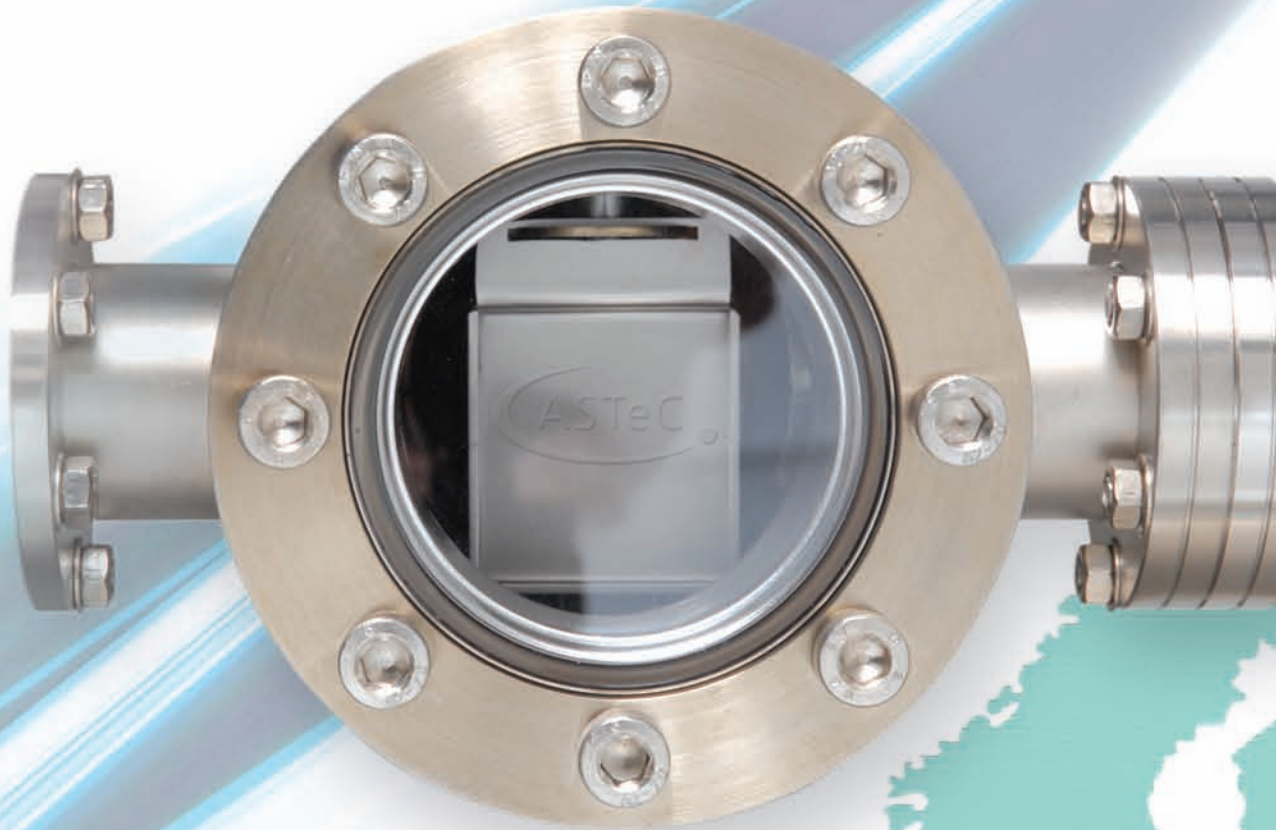
ASTeC

Accelerator Science and Technology Centre



ASTeC Annual Report 2005 - 2006

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ASTeC

Accelerator Science and Technology Centre

Annual Report
2005 – 2006

This report covers the work accomplished by the Accelerator Science & Technology Centre (ASTeC) for the financial year 2005 – 2006.

Editors: Neil Thompson and Naomi Wyles.
Designed & produced by: Media Services, Daresbury Laboratory.

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Foreword

This work outlined in this latest ASTeC Annual Report represents a consolidation of the broad programme of scientific and technological activities that were previously initiated. As is revealed in the Financial Summary, a large part of this programme is devoted to two studies of a future Linear Collider and Neutrino Factory, in both cases as part of national collaborations funded jointly with PPARC but also undertaken in a wider international context. In this latter regard it is a great pleasure to highlight the outstanding contribution of ASTeC staff on this world stage, with their recognised leadership in key topic areas on both projects.

ASTeC also continues to make a major contribution to the evolution of the design of 4GLS, culminating this year in wide ranging input to the Conceptual Design Report (CDR) that has now been published. At the same time the precursor ERLP project has moved on from design into an assembly and commissioning phase where many of the same ASTeC staff play a leading and critical role. Designing, building and operating ERLP has promoted ASTeC (and the UK) into a world leading position in this frontier technology but this has only been possible due to excellent collaborations with other CCLRC Departments and wider partnerships with UK HEIs and overseas Laboratories.
I wish to emphasise the relevance of this theme for all ASTeC activities; success increasingly depends on identifying and delivering such collaborations. An additional element in this scenario is the creation by PPARC of two new Accelerator Institutes and this year ASTeC has been developing new partnerships with both of them.
ASTeC's interests are not restricted to these major projects. As is described in this Report, there have been significant contributions both to Diamond and to SRS support. Diamond's successful commissioning and operation in coming months will be a tribute to its design foundations previously laid by ASTeC staff and to the effective ongoing collaboration with their DLS colleagues. SRS science delivery as it passes its 25th anniversary continues to benefit from strong ASTeC support, both to operations and to its final upgrade development projects.

Underpinning R&D remains a critical area of the ASTeC portfolio and it is also essential that a long term skill base is nurtured through this route. This implies ongoing investment in technical infrastructure, which includes suitably equipped laboratories. Completion of ERLP will provide a potential accelerator test facility of wide applicability, including the proposed EMMA injector role described later. Infrastructure for development of superconducting RF systems has also been identified as an ASTeC priority of relevance beyond individual project solutions.

None of the achievements reported here would have been possible without the wholehearted support of ASTeC staff and our other collaborators and I thank them all here. The period of rapid ASTeC expansion is probably now over but the demands on us all will continue to be high and the value of ASTeC unquestionable.

Professor Mike Poole,
Director

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ASTeC Overview

ASTeC MISSION – MIKE POOLE, DIRECTOR

As a Centre of Excellence ASTeC offers high quality advice and services to stakeholders on development and application of advanced accelerator systems. The ASTeC skill base covers all modern accelerator challenges, from complex particle beam dynamics to demanding technologies such as magnetics, radiofrequency systems and vacuum science. As well as design of new Large Scale Facilities, often collaborating with HEIs or overseas Laboratories, a R&D programme ensures UK access to the latest developments, making us a partner of choice nationally and internationally and gaining leadership in many cases. Other aspects include an education remit, collaborating with many universities, and a commitment to knowledge exchange with industry. ASTeC's mission is to deliver all of these features to a world class standard.

Accelerator Physics Group

led by Susan Smith

Our aim is to push accelerator performance by understanding the physical processes involved. We support and collaborate in many electron accelerator projects, nationally and internationally. We use our skills to improve existing accelerators and to design new facilities. Our expertise includes linear and non-linear lattice design, the use and development of accelerator modelling tools, and the optimisation, characterisation and tuning of accelerators. We encourage accelerator physics education through links to many universities and departments.

Intense Beams Group

led by Chris Prior

The ASTeC Intense Beams Group, based at RAL, works on theoretical studies of future accelerators, upgrades to accelerators and, from time to time, on understanding issues such as unexplained beam behaviour in existing machines. Current projects include high intensity proton and muon accelerators for a neutrino factory and ideas for spallation neutron sources. The work involves computer modelling with a range of tools, mostly software that members have developed and written themselves. There are frequent collaborations on international projects with laboratories worldwide, notably CERN, GSI, KEK, BNL and Fermilab.

Magnetics and Radiation Sources (MaRS) Group

led by Jim Clarke

The MaRS group has expertise over a wide range of accelerator science and technology. We have projects in electromagnets, superconductors and permanent magnets. Many of these magnets (undulators and wigglers) are used to generate synchrotron radiation and our group is not just responsible for their design, construction and measurement but also for calculating their radiation emission. A specialist application is in free-electron lasers and our group has expertise in these advanced accelerator based light sources. We use state-of-the-art design and simulation codes for magnets, synchrotron radiation emission and free-electron lasers. In addition we have a magnet test laboratory in which advanced measurement techniques are applied to all types of accelerator magnets.

RF and Diagnostics Group

led by Peter McIntosh

The RF and Diagnostics group has expertise ranging over RF, diagnostics, cryogenics and laser system specialties. The group can design, procure, install and commission each of these systems. The group leads and contributes to a number of UK R&D projects. The Muon Ionisation Cooling Experiment (MICE) at RAL is an international validation experiment for a Neutrino Factory - the group is leading development and fabrication of the RF drive at the heart of the experiment. On top of this catalogue of cutting edge development, the group continues to support the SRS to ensure maximum operability and reliability.

Vacuum Science Group

led by Joe Herbert

The Vacuum Science group has expertise in vacuum technology, vacuum science and the application of those disciplines to accelerator vacuum system design. We work on many projects, carrying out design, equipment procurement, and system commissioning. Major new activities include developing vacuum systems for a photoinjector and the superconducting RF accelerating module for ERLP. The group are designing the vacuum system for 4GLS. The group also has a significant role in the ILC project particularly in the design of the damping ring and beam delivery vacuum systems. R&D work in the Vacuum Science Laboratory has included studies of Non Evapourable Getters (NEG), photocathode preparation and XHV techniques.

News & Events

Football Tournament

Two teams from ASTeC entered the summer 2005 Daresbury lab football tournament. ASTeC 1 (pictured left) played well and went on to lift the trophy. ASTeC 2 (pictured right) did not fare so well and ended up with the wooden spoon.

Particle Physics Masterclass

ASTeC staff were involved in the annual particle physics masterclass for sixth form students. Students from several schools in the North West were given a talk on accelerators and took part in an experiment to measure the energy of the SRS linac.

Daresbury Laboratory Open Day

ASTeC staff were involved in open days in October 2005 to celebrate 25 years of the SRS. Visitors and staff were shown around the Insertion Devices Laboratory, given virtual tours of ERLP and shown around the SRS and ERLP.

Retirements

Two long serving members of ASTeC staff retired in 2006. Ron Reid (right), who led the Vacuum Science Group, had been at Daresbury for over 30 years. Mike Dykes (left), who led the RF and Diagnostics Group had worked at the Lab for over 41 years. Both have continued in post retirement consultant roles.

When Worlds Collide

Scientists in ASTeC are playing key roles in the design of the International Linear Collider (ILC), a new matter-antimatter collider that will allow physicists to explore energy regions beyond the reach of today's accelerators and recreate the conditions that existed at the birth of the Universe.

In the ILC design, two superconducting linear accelerators, each 20 kilometers long, accelerate beams of electrons and positrons towards each other to an energy of 250 GeV. Each beam contains ten billion particles and is compressed to a few-nanometres thickness. The beams meet at the interaction point in an intense crossfire of collisions, generating showers of new subatomic particles which will enable physicists to identify dark matter and search for extra dimensions.

Enhancing Luminosity

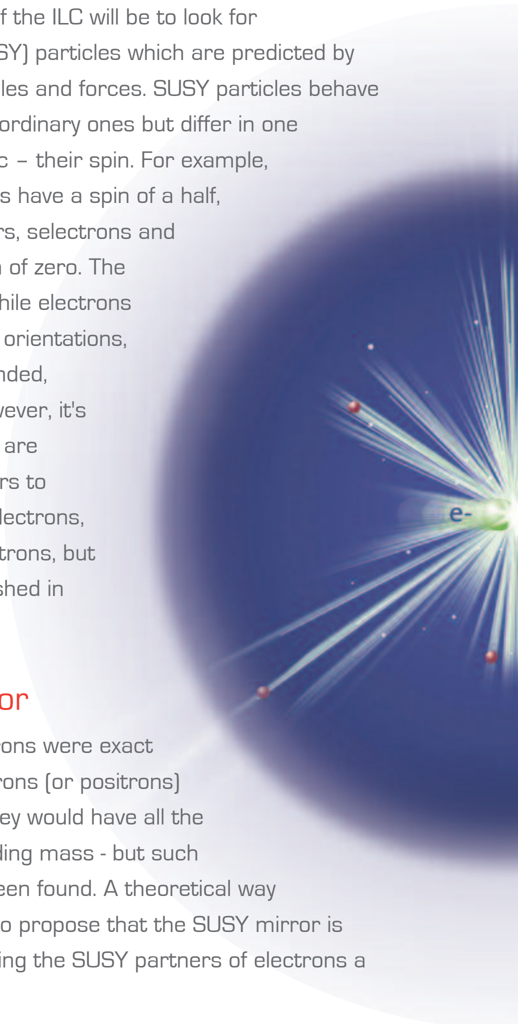
In order to maximise the luminosity (a measure of the collision efficiency) in the two proposed interaction regions ASTeC scientists have been developing a crab cavity system. Positron and electron beams must collide such that their volumes optimally overlap, but because the beams don't collide head on (due to the difficulty of separating the beams post-collision) this is hard to achieve. The crab cavity, as its name suggests, manipulates the beams by rotating the head and tail of each bunch, such that at the interaction regions a head on collision is replicated. This maximises the luminosity.

The crab cavities are located very close to the interaction regions and yet their interaction with the beam must be limited to giving the required bunch rotation. The beams themselves induce electromagnetic fields within the cavities (referred to as wakefields) which sustain long enough to interact with the next rotated bunch. The wakefields distort the rotation and can badly affect the luminosity. The cavity must therefore be designed to minimise wakefields.

Timing is also critical. Each bunch must arrive and interact at precisely the correct moment, requiring an electronics control system that can synchronise the rotation of both beams to within 500 femtoseconds. This level of control has not been routinely achieved in the world's accelerators to date - providing such a system for the crab cavity on ILC will put ASTeC at the forefront of low level RF (LLRF) feedback system development.

Searching for SUSY

One of the objectives of the ILC will be to look for "supersymmetric" (SUSY) particles which are predicted by theories unifying particles and forces. SUSY particles behave like mirror versions of ordinary ones but differ in one quantum characteristic – their spin. For example, electrons and positrons have a spin of a half, but their SUSY partners, selectrons and spositrons, have a spin of zero. The consequence is that while electrons have two possible spin orientations, right-handed or left-handed, selectrons do not. However, it's still thought that there are seperate SUSY partners to right and left-handed electrons, the left and right selectrons, but they must be distinguished in another way.



A Cracked Mirror

Furthermore, if selectrons were exact SUSY mirrors of electrons (or positrons) – apart from spin – they would have all the same properties including mass - but such particles have never been found. A theoretical way out of this problem is to propose that the SUSY mirror is slightly 'cracked' so giving the SUSY partners of electrons a heavier mass.

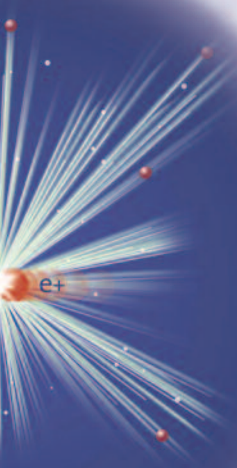
To prove this requires subtle measurements. In one experiment incoming polarised electrons and non-polarised positrons scatter with a SUSY particle and are 'transformed' into selectrons. This mechanism allows the identification and characterisation of selectrons produced from differently polarised electrons to prove or disprove the theory.

Distinguishing between the corresponding sets of products is very difficult, but can be made easier by polarising both the electron beam and the positron beam. Electron beams have been successfully polarised at the Stanford Linear Accelerator

Centre (SLAC) in California, but no one has ever used polarised beams of positrons in a linear collider. It requires a completely new technique to produce them - this is where ASTeC comes in.

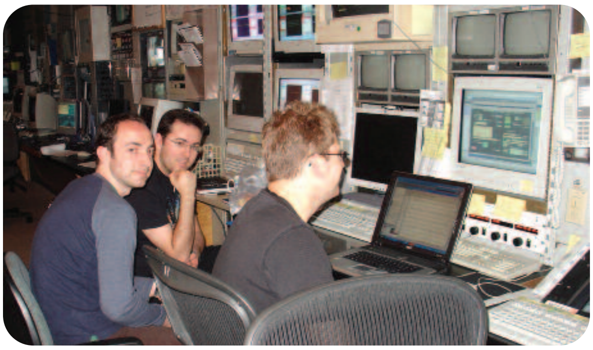
Antimatter Beams

ASTeC has a prominent role in the design and specification of the ILC positron source. Positrons are generated by passing an electron beam through a system of magnets known as a helical undulator and generating gamma rays. Looking head on the electrons appear to be moving in a circle as they corkscrew down the undulator, meaning that the gamma rays produced are also circularly polarised. The gamma rays collide with a metallic target generating polarised electron-positron pairs. The polarised positrons are then captured and accelerated to the ILC interaction point where they finally collide with polarised electrons.



Working closely with other CCLRC engineers, two short (approximately 30 cm) helical undulators have been built, one based on permanent magnets and the other on superconducting magnets. After extensive tests carried out at Daresbury Laboratory, Rutherford Appleton Laboratory and the Paul Scherrer Institute in Switzerland, the superconducting magnet was chosen as it provided the best quality magnetic field and operational flexibility.

An international collaboration named E166, involving around 50 people from 20 institutions worldwide, was set up to demonstrate polarised positron production using a helical undulator. The E166 project at SLAC passed a 50 GeV electron beam through a 1 metre-long helical undulator to



ASTeC Staff working on the End Station A facility at the Stanford Linear Accelerator Centre.

produce circularly polarised photons. Polarised positrons were then created by colliding the photons with a thin titanium target and the polarisation characteristics of both photons and positrons were analysed. "After two months of data taking the results indicated that polarised positrons had been created and detected - the scheme had worked!" says ASTeC physicist Duncan Scott.

Making an Empty Space

ASTeC scientists have been researching ways of creating a vacuum level of 10^{-7} mbar inside the 200m long by 6mm diameter helical undulator.

“The small diameter to length ratio of the undulator makes it particularly difficult because the vacuum conductance in such a capillary is very low,” explains Oleg Malyshev, who has been working on the problem. In such a long undulator some photons will hit the vacuum chamber walls causing photon stimulated gas desorption.

In the superconducing undulator the gas density increases with time due to a three-step process: photon induced desorption of molecules from the sub-surface layers of the vacuum chamber, cryosorbing of these molecules on the surface and then secondary photon induced desorption of the cryosorbed molecules. The proposed solution is to limit the number of photons striking the cryogenic surface by creating a shadow with a collimator.

The ILC damping rings also present challenges to the design of the vacuum system. It is important to sort out the vacuum system at an early stage because the vacuum design is likely to affect other technical systems. This year ASTeC's vacuum scientists have evaluated the implications of synchrotron radiation emission on the vacuum system design. They have calculated the average pressure for different damping ring lattice designs and considered well-known vacuum problems such as thermal and photon induced gas desorption. After modelling the present baseline design they recommended the optimum technology - a tubular vacuum chamber with NEG coating and 20 l/s sputter ion pumps distributed every 20-80 m around the ring.

Testing Out Ideas

Since 2005 ASTeC has joined international efforts on the End Station A (ESA) facility at SLAC. The 2-mile linear accelerator at SLAC can produce beams with some similar qualities to the beam of the proposed ILC. The accelerated electron beam is steered into End Station A to test various components of the ILC design. In January 2006 members of ASTeC travelled to

SLAC to play a key part in the test programme. One experiment involves the collimators of the ILC Beam Delivery System. Collimators will be used to scrape off the halo of the ILC beam, but they may also disturb the beam, lowering its quality. Theoretical treatment of this phenomenon is difficult and the aim of the ESA experiment is to make real measurements of the effect. Several collimators with different shapes were sent to SLAC to be tested. The ASTeC Radio Frequency group is analysing the data taken during these beam tests.

Meanwhile, the ASTeC Accelerator Physics group has been preparing the optical set-up of the beam in the End Station. The various ILC test experiments all require different beam sizes. For example, the collimator studies require a beam with a small vertical size. To control the beam size a series of quadrupoles is used for focussing. In January 2006 ASTeC undertook the first measurements of the optical beam properties, which will be used to determine the amount of quadrupole focusing required for the upcoming experiments.

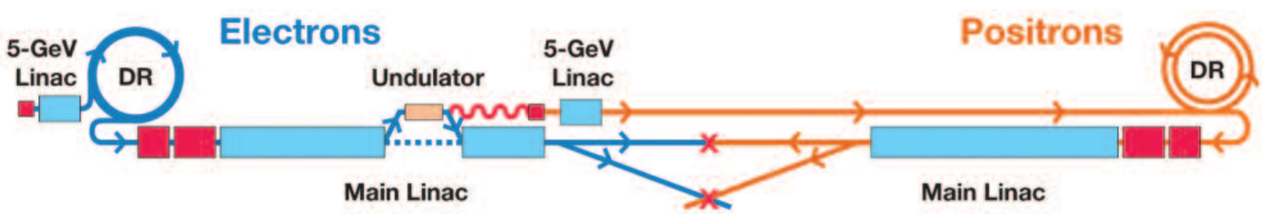
A Global Effort

A project like the ILC costs billions of dollars and cannot be built by any one country alone. A new international organisation, the Global Design Effort (GDE), has been formed to co-ordinate the ILC design programme. Headed by Barry Barish, former director of the LIGO laboratory, the GDE sets the strategy and priorities. The mission of the GDE is to produce a design for the ILC that includes a detailed design concept, performance assessments, reliable international costing, an industrialisation plan, siting analysis, as well as detector concepts and scope.

As a first milestone the GDE set a goal to finalise the baseline configuration for the ILC before its meeting in Frascati in December 2005. The possible alternatives for various subsystems for the ILC (for example linac gradient, damping ring configuration, choice of positron source, one versus two tunnels and beam delivery system configuration) were debated during the Snowmass workshop in August 2005 and later followed by white papers to reach some conclusions. ASTeC staff took a lead role in the choice of positron source, BDS layout, optics and collimation and the crab cavity system.

The positron source based on the undulator was accepted for the baseline design, as was a BDS with two interaction regions.

Poster for the Snowmass Workshop.



Schematic layout of the International Linear Collider.

Nanosecond Feedback

Any ground motion beneath the International Linear Collider could disturb the incoming beams. ASTeC scientists are working on cutting-edge technology to compensate for the smallest vibrations and keep the ILC beams on target for collision.

The incoming beams of the ILC are only a few nanometres wide so the smallest vibration would be enough to reduce the luminosity or stop the beams colliding at all. To counter this effect, the FONT (Feedback On Nanosecond Timescales) project is developing a fast feedback system for steering the beams at the interaction point. The project is an international collaboration led by the John Adams Institute (Oxford) and includes scientists from ASTeC, SLAC in the USA and DESY in Germany.

The principle of the sytem is straightforward - the position of one of the beams after the interaction point is measured and if the beam is off track a fast magnet is used to apply a compensating kick to the other beam. This makes sure the beams collide as intended and that the required luminosity is maintained.

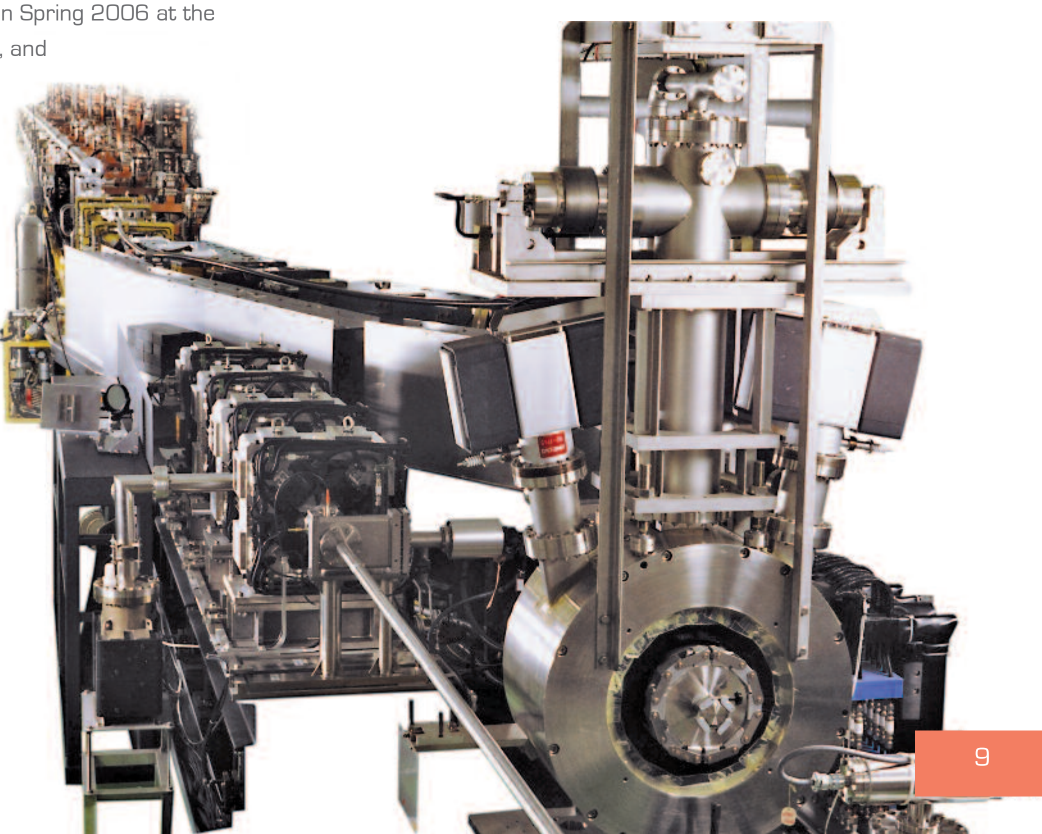
Prototype Testing

In 2005-6 the team took a step forward from previous proof-of-principle experiments – they developed a prototype of a digital feedback processor. This is real progress towards a feedback system based on a Digital Signal Processor (DSP). The prototype was used on a real beam in Spring 2006 at the Accelerator Test Facility at KEK in Japan, and the tests showed that the prototype works. However, there are still software and electronics problems to be solved.

Ghosts in the Machine

This year the FONT team started an interesting new experiment. As the ILC beams collide they are expected to produce so called "hot showers" of secondary ghost particles. If the number of these particles exceeds a certain threshold the beam feedback monitor downstream will be partially blinded. Oxford University computer simulations suggested the number of secondary particles was dangerously close to the threshold so a decisive experiment was needed.

The experiment is done by using the Stanford Linear Accelerator (SLAC) to produce a high energy 'spray beam' modelling the ILC secondary electron-positron flux. To model the ILC environment within the High Energy Physics Detector a mock-up section has been designed at SLAC and Oxford University, then engineered and fabricated at Daresbury Laboratory. The mock-up has now had its first hot showers and the effects of the secondary particles are being examined. The results are of direct importance to the ILC but are more generally applicable to any beam diagnostics system operating in the presence of secondary particles.



The Accelerator Test Facility at KEK, Japan, where the digital feedback processor prototype was tested.

Lighting The Way

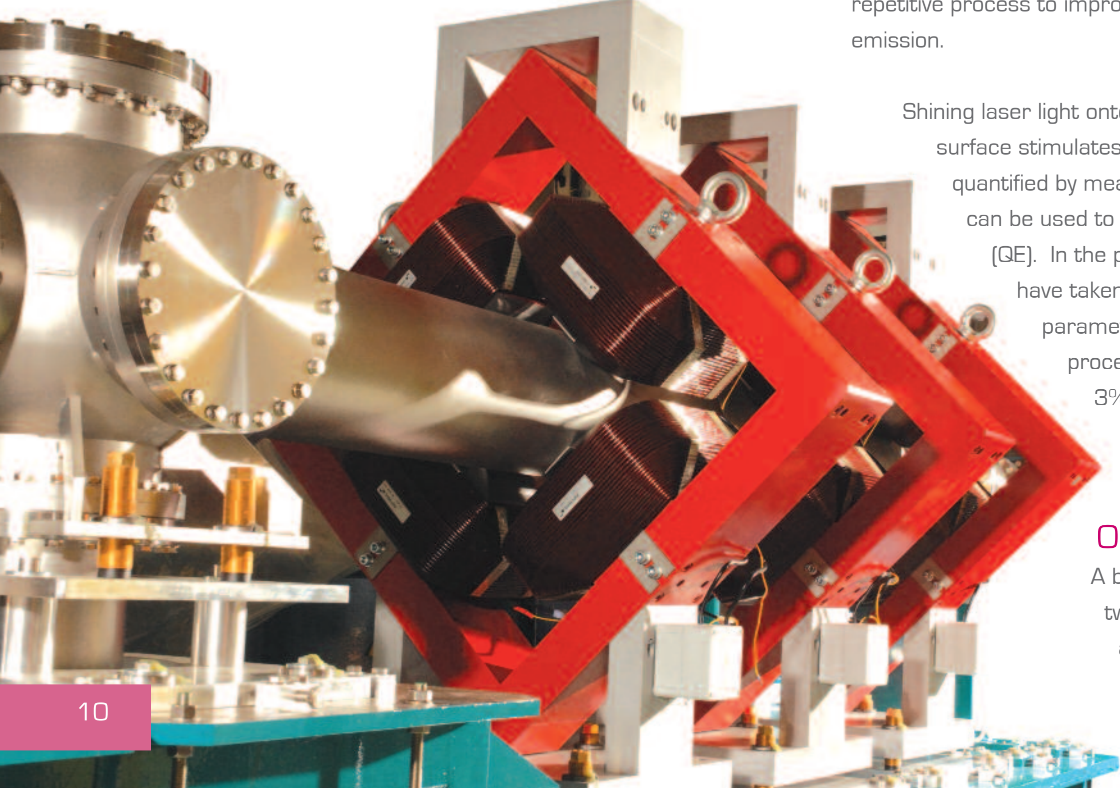
Once home to the world's highest energy Van de Graaff Generator, the Tower at Daresbury Laboratory now houses an accelerator that is the first of its kind in Europe, and a prototype for a next generation light source.

Whereas most particle accelerators just accelerate particles, the Energy Recovery Linac Prototype (ERLP) will do more than that. It will decelerate them too. This has not been done before in Europe. The deceleration recovers the energy of the particles and uses it to accelerate fresh particles, dramatically decreasing the amount of power consumed by the accelerator and enabling higher-current electron beams to be used. The very bright light at the end of the tunnel, which drives this work forward, is the prospect of 4GLS, Daresbury's next generation light source proposal reported on pages 12-15 of this report. The purpose of ERLP is to study the beam dynamics and accelerator technology relevant to 4GLS. In particular ERLP will demonstrate photoinjector gun technology, superconducting linac technology, energy recovery and synchronisation of photon beams.

Creating the beam

The first component to be installed was the photoinjector laser. It was specified in collaboration with CCLRC's Central Laser Facility. The energy-per-pulse is up to 60 nJ, and will easily stimulate the emission of the 80 pC electron bunches required for injection into the ERLP.

Close up of the large quadrupole magnets prior to the ERLP beam dump.



Since installation the full-power beam has been successfully delivered to the cathode chamber in the accelerator hall, via an enclosed optical path consisting of several lenses and mirrors. Beam positioning on the cathode surface is realised using two motorised mirrors, the performance of which have been calibrated during their commissioning.

A Virtual Cathode

A 'virtual cathode' adjacent to the actual cathode chamber receives a 1% fraction of the laser beam. At its heart is a precisely aligned camera that provides the operator with visual feedback of the laser spot position. The image generated by the camera is a facsimile of the real cathode surface.

Making a Real Photocathode

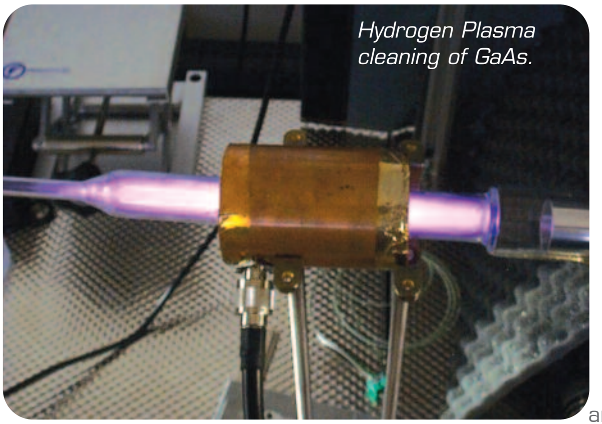
The ERLP electrons are generated via photoemission from a gallium arsenide (GaAs) wafer in the photocathode. Preparing the wafer requires an extremely high vacuum environment to improve and protect the cathode lifetime. In addition hydrogen plasma cleaning of the wafers is needed to remove any residual hydrocarbons or contamination.

The GaAs wafer is then subjected to a 575^{o}C heat cycle for 3 hours to remove any hydrogen embedded in the surface and to restore its structure. Caesiation of the GaAs surface is carried out by evaporation from a Cs source. The final process is oxidation of the surface using NF_3 or O_2. Subsequent caesiations and oxidations are performed in a repetitive process to improve the efficiency of electron emission.

Shining laser light onto the carefully prepared GaAs surface stimulates emission of electrons. This is quantified by measuring the drain current, which can be used to calculate the Quantum Efficiency (QE). In the past year significant developments have taken place in understanding the critical parameters of the wafer preparation process resulting in GaAs wafers with 2-3% QE. This meets the ERLP requirements.

Optimising Booster Power

A booster accelerator, consisting of two superconducting cavities, accelerates the beam to 8.35 MeV immediately after the buncher cavity. In the original ERLP design the booster cavities were to operate using continuous wave (CW) RF at up to 16 kW by Inductive Output Tubes (IOT). Further design optimisation has shown that better performance can be achieved using 31 kW in the first cavity


Hydrogen Plasma cleaning of GaAs.

and 21 kW in the second cavity. The RF power coupler has only been tested at 16 kW CW: to provide the required power a pulsed RF system is required. A prototype pulsed LLRF has been successfully tested at Forschungszentrum Rossendorf (FZR) and will be used on ERLP.

Piecing it together

The remainder of the ERLP electron beam transport system is being put together in sections on girders in a dedicated assembly area at Daresbury Laboratory. All of the vacuum chambers are subjected to a particle cleansing process in the clean room until the stringent ISO 5 standard has been achieved. The sections are being moved into the accelerator hall as they are completed.

Preventing Disasters

It is vital that the ERLP has a protection system. If an electron beam is mis-steered then the protection system will prevent both damage to vital machine components and the production of undesirable excess radiation. It must be able to detect a misaligned beam and reduce ERLP to a safe condition before damage to the complex hardware can occur.

The protection system must be multi-layered and reliable with a simple interface. A Long Ionisation Chamber system will be used to detect any excess radiation produced from a collision whilst a Current Difference Monitoring system will detect any loss of beam. The system is on schedule and will provide an essential diagnostic tool for the ERLP.

Beam Control and Manipulation

Hopefully the ERLP protection system will have an easy job, assuming the steering and manipulation of the electron beam goes according to plan. One of the required manipulations is to control the bunch length as the electrons come off the gun. This is done with a buncher cavity.

ASTeC scientists carried out initial measurements on the buncher and found that the resonant frequency is different from the desired centre frequency. Iterations were done to shorten the buncher cavity tuning posts and benchmark with numerical simulations. This work provided the desired centre frequency with both tuning posts penetrating the cavity similar distances: this avoids asymmetric fields in the cavity. Since then the cavity has been installed on the injector line.

The Final Countdown

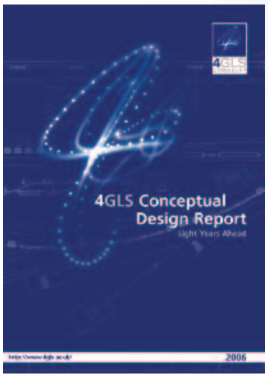
"ERLP is like a jigsaw at the moment. All the pieces are there and are being put together," says David Holder, a member of the accelerator physics group. Currently the project is on target to be up and running by April 2007.

Installation of the ERLP Booster Accelerator.

Let There Be Light

How do massive stars evolve? Why does chlorine encourage ozone molecules to break apart? How do enzymes in our gut help to speed up digestion? These are the kind of fundamental questions that Daresbury Laboratory's 4th Generation Light Source (4GLS) may help scientists to answer.

4GLS also has the potential to aid development of new nanoscale devices, through the understanding of electron charge and spin transport. It will fast-track the development of new dynamic imaging techniques to improve early diagnosis of conditions such as cancer and prion based disease. It will enable new understanding of the interactions of gas molecules and ions with intense photon fluxes that will revolutionise our understanding of stellar coronae, massive star evolution, planetary nebulae, cooling flows in galaxies, active galactic nuclei and the accretion disks around black holes. From the very small to the very large, 4GLS will have an impact.



The Next Generation

3rd Generation synchrotron radiation sources enable the determination of static structure on very small spatial scales. 4GLS will add the ability to look at how this structure changes on

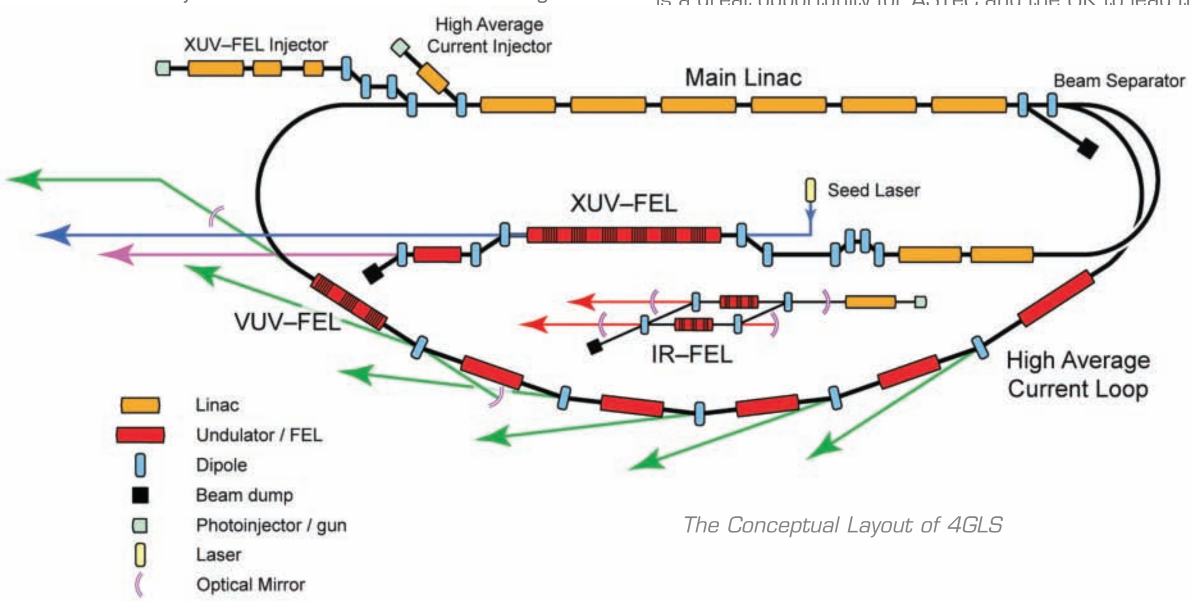
The facility is naturally suitable for ultrafast dynamics because many of the photon sources combined in a single experiment will originate from the same electron bunch and so be naturally synchronised.
This will enable the study of real time molecular processes and reactions on timescales down to tens of femtoseconds in short-lived, nano-structured or ultra-dilute systems.

The peak brightness of the 4GLS sources has a typical enhancement of eight orders of magnitude (100,000,000) when compared with 3rd generation light sources such as Diamond. The wavelength coverage provided by the FELs complements available table-top laser sources and it is envisaged that 4GLS may be powerfully combined with these sources in many experiments.

The 4GLS plans have developed this year through the continued construction of the Energy Recovery Linac Prototype source (ERLP). A major milestone was met in March 2006 when the 4GLS Conceptual Design Report was published. This document has been very well received both nationally and internationally.

Taking a look inside

So how will 4GLS work? The idea is to site a VUV-FEL, IR-FEL and single-pass XUV-FEL at one experimental facility, which will in addition simultaneously provide short pulse spontaneous undulator and bending magnet radiation in the THz – soft X-ray frequency ranges. "This has never been done before, and is a great opportunity for ASTeC and the UK to lead the



The Conceptual Layout of 4GLS

world!" says Jim Clarke, one of the scientists working on the 4GLS design.

Shared Acceleration.

The proposed design uses simultaneous acceleration of two distinct electron bunch species in the main accelerator system. A high-charge (1 nC) bunch will be delivered at 1 kHz to the XUV-FEL which will produce a GW peak power photon beam tunable between 8 eV and 100 eV. A low-charge (77 pC) bunch will be delivered at up to 1.3 GHz in a High-Average-Current Loop (HACL) to a suite of spontaneous insertion devices and a VUV-FEL.
The VUV-FEL will operate over the photon energy range 3–10 eV with peak powers of hundreds of megawatts. The very high 60 MW beam power in the HACL requires the energy to be recovered from this beam. This will be accomplished using the Energy Recovery Linac principle, in which the recovered bunches are decelerated in the same superconducting linac as used for acceleration.

The XUV-FEL bunches share the same superconducting linac as the HACL bunches. To avoid beam loading problems a novel scheme is proposed whereby the XUV-FEL bunches are accelerated on the opposite radio frequency (RF) phase to the HACL bunches in the main superconducting linac.

Producing Short Electron Bunches

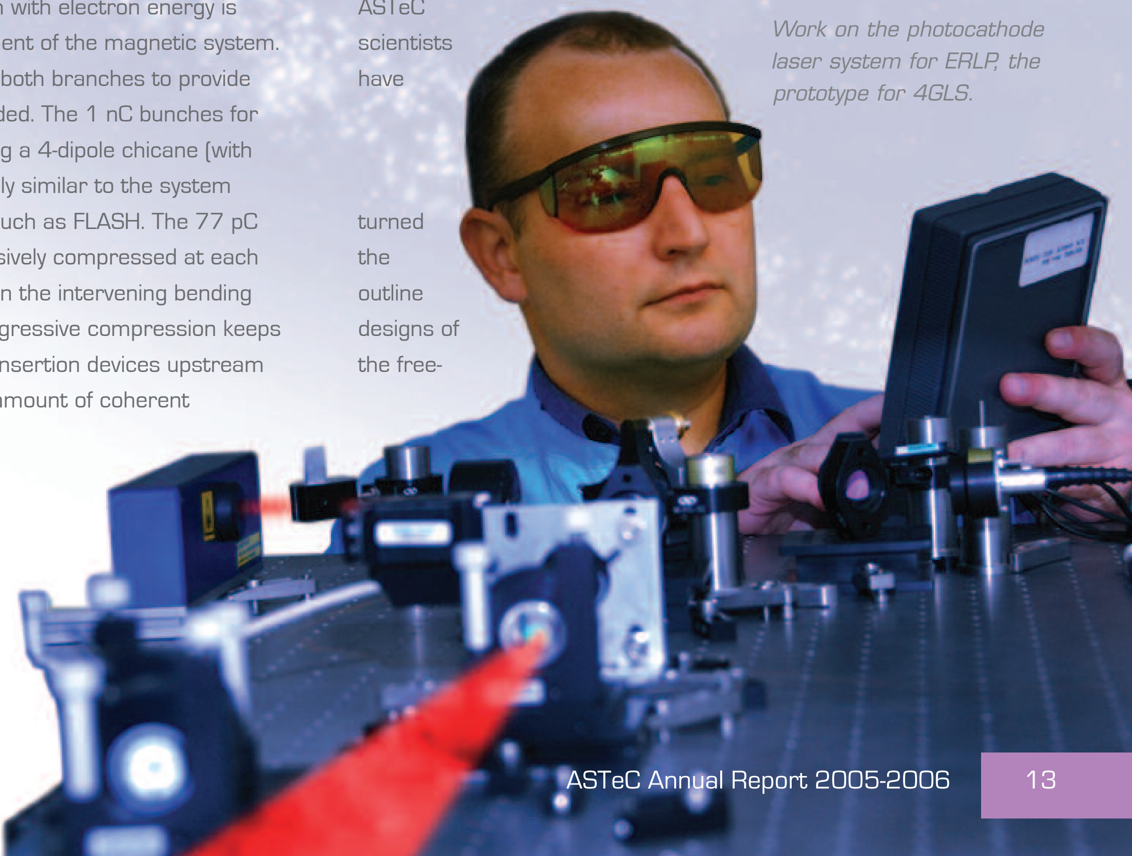
Producing femtosecond-scale photon pulses requires femtosecond-scale electron bunches. This is done by bunch compression. After acceleration in the linac the electron bunches have an energy chirp, meaning that the electron energy varies along the bunch. This is exploited by the magnetic transport downstream to compress the bunch length. The variation of path length with electron energy is characterised by the R_{56} component of the magnetic system. The value of the R_{56} is tailored in both branches to provide the appropriate compression needed. The 1 nC bunches for the XUV-FEL are compressed using a 4-dipole chicane (with R_{56} of around 10 cm) magnetically similar to the system used in linac-based light sources such as FLASH. The 77 pC bunches in the HACL are progressively compressed at each insertion device (by using an R_{56} in the intervening bending cells of 0 to 1 cm). The use of progressive compression keeps the bunches slightly longer in the insertion devices upstream of the VUV-FEL. This reduces the amount of coherent synchrotron radiation which is emitted, and reduces the wakefield drag on the bunches, allowing smaller undulator gaps to be used.

Do Not Disturb

Wakefields and coherent synchrotron radiation are two of the collective processes which can disrupt the intense bunches transported in 4GLS. A careful study of these processes has been done, simulating the transport of the bunches from the start of the accelerator to the various output devices. This work has confirmed that the adopted schemes will deliver the required beam qualities.

Bright FEL Design

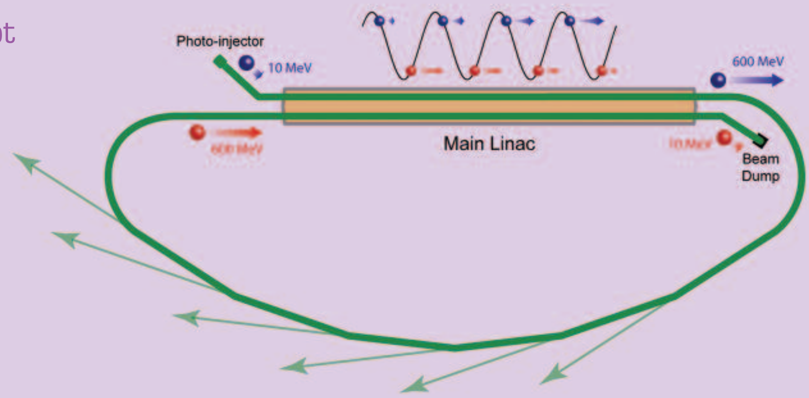
This year, working in collaboration with academic staff from the University of Strathclyde, ASTeC scientists have turned the outline designs of the free-



Work on the photocathode laser system for ERLP, the prototype for 4GLS.

The Energy Recovery Concept

In the 4GLS high-average-current loop (HACL) electron bunches with high brightness are accelerated in a superconducting linac. After one pass through a series of electromagnetic output devices they return their energy to the linac to be used to accelerate later bunches.



electron lasers into full specifications. State-of-the-art analytical methods and numerical simulation codes have been used to predict the output of the FELs and help optimise the design parameters. The advanced features of the FEL designs have meant that the most advanced simulation codes are at the limits of their applicability, so care has to be taken in the interpretation of the numerical results.

Amplified Harmonics

An example of this is found in the XUV-FEL system. Here, a high power infra-red laser is fired into a jet of inert gas, such as Argon or Helium, generating a comb of higher harmonic radiation. This radiation is then fed into the XUV-FEL free-

The Conceptual Design Report Launch.

electron laser as a high quality seeding pulse and amplified by many orders of magnitude by the interaction with the electron beam. This produces the final GW-level FEL output pulse.

However, a feature of the input seed is that there is temporal structure at the attosecond timescale. The question is: does this structure also get amplified by the free-electron laser interaction leading to an FEL pulse with attosecond structure? Current simulation codes are not designed to cope with such small structure so the validity of the results is a topic for debate, and has been discussed at international workshops devoted to the development of advanced future light sources.

All Done with Mirrors

The 4GLS VUV-FEL is also pushing at the boundaries of FEL technology. It will be the shortest wavelength FEL in the world utilising a resonator cavity. This cavity acts as a feedback system and provides stability to the train of output FEL pulses. The cavity length can be adjusted to simultaneously control the peak power in the pulses and their duration. Simulations have indicated that this cavity length detuning could be used to stimulate the FEL into operating in a `superradiant' mode where the output power is enhanced by a factor of three or four while the pulse duration is shortened by about the same factor. This mode of operation was predicted theoretically many years ago, and has been observed in resonator FELs operating at longer wavelengths (in the infra-red) so the ability to operate for the first time in this mode at the shorter VUV wavelengths would be very exciting.

The IR-FEL has been designed to produce high intensity radiation with variable pulse lengths, flexible output pulse patterns and variable polarisation over the wavelength range 2.5 to 200 μm. The high-Q cavity-based design employs two undulators and two optical cavities and hence offers the potential to satisfy user experiments at two different wavelengths simultaneously.

Controlled Acceleration and Deceleration

The RF and Diagnostics group within ASTeC have designed the accelerating and diagnostics systems which are fundamental to the facility. A 100 mA electron beam accelerated to 600 MeV would normally require about 100 MW of electrical power. With energy recovery only 5 MW is needed so the efficiency gain is enormous. Energy recovery is only possible using Superconducting RF (SRF) technology which has been under development for many years for the International Linear Collider (ILC). The 4GLS designs have been adapted to optimise the simultaneous acceleration of the XUV-FEL and HACL bunches, as well as the deceleration of the HACL bunches, while minimising instabilities.

These instabilities can be caused by the growth of higher order modes in the accelerating cavities and if unchecked lead to beam break-up (BBU). The RF and Diagnostics group have carefully analysed the cavity-beam interactions to understand how BBU develops and can be controlled. Mechanisms for increasing the threshold current at which BBU occurs have been identified and will be implemented.

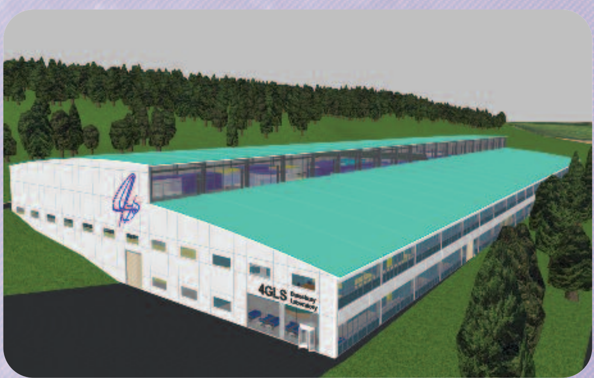
In order to optimise the performance of the 4GLS photon sources the acceleration and deceleration of the electron bunches must be very stable. The phase of the accelerating RF field must be controlled to within 0.01° and the amplitude to within one part in 10,000. The RF and Diagnostics group have designed a fast control system which uses low level RF (LLRF) feedback to meet these requirements.

Colder than Space

The SRF accelerating structures are cryogenically cooled to extremely low temperatures (2 K). This maximises the efficiency of acceleration by minimising the RF power losses. A flexible and reliable cryogenic system has been developed by the RF and Diagnostics group. The cryogenic plant for 4GLS will be the largest single 2 K plant installation in the UK.

Diagnosis Success

Advanced electron beam and photon diagnostics are crucial for 4GLS to succeed in its core capability: the femtosecond-scale synchronisation of combined FEL sources, undulator sources and conventional laser sources at a single interaction point. This capability facilitates scientific experiments that cannot be performed anywhere else in the world. This year the RF and Diagnostics group have applied their expertise to the



Proposed 4GLS building.

development of cutting-edge beam and photon diagnostics, capable of pinpointing beam positions to the micron level and resolving electron bunch and photon arrival times to tens of femtoseconds.

Diagnostics in a Flash

Some new particle accelerators are designed to produce extremely short particle bunches with durations less than 200 femtoseconds. Measuring the temporal profile of these bunches needs new methods, such as the electro-optic techniques being developed by ASTeC scientists and recently trialled on FLASH, the short-wavelength free-electron laser at DESY, Hamburg.

The goal is to measure time resolutions approaching 10 femtoseconds over a full bunch profile that may extend from 100 femtoseconds to several picoseconds. Ideally, the measurements should be single-shot and not destroy the properties of the bunch. In ten femtoseconds light will travel just three microns – this illustrates the scale of the challenge.
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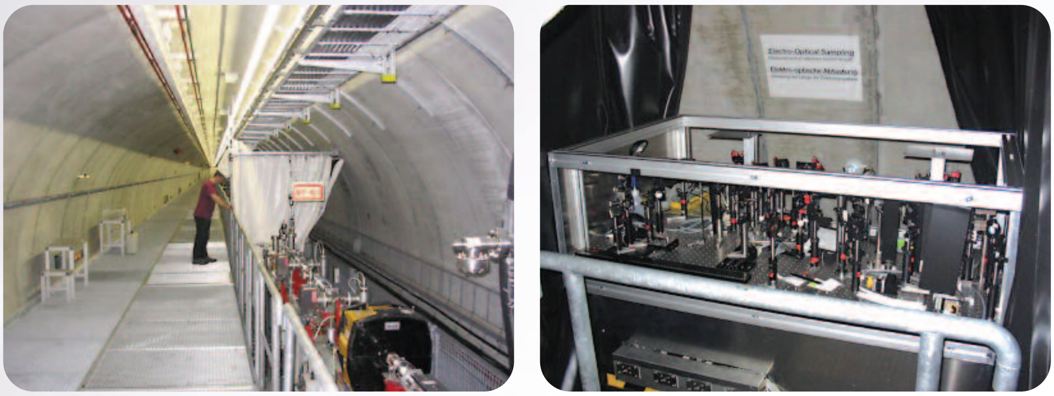


The accelerator tunnel at FLASH (left) and a closer look at the electro-optic equipment set-up in the tunnel (right).

Ultra-fast Solutions

ASTeC scientists are pursuing a solution involving ultra-fast electro-optic (EO) laser techniques as part of the International Linear Collider programme. The method uses non-linear dielectric crystal materials, which have a refractive index that is modified when an external electric field is applied to the material. This refractive index change can be measured through its effect on the polarisation of a probe laser.

In electron bunch diagnostics the electric field is provided by the Coulomb field of the bunch. This field extends radially out from the bunch so the field profile closely follows the bunch current profile. To measure the profile in a single shot, a laser pulse of approximately 10 picoseconds is used to probe the time-varying refractive index change. Various approaches can then be used to measure the time-varying polarisation state of the probe laser and hence determine the electron bunch profile.

FLASH Results

During 2005-2006, together with collaborators at DESY, FELIX, and UK universities, a series of internationally-leading experiments were done on FLASH, taking advantage of the very short bunches available at FLASH to test the electro-optic "temporal decoding" techniques. An amplified laser system was set up outside the accelerator tunnel and characterisation of longitudinal bunch profiles with sub 200 femtosecond current spikes was achieved. The time resolution of these measurements is the best attained anywhere to date using an electro-optic technique.

The bunch profile could be measured non-destructively, in a single shot, with a time window extending out to greater than 10 picoseconds. The measured bunches were used successfully downstream in the free-electron laser, producing SASE (Self-Amplified Spontaneous Emission) radiation. The FEL is very sensitive to certain electron bunch properties, such as peak current, emittance and energy spread – the fact that lasing was unaffected by the measurements showed these properties were unchanged. It was, as had been intended, a non-destructive measurement.

Another great achievement at DESY has been the comparison of the EO measurements with another diagnostic technique which uses a transverse deflecting cavity known as a 'LOLA cavity'. This is the first time any electro-optic technique has been bench-marked against any diagnostic with comparable time-resolution.

European Collaborations

Accelerator science requires a wide range of skills and expertise. Currently ASTeC scientists are participating in two major European collaborations, sharing knowledge and technology across international boundaries. Together the scientists are achieving goals that would be impossible if working alone.

EUROTeV

EUROTeV is a design study for a TeV energy range linear collider involving 28 European Institutes. EUROTeV comprises seven scientific Work Packages, namely Beam Delivery System, Damping Rings, Polarised Positron Sources, Diagnostics, Integrated Luminosity Performance Studies, Metrology and Stabilisation, Global Accelerator Network and Multipurpose Virtual Laboratory. ASTeC is co-ordinating the Beam Delivery System and the Polarised Positron Sources work packages and is also participating in the Damping Rings work package.

The first EUROTeV scientific workshop was held in June 2005 at Royal Holloway University, London, where the technical programme was discussed and milestones agreed. Since then ASTeC scientists have been designing a method to generate large quantities of polarised positrons, and this has now been selected for use on the ILC and is discussed in more detail on pages 6 and 7 of this report. The solution involves passing the very high energy electron beam through an undulator with a helical magnetic field.

Meanwhile, the beam delivery system team has been contributing to the small crossing angle configuration for one of the two interaction regions for the ILC and improving the collimation performance. In addition to lattice design work, ASTeC contributes to the design of the collimators, crab system and beam-beam feedback.

Finally, ASTeC has been participating in the damping ring work package in two critical areas: low emittance tuning and vacuum design of the damping ring.

EUROFEL

Since January 2005, 16 European institutions have been working together on the European free-electron laser (EUROFEL) Design Study – a three-year, €9 million project, funded by the European Union's Sixth Framework Programme. The aim is to prepare for the construction of the next-generation of free-electron laser light sources proposed in Europe.

ASTeC is most heavily involved with the beam dynamics work package, which it leads. This includes the development and use of codes and models for the reliable simulation of high quality electron beam transport. Calculations of the beam break up threshold for 4GLS have been made, both for the existing state-of-the-art superconducting linac designs and for possible future designs.

A significant contribution to the seeding and harmonic generation package has been made by ASTeC scientists working together with Scottish researchers on an idea dreamt up at the University of Strathclyde. Together they have developed a design for a novel free-electron laser called the Harmonic Amplifier FEL – through the use of small magnetic chicanes distributed along the FEL undulator, the FEL can be operated so that only the harmonic radiation is amplified. The technique could potentially be applied at existing (or proposed) free-electron lasers to allow them to reach shorter wavelengths.

EUROFEL has four other work packages as follows; photo-guns and injectors; synchronisation; superconducting cw and near-cw linacs and cryomodules technology transfer. Working together with Forschungszentrum Rossendorf (FZR) in Dresden, Germany, and Deutsches Elektronen Synchrotron (DESY) in Zeuthen, Germany, ASTeC scientists have also made significant contributions to these other work packages.

Introducing EMMA

Many new applications can be found for a high-power particle accelerator that is compact, reliable and economical. A novel protoype of such an accelerator has been designed by ASTeC scientists. They call her EMMA.

In recent years accelerator science has spread its wings, with applications ranging from the treatment of cancer to medical isotope production and secondary muon beam production for studying the structure and dynamics of materials. This has pushed requirements towards higher beam power, higher duty cycle and precisely-controllable beams, at reasonable cost and with good reliability. Fixed-field alternating-gradient (FFAG) accelerators offer a radical alternative to conventional accelerator technologies as they can deliver these requirements simultaneously.

A key feature of FFAG accelerators is the fixed magnetic field, which enable beams to be cycled faster than synchrotrons, leading to simpler and cheaper power supplies. What is more, they have larger beam acceptance, allowing high intensities with low beam loss, so that operation and maintenance are easier, safer, and more cost-effective.

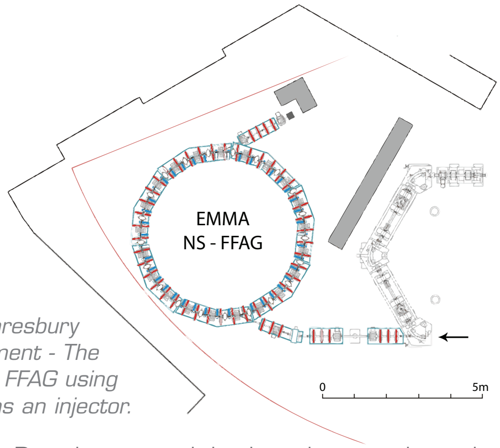
Scaling or not

All of the current FFAG designs are 'scaling', where the accelerated beam has geometrically similar orbits of increasing radius and the number of transverse oscillations per turn remains fixed leading to inherently stable particle motion. However, the magnets for scaling FFAGs are large, complex and expensive to manufacture, which limits their use in industry and medicine.

The non-scaling (NS) FFAG was invented in 1999. Its design compresses the range of orbit radii (and thus the magnet aperture) and uses only simple dipole and quadrupole magnets. This all leads to simplification and cost reduction compared with scaling machines. Until now, no such machine has been built.

The Daresbury Experiment

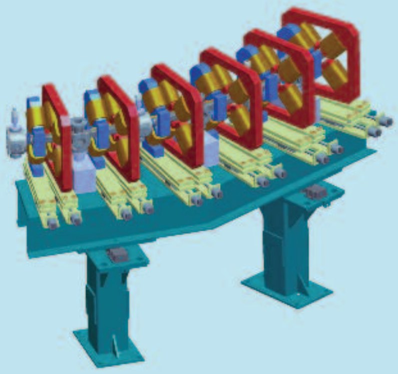
After consultation with an international partnership a proposal emerged to build a proof-of-principle NS-



The Daresbury Experiment - The EMMA FFAG using ERLP as an injector.

FFAG at Daresbury to study its dynamic properties and to learn how to optimise the design for different applications. This is EMMA (Electron Model for Many Applications).

Detailed simulation studies have been done. The selected accelerator is a 10-20 MeV electron NS-FFAG of 16.5 m circumference. EMMA will use the ERLP accelerator at Daresbury as an injector – the shared infrastructure will bring considerable cost savings.

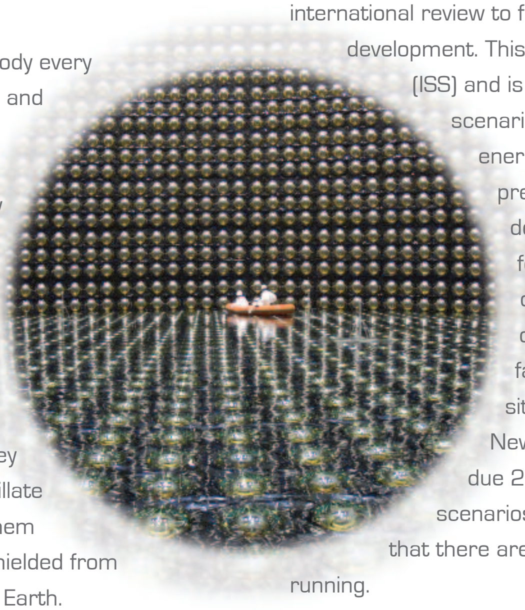


EMMA Design Features

To provide the focusing and bending components required by the EMMA focusing scheme, where the focusing strength is much stronger than the dipole field, a very unusual arrangement is proposed whereby EMMA is completely composed of offset quadrupoles, shown on the left. Adjustment of the dipole bending fields is then achieved by moving all 84 quadrupoles across the beam. The quadrupoles are mounted with 21 RF accelerating cavities, the injection and extraction system, and the ancilliary vacuum and diagnostics instruments, on a modular girder system in 7 units.

Neutrinos for all

Neutrinos are elusive and mysterious – understanding their behaviour could unlock the answers to profound questions in physics. The ASTeC Intense Beams Group are helping international efforts to develop a Neutrino Factory to let physicists study these strange particles.



Millions of neutrinos pass through your body every second. They do no harm, leave no trace, and are incredibly difficult to detect. But just because these particles are elusive doesn't mean they aren't important. They are now believed to be equivalent in mass to all the stars in the Universe and may explain the origins of the building blocks of all atoms: neutrons, protons and electrons. Neutrinos come in three flavours: electron neutrinos, muon neutrinos and tau neutrinos. As they travel though matter and space they oscillate from one flavour to another. Observing them requires a deep underground detector shielded from other cosmic particles that bombard the Earth.

Mass production

The Neutrino Factory is a groundbreaking project using accelerators to produce neutrino beams for physicists to study under laboratory conditions. The beams will travel thousands of kilometres through the Earth to detectors that measure the oscillations between flavours. These 'long-baseline' experiments will estimate the neutrino's mass and unravel the oscillation mechanism.

Main picture: the inside of the Super-Kamiokande neutrino detector, 1000m underground at the Mozumi mine in Japan. Photograph courtesy Kamioka Observatory, ICRR (Institute for Cosmic Ray Research), The University of Tokyo.

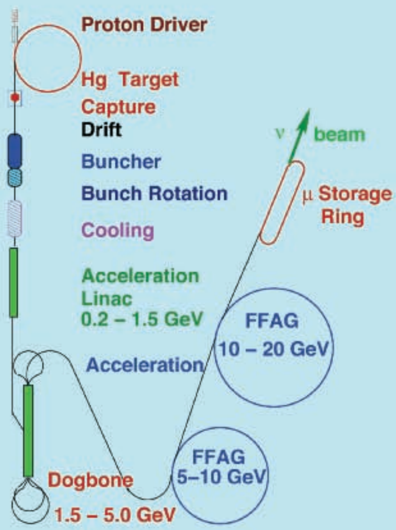
International Scoping Study

Last year, John Wood, CEO of CCLRC, suggested an international review to find a workable design for future development. This is the International Scoping Study (ISS) and is fronted by CCLRC. The overall scenario has been examined. Proton driver energies in the range 8-15 GeV are now preferred for good pion production. New decay rings have been designed in the form of isosceles triangles, able to direct neutrinos to two different detectors at once. For example, for a factory in the UK, possible detector sites might be in Crete (2750 km) and New Mexico (7500 km). The ISS report, due 2006, will show that most earlier scenarios are unsuitable - but the good news is that there are ASTeC designed schemes still in the running.

The Neutrino Factory Concept

First, a high intensity proton accelerator will deliver 4 to 5 MW of pulsed beam power to a pion production target.
The target will be made of either liquid mercury, solid metal or even a rotating metal band. Pions, which decay in nanoseconds to muons with a mean lifetime of 2.2 μs,
will be captured in a high-field solenoid channel.

The muons must then be accelerated very quickly so that relativistic time dilatation can be used to get enough through to the final decay rings. After initial acceleration in a
re-circulating linac the beam goes into one or more fixed-field alternating-gradient (FFAG) accelerators to be brought up to 20-50 GeV. Finally the muons enter a storage ring, where they decay into neutrinos in long straight sections pointing towards distant detectors.



A Silver Celebration

The Synchrotron Radiation Source (SRS) at Daresbury Laboratory continues as a high quality source of synchrotron radiation. Regular upgrade and support work by ASTeC scientists and engineers is vital to its successful operation.

This year the Synchrotron Radiation Source (SRS) celebrated its 25th birthday. Not all particle accelerators reach such an age, but the SRS, based at Daresbury Laboratory, is still going strong. Many ASTeC scientists and engineers gained their experience on this machine and thanks to regular upgrade work the SRS continues to provide internationally competitive synchrotron radiation to a wide ranging and active user community.

Groups within ASTeC have continued to support and improve the operation of the SRS by carrying out regular periods of beam studies to diagnose faults and optimise the machine settings, and by providing a continuous on-call support during user operations.

Preventing beam loss

In recent years the SRS has had a beam loss monitoring system installed. Detectors were placed inside the storage ring to monitor electron loss and beam decay. Data is fed back electronically and used to optimise the beam parameters and minimise beam loss.

One of the main concerns is beam loss during injection and the energy ramp. It is believed the problem is an issue with the relatively small apertures of four out of the six insertion devices and other aperture restrictions within the beam pipe. Beam loss monitors could be used when the stacking rate cannot be improved by other optimisations, such as transport line set up. For this reason ASTeC scientists have done work characterising the operation of the loss monitor.

The aim is to produce fully characterised monitors that can then be employed as a future diagnostic facility in situations of frequent beam loss. Some beam loss is caused by errors in the steering of the closed orbit beam. If this can be detected with the beam loss monitoring system then it could be used to verify the credibility of the data from the Electron Beam Position Monitors.

Experimenting with APPLE

This year an APPLE-II type undulator, designed by ASTeC and constructed and measured in the Magnet Measurement Laboratory, was commissioned in opposing mode, enabling the SRS to produce variably linear polarised synchrotron radiation. Altering the positions of the magnet arrays in the undulator determines the plane of linear polarisation. Previously it had been commissioned in mutual mode, which produces synchrotron radiation with elliptical polarisation.

Work has also been carried out by ASTeC to optimise the rate electrons are injected into the SRS and the number that can be stored in the storage ring. Improvements were made by optimising magnet settings and positions, which improved the steering of the beam and therefore reduced losses. Checks were also carried out to make sure the beam position monitors were in the correct places. Finally the electron beam orbit was adjusted so that the synchrotron radiation produced is directed down the user beam lines with minimal losses.

All this work keeps the SRS, a valuable user facility, as the longest running X-ray synchrotron radiation source in the world as it enters its final years of operation.

DIAMOND Days

ASTeC scientists have continued their work on Diamond, the UK's next synchrotron light source designed at Daresbury Laboratory as a replacement for the SRS.

Diamond is a 562 m electron storage ring operating at 3 GeV. It has a full energy booster synchrotron, which accelerates electrons exiting the linac at 100 MeV to the full 3 GeV required in the main storage ring. Construction of the linac, booster and most of the storage ring is finished, with all magnets and associated service connections finalised.

ASTeC work this year has concentrated on fine tuning the non-linear design of the storage ring. This enables electrons from the booster synchrotron to be captured more efficiently in the ring, reducing radiation losses, and also enabling captured electrons to be stored for longer, increasing the lifetime of the beam.

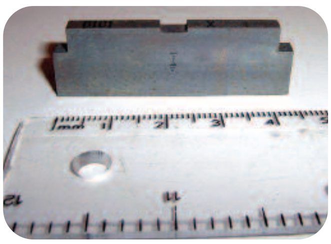
The highly non-linear nature of the storage ring is due to its very strong focusing design. This enables the beam to be made very small at the insertion devices and dipoles where the synchrotron light is produced.

The collaboration between Diamond Light Source (DLS) physicists and those at ASTeC led to many new candidate solutions, one of which has been selected as the new baseline configuration. Many novel tools were used in the optimisation procedures, which allowed a wider spectrum of designs than traditional methods.

As the new light source takes shape, commissioning is required to ensure that the beam quality on the 1st day of user beam is as good as possible. ASTeC physicists were involved in two separate stages of booster synchrotron commissioning and will continue to be involved in the commissioning process in the coming year.

The ALPHA-X Men

An accelerator that could produce GeV particle beams, yet fit onto a tabletop - this is the vision of the scientists working on the ALPHA-X project.


An undulator magnet block.

ALPHA-X is a four-year Basic Technology collaboration between several UK universities and CCLRC. The aim is to build a laser plasma wakefield accelerator - a high-intensity laser pulse is focused into a narrow plasma channel and a short bunch of low-energy electrons follows. The electrostatic 'wake' set up by the laser's electric field creates huge accelerating gradients for the electron beam. Such technology could eventually lead to compact accelerators that would fit inside an ordinary room.

ASTeC has contributed with construction and delivery of a pair of permanent magnet undulators. On extraction from the plasma channel the accelerated electron beam will be injected into these undulators to produce short pulses of X-ray radiation which could be used, for example, to do time-resolved studies. "We could look at processes going on in living cells, for instance," says Ben Shepherd, who has been working on the project.

The undulators have a novel design which allows them to accept and focus electron beams with a wide range of parameters. Magnetic testing of the undulators was carried out in the Insertion Device test laboratory at Daresbury. A moving Hall probe was used to build up a field map of each device. Following exhaustive testing, both undulators were found to meet the demanding requirements of ALPHA-X and will perform well within specifications. They have now been delivered to Strathclyde University where the ALPHA-X project is based.

Around the Labs

Vacuum Laboratory

NEG Coatings Research

Non evaporable getters (NEGs) are a special kind of coating that can absorb gases. This characteristic means that NEGs can help to maintain a vacuum inside a chamber by absorbing particles. ASTeC scientists have continued to work with colleagues at Manchester Metropolitan University to develop NEG coatings.

Much of the work this year has focused on understanding NEG planar samples and why they have not been successful. It is believed that the activation of the NEG coatings is a critical process and the ratio of NEG coated surface to uncoated surface plays a significant role in whether the coating works. This work was presented at the 45th IUVSTA workshop on NEG coatings.

Future work will look at depositing these NEG coatings using different deposition techniques. The current method restricts the type of vacuum components that can be coated, as only uniformly shaped vessels can be coated.

Outgassing Test Facility

Trichloroethylene is normally the solvent of choice for keeping a vacuum chamber clean, but it also spells bad news for the ozone layer. Instead the Vacuum Group have been experimenting with Hydrofluoroether (HFE) as an ozone-friendly alternative - it is found that that HFE is suitable, but an expensive option. Now they are looking at more cost-effective ways of using HFE.

They are investigating a two-stage cleaning process that uses a cheap hydrocarbon based solvent, followed by the HFE in the second stage. Thus far results with the co-solvent have been promising, passing the ASTeC cleaning specification for cleaning of vacuum components, but results have not been as successful as when only the HFE was used.

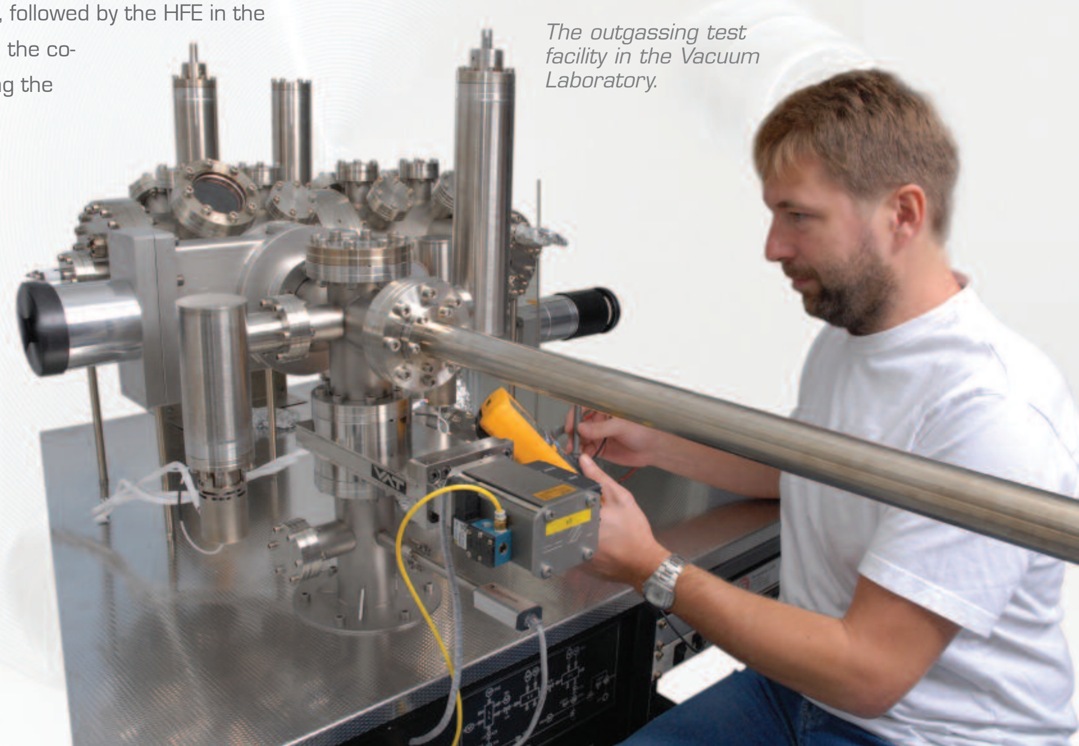
Calibration Facility

This year the total pressure gauge calibration facility has been used extensively to secondarily calibrate all total pressure gauges in the vacuum science laboratory. Two calibrated extractor gauges were used as the standard against which other gauges were compared and all gauges were calibrated in the pressure range from 10^{-10} – 10^{-5} mbar.

Insertion Device Laboratory

The facilities available in ASTeC's dedicated Insertion Device Test Laboratory continue to improve. The flipping coil and Hall probe benches have now been combined to facilitate faster and more accurate measurement and correction of insertion devices. It is no longer necessary to swap devices between benches to characterise them completely prior to installation.

To augment ASTeC's magnet measurement capabilities, a pulsed-wire bench is being planned for installation. This will use a single strand of wire to map out the field from an insertion device. A pulse of current (200A) is sent down the wire, and as it passes through a changing magnetic field, the current pulse is deflected from side to side just as an electron beam would be. Tiny deflections in the wire are detected using a laser and plotted out as the current pulse travels down the wire. This technique allows extremely rapid characterisation of insertion devices, and will be invaluable for work on 4GLS.



The outgassing test facility in the Vacuum Laboratory.

ASTeC Publications

Optics and Beam Transport in Energy Recovery Linacs
Hoffstaetter GH, Litvinenko V & Owen HL, Nuclear Instruments and Methods A557 (1), 345-353, 2006

Electro-optic techniques for temporal profile characterisation of relativistic Coulomb fields and coherent synchrotron radiation
Jamison SP, Berden G, MacLeod AM, Jaroszynski DA, Redlich B, van der Meer AFG and Gillespie WA, Nuclear Instruments and Methods A557 (1), 305-308, 2006

Harmonic Lasing in a Free-Electron-Laser Amplifier
McNeil BWJ, Robb G, Poole MW & Thompson NR, Physical Review Letters 96, 084801, 2006

Optics Issues in ongoing ERL projects
Smith S L et al, Nuclear Instruments and Methods A557 (1), 145-164, 2006

Proceedings of the 2005 Particle Accelerator Conference, May 2005, Knoxville, USA

Proposal of the next Incarnation of Accelerator Test Facility at KEK for the International Linear collider
Araki S et al

Overview of Accelerator Physics Studies and High Level Software for the Diamond Light Source
Bartolini R, Baldwin AI, Belgroune M, Christou C, Kempson VC, Martin IPS, Rowland J, Singh B, Holder DJ, Jones JK, Smith SL, Varley JA, Wyles NG

Non-Linear Beam Dynamics Studies of the Diamond Storage Ring
Belgroune M, Baldwin AI, Bartolini R, Jones JK, Martin IP, Rowland J & Singh B

Tests of the FONT3 Linear Collider Intra-Train Beam Feedback System at the ATF
Burrows PN et al

Commissioning of an APPLE-II Undulator at Daresbury Laboratory for the SRS
Clarke, J, Hannon FE, Scott DJ, Shepherd BJA, Wyles NG

Start to End Simulations of the ERL Prototype at Daresbury Laboratory
Gerth C, Bowler M, Muratori B, Owen HL, Thompson NR, Faatz B, McNeil BWJ

Development of a Superconducting Helical Undulator for a Polarised Positron Source
Ivanyushenkov Y, Carr F, Clarke JA, Malyshev O, Scott DJ, Shepherd BJA, Baynham E, Bradshaw T, Rochford J, Barber D, Moortgat-Pick G, Cooke P, Dainton J, Greenshaw T

Inducing Strong Density Modulation with Small Energy Dispersion in Particle Beams and the Harmonic Amplifier Free Electron Laser
McNeil BWJ, Robb G & Poole MW

Low Level RF System for the Energy Recovery Linac Prototype
Moss A

Space Charge Effects for the ERL Prototype Injector Line at Daresbury Laboratory
Muratori BD, Owen HLO, Gerth CKM, van der Geer SM & de Loos MJ

4GLS and the Energy Recovery Linac Prototype at Daresbury Laboratory
Poole MW & Seddon EA

High Power Coupler Studies for the ERLP
Rogers J, Beard C & Corlett P

New Electron Beam Position Monitoring and Feedback System Upgrades for the Synchrotron Radiation Source at Daresbury Laboratory
Smith RJ, Cox G, Dufau MJ & Martlew BG

A Test Facility for the International Linear Collider at SLAC End Station A for Prototypes of beam delivery and IR components
Woods M et al

Combining Cavity for RF Power Sources: Higher Power Testing and Further Simulation
Wooldridge E, Corlett P & Rogers J

Proceedings of the 27th International Conference on Free-Electron Lasers, August 2005, Stanford, USA

Design Considerations for the 4GLS XUV-FEL
McNeil BWJ, Robb GRM, Thompson NR, Jones JK, Poole MW & Gerth CKM

Harmonic Lasing in an FEL Amplifier
McNeil BWJ, Robb GRM, Poole MW, Thompson NR

A VUV-FEL for 4GLS: Design Concept and Simulation Results
Thompson NR, Poole MW & McNeil BWJ

Proceedings of NANOBEAM 2005, 36th ICFA Advanced Beam Dynamics Workshop, October 2005, Kyoto

Laser wire location in ILC diagnostics section and tune up extraction
Angal-Kalinin D & Woodley M

Update on 2 mrad crossing angle extraction line for the ILC
Angal-Kalinin D, Appleby R, Bambade P, Seryi A, Nosokhkov Y, Carter J, Dadoun O, Napoly O

Other Conferences

Beam Delivery WG summary : Optics, collimation & background
Angal-Kalinin D, Jackson F, Mokhov N, Kuroda S, Seryi A, Proceedings of the 2nd ILC Accelerator Workshop, Snowmass,
August 2005

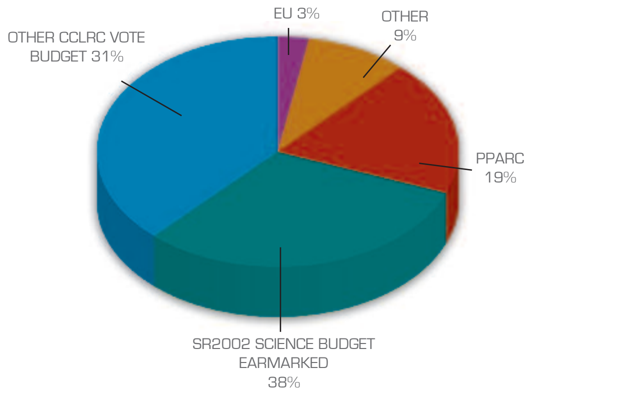
Optics of the ILC extrfaction line for 2 mrad crossing angle
Angal-Kalinin D, Appleby R, Nosochkov Y, Moffeit K, Parker B, Seryi A, Spencer C, Woods N, EuroTeV-Report-2006-001-1

Measurements on Ion-beam Loss Induced Desorption at GSI
Kollmus H, Bender M, Bellachioma MC, Mahner E, Krämer A, Westerberg L, Hedlund E, Malyshev O, Reich-Sprenger H,
AIP Conference Proceedings 773 (2005)

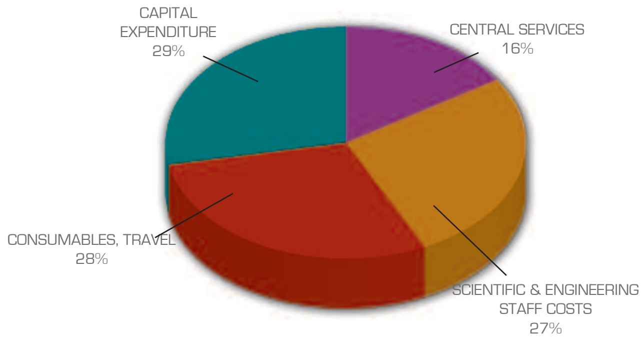
Cleaning of Stainless Steel for use in Accelerators
Middleman KJ, & Herbert JD, Proceedings of the 9th European Vacuum Conference, Paris,
April 2005

Finance

INCOME SOURCES 05/06	£K
PPARC	1351
SR2002 SCIENCE BUDGET EARMARKED	2691
OTHER CCLRC VOTE BUDGET	2240
EU	208
OTHER	623
	7113



EXPENDITURE 05/06	£K
SCIENTIFIC & ENGINEERING STAFF COSTS	1919
CONSUMABLES, TRAVEL	1962
CAPITAL EXPENDITURE	2014
CENTRAL SERVICES	1153
	7048



EXPENDITURE BY PROGRAMME 05/06	£K
PPARC/CCLRC LC-ABD PROGRAMME	1404
PPARC/CCLRC UK-NF PROGRAMME	434
HIGH POWER PROTON ACCELERATORS	1385
HIGH BRIGHTNESS ELECTRON ACCELERATORS	802
UNDERPINNING RESEARCH	1369
OTHER PROFESSIONAL ACTIVITIES	556
EU AND REPAYMENT WORK	1098
	7048