch - April 2008
2. Definition of priority scientific requirements - October 2008
3. Definition of generic facility solution - January 2009
4. Submission of costed conceptual design - Autumn 2009

Early in 2008, the technical teams within ASTeC launched into a preliminary phase concepts exercise. These initial studies built on our extensive 4GLS expertise enabling immediate examination of the capabilities of a single pass, superconducting linac driven, FEL to deliver short pulse x-ray beams.

The final meeting of the International Advisory Committee to the 4GLS project was held in February 2008. The Committee advised the design team on which aspects of the project would be worthwhile considering taking forward into a new future facility and reiterated the importance of the activities on ALICE to the R&D programmes within ASTeC.

NLS Launch at The Royal Society London

Next Generation Free Electron Lasers

There is great demand for a radiation source capable of imaging the ultrafast dynamics of matter on the nanoscale. Recent research within ASTeC has been directed towards achieving this through improving the temporal properties of free electron lasers, including a novel scheme to generate extremely short pulses.

There is great demand over a wide range of scientific disciplines for a radiation source capable of imaging the ultrafast dynamics of matter on the nanoscale. In simple terms, the size of the structures that can be resolved is on the scale of the radiation wavelength, while the duration of the radiation pulse sets the temporal resolution. For many years, the most important types of photon source facility have been storage ring synchrotrons and conventional lasers. However, while storage ring synchrotrons are capable of reaching the desired x-ray wavelengths, they may only resolve short timescales through implementing 'slicing' techniques which severely limit the intensity of the radiation, and hence their usefulness in this respect. Advanced conventional lasers can achieve very short pulses and hence good temporal resolution, however they are limited by the lack of suitable optics to ultraviolet wavelengths and longer.

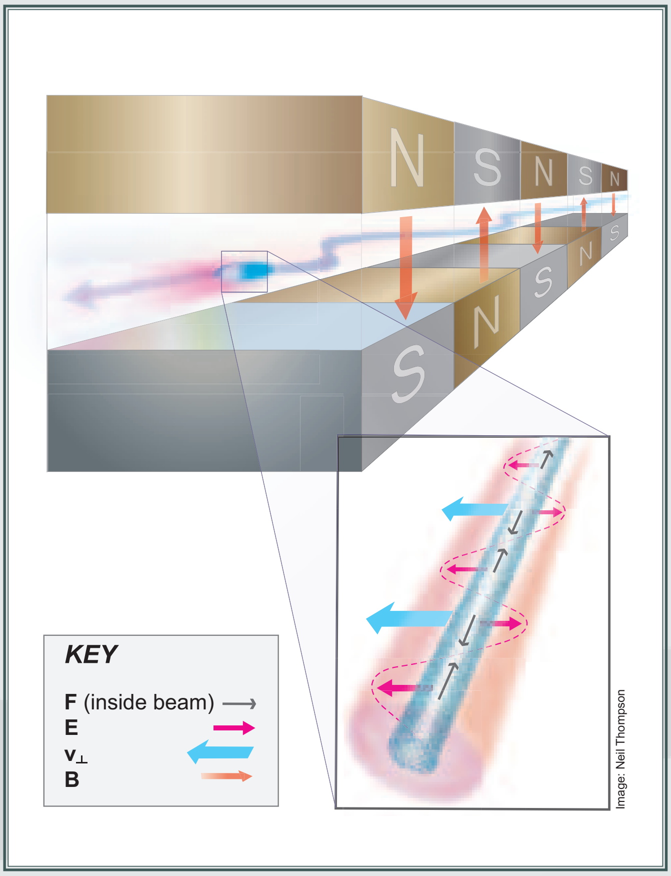
Free electron lasers (FELs) are advanced photon sources based on accelerator technology that have the potential to deliver short pulses of extremely intense radiation at short wavelengths. They operate through the transference of energy from a relativistic electron beam to a radiation field in a periodic magnet called an undulator. The process is illustrated schematically in Figure 1.

FEL designs may be divided into two categories: low gain and high gain. Low gain FELs use a short undulator and a high-reflectivity optical cavity to increase the radiation intensity over many undulator passes; hence they are limited in their wavelength range by the availability of suitable mirrors in the operating wavelength - in the same way as conventional lasers.

Figure 1: Schematic of the high gain FEL interaction in an undulator. The electron beam (blue), propagating out of the page, oscillates transversely in the magnetic undulator field. The inset shows the interaction of a small section of the electron beam, of transverse velocity $v_{\perp}$ (blue arrows), with the electric field (red arrows) of the co-propagating light of wavelength λ. The transverse velocity of the electrons couples with the fields to create a force (black arrows) that acts to bunch the electrons at the radiation wavelength and generate coherent radiation. This is a cooperative effect that is exponentially unstable and can start from intrinsic noise in the system.

High gain FELs use a much longer undulator section to reach high intensity in a single pass, hence removing the need for mirrors and therefore allowing operation in any wavelength range. The disadvantage of this technique is that a 'seed' pulse – typically from a laser - must be used to achieve a predictable and repeatable temporal pulse profile. In the absence of a seed the amplification process starts up from small random density variations in the electron beam (so called "shot noise") and has an unpredictable temporal pulse profile. This is called self-amplified spontaneous emission (SASE), and this mode of operation will be used for the current state of the art high gain FEL projects under construction (LCLS, XFEL, SCSS).

Recent research within ASTeC, in collaboration with the University of Strathclyde, has been directed towards improving the temporal properties of FELs in two ways: producing shorter pulses and improving the temporal coherence at short wavelengths.



ATTOSECOND PULSES

A method has been proposed to generate trains of extremely short pulses from a high gain free electron laser. The idea is to borrow the concept of modelocking from conventional quantum cavity lasers - which allowed a reduction of achievable pulse lengths by three orders of magnitude – and apply it to high gain FELs to achieve a similar reduction in achievable pulse length.

The mode-locking concept in a quantum cavity laser is quite straightforward. The emission from the gain medium contains a broad spread of wavelengths. This emission circulates within the cavity over many round trips and due to constructive and destructive interference, only certain wavelengths persist and are amplified in the gain medium. These 'allowed' wavelengths are called the cavity modes. If a modulation is applied at a frequency equal to the spacing between these modes (such as a modulation to the cavity length) each mode is able to interact with its adjacent modes such that all the modes start to oscillate in phase and the output comprises one dominant short pulse per cavity round trip.

An obvious problem with applying this technique to a high gain FEL is the lack of an optical cavity. Instead, in the proposed scheme the cavity modes are synthesised by inserting magnetic chicanes at regular intervals along the undulator. These chicanes delay the electron bunch with respect to the co-propagating radiation, so that the emission from one undulator section is delayed with respect to the emission from the previous undulator section. In this way, a series of time delayed copies of the emission from a single undulator section are overlaid, and due to constructive and destructive interference (exactly as in the optical cavity of the quantum laser) only certain allowed frequencies, or modes, are amplified. The modes are locked by pre-modulating the input energy of the electron beam at the spacing of the mode frequencies. Due to the physics of the FEL interaction, this energy modulation leads to a combined gain/frequency modulation. The scheme is illustrated schematically in Figure 2.

The scheme has been simulated in state-of-the-art computer codes and results for a system operating in the XUV region of the spectrum, at wavelength 12 nm, are shown in Figure 3. It is seen that for the SASE case the full-width duration of each spike varies between 10-20 fs. For the mode-locked case, shown at the bottom, the output comprises a train of near-identical evenly spaced spikes, with the width of each spike close to 400 attoseconds, a reduction compared to the SASE case by a factor of 50. The peak power in each spike is up to 1.5 GW; not reduced at all compared to the SASE case.

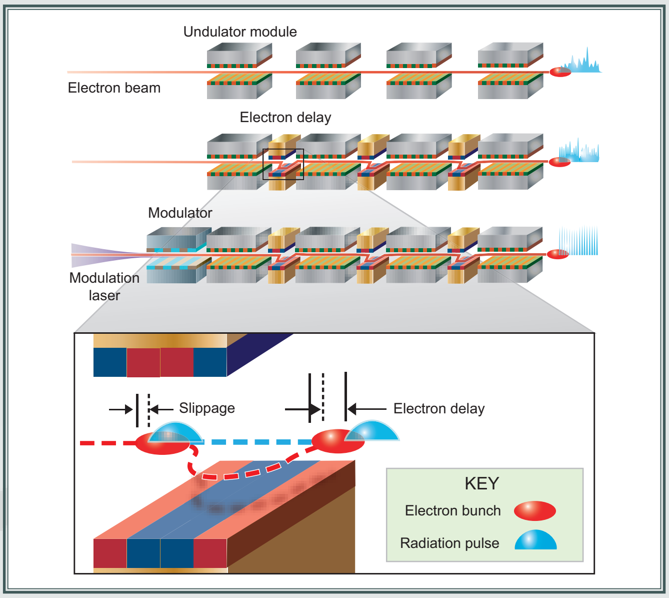


Figure 2: Schematic of the scheme to generate attosecond FEL pulses. At the top is shown a normal SASE FEL, with its long undulator broken into short sections, allowing diagnostic devices to be inserted. In the middle is an FEL with electron beam delays inserted between undulator sections. This is termed 'mode coupled' because the modes are created but not locked together. At the bottom is the mode-locked amplifier FEL, where a short modulator undulator and laser are used to premodulate the electron beam energy and hence lock the modes to generate ultrashort pulses.

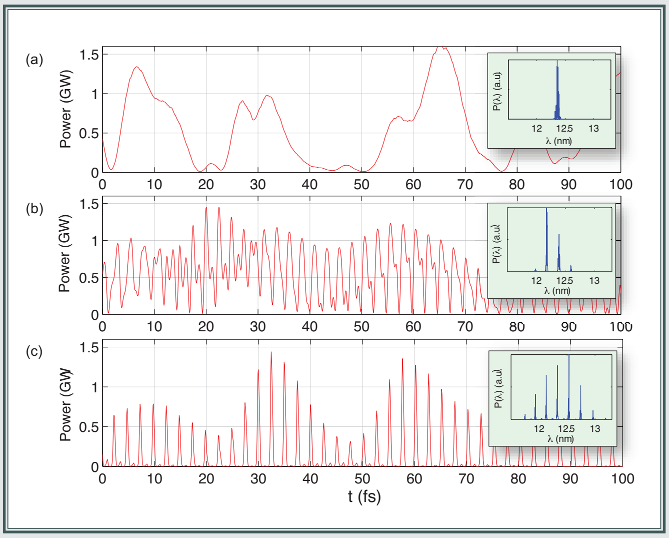


Figure 3: Simulation results for the three cases shown in Figure 2, at a wavelength of 12nm. At the top is the SASE case, in the middle the mode-coupled case, and at the bottom the mode-locked case. For the SASE case the typical spike length of the FEL output is 10 fs, whereas for the mode-locked case the spikes each have a width of around 400 attoseconds.

Simulations have also been done in the x-ray region of the spectrum. For a system operating at 1.5 Angstrom (the same as the LCLS) the predicted output is a train of evenly spaced spikes, each spike of peak power up to 5 GW and duration 23 attoseconds. The spikes are thus shorter than the atomic unit of time (24 attoseconds), the time taken in the classical model of the hydrogen atom for the electron to travel one radian of its orbit around the proton. Such a source of radiation, with its combination of short wavelength, ultrashort time structure and extremely high power, could therefore open up the possibility of stroboscopic interrogation of matter using light with the spatiotemporal resolution of the atom.

IMPROVED TEMPORAL COHERENCE

It is understood that the highest scientific impact for experiments is made possible by the availability of transform limited pulses – where energy and time spread are close to the uncertainty limit. As part of the 4GLS project, a design for a regenerative amplifier FEL (RAFEL) was proposed; this is a high gain FEL which uses a low feedback optical cavity to improve the temporal coherence. The cavity returns a small field to the start of the undulator to seed the interaction with the subsequent electron bunch. This is shown in Figure 4.

We have shown that the operating range of such FELs may be extended to significantly shorter wavelengths than current designs (into the XUV regions of the spectrum and beyond - where seeds are not available) through the use of very low reflectivity mirrors.

We considered a generic RAFEL design and numerically optimised the feedback fraction to optimise output power and temporal coherence. The greatest temporal coherence is seen when the power feedback is approximately double the shot noise power; this may be achieved with cavity feedback factors as low as 5×10^{-6}.

Using the optimum feedback fraction, the average time bandwidth product is just double that of a transform limited Gaussian pulse. This is more than five times better than the equivalent SASE result. It is also seen that if the feedback factor is too high then the pulse properties are similar to the equivalent SASE case. Typical output from a RAFEL for a range of feedback fractions is shown in Figure 5. Methods of attaining the low feedback factors were not studied, however the fact that they may be so small indicates that there is significant scope in extending the low feedback RAFEL concept into the XUV and possibly further. The possibility of combining harmonic generation methods and RAFELs also exists and these exciting possibilities will be the subject of future research.

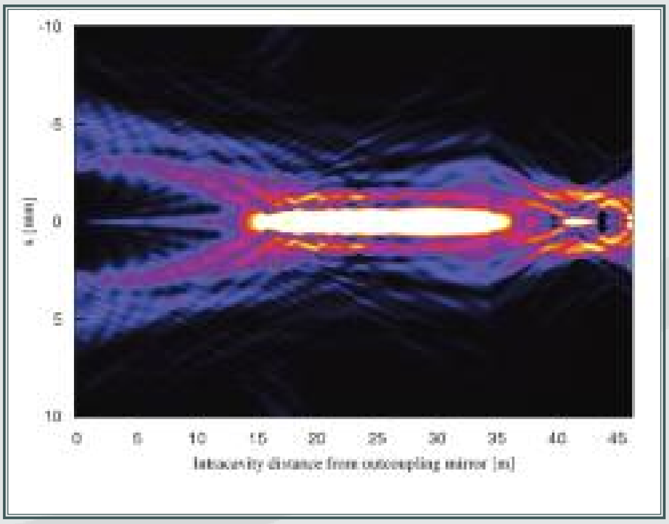


Figure 4: Reflected pulse profile in a RAFEL. The centre of the pulse is outcoupled through a hole in the cavity mirror while the reflected fraction is returned to the undulator entrance; developing significant on-axis intensity in the process.

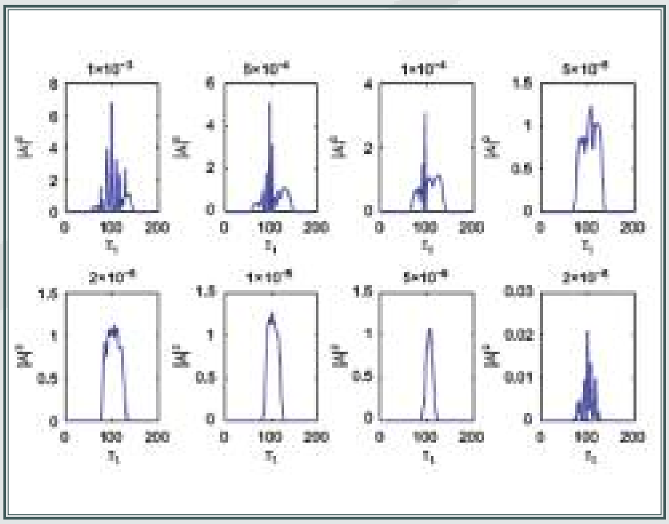


Figure 5: Typical output pulses of the low feedback RAFEL system. The feedback fraction is shown above each plot, and varies from $F = 1\times10^{-3}$ to $F = 2\times10^{-6}$.

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International Linear Collider

ASTeC is a strong collaborator in the international effort on designing and addressing the critical R&D issues for the International Linear Collider (ILC) and has contributed to the ILC Reference Design Report published this year by the international global design effort team. The global design effort brings expertise from all the three regions (Europe, Asia, and the Americas) to make technical advancements to the challenging requirements for this future lepton collider.

THE POSITRON SOURCE

The positron source for the ILC is more demanding than any yet built. ASTeC is responsible for managing the design of the complete system which is carried out by a large international collaboration. As well as this leadership role, ASTeC has particular responsibility for the ~ 200 m long undulator system. Over the past year a full scale prototype undulator module (4 m long) has been constructed for the first time. This is a complex high field strength superconducting helical magnet with a very narrow aperture.

4m long undulator prototype

The Magnetics and Radiation Sources Group of ASTeC, supplemented by an industrial placement student from Bristol University and collaborators at UCLA in California, has developed a new code for calculating the synchrotron radiation produced in the ILC positron source undulator. This type of magnet is too long to be accurately simulated by available codes. The new code is designed to make use of parallel processing to efficiently calculate the radiation produced from an undulator many hundreds of meters long. An efficient way of handling all the data is also required. The code works for ideal undulators, with no magnetic field errors, as well as for a real or arbitrary field defined by the user, such as the measured fields from the 4 m long prototype that has recently been constructed. Initial benchmarking against other codes has been successful and the next steps are to use the code to model the ILC positron source.

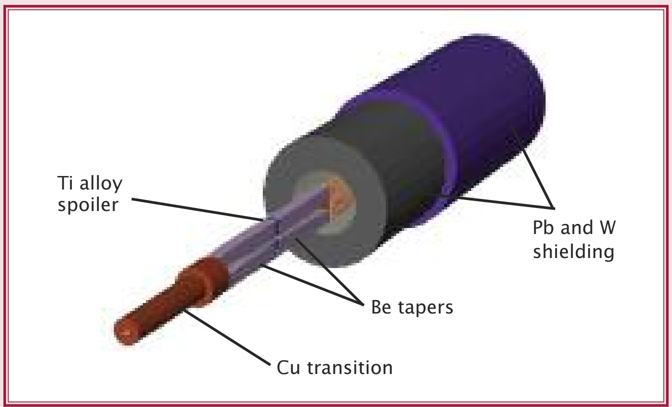
With new light source accelerators moving towards shorter and shorter electron bunch lengths a new regime involving resultant emission of THz frequency fields is opening up. It is important to understand how these fields from the electron bunch interact with the vacuum vessel. This is essential, as the fields can reflect back from the vessel and destroy the bunch that created them. An experiment using THz fields created by a laser and non-linear crystal has been set-up at Daresbury to study this interaction.

BEAM POSITION MONITOR

In most modern electron accelerators, the electron bunch is a cloud of billions of electrons confined in a tiny flat volume which can be several millimetres long and as slim as about 20 micrometers. The electrons are compressed to this extent intentionally, as it is necessary for many applications. One more requirement is that these compressed 'micro-bullets' in a sequence should not scatter more than say, 1/10th of their transverse size. Various methods are used to reduce bunch scattering and stabilise the beam. All of them need an instrument to measure bunch jitter, either to verify acceptable scattering residue or in some cases, to supply a direct signal for feedback-based stabilisation. A high resolution Beam Position Monitor (BPM) that is suitable for these tasks has been developed at ASTeC. It uses a pair of opposite pickup electrodes placed inside the vacuum pipe. The electron bunch induces an instantaneous voltage impulse on each electrode. The voltage difference is proportional to bunch offset. Many engineering problems are overcome to achieve a BPM position reading with jitter close to the ultimate thermal noise limit achievable. Recent beam tests at Accelerator Test Facility (ATF), KEK in Japan have shown for this new BPM that the measured noise is about 1 micrometer, which equates to only 3 times the thermal noise limit.

COLLIMATION SYSTEMS

The staff members in ASTeC have continued to optimise the collimation optics for the beam delivery system, achieving much better performance. The two stage collimation approach, of thin spoiler and a thick absorber at appropriate locations, ensures minimum background in the detector. The spoiler protects the main absorber by dispersing the beam, via multiple Coulomb scattering, in case of a direct hit. This reduces the beam energy density and thus avoids severe radiation damage. The spoiler effect on the beam during normal operation due to wakefield effects has to be reduced to a minimum. Experimental data from beam tests performed at SLAC End Station A interacting with different spoiler geometries, has provided a comparison with analytical calculations with a precision of 10%. Radiation damage and activation simulations have resulted in the selection of a geometry using beryllium tapers with a titanium alloy central body. Several prototype designs are under consideration and studies of activation are being performed.



Spoiler prototype with absorber and shielding model for radiation simulation.

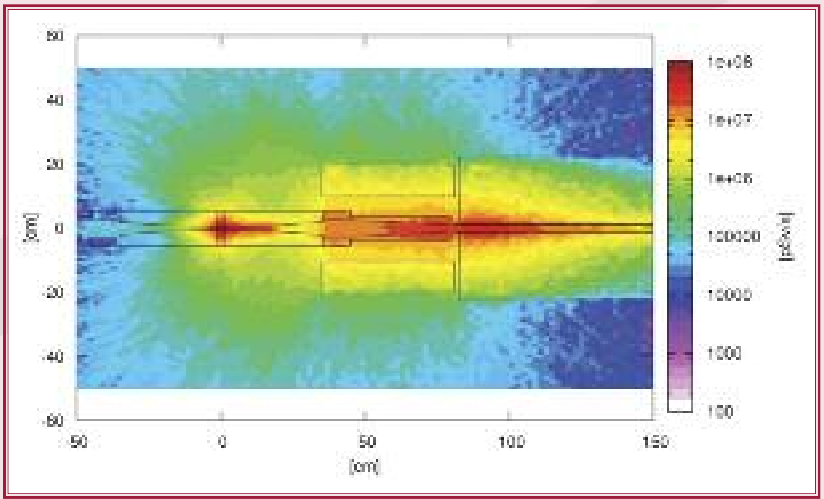
LOW EMITTANCE TUNING

As the designs of the damping rings have evolved, accelerator physicists at ASTeC continued to refine and analyse models of the low emittance tuning of the machine, vital for achieving the final luminosities of the machine. Novel tuning algorithms have been developed to achieve required nanometer beam sizes at the collision point. The algorithms are vital to remove errors in the machine just before collisions of the particles. To test these algorithms staff have been involved in the Accelerator Test Facility (ATF), Japan, and specifically in the design of an upgrade to that machine, that will closely mimic the design of the future linear collider final focus design. As part of this effort, ASTeC staff members have been to the test facility to help with understanding the current machine, and correct possible limitations in the upgrade. The extension to the ATF named ATF2 is planned to come online in December 2008, with full commissioning starting in early 2009.

VACUUM DESIGN

The vacuum design team at ASTeC evaluated the implications of electron multipactoring on the damping ring vacuum system design and the study of ion induced pressure instability in a positron damping ring. The engineering design of a proposed damping ring has started with the help of mechanical designers in collaboration with University of Liverpool, The Cockcroft Institute.

The interaction region vacuum design for the ILC poses several challenges due to its push-pull configuration, cold and warm transitions and different detector configurations. These challenges were discussed during the Interaction Region Engineering workshop organized at SLAC (IRENG07) in October'07, where ASTeC staff suggested several solutions to deal with the vacuum design for this complex region.



Residual equivalent dose rate due to beam halo after 2 months of constant operation on a plane cutting longitudinally the spoiler prototype shown.

Muons – The Key to Unveiling the Underlying Laws of the Universe

Nature supplies physicists with a limited range of stable charged particles to use in accelerators. Protons and electrons, the components of hydrogen gas, are about all there is. However, the demand for beams of more exotic particles has been increasing worldwide for decades. The ISIS spallation source at Rutherford Appleton Laboratory (RAL) produces beams of neutrons for materials studies and muon and kaon physics are also both active fields. The demand for muons will increase in the future with proposals such as the neutrino factory, where neutrinos are made from muons, and the muon collider, a high-energy frontier machine for studies post-LHC. It is projects such as these that form the focus of work by ASTeC's Intense Beams Group, based at RAL.

DESIGNING A HIGH INTENSITY PROTON DRIVER

At the heart of plans for the future lies a multi-megawatt proton driver, which drives a very intense beam into a fixed target. At least half a dozen designs of the proton accelerator have been produced at RAL in recent years. A prime consideration is very low beam loss and the key to achieving this lies with the Front End Test Stand (FETS), currently under construction at RAL. FETS is developing a high current ion source in combination with the linac post accelerator and will examine the feasibility of fast beam chopping – creating the necessary gaps in the linac bunch train to facilitate the low-loss injection into the ring. If successful, FETS will not only clear one of the hurdles for proton driver studies worldwide but, will be the forerunner for any proposal to upgrade ISIS.

UPGRADING ISIS

The ISIS linac is an ageing machine and the ASTeC Intense Beams group is part of a team analysing several upgrade options. One possibility is to replace the linac, probably at a slightly increased top energy, to ensure continued operation for the next ten to twenty years. Another possibility is to have an 800 MeV linac injecting into a new 3 GeV synchrotron. Designs for both the linac and the 3 GeV synchrotron have emanated from ASTeC and are currently the subject of detailed analysis. The work involves simulation studies of high intensity linac beam dynamics and transport, and an examination of different types of room temperature and superconducting RF structures.

MAKING EXOTIC PARTICLES FROM INTENSE BEAMS

The proton beam smashes into the production target, and one issue still to be resolved, is the choice of material and engineering design to cope with a beam of multi-megawatt power. Members of ASTeC have been running simulations of the fragmentation of the incoming particles and nuclei of the target into the exotic particles of interest. The particles produced fly in all directions and, for exotic beams, powerful confinement systems must be designed to transport them to the experiment. The constant bombardment of the target by the proton beam also puts huge mechanical and thermal stresses on the target material and makes it highly radioactive by transmuting some of its elements. With beam powers measured in megawatts, this presents serious engineering challenges. The distribution of particles produced from a hadronic target

The distribution of particles from a hadronic target

can be quite diffuse. Particle tracking codes are required to calculate the fraction that can be captured.

PREPARING MUON BEAMS

Pions from the production target quickly decay into muons and, in the neutrino factory, a series of solenoids and techniques such as phase rotation are used to form particles into a beam. However the muon beam is naturally very large and dispersed, and its emittance needs to be reduced using a special technique known as ionization cooling. Designing an ionisation cooling channel is a challenging task. High power RF, emittance absorbers and superconducting magnets all need to be packed into close proximity. Members of ASTeC are addressing this challenge by studying new lattices that would provide more cooling or make construction and operation of the cooling channel easier. In parallel, there is work on the MICE prototype cooling channel at the ISIS facility aimed at proving the principle of ionisation cooling and calibrating the theoretical performance against actual measured results.

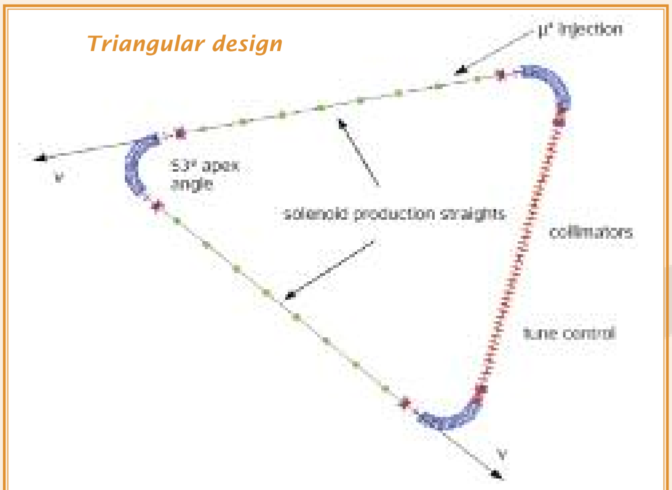
TRANSPORTING MUON BEAMS

Due to short half-life of 2 micro-seconds in their rest frame, muons need to be accelerated quickly. Synchrotrons, where fields take time to be ramped, are not a realistic option. In their place, members of ASTeC are studying a fixed field alternating gradient accelerator (FFAG). The dynamics of the beam in FFAG is far from that in a conventional circular accelerator, especially when applied to muon acceleration. With a huge energy gain, by the time the beam completes one turn, beam properties such as momentum, emittance, and orbit are markedly changed. From the beam point of view, the properties of the lattice seem to alter although in fact it is the beam and not the lattice that changes in time.

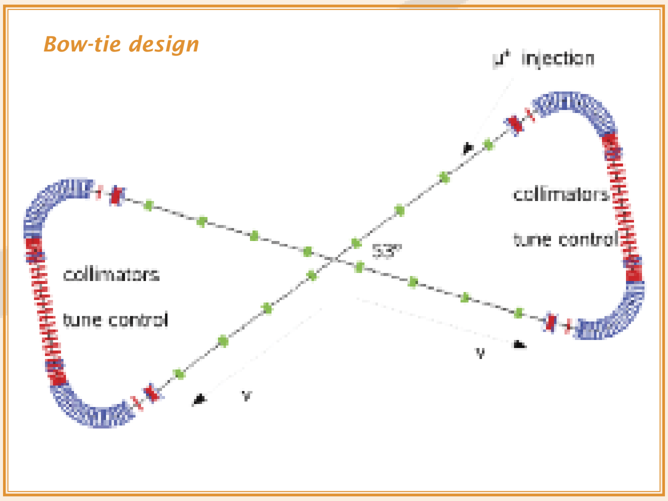
The re-birth of FFAGs was instigated in Japan, through the J-PARC project and studies of a possible Japanese neutrino factory. Two prototype accelerators were constructed of the scaling kind. However a new type of beam dynamics known as non-scaling now seems most appropriate for handling muon beams. The EMMA accelerator at Daresbury Laboratory, described elsewhere in this report is a prototype electron model to explore ideas for a non-scaling FFAG for muons. When it comes online, it should confirm if the theories are correct and whether belief in its future promise is justified.

CREATING NEUTRINOS

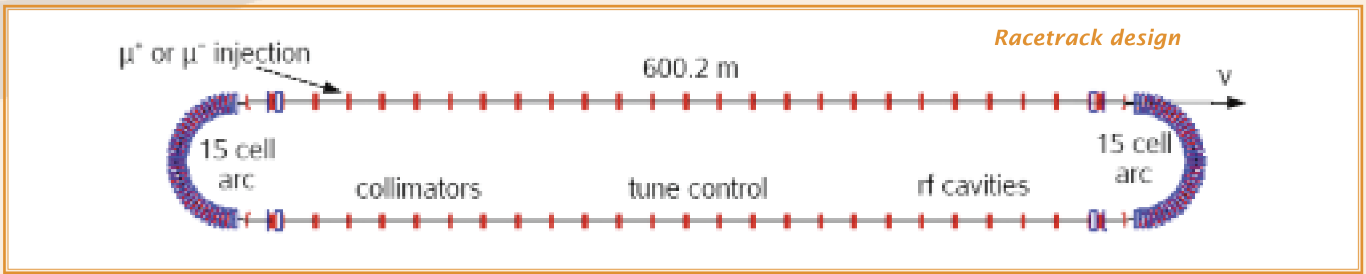
Neutrinos are created from the decay of the muons once they have been accelerated to energies in the range 20-50 GeV. Special rings are needed for this, with long production straights pointing at the chosen detector sites. Particle physicists are currently asking for baselines of about 4000 km and 7500 km, which mean that for a facility based in the UK, detectors could be at the Indian Neutrino Observatory, at Pykara, and in a mine at Gaspe near Montreal. The ASTeC team has designed possible muon storage/decay rings with triangular, bow-tie and racetrack geometries. The tricky optics for these designs requires the beam to be fairly small in the bends but very large in the straights so that envelope oscillations do not add to the normal cone of the neutrino radiation. Electrons produced by the muon decay also need to be handled, and, with such a huge beam power in the ring, an advanced collimation system is essential.



Triangular design



Bow-tie design

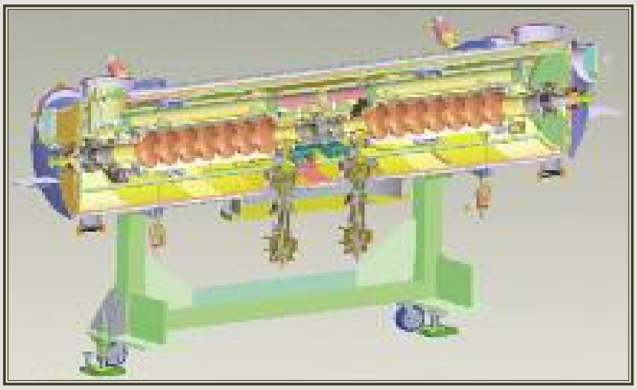


Racetrack design

Daresbury International Cryomodule Collaboration

As part of the 4GLS design process, ASTeC embarked on a collaborative design project with Stanford and Cornell Universities, the Lawrence Berkeley National Laboratory in the USA and FZD-Rossendorf in Germany to develop a superconducting cryomodule for optimised operation on energy recovery facilities and other high duty cycle accelerators.

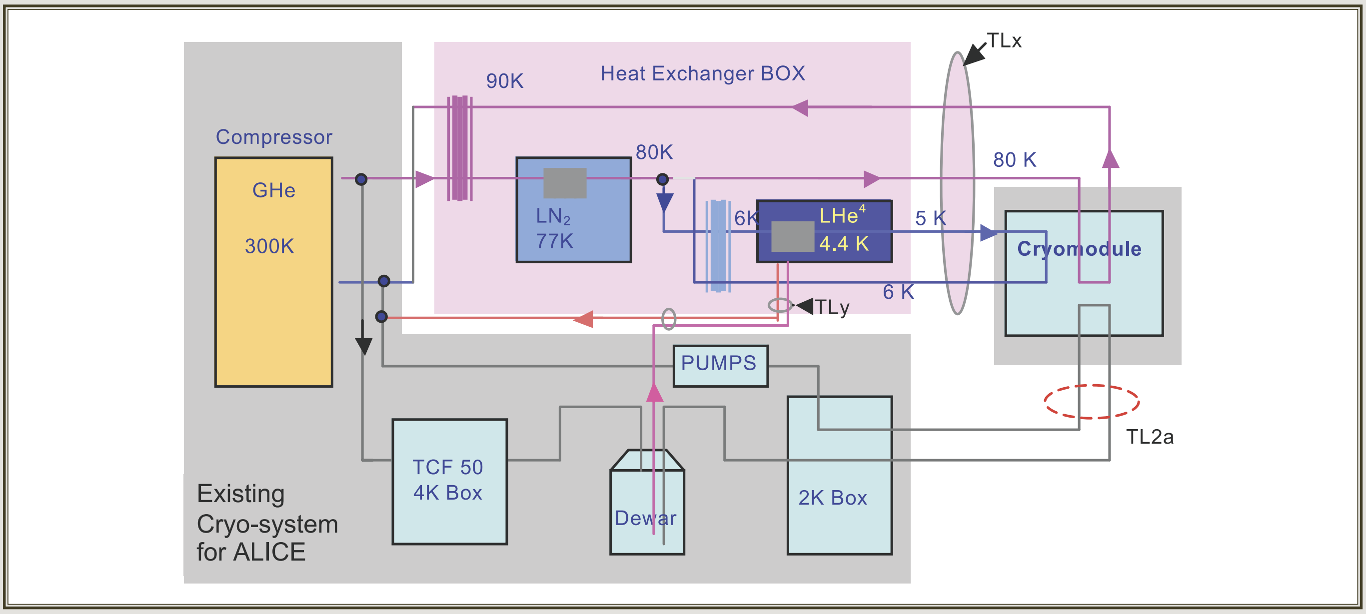
The Daresbury International Cryomodule Collaboration (DICC) has enabled ASTeC to take responsibility for coordinating the design, development and integration of the various cavity and cryomodule components to ensure improved performance over the existing ALICE cryomodules procured from industry. Fabrication of the various cavity and cryogenic components, including all tooling and fixtures required to perform the system integration, is now well underway and full system assembly is scheduled for 2009.



DICC Cryomodule Assembly

SYSTEM FOR COOLING TO INTERMEDIATE TEMPERATURES (COOL-IT)

The process of operating the DICC cryomodule in CW mode increases the demand for the cooling power at 80K by almost a factor of 10, compared to the existing ALICE cryomodules, mainly due to the generation of Higher Order Modes (HOM). Moreover, to minimise microphonics generation, the use of liquid nitrogen will be replaced by cold helium gas. The existing cryo-system for ALICE does not have the capability to provide the additional cooling power through cold helium gas at 80K. An indigenous cryogenic system 'COOL-IT' (system for **COO**ling to **I**ntermediate **T**emperatures) is being developed to meet these additional cooling requirements. At the heart of COOL-IT is a network of four heat exchangers interacting with each other via three independent flow loops: liquid nitrogen, liquid helium and gaseous helium. The process will be able to provide two streams of cold helium gas, at 5K and 80K respectively, which are transported to the Linac via a compound transfer line TLx. The diagnostics and control system for the new process are also being developed. The complete system will be integrated into the existing cryo-system for ALICE via only 4 interconnections; 2 supply and 2 return lines.



Schematic for COOL-IT

Vacuum Science Facility Developments

The Vacuum Science laboratory of ASTeC continued to develop the essential vacuum facilities to support various R&D activities. The new surface analysis facility will play a strong role in ALICE photoinjector development activities.

NEW SURFACE ANALYSIS FACILITY

With the closure of the SRS an opportunity arose to relocate a beamline end station belonging to Liverpool University into the vacuum science laboratory. This surface analysis system allows techniques such as X-ray Photoelectron Spectroscopy (XPS), Ultra-violet Photoelectron Spectroscopy (UPS) and Low Energy Electron Diffraction (LEED) to be used to probe what is happening on the atomic scale at the surface. The development of this system has enabled the vacuum science group to support a Ph.D. programme in collaboration with Manchester University dedicated to studying the surface characteristics of photocathode materials. This programme of work strongly influences ALICE photoinjector activities and underpin in longer term photocathode development for new applications. Activations of GaAs in the vacuum science laboratory are now a routine procedure with quantum efficiencies (QE) in excess of 2.5% regularly achieved. This has led to an improvement in the QE values obtained on ALICE, which has resulted in the specified electron beam parameters for ALICE being achieved.

Surface analysis facility

BAKEOUT COATING

A joint invention was made following collaboration between ASTeC Vacuum Science group, CLIK and an industrial partner. The 0.1 mm thin coating on the outer surface of the vacuum chamber allows bakeout of the vacuum chamber up to 300˚C with or without a heat insulation jacket. This invention allows for a reduction in the cost of accelerator magnet systems by reducing the gap between the magnet poles in the case where the vacuum chamber needs to be baked *in-situ*. A patent has been filed.

VACUUM SEALS

Tests on a new UHV sealing technique were investigated for use on EMMA. Conflat joints have always been the preferred choice at Daresbury Laboratory. For EMMA however, it was necessary to optimise the use of space and therefore adapt a sealing technique that requires less space once assembled. The tests conducted in the vacuum science laboratory determined that the correct machining of the sealing faces was critical to its vacuum performance. Once this issue had been addressed the seal met the leak rate requirements of <1 x 10^{-9} mbar l/s.

Non-Evaporable Getter Coatings Development

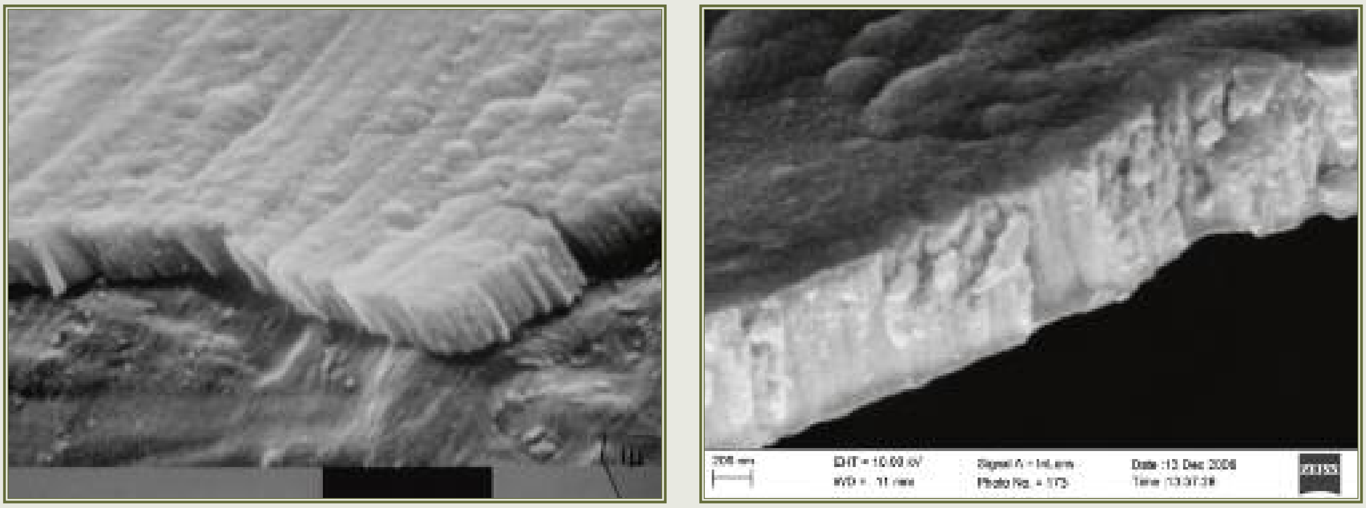
The ongoing collaboration between ASTeC and Manchester Metropolitan University (MMU) aims to study and further develop a novel vacuum technology – Non-Evaporable Getter (NEG) coatings.

The NEG technology which originated at CERN allows coating of a large part of the beam vacuum chamber of the particle accelerator to reduce gas desorption and to provide distributed pumping speed at lower cost. An additional benefit of such coating is low photon and secondary electron emission yields. However to use this coating in a design of future particle accelerators one needs to have reliable and reproducible data as well as good understanding of how the required specifications can be achieved. To gain better knowledge and experience, the studies focused on Physical Vapour Deposition (PVD) with planar and solenoid magnetron sputtering to make different coatings. The coating materials Ti, Zr, V and Hf were used in different combinations such as single, dual, triple and quadruple films. By varying the deposition parameters it was possible to deposit films with different structure and morphology, which were analysed using techniques such as Scanning Electron Microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS) and Rutherford Back Scattering (RBS).

The pumping properties of the samples were studied after NEG activation in the range of temperatures between 160˚C and 300˚C. It was shown that the NEG coatings can be made to provide the necessary pumping properties after activation at 160˚C for 24 hrs. This activity required regular modelling for each kind of sample to treat the experimental data.

The disadvantage of the PVD coating method is the difficulty to perform coating on arbitrary shape and inside a vessel with a cross-section smaller than 6 mm. In order to address this problem another method, Chemical Vapour Deposition (CVD), was proposed. A deposition technique for the binary and ternary alloys with Ti, Zr and V was developed. A patent on CVD NEG coating has been filed by the collaboration.

The unique and very useful experience of the behaviour of NEG in different conditions was gained by the ASTeC vacuum scientists.



SEM images of NEG films with columnar (left) and dense structure (right)

Electro-Optic Diagnostics

A period of experimental studies of ultrafast Electro-Optic (EO) beam diagnostics on the FLASH-FEL facility at DESY in Germany came to a conclusion during 2007.

These studies involved both dedicated beam shifts and periods of electron beam measurement during FEL user operation, and achieved a number of significant milestones in the development of EO diagnostics. Bunch structure as short as 60 fs rms was measured, the shortest obtained worldwide with any
non-destructive technique. A simultaneous cross-comparison of the EO technique and transverse deflecting cavities was undertaken for the first time, providing confirmation of the accuracy of the EO profile measurements. This period of measurements culminated in a publication of the most significant results in Physical Review Letters in October 2007.

Synchrotron Radiation Source

ASTeC scientists have continued to provide support for the last full year of operation of the Synchrotron Radiation Source (SRS). This year began with a change of cathode to ensure smooth running till the final shutdown next year, and with planned closure of certain beamlines the staff had to deal with difficulties to control the desired beam positions.

Old cathode being removed

In the last full year of operation of Daresbury's Synchrotron Radiation Source (SRS), ASTeC has continued to provide support when needed. After many years of maintaining an active accelerator physics programme on the SRS, latterly the emphasis has been on treating the machine more venerably in order that it can fulfil its outstanding user commitments before shutting down for good next year. Hence most of the emphasis has been on dealing with any operational issues that might affect reliability without pushing the hardware beyond its normal operational limits.

The year started with recovery from a problematic cathode change, as it was felt that the existing gun cathode would not quite last until the end of user operation in August 2008. A new cathode, with a high level of emission, was required for the final year and a half of running.

In addition, the technically difficult mode of single bunch, when just one of the SRS's 160 RF buckets are filled with electrons, while all the other buckets contain less than 0.1% of the main bunch's charge, was offered twice. This requires a significant amount of support from ASTeC to do successfully and once again the SRS's users were pleased with the results obtained.

Another issue that had to be dealt with was the effect of the planned closure of certain beamlines on the global vertical beam position servo. This relies on photon beam position monitors (called TVMs for Tungsten Vane Monitors) which are usually incorporated in the beamline ports. As the numbers of ports reduce, there are less data available to feed into the SVD algorithm therefore leading to difficulties in controlling the position of the beam to the accuracy one would like in certain parts of the ring.

However despite these issues, the twenty seventh year of SRS operation was successfully navigated with the support of ASTeC.

Partially dis-assembled cathode mount

Workshops & Meetings

Energy Recovery Linacs (ERL07)

The 41st Advanced ICFA Beam Dynamics Workshop on Energy Recovery Linacs, "ERL07" was held at the Cockcroft Institute, from May 21-25, 2007 organised and chaired by ASTeC. The workshop attracted 91 registered participants, with representatives present from a total of 24 different laboratories and institutes world wide. The first day comprised 11 plenary talks covering the status of ERL projects, prototypes development and the major technology areas for these accelerators. The next three days were reserved for break out sessions with around 100 presentations being made in the four workgroups namely: injectors; optics; synchronization, diagnostics and instrumentation; and superconducting RF. All working groups had charges to look at the latest developments and possible common problems facing the accelerator community in specialized areas in the ERL laboratories around the world. More information can be found at http://www.astec.ac.uk/ERL07/

Workshops & Meetings

Intermediate CERN Accelerator School (CAS)

In September 2007, ASTeC, along with other members of the Cockcroft Institute, hosted an intermediate Accelerator Physics course, organised by the CERN Accelerator School. The two week long course was attended by 90 physicists and engineers from many accelerators and associated centres in the world. The topics covered a very broad range, from basic theory to engineering techniques and best practice for application to the design and operation of particle accelerators. In spite of the formal title of the course, much of the material presented was of an advanced nature, and built on the material presented in a basic accelerator physics course that had been held in the earlier year in Zakopane (Poland).

The lecturers delivering the tuition came from many accelerator institutes and laboratories and included a number of individuals from ASTeC and the Cockcroft Institute at Daresbury, acknowledging the eminence of our local experts in a number of specialised areas. More junior ASTeC staff also benefited from the visit by the CERN school, for all were able to 'sit-in' on plenary sessions of their choice, without having formally registered.

The complete course was subsequently recognised as a valuable education opportunity for all who attended and ASTeC and the Cockcroft Institute were thanked for their local organisation and provision of both lecturers and facilities.

Workshops & Meetings

Workshop on Modern Problems and Capability of Vacuum Gas Dynamics

The 51st IUVSTA (International Union for Vacuum Science, Technique and Applications) was organised jointly by ASTeC and the Federal University of Parana (Brazil) in Sweden from 9-12th July 2007. The workshop was supported by IUVSTA, ASTeC, The Swedish Research Council (Vetenskapsrådet) and Kurt J. Lesker Company (UK).

Two scientific communities work in the gas dynamics: the Rarefied Gas Dynamics (RGD) community focused mainly on transitional and hydrodynamic regimes and the Vacuum Science (VS) community focused mainly on a free molecular flow regime. Meanwhile the interests of both communities are overlapping well and there were many attempts to bring the two communities together. In the progress of science some research and applications require knowledge of both rarefied gas dynamics and vacuum science. Such practical applications made it possible that 55 scientists were interested in attending a common meeting.

The workshop brought together vacuum scientists and engineers interested in all aspects of gas flow modeling in vacuum systems with researchers who develop numerical and analytical methods of calculation of gas flows in the whole range of the gas rarefaction including the free molecular, transitional, and hydrodynamic regimes.

The meeting was found to be very useful and it was decided to run this workshop every 2-3 years.

The details can be found on the workshop website: http://www.vgd07.dl.ac.uk/

Workshops & Meetings

EPS-HEP2007

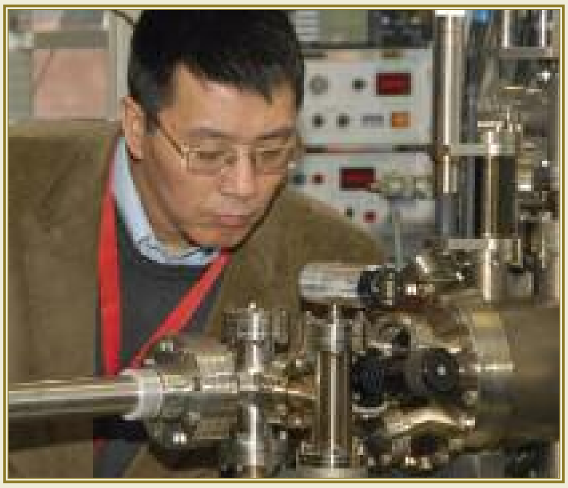
EPS-HEP2007, the conference of the European Physical Society Particle Physics Group, was held in Manchester on 19-25th July 2007. This is one of the big three particle physics conferences, held every two years, and was attended by 576 delegates from all over the world.

The conference proved to be a great success at every level. A highlight was the award of the EPS prize to Professor Makoto Kobayashi and Professor Toshihide Maskawa - an award endorsed by their Nobel prize a year later. The Bridgewater Hall was an excellent and highly impressive venue for the plenary sessions, and the parallel talks were conveniently co-located on the Manchester university campus.

As well as the usual talks and conference banquet there were some unique features like the brass band concert and the beer festival. ASTeC staff provided an excellent administrative support to organise this conference and their key role in the organisation made it possible to smoothly run the event from start to finish, which was much appreciated by the delegates as well as the organising committee.

Workshops & Meetings

Operation of LArge Vacuum Systems II (OLAV II)



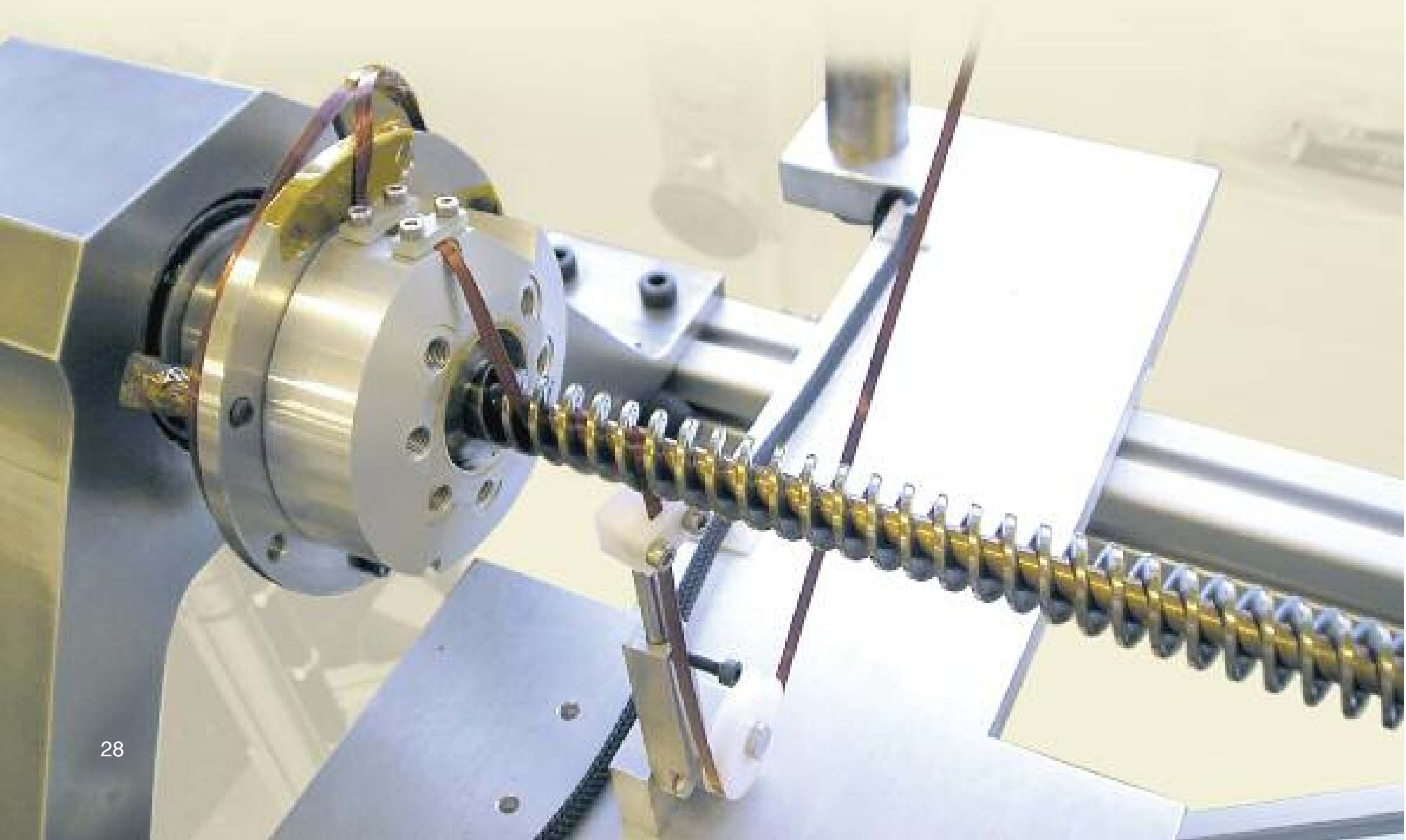
Following a very successful 1st OLAV meeting held at CERN in 2005, ASTeC was pleased to welcome more than 50 scientists and engineers to OLAV II. The workshop style meeting was held at Daresbury Laboratory from 10-12th March 2008. The meeting brought together representatives from many of the world's large vacuum systems such as the LHC at CERN (Switzerland), ITER at Cadarache (France) and TRIUMF at Vancouver (Canada). The aim of the meeting was to discuss the operational issues associated with large vacuum systems with participants being encouraged to share both their successes and failures. Topics included: flange specification issues, activation recipes for NEG films, age related water cooling circuit failures, particle control measures and procurement related problems. The meeting included tours of the ALICE facility, the SRS and the ASTeC Vacuum Science Laboratory as well as a small commercial exhibition. The meeting was very successful and a 3rd meeting is already being planned.

For more details of the meeting visit:
http://www.astec.ac.uk/OLAVII/index.htm.

Workshops & Meetings

ILC Positron Workshop

The positron source for the International Linear Collider was the subject of a two day workshop hosted by ASTeC at Daresbury Laboratory in October 2007. The positron source is one of the most demanding parts of the complete accelerator facility and there are competing technologies which may provide the best solution, one of which is championed by ASTeC. Consequently, the workshop was very lively but also very constructive with all of the delegates having the same goal in mind - the design of a highly optimised positron source for the ILC.



EUROFEL and EUROTeV Design Study Projects

The two projects EUROFEL (European FEL Design Study) and EUROTeV (European design study towards a global TeV linear collider) were funded by the European Union's "Sixth Framework Programme" which commenced on 1st January 2005 for a period of three years. The EUROFEL project ended on 31st December 2007. The EUROTeV project was extended till 31st December 2008.

EUROFEL was a joint effort of sixteen European institutions to prepare for the construction of next-generation of free-electron laser (FEL) light sources around Europe. Coordinated by DESY Hamburg and divided into six work packages, ASTeC contributed to five work packages and led the one dedicated to beam dynamics studies.

The beam dynamics work package concentrated on studying and modelling the effect of space charge, wakefields and coherent synchrotron radiation (CSR) on pulsed electron beams with very high peak currents, through their production, transport and compression processes. High charge density bunches are typically produced in RF photoguns where the electrons' own strongly-repelling electric fields can cause growth in all three dimensions, a phenomenon called space charge. This can also be a problem in subsequent longitudinal bunch compression systems, until the beam has gained sufficient energy for it to become insignificant.
Unfortunately, these high-peak current beams also induce electromagnetic fields in their surrounding vacuum chamber, known as wakefields. The effect of these fields on the electron beam will further disrupt the beam quality.

Finally as the beam passes along a curved trajectory, the electric field from the bunch tail can reach the head and produce coherent synchrotron radiation (CSR) which leads to further deterioration in the beam quality. Reliable tools are needed to calculate the impact of these processes on beam parameters with precision. As part of the EUROFEL beam dynamics work package, a number of simulation codes were further developed and benchmarked on experimental accelerator facilities.

EUROTeV project, where ASTeC is co-ordinating the Beam Delivery Sytem and the Polarised Positron Sources work packages and participating in the Damping Rings work package was extended till 31st December 2008.

To read all the reports produced by
the EUROFEL and EUROTeV projects, visit:
http://www.eurofel.org
http://www.eurotev.org

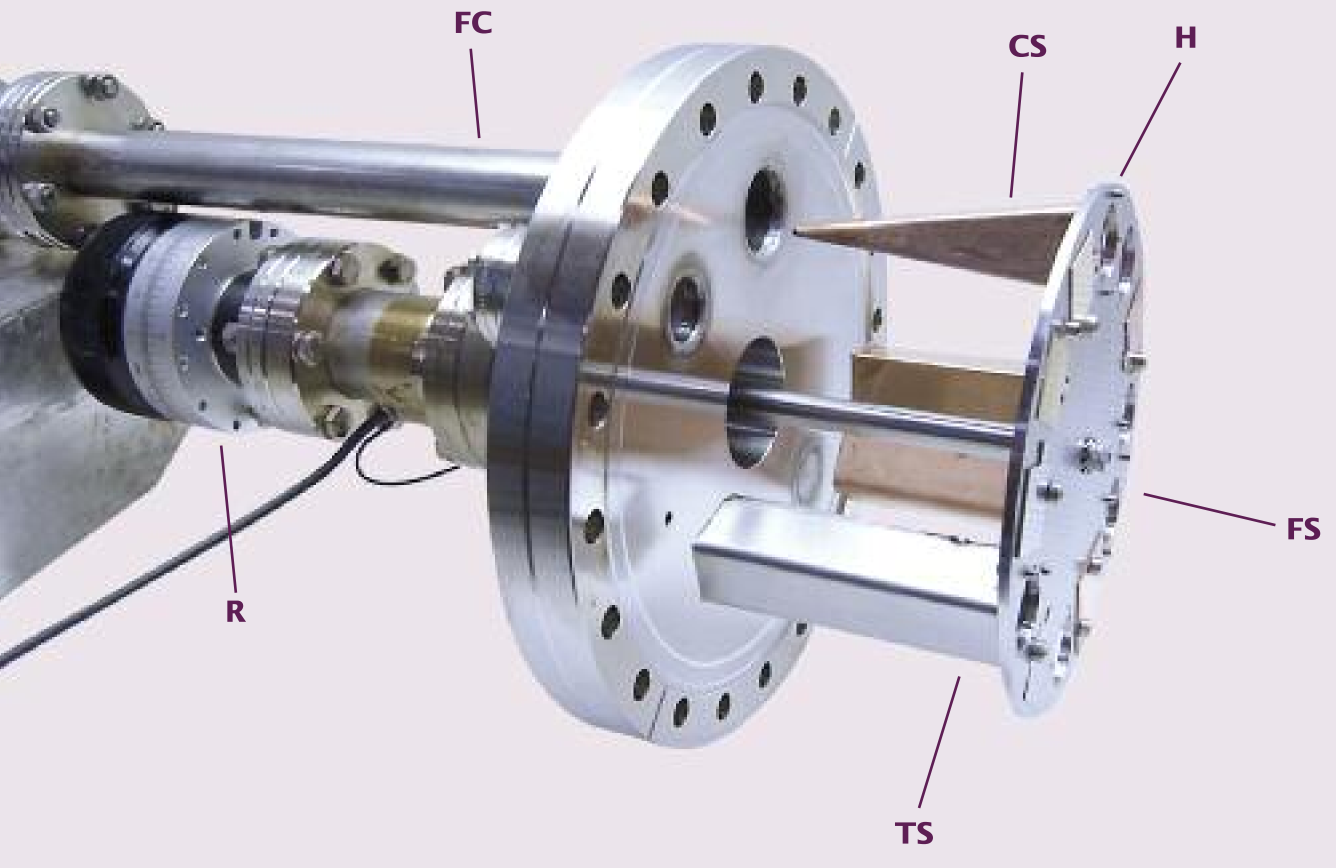
Heavy Ion Beam Induced Pressure Instability

As part of the European Union's "Sixth Framework Programme", vacuum scientists from ASTeC participated in collaborative studies on the beam induced pressure instability in heavy ion machines.

Heavy ion beam accelerators have shown a significant pressure rise when the intensity of the beam is increased above a certain level. This unacceptably high pressure rise is due to ion induced desorption which is the result of beam ions colliding with the residual gas molecules in a beam pipe where they undergo charge exchange. This causes them to hit the vacuum chamber after the next dipole magnet releasing gas which increases the pressure. The following beam bunches thus travel in much higher pressure environment and thus lose more ions from the beam causing even higher pressure rise downstream, losing even more ions and so on. This phenomenon severely limits the accelerator operation due to very short beam lifetime. To study this beam induced pressure instability in heavy ion machines, DIRAC (Darmstadt Ion Research and Antiproton Center)-Phase-1 collaboration was set up between GSI, the Uppsala University and ASTeC under the European Union's Framework Programme 6.

During this year, a series of intense experiments were prepared and run at the Svedberg Laboratory with the aim to measure the heavy ion induced gas desorption yields for different materials and ions and their energies. A sample holder with 10 different samples measured total desorption yields. ASTeC's Vacuum Science group took a lead role in these experiments by participating in the experimental design and experiments as well as coordinating and analysing the data. The results of these studies are published and submitted for journal publications.

The sample holder assembly: a sample holder (H) with flat (FS), tubular (TS) and cone (CS) sample, a rotator(R) and a Faraday cup (FC).



A Week in Westminster

Jim Clarke from ASTeC spent a week in Westminster as part of the Royal Society MP-Scientist Pairing Scheme in November 2007. The purpose of the scheme is to help scientists understand how science is used within government to respond to issues and also to help form policy. Jim was paired up with Mike Hall, the Member of Parliament whose constituency contains Daresbury Laboratory. During the week Jim was able to observe debates in the House of Commons and House of Lords, as well as sitting in on Select Committees that were considering topical issues. Mike took part in a reciprocal visit to ASTeC in January 2008.

Mike Hall MP and Jim Clarke outside the Houses of Parliament. Photograph © The Royal Society.

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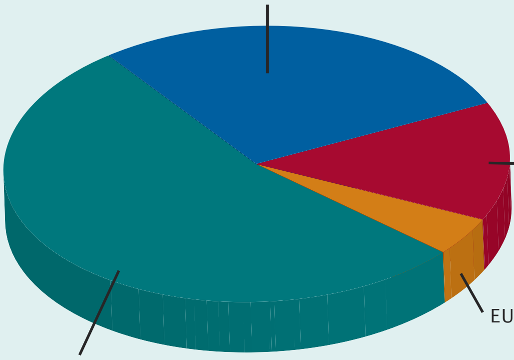
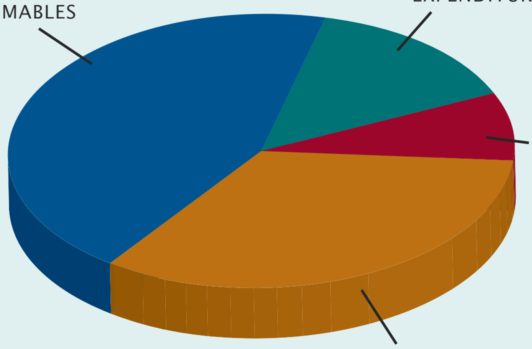
Financial Summary

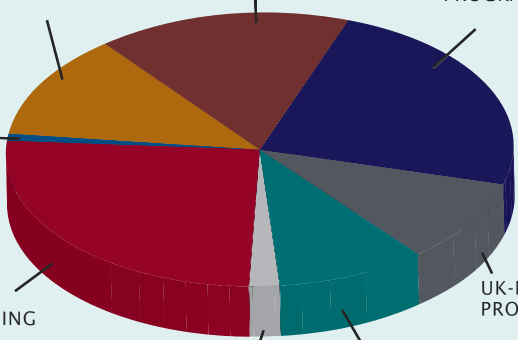
INCOME SOURCES 07/08	£K
STFC SCIENCE PROGRAMME OFFICE	2583
STFC VOTE FUNDED ACTIVITIES	4901
EU	389
GRANTS AND OTHER EXTERNAL FUNDING	1295
	9168



EXPENDITURE 07/08	£K
SCIENTIFIC & ENGINEERING STAFF COSTS	3081
CONSUMABLES	4031
CAPITAL EXPENDITURE	1314
SUPPORT AND SITE SERVICES	742
	9168



EXPENDITURE BY PROGRAMME 07/08	£K
LC-ABD PROGRAMME	2184
UK-NF PROGRAMME	907
HIGH POWER PROTON ACCELERATORS	856
HIGH BRIGHTNESS ELECTRON ACCELERATORS	185
UNDERPINNING RESEARCH	2352
NEW INITIATIVES	91
OTHER PROFESSIONAL ACTIVITIES	1107
EU AND REPAYMENT WORK	1486
	9168



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