IOP Plasma Physics Conference 2009

University of Warwick

Centre for Fusion, Space & Astrophysics

30 March - 2 April 2009

Dear Colleagues,

It is our great pleasure to welcome you to the 2009 IOP Plasma Physics Conference here at Warwick University.

The 36th IOP annual conference on plasma physics is organised by the Centre for Fusion Space and Astrophysics of the University of Warwick. It is an ideal opportunity for plasma physicists from all areas (including magnetic fusion, high energy density laser plasmas, astrophysics, low temperature and dusty plasmas) to meet and discuss ideas and recent developments. Young researchers are particularly encouraged with reduced rates available for students. Additionally, a satellite workshop on instabilities and turbulence in magnetised plasma is organised.

This year's meeting has again received a large amount of contributions from various fields. A total of 36 talks and 47 posters will be presented at the meeting. The poster sessions are organised with a buffet and wine, which we hope will generate the right atmosphere for an informal exchange of ideas.

The IOP meeting on plasma physics is generously sponsored by various organisations including UKAEA Culham, the Atomic Weapons Establishment (AWE), the STFC Central Laser Facility, the STFC space science and technology department and IOP Publishing. The sponsoring allows for the reduced fees of PhD students, and for the poster and thesis prizes, as well as the wine during the poster sessions.

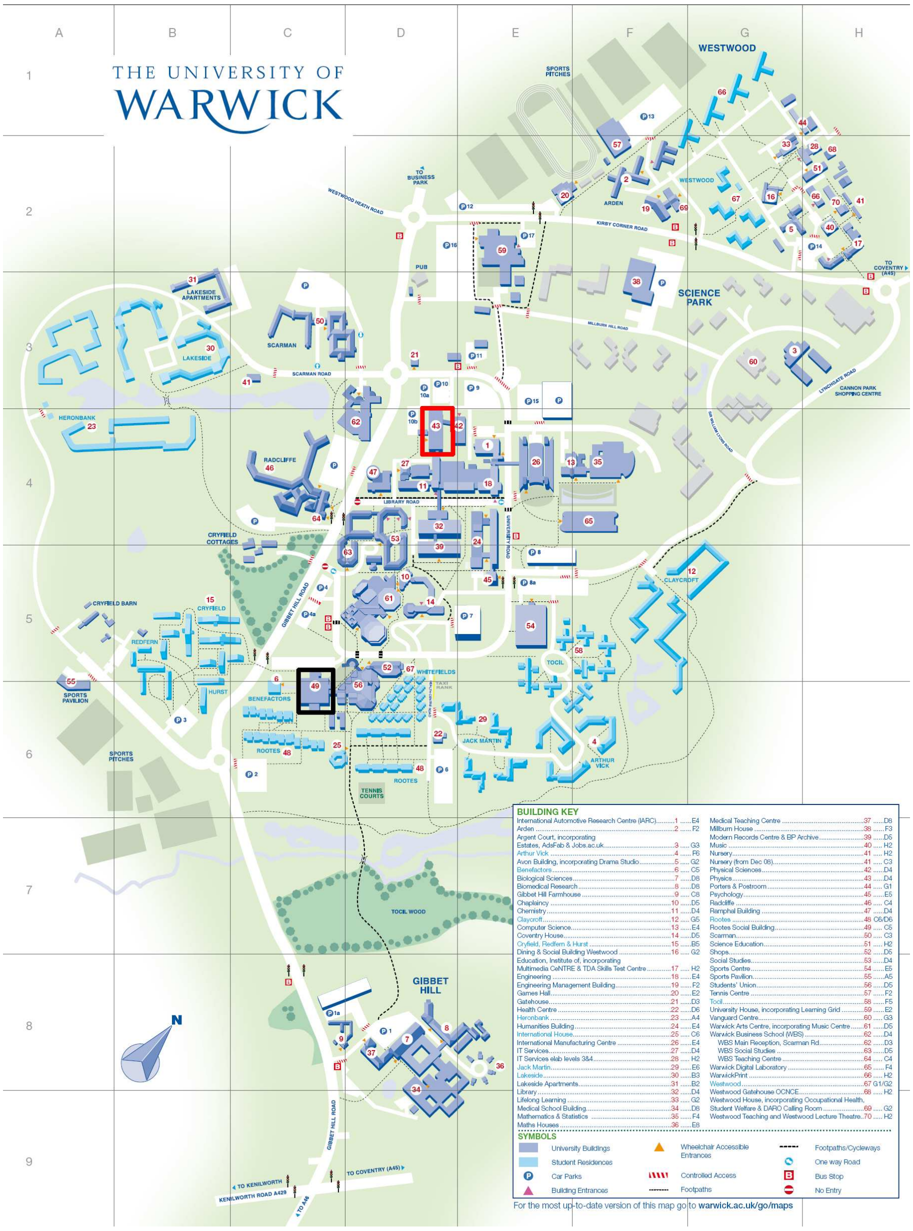
Hoping for a successful conference with inspiring talks and discussions,

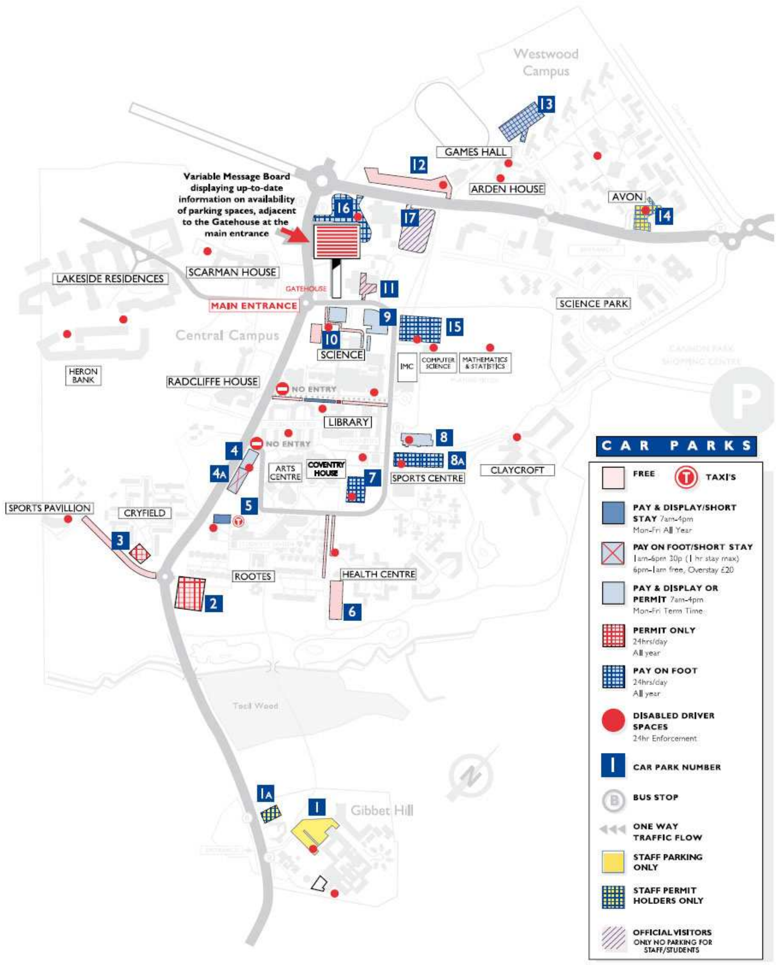
Yours sincerely,

The local organising committee:

Arthur G. Peeters
Jan Vorberger
James W. Cook
Mary Peterson

IOP Conference Information





Parking on Campus

- Car parks 1, 3, 6, 11, 12 & 13 are free all day.
- Car parks 4a & 7 are free after 6pm.
- Car parks 4, 5, 8, 9, 10 & 14 are free after 4pm.
- Car Park 8a is restricted to Day permit holders only and members of Warwick Sport using the facilities for a maximum of 2 hours.
- Car parks 4, 8, 9, 10, 14 15 and 16 and designated car parks at Gibbet Hill are Pay and Display.
- Charges are 1.90 per day/1.00 up to 4 hours term time only (7.00am - 4.00pm Monday-Fri) except 15, 16, 5, 4a and Library Road (Blue Bays) where charges apply all year.
- There are disabled parking spaces near all buildings on campus. Should you wish to use Car Park 7 contact University House staff for further assistance on (024) 7657 5477.

Bus from Coventry City Centre

The Travel Coventry services 12 and 12A (which display the destination, University of Warwick or Leamington) run from the city centre bus station, Pool Meadow, to the University Central Campus passing the Westwood campus en route (travel time approx. 25 mins).

Timetable information for West Midland service number 12 can be found at http://www.travelcoventry.co.uk/. When going to the Coventry train station by bus, get off when you see King Henry VIII school on your left.

Stagecoach also provides a service that passes the University. The Unibus (U1) is a dedicated frequent bus service to Leamington and Sydenham that passes through campus. There is a second version of this route that passes through Kenilworth and is named the U2. For information on this service, please visit http://www.stagecoachbus.com/.

The number 12 bus runs regular services between Coventry and Leamington Spa.

Bus from Coventry Railway Station

Visitors should follow the signs from the station to Warwick Road (a 2 minute walk) and from there catch the Travel Coventry services 12 or U1 (see above) which travel onto the main campus. The Stagecoach service U1 travels along Warwick Road and onto the Central Campus.

It is also possible to catch the Travel Coventry number 42 which goes to Cannon Park Shopping Centre which is a 5-10 minute walk from central campus.

The Stagecoach service X17 runs from the city centre, passing the junction of Gibbet Hill Road and Kenilworth Road. The entrance to the Gibbet Hill campus is about 5 minute's walk from this bus stop. The Central Campus can also be reached from this site by following the campus footpath, which takes about 10 mins.

The Travel Coventry route 801 travels from the University to Cheylesmore, Binley and Walsgrave Hospital via Finham, Whitley and Willenhall.

Rail

The nearest rail station for the University is Coventry. Coventry Station is easily reached from London (Euston), Birmingham (New Street) and Leicester, all of which run regular and frequent services direct to Coventry. From Coventry Station, there are frequent local bus services to the University. The station that serves Birmingham Airport is Birmingham (International). Detailed travel information and timetables can be found at Railtrack. Taxis are also available from outside of the station.

	Monday	Tuesday	Wednesday	Thursday
Time				
9.00 – 9.40		B.D. Dudson	S.D. Pinches	G. Gregori
9.40-10.00		Y. A. Gonzalvo	J. McCone	P.P. Rajeev
10.00-10.20		I.V. Konoplev	P. Petkaki	X.H. Yuan
10.20-11.00		coffee	coffee	coffee
11.00-11.40	IOP conference Registration with coffee and Lunch	A. Grinenko	S.W. Rowe	N.F. Leureiro
11.40-12.00		J.P. Coad	S. Cipiccia	M.N. Quinn
12.00-12.20		T. Neukirch	A.J. De-Gol	R.J. Buttery
Lunch		Lunch	Lunch	IOP Conference ends with Lunch
13.40 -14.20	Y. Camenen	M. Coppins	S. Schwartz	
14.20-14.40	J.E. Allen	R.J. Chin	C.J. Ham	
14.40-15.00	B. Bahnev	Z. Najmudin	A. Chmura	
15.00-15.40	coffee	coffee	coffee	
15.40-16.20	K.L. Lancaster	A.J. Kavanagh	H.E. Potts	
16.20-16.40	Z. Ehsan	J.W.S. Cook	N. Singh Saini	
16.40-17.00	T.J. Goldsack	A. Robinson	R. Trines	
17.00-17.30	Posters with Dinner and wine	Posters with Dinner and wine	AGM meeting	
17.30-19.00			Conference dinner	

- invited talks (40 minutes) are coded in yellow
- contributed talks (20 minutes) are coded in green
- the titles of invited talks have a red color coding in the abstract book
- all talks will be given in the physics lecture theatre in the physics building (red square on the map, #43).
- the poster session will take place on the physics concourse next to the physics lecture theatre.
- lunch will be taken in the Rootes restaurant (black square on the map)

Contents

Monday, 30 March 2009, 13:40-14:20:

Effect of the Coriolis drift on turbulent cross-field transport in magnetised plasmas

Y. Camenen[1], A.G. Peeters[1], C. Angioni[2], F.J. Casson[1], W.A. Hornsby[1], A.P. Snodin[1], D. Strinzi[3]

[1] *Centre for Fusion, Space and Astrophysics, Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom*

[2] *Max-Planck-Institut für Plasmaphysik, EURATOM-IPP Association, 85748 Garching, Germany*

[3] *National Technical University of Athens, EURATOM Association, GR-15773 Athens, Greece*

In a rotating magnetised plasma, the gyrocenter drifts due to the inertial forces can affect the small scale instabilities. Namely, provided the angular rotation vector has a component perpendicular to the magnetic field, the Coriolis drift couples density, temperature and parallel velocity fluctuations. Such a coupling results in additional contributions to the cross-field transport, which can lead to peaked profiles even in the absence of sources. The particle, heat and parallel momentum fluxes generated by the Coriolis drift are by essence proportional to the plasma angular rotation and to the mass to charge ratio. A detailed analysis of the effect is carried out by, first, deriving a simplified fluid model to highlight the physical mechanisms at play, second, performing flux-tube gyrokinetic simulations to quantitatively assess the Coriolis fluxes in realistic conditions.

Monday, 30 March 2009, 14:20-14:40:

The plasma-sheath boundary; its history and Langmuir's definition of the sheath edge.

J.E. Allen

University College, Oxford OX1 4BH, UK

The introduction of the terms sheath in 1923 and plasma in 1928 by Langmuir is described, followed by their use in the Tonks and Langmuir in 1929. The well-known Bohm criterion for sheath formation, published in 1949, is shown to be closely related to the earlier work of Tonks and Langmuir. The much-used version of the Bohm criterion with the equality sign is obtained by employing the two-scale theory of the plasma and sheath.

Monday, 30 March 2009, 14:40-15:00:

DNA damaging as a detection of plasma boundaries in the open atmosphere

Blagovest Bahnev, Mark Bowden, Sylwia Ptasinska, Agnieszka Stypczynska, Nicholas St. J. Braithwaite

Department of Physics and Astronomy, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK

Plasmas operated in open atmospheres usually have a clearly visible component in which energetic electrons induce light emission, but the effect of the plasma may extend much further than this visible region as plasma species diffuse into surrounding atmosphere. The extent of this open boundary is difficult to quantify with conventional plasma measurement techniques because these techniques usually rely on detecting particle species that may exist only at low density in this extended plasma region. In this study, we investigated a new technique that opens up the possibility detecting this region. This technique is based on the exposure of plasmid DNA to the discharge. The plasmid DNA is very sensitive to impact of low energy electrons, ions and neutral species. The extent of the plasma region is determined by analysing the damage caused by the plasma to the DNA.

In this study we used a low frequency atmospheric pressure plasma jet made from a quartz tube with 4 mm inner diameter and two ring electrodes around the outside the tube. Helium gas flows through the tube into the atmosphere. A discharge is generated inside the tube by a 3.2 kHz rf voltage applied to the ring electrodes. This also produces a plume of plasma outside the tube. Depending on the discharge conditions, the plasma plume may extend up to 70 mm from exit of the tube. Electrical and optical measurements were used to characterise the discharge. Plasmid DNA was deposited onto mica substrates and exposed to the plasma. During exposure to plasma, the DNA molecule changes from its natural supercoiled form into two types of damaged forms. This change may be induced by charged particle impact, radical impact and/or impact of UV photons. The change in DNA structure was determined by analysing exposed samples with an agarose gel electrophoresis measurement.

Measurements of DNA damage were made by varying between the mica substrate and the end of the plasma plume. When the substrate touched the tip of the plasma plume, the measured DNA damage was approximately 70%. This damage reduced as the distance between the visible plasma and the substrate was increased. Although the visible plasma extended for only 70 mm, DNA damage was observed for distances of up to 180 mm from the end of the dielectric tube. Measurements with a UV filter showed that UV photons generated in the discharge were not responsible for this DNA damage. At present we believe that the damage must be due to species (electrons, ions, neutrals) generated in the high-energy part of the plasma and carried downstream to the DNA sample by the helium flow. Further measurements are needed to confirm this hypothesis and identify the species responsible for damage. This method of measuring the extent of weak atmospheric pressure plasmas should be applicable for wide range of discharges operated in open atmosphere.

Monday, 30 March 2009, 15:40-16:20:

Developments in fast ignition and the future of intertial fusion energy

K.L. Lancaster

Central Laser Facility, Rutherford Appleton Laboratory, Oxford, UK

With the advent of large scale facilities across the globe, Inertial fusion energy (IFE) is becoming a rapidly expanding, rapidly progressing field of study. One attractive method of gaining energy from laser driven fusion is the so called 'fast ignition' scheme, first published by M. Tabak [1] in 1994. This scheme involves compressing a DT spherical capsule to hundreds of times solid density and then injecting a high intensity laser beam to produce hot electrons which subsequently travel into the fuel to ignite it. This talk aims to chart the major developments in the fast ignition scheme, covering the major experimental and theoretical insights that have occurred over the last 15 years. The future of fast ignition and the HiPER project will also be discussed in detail.

[1] M. Tabak et. al. Physics of Plasmas 1 1626 (1994)

Monday, 30 March 2009, 16:20-16:40:

Nonlinear Landau damping of dust-helicon waves

Z. Ehsan[1], N. L. Tsintsadze[2]

[1] *Imperial College London, Blackett Laboratory, London SW7-2AZ, UK*

[2] *Salam Chair and Department of Physics GC University, Lahore*

The problem of Nonlinear Landau damping of helicon waves in dusty plasma in particular emphasis to the acceleration of soliton is presented here. This in the framework of a collisionless, anisotropic homogeneous dusty plasma in one dimension, can be well described by two coupled dynamical equations of the generalized Zakharov type, with one extra nonlocal term coming from Landau damping. Nonlinear-nonlocal term gives rise to essential contributions relative to the local term. Then under different conditions, kinetic nonlinear Schrödinger (KNLS) equation is constructed and nonlinear decrement is obtained for each case. It is noticed that time dependant term in the ponderomotive force plays significant role for this kind of damping. Additionally, it is shown that nonlinear Landau damping leads to the amplitude modulation of dust helicon waves, further modulational instability and maximal growth rate is obtained when the group velocity of helicon wave reaches the dust-acoustic speed. It is demonstrated that how the nonlinear Landau damping leads to the acceleration of soliton which is eventually slowed down after transferring some of its energy to the wave, and radiation of dust-acoustic wave by accelerated soliton is discussed briefly.

Monday, 30 March 2009, 16:40-17:00:

The ORION laser at AWE: progress and academic access

T.J. Goldsack

Building E3, AWE Aldermaston, Reading, RG7 4PR, England

The ORION laser is under construction at AWE, with completion scheduled for March 2011, and full operational status in March 2012. Thereafter, approximately 15% of laser time will be available for academic collaboration with AWE. This talk will present an update on construction, predicted laser performance, and available diagnostics. Areas for possible collaborative experiments will be explored together with the administrative arrangements to be put in place for access by academic collaborators.

Tuesday, 31 March 2009, 9:00-9:40:

Edge Localised Modes: Experiment and Simulation

B.D. Dudson[1], M.V. Umansky[2], X.Q.Xu[2], A. Kirk[3], P.B. Snyder[4], H.R. Wilson[1]

[1] *Department of Physics, University of York, Heslington, York YO10 5DD, UK*
[2] *Lawrence Livermore National Laboratory, Livermore, CA 94550, USA*
[3] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Oxfordshire OX14 3DB, UK*
[4] *General Atomics, San Diego, CA 92186, USA*

The efficient performance of future tokamak devices such as ITER depends on achieving high plasma pressures. During high-confinement operation (H-mode), a transport barrier forms close to the plasma edge which supports a large pressure gradient. This barrier is prone to repetitive instabilities known as Edge Localised Modes (ELMs) which – if uncontrolled - are expected to release ∼20MJ of energy in ∼100 microseconds in ITER. This would limit the lifetime of plasma facing components. Understanding the triggering, non-linear development, and control of ELMs is therefore a pressing concern.

The current state of ELM research is reviewed, in particular experimental results from the Mega-Amp Spherical Tokamak (MAST). These have been some of the most striking results in this field in recent years, and have contributed greatly to the current understanding of ELMs in terms of erupting plasma filaments driven by peeling-ballooning modes.

Understanding the behaviour of ELMs in future devices requires non-linear simulations of these events. This is a challenging task which is being undertaken by several groups around the world. Here, simulations using the new BOUT++ code [1] will be presented. This code has been designed as an extensible tool for studying non-linear plasma phenomena such as ELMs. It is a general framework capable of solving an arbitrary number of scalar and vector fluid equations in curvilinear geometry. Linear simulations of 3-field reduced MHD (pressure, vorticity, parallel vector potential) are compared with the ELITE linear MHD code [2,3]. These results show good agreement in both the mode structure and growth rates, giving confidence that BOUT++ can reproduce the ideal ballooning mode. The non-linear development of these simulations shows eruption of filaments from the plasma edge which accelerate outwards, in qualitative agreement with observations.

[1] B.D.Dudson et. al. Pre-print arXiv.org:0810.5757

[2] P.B.Snyder et. al. Physics of Plasmas 9 (2002) 2037
[3] H.R.Wilson et. al. Physics of Plasmas 9 (2002) 1277

Tuesday, 31 March 2009, 9:40-10:00:

Molecular beam mass spectrometry and SIMS measurements for surfaces modified by plasmas at atmospheric pressure

Y. Aranda Gonzalvo, G.A. Cooke, T.D. Whitmore, D.L. Seymour, C.L. Greenwood, J.A. Rees

Plasma & Surface Analysis Division, Hiden Analytical Ltd., 420 Europa Boulevard, Warrington WA5 7UN, UK

Electrical plasmas can be produced readily at atmospheric pressures and have relatively low running costs. They are idea for a variety of industrial processing applications for many materials. Processing using non-thermal atmospheric plasma currently extends to areas such as surface cleaning and functionalisation, plasma activation, tissue engineering and sterilisation. To aid in understanding the mechanisms involved in plasma/surface interaction we present results of both plasma measurements and surface composition studies for a range of materials treated using an atmospheric dielectric barrier discharge (DBD). The plasma properties were determined using an energy-resolved molecular beam mass spectrometer (MBMS). The surface compositions of the materials before and after treatment were compared using a static SIMS instrument. The dielectric surface barrier discharge was operated using helium and applied to molybdenum, hard disc and silicon wafers. For some of the samples, contact angle measurements were used to determine the changes in the wettability of the surfaces brought about by the plasma treatment. Silicon test pieces were treated using hydrofluoric acid to produce a strongly hydrophobic, hydrogen-terminated surface. The hydrophobicity of the surfaces could be significantly reduced by short exposure to certain plasma conditions. Static SIMS analyses of these surfaces showed a significant reduction in the observed SiH^+ signal and an accompanying increase in the Si and the reactive silanol groups [Si-OH]. MBMS consists of an energy mass spectrometer (QMS) with a differentially pumped three-stage inlet system. The pressure reduction stages are separated by aligned skimmer cones and continuously pumped by separated turbomolecular pump sets. A free-jet expansion from atmospheric pressure into the primary low-pressure stage is skimmed to produce a molecular beam. The beam is then directed into the extraction lenses and electron impact ion source of the QMS. External ions and ions generated via the ionisation process enter the energy filter, mass analyser and finally detected. The plasma generated with the DBD source was directly aligned with the mass spectrometer inlet. The conditions in the first pumped space exclude the possibility of collisions of ions with gas molecules and hence exclude the possibility of cluster formation. Mass spectra of the ions generated in the helium show a high concentration of monoatomic and diatomic oxygen. Measurements of the ion energies show that the ions generated in the DBD source and entering the mass spectrometer inlet orifice are fully thermalized and hence their energies are close to 0.03 eV. MBMS analyses of the plasmas provided information on the relative contributions of ionic and radical species to the changes in the surface structure and the combination of data from the two diagnostic techniques contributes to our general understanding of such plasma/surface processing.

Tuesday, 31 March 2009, 10:00-10:20:

High Power W-Band Maser Based on a Two-Dimensional Periodic Structure

I. V. Konoplev, L. Fisher, A. W. Cross, A.D.R. Phelps, K. Ronald

SUPA, Department of Physics, University of Strathclyde, 107 Rottenrow, Glasgow, G4 0NG, UK

High power millimetre-wave sources operating in the W-band (75GHz-110GHz) frequency range are attractive devices for a number of applications. We present the concept, numerical study and design of a high power maser based on a 2D periodic structure and operating in the W-band (75GHz-110GHz) frequency range, which is capable of generating spatially and temporally coherent radiation at a power of up to 30 MW. To generate high powers an oversized (with respect to the wavelength of operation) high-current but moderate space charge density electron beam will be used to overcome problems associated with high electromagnetic power; such as electric field breakdown in the interaction space. A two-dimensional periodic structure is used to provide the distributed feedback and synchronize the radiation from the different parts of the electron beam ensuring spatial and temporal coherence of the radiation as well as increasing the output power of the maser [1,2]. The periodic lattice is in the form of a two dimensional corrugated structure which acts also as a slow wave structure to ensure an effective interaction between the radiation and an annular electron beam. The numerical studies of a new Cherenkov maser based on a periodic lattice demonstrate single frequency operation of the device when driven by an oversized annular electron beam. The results of the numerical studies will be presented and the design of the maser will be discussed. The recent progress made towards the construction of a Cherenkov maser which uses two-dimensional distributed feedback operating in the W-band frequency band will be presented.

1. L. Fisher, I. V. Konoplev, A. W. Cross and A. D. R. Phelps, 2007 IEEE Pulsed Power Conference, (PPPS-2007), Albuquerque , USA, 2007.

2. L. Fisher, I. V. Konoplev, A. W. Cross and A. D. R. Phelps, The 32nd International Conference on Infrared and Millimetre Waves and 15th International Conference on Terahertz Electronics', September 2-7, 2007.

Tuesday, 31 March 2009, 11:00-11:40:

Dynamic Compression Driven by Heavy Ion-Beams

A. Grinenko[1], J. Vorberger[1], S.H. Glenzer[2], D. Varentsov[3], D.O. Gericke[1]

[1] *Centre for Fusion, Space and Astrophysics, Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom*

[2] *Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94551, USA*

[3] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany*

Researches carried out in astrophysics, planetary and material sciences seek after a thorough understanding of the behavior of matter at high pressures. For example, the equation of state of iron at pressures of $1 - 4$Mbar is crucial in order to determine the state of the Earth's core. Equation of state data at 0.1Mbar is required to establish the state and the composition in Earth's lower mantle, while the dynamics of the processes in the mantle is considered to be dependent on the structural phase transformation kinetics. The pursuit after materials for technological applications also entails a detailed understanding of the kinetics of the high-pressure phase transitions. Modeling the physical processes during the projectile impact relevant to meteoroid protection and crater formation requires the solid-state dynamical response data at ultrahigh strain rates. The questions associated with the hydrogen at high pressures are especially important for understanding the structure and evolution of the hydrogen-bearing astrophysical objects such as the giant planets like Saturn and Jupiter as well as for the inertial fusion energy research.

We investigate the capabilities of dynamic compression by intense heavy ion beams to yield information about the high pressure phases of hydrogen and solids. Employing *ab initio* simulations and experimental data, a new wide range equation of state for hydrogen is constructed. The results show that the melting line up to its maximum as well as the transition from molecular fluids to fully ionized plasmas can be tested with the beam parameters soon to be available. We demonstrate that x-ray scattering can distinguish between phases and dissociation states.

Also a new design for heavy-ion beam driven isentropic compression experiments is suggested and analysed. The proposed setup utilizes long stopping ranges and the variable focal spot geometry of the high-energy uranium beams delivered at the GSI Helmholtzzentrum für Schwerionenforschung and Facility for Antiproton and Ion Research accelerator centers in Darmstadt, Germany, to produce a planar ramp loading of various solid samples. In such experiments, the predicted high pressure amplitudes ($<$ 10Mbar) and short timescales of compression ($<$ 10ns) will allow testing the time dependent material deformation phenomena at unprecedented extreme conditions.

Tuesday, 31 March 2009, 11:40-12:00:

The JET ITER-like Wall Experiment

J.P. Coad[1], A. Loving[1], G.F. Matthews[1], V. Riccardo[1], A. Widdowson[1], JET-EFDA contributors as in Appendix of F Romanelli et al., Fusion Energy Conference 2008 (Proc. 22nd FEC Geneva, 2008) IAEA, (2008)[2]

[1] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK*

[2] *JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK*

Operation of JET with an ITER-like Wall (ILW) will be the largest fusion experiment in Europe this decade, and is seen as an essential step before committing to the choice of wall material for ITER. Most of the tokamaks in the world so far have used carbon as the first-wall material since it is virtually indestructible and also of low atomic number. However, carbon readily combines with the deuterium-tritium (D-T) plasma gas mixture to form hydrocarbon deposits, and this probably makes it unacceptable for ITER. Thus ITER plans to use tungsten (W) as the divertor material for the D-T phase, and beryllium (Be) for the main chamber walls (though carbon targets may be used for setting up prior to the introduction of T). However, no tokamak has operated with this mix of plasma-facing materials, and a number of potential problems must be investigated and solved in advance of ITER operation to minimise financial risk and speed up the early development phases; this is the purpose of the JET ILW.

The ILW components (involving several thousand tiles) are now in an advanced stage of procurement. The first wall will comprise solid Be tiles on inconel supports for power loading up to 2 MWm-2 and Be-coated inconel for low flux regions of the main chamber, and W-coated CFC tiles in the divertor or areas at risk of high power loads in the main chamber. There will also be some solid W target tiles in the divertor in areas where the highest heat loads are expected. Issues that have had to be addressed included: stress analysis of tile shapes and relief using castellations and profiling, power loading under various plasma configurations, and reducing electrical conductivity to minimise halo current forces; the solid tungsten targets have been especially challenging. Thick tungsten coatings on CFC tiles have also been developed that can survive repeated ELM-like pulses of up to several GWm-2 for fractions of a second each. All components will be installed in JET by Remote Handling, and this has required development of the articulated boom systems and the design of many hundreds of special tools to cope with the complex arrays of tiles and new diagnostics that will be installed.

Once the installation of the ILW is complete, the first objectives will be to learn how to mitigate plasma interaction with a Be first wall (e.g. studying turbulence in the plasma boundary, fast electrons produced by the auxiliary heating systems planned for ITER, ELM effects, etc), to study Be/W interaction effects such as alloying and melting point reduction, melt layer dynamics and vapour shielding, and power density limitation in a W divertor (ELM mitigation, impurity introduction to increase radiated fraction, Zeff control, etc). It is also necessary to demonstrate that there will be a significant reduction in H-isotope retention by means of gas balance and the analysis of components removed from the torus after the first period of operation, the latter requiring provision of new analytical facilities.

Tuesday, 31 March 2009, 12:00-12:20:

A one-dimensional Vlasov-Maxwell equilibrium for the force-free Harris sheet

T. Neukirch, M. G. Harrison

School of Mathematics and Statistics, University of St. Andrews, St. Andrews, KY16 9SS, United Kingdom

A non-linear force-free equilibrium of the Vlasov-Maxwell equations is presented. One component of the equilibrium magnetic field has the same spatial structure as the Harris sheet, but whereas the Harris sheet is kept in force balance by pressure gradients, in the force-free solution presented here force balance is kept by magnetic shear. Magnetic pressure, plasma pressure and plasma density are constant. The method used to find the equilibrium is based on the analogy of the one-dimensional Vlasov-Maxwell equilibrium problem to the motion of a pseudo-particle in a two-dimensional conservative potential. This potential is equivalent to one of the diagonal components of the plasma pressure tensor. After finding the appropriate functional form for this pressure tensor component, the corresponding distribution functions can be found using a Fourier transform method. The force-free solution can be

generalized to a complete family of equilibria that describe the transition between the purely pressure-balanced Harris sheet to the force-free Harris sheet.

Tuesday, 31 March 2009, 13:40-14:20:

Modelling dust in tokamaks: the critical issues

M. Coppins
Department of Physics, Imperial College London, London, UK

Dust is generated in tokamaks through plasma-surface interactions. It can act as a source of unwelcome impurities, and its presence also has operational and safety implications. It is therefore important to know, firstly, where does the dust come from? and, secondly, where does it go? We have developed a dust transport simulation, DTOKS, to try to answer the second of these questions. This code is based on a detailed model of the dust-plasma interaction. However, many aspects of the basic physics are still poorly understood. The critical issues for modelling the motion and lifetime of tokamak dust are reviewed. In particular, two very fundamental and important aspects of the dust-plasma interaction are highlighted, namely, the floating potential of the particles and the ion-drag force acting on them.

Tuesday, 31 March 2009, 14:20-14:40:

Two-fluid equilibria of rotating spherical tokamak plasmas

R. J. Chin[1], E. Verwichte[1], K. G. McClements[2], A. Thyagaraja[2], P.J. Knight[2]
[1] *Department of Physics, University of Warwick, Coventry, CV4 7AL*
[2] *UKAEA Culham Division, Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB*

Toroidal rotation velocities comparable to or exceeding the local sound speed have been produced in the MAST spherical tokamak through the use of neutral beam injection [1]. Strongly sheared flows can improve the performance of tokamak plasmas by suppressing turbulence and MHD modes. However, it is important to determine accurately the effect of flows on the equilibrium since this also impacts on the plasma's stability and transport properties. Equilibria of MAST-like plasmas with transonic toroidal flows are calculated numerically in the framework of two-fluid theory [2] using a fixed-boundary equilibrium solver, GRASS. In the dissipationless limit, with momentum sources neglected, two-fluid analysis leads to interdependence between the rotation, temperature and density profiles, and the possibility of a departure from rigid-body rotation of flux surfaces. The effects of toroidal flows on the position of the magnetic axis, the plasma safety factor profile and the density profile are determined for a range of scenarios, including rigid body rotation. Electron temperature and ion temperature are assumed to be flux functions, with profiles that are broadly consistent with measurements from MAST.

This work was funded by the Engineering and Physical Sciences Research Council (EPSRC) and by the European Communities under the Contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission. RC is supported by an EPSRC Innovation Award (EP/D062837/1).

[1] Akers R J et al. Proc. 20th IAEA Fusion Energy Conf., paper EX/4-4 (2005)
[2] Thyagaraja A & McClements K G Phys. Plasmas **13**, 062502 (2006)

Tuesday, 31 March 2009, 14:40-15:00:

Acceleration to near GeV energies by self-guided laser pulses, and their betatron radiation properties

Z. Najmudin[1], S. Kneip[1], S.R. Nagel[1], C. Bellei[1], V. Chvykov[2], F. Dollar[2], R. Fonseca[3], F. Fiuza[3], C. Huntington[2], G. Kalintchenko[2], K. Krushelnick[1,2], A. Maksimchuk[2], S. Martins[3], T. Matsuoka[2], S.P.D. Mangles[1], C. McGuffey[2], C. Palmer[1], P.P. Rajeev[4], L.O. Silva[3], J. Schreiber[1], M.J.V. Streeter[4], K. Ta Phuoc[5], J. Vieira[3], V. Yvanovsky[2]

[1] *The Blackett Laboratory, Imperial College London, UK*
[2] *Center for Ultrafast Optical Science, University of Michigan, Ann Arbor USA*
[3] *GoLP/Inst Plasmas & Fusao Nucl, Instituto Superior Tecnico, Lisbon, Portugal*
[4] *Central Laser Facility, Rutherford Appleton Laboratory, UK*
[5] *Laboratoire d'Optique Appliqué, Ecole Polytechnique, Palaiseau, France*

Electrons are accelerated to near GeV quasi-monoenergetic beams with a self-guided laser plasma wakefield accelerator. Experiments were carried out on the Astra Gemini Laser (at the Rutherford Appleton Laboratory). Up to 12 J of 55 fs, 800 nm laser light was focused with an $f/20$ parabolic mirror onto the front edge of gas jets of 3 to 15 mm length. Exit mode imaging of the laser light from the end of the gas jet indicates self-guiding over the full interaction length. Electron beams with < 3 mrad divergence and < 5 mrad RMS pointing stability are observed for a range of plasma densities and interaction lengths. At constant plasma density, the maximum achievable electron energy is found to scale linearly with the interaction length up to a maximum of $\sim$ 800 MeV. This is found to be due to the effect of self-amplication and the corresponding increase in the amplitude of the non-linear plasma wave. 3D particle-in-cell simulations confirm these phenomena. These experiments illustrate that near GeV electron beams can now be produced without the need for an external guiding structure.

Furthermore, the interactions are found to produce a bright source of 10 keV synchrotron radiation from electrons undergoing betatron oscillations in the plasma channel is observed in the laser direction. Further investigations demonstrate that the energy spectrum of these may be selectable by controlling the properties of the accelerated electrons. We show that these sources are already comparable in brightness to third generation x-ray sources, and suggests the use of compact plasma accelerators in light source applications.

Tuesday, 31 March 2009, 15:40-16:20:

Plasma physics in the great outdoors

Andrew J. Kavanagh

Department of Communication Systems, Infolab21, Lancaster University, Lancaster, LA1 4WA

Our solar system provides a rich environment for studying plasma processes under varying conditions; from the fast flowing solar wind to the magnetically confined plasma environments of the gas giants. Over the years numerous satellites have enabled us to study magnetic flux emergence on the Sun, turbulence and shocks in the solar wind and instabilities in the Earth's own magnetosphere. The evolution of missions has provided opportunities to look with unprecedented resolution at solar phenomena and small-scale structures in the magnetosphere and will hopefully soon allow us to study the nonlinear coupling of electron, ion and fluid scale processes. The Earth's ionosphere provides a unique laboratory for studying both large and small scale plasma processes. Studies of auroral dynamics have shed light on the mechanisms of plasma heating, magnetic reconnection and transport. The ionosphere is readily accessible, whether by satellite observation, rocket-borne sensors or a wealth of ground-based platforms, such as radars and cameras. Although passive observation of the dynamic ionosphere can be illuminating a more direct approach has proven effective on a number of fronts. Active stimulation of ionospheric plasma via high-power, high-frequency radio waves is a powerful tool when combined with suitable diagnostics. Ongoing experiments range from the production of artificial aurora in the collisionless F-region to modification of dusty plasma in the collision dominated D-region, both of which have relevance to understanding energy flow in the natural environment. In this talk I hope to give an entertaining overview of just some of the space plasma physics that is being carried out by the solar-terrestrial physics community, with particular reference to the ionosphere and facilities available for carrying out this research.

Tuesday, 31 March 2009, 16:20-16:40:

Particle-in-cell simulations of the emission mechanism for fusion product-driven ion cyclotron emission from tokamak plasmas.

J.W.S. Cook[1], S.C. Chapman[1], R.O. Dendy[2,1]

[1] *Centre for Fusion, Space and Astrophysics, Department of Physics, Warwick University, Coventry CV4 7AL, U.K.*

[2] *Euratom/UKAEA Fusion Assocaition, Culham Science Centre, Abingdon, Oxfordshire OX14 3DB, U.K.*

Suprathermal ion cyclotron emission (ICE) was the first collective radiative instability, driven by fusion products, that was observed on JET and TFTR (R O Dendy *et al.*, *Nucl. Fusion* **35**, 1733 (1995)). Strong emission is found at sequential cyclotron harmonic peaks of the energetic ion population, as evaluated at the outer mid-plane edge. The measured intensity of ICE spectral peaks scales linearly with measured fusion reactivity, including its time evolution in the course of a discharge. It appears that the underlying emission mechanism is the magnetoacoustic cyclotron instability (MCI), identified theoretically by Belikov and Kolesnichenko *Sov. Phys. Tech. Phys.* **20**, 1146 (1976) and subsequently extended to JET and TFTR regimes (R O Dendy *et al.*, *Phys. Plasmas* **1**, 1918 (1994); S Cauffman *et al.*, *Nucl. Fusion* **35**, 1597 (1995)). The MCI involves resonance between: the fast Alfvén wave; cyclotron harmonic waves supported by the energetic particle population and by the background thermal plasma; and a subset of the centrally born fusion products, lying just inside the trapped-passing boundary in velocity space, whose drift orbits make large radial excursions to the outer mid-plane edge. The properties of the linear growth rate of the MCI in this regime have been intensively studied analytically, and yield good agreement with the key observational features of ICE. Remarkably, this agreement extends into areas where a nonlinear treatment might be thought necessary, notably the scaling of intensity with fusion reactivity and the fine structure of the spectral peaks. To explain this, and to address outstanding issues still in need of explanation, notably observed emission at background cyclotron harmonics that are not degenerate with energetic particle harmonics, we have developed a fully nonlinear first principles treatment of the MCI scenario for ICE. This is based on a particle-in-cell (PIC) code which self-consistently evolves electron and multi-species ion macroparticles together with the electromagnetic field. Extensive benchmarking of our PIC code against the many complex analytical formulations relevant to ICE and to cyclotron harmonic wave phenomenology has taken place. The growth rate of the MCI, as it evolves from the linear into the nonlinear regime for JET-relevant parameter sets, has been studied, and these results form the focus of this paper.

This work was partly funded by the United Kingdom Engineering and Physical Sciences Research Council under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Tuesday, 31 March 2009, 16:40-17:00:

Magnetic Collimation and Filamentation in Laser-Solid Interactions

A. Robinson[1], P.A. Norreys[1], D. Neely[1], P. McKenna[2]

[1] *Central Laser Facility, Rutherford-Appleton Laboratory, STFC, HSIC, Didcot, OX11 0QX*

[2] *SUPA, Dept. of Physics, University of Strathclyde, Glasgow,G4 0NG*

In ultra-intense laser-solid interactions, a significant amount of laser energy is absorbed into a population of multi-MeV electrons which can propagate without collisions for over a hundred microns in a solid target. The propagation pattern of the fast electrons is crucial to a number of potential applications , especially fast ignition ICF and proton acceleration. Global magnetic collimation and filamentation are major issues. The strength of the global collimation or pinching effect will have a huge impact on the energetic feasibility of fast ignition ICF for example. The evidence for strong global magnetic collimation in PW experiments is somewhat limited. In this presentation we will discuss the global magnetic collimation issue, how global collimation affects filamentation, and what insights three recent experiments might provide us with.

Wednesday, 1 April 2009, 9:00-9:40:

The Physics of Fast Ion Driven Instabilities in Fusion Plasmas

S.D. Pinches, MAST Team, JET EFDA Contributors

EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK

As the fusion community moves towards the realisation of devices containing burning plasmas, i.e. devices in which the intrinsic heating from energetic particles created as by-products of fusion reactions is dominant, it is timely to examine the recent progress made to understand the range of energetic particle driven modes observed and their consequences in terms of fast ion redistribution and loss.

In the MAST low aspect ratio tokamak, the population of fast ions created by the neutral beam injection system is super-Alfvénic and both the normalised fast ion pressure, β_f, and the ratio of fast ion energy content to thermal energy content are in excess of the values expected in a future fusion power plant, thus allowing interpolation (and not extrapolation) of the parameter space.

JET's large size and high current capabilities furnish it with excellent fast ion confinement properties which together with its extensive range of dedicated fast ion diagnostics and extensive range of sensitive fluctuation measurements make it an ideal testing ground for investigating the instabilities driven by fast ions with energies in the MeV range. Dedicated experiments examining fast ion losses and redistribution have been conducted on JET, drawing together the extensive range of diagnostic information to reveal the modes responsible, together with quantitative measurements of their consequences in terms of fast ion redistribution and loss.

The magnetic diagnostics installed on MAST are digitised such that modes with frequencies up to 5 MHz can be studied. However, within the nuclear environment of a burning plasma, high frequency magnetic measurements may no longer be possible due to the blanket requirements. Alternative diagnostics capable of providing information on the perturbations present are therefore being investigated. On JET, the use of X-mode reflectometry techniques to detect and localise modes has been pioneered. Experiments examining fast ion losses due to tornado modes (core-localised toroidal Alfvén eigenmodes) have been conducted using far infra-red interferometry measurements to detect these Alfvénic perturbations.

Instabilities identified as being driven by the population of fast ions present have been observed over a very wide frequency range on MAST; from around the plasma rotation frequency (∼10 kHz) all the way up to around the on-axis ion cyclotron frequency (∼4 MHz). A study of the polarisation of these modes has been enabled by the presence of many spatially orthogonal magnetic pick-up coils. New analysis tools have been developed to make use of these signals to routinely identify and visualise the polarisation of the perturbations observed.

In general, the radial gradient of the fast ions provides the drive for modes, however recently Alfvénic modes that propagate both co and counter to the plasma current have been observed on JET, indicating the possibility that such modes can be driven by fast ion anisotropy.

As a result of these advances, both our linear and nonlinear understanding of the phenomena expected to arise in burning plasmas have been enhanced and we can move towards the realisation of fusion devices with an increased level of confidence.

This work was funded jointly by the UK EPSRC and by the European Communities under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Wednesday, 1 April 2009, 9:40-10:00:

Comparison of measured poloidal rotation in MAST plasmas with neo-classical predictions

J. McCone[1], A.R. Field[2], N.J. Conway[2], S. Newton[2], M. Wisse[2]

[1] *1 University College Cork, Ireland*

[2] *2 EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*

Neo-classical tokamak plasma theory predicts poloidal rotation of the bulk ions of order $v_\theta^i \sim v_{th,i}\frac{\rho_i}{L_{Ti}}$ which is driven by the temperature gradient. In conventional aspect ratio tokamak plasmas, e.g. on JET and DIII-D, poloidal velocities considerably in excess of the neo-classical values have been measured, particularly in the presence of internal transport barriers (ITBs), by means of charge-exchange recombination spectroscopy (CXRS) on the fully ionised C^{6+} impurity ions. Comparison between such measurements and theoretical predictions require careful corrections to be made for apparent 'pseudo' velocities, which can arise from the finite lifetime of the excited atoms in the magnetised plasma and the energy dependence of the charge-exchange excitation process. This correction to the measured velocity is expected to scale as $\Delta v_{cx}^* \sim v_{th,i}B$, thus the relative magnitude of the correction to the neo-classical velocity scales as $\frac{\Delta v_{cx}^*}{v_\theta^i} \sim B^2$. Hence, on a spherical tokamak (ST) with $B_t \sim 0.6T$, the relative magnitude of this correction will be at least an order of magnitude smaller than on large conventional tokamaks, which operate at higher toroidal field. Such measurements on ST plasmas allow a very sensitive comparison.

On MAST measurements of toroidal and poloidal flows of the C^{6+} impurities are available from a state-of-the-art CXRS system with a radial resolution $\Delta R \sim \rho_i \sim$ 1cm. The appropriate corrections for the pseudo-velocities, which are of order 1 km/s, are then made to the measured velocities determined from the Doppler shifts of the spectra, which are up to an order of magnitude larger than the corrections. Comparison of the measured C^{6+} velocities with neo-classical theory requires an appropriate calculation of the impurity flow, which differs from that of the bulk ions due to the respective diamagnetic contributions for each species and inter-species friction forces. Here, comparisons are made with the predictions of the theory of Newton and Helander [1], which calculates the full neo-classical transport matrix for bulk ions and a single impurity species in a strongly rotating plasma as well as a simpler theory of Y.B Kim [2]. Initial results for both L- and H-mode plasmas show that, within the measurement uncertainties, the measured poloidal rotation is consistent with the neo-classical predictions.

[1] S. Newton and P. Helander, Phys. Plasmas, 13 (2006) 102505.

[2] Y. B. Kim, P. H. Diamond and R. J. Groebner, Phys. Fluids B, 3 8 (1991) 2050–2059.

This work was funded jointly by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Wednesday, 1 April 2009, 10:00-10:20:

Nonlinear dependence of anomalous ion-acoustic resistivity on electron drift velocity

P. Petkaki, M.P. Freeman

British Antarctic Survey, Madingley Road, Cambridge, CB3 0ET, UK

We investigate the dependence on the initial electron drift velocity of the current driven ion-acoustic instability and its resulting anomalous resistivity. We use Vlasov simulations with real mass ratio for a range of drift velocities and for electron to ion temperature ratios 0.9, 1 and 2. We show that the ion-acoustic anomalous resistivity depends nonlinearly on the electron drift velocity for the low temperature ratios examined, in contrast to the linear dependence predicted by theory.

Wednesday, 1 April 2009, 11:00-11:40:

Dynamic Plasma Sheath Breakdown, in HV Vacuum Circuit Breakers

S.W. Rowe

Schneider Electric, 38050 Grenoble cedex 09, France

The performance of high current vacuum circuit breakers has increased enormously since their introduction. This progress is now slowing down as we approach the intrinsic limitations imposed by physics and economic considerations. It is thus of prime importance to understand exactly what the principal limiting physical mechanisms are. Several different physical mechanisms come in play following arc extinction, any one of which can provoke interruption failure. We will describe some of these.

Wednesday, 1 April 2009, 11:40-12:00:

Betatron radiation production from a laser plasma accelerator

S. Cipiccia[1], R. Islam[1], R. Issac[1], G. Vieux[1], S.M. Wiggins[1], R.P. Shanks[1], A. Reitsma[1], D. Maneuski[2], V. Oshea[2], N. Lemos[3], R. Bendoyro[3], J. Martins[3], F. Fiuza[3], M. Marti[3], J.M. Dias[3], L.O. Silva[3], R. Pattathil[4], P. Foster[4], N. Bourgeois[5], T. Ibbotson[5], S.M. Hooker[5], D.A. Jaroszynski[1]

[1] *Strathclyde University, UK* ;[2] *Glasgow University, UK* ;[3] *IST Lisbon, Portugal* ;[4] *CLF, STFC, UK* ;[5] *University of Oxford, UK*

Intense synchrotron-like betatron radiation is emitted when laser plasma accelerated 500 MeV electrons undergo periodic transverse oscillation due to the restoring force of ions in the laser wake bubble. We present a theoretical discussion of the emission and photon energy scaling a spectra, angular distribution and emission rate and recent experimental results obtained using the RAL Astra Gemini laser.

Wednesday, 1 April 2009, 12:00-12:20:

Plasma response to a forced wave in a 1D modified Vlasov system

A.J. De-Gol[1], R.G.L. Vann[1], S.D. Pinches[2]
[1] *Department of Physics, University of York, Heslington, York, YO105DD, U.K.*
[2] *Euratom/UKAEA Fusion Association, Culham Science Centre, Oxon. OX14 3DB, U.K.*

Magnetic confinement fusion (MCF) requires a sufficiently hot and dense plasma to be confined long enough for fusion to occur. Instabilities may result in a degradation of the plasma confinement, in severe occurences causing damage to the holding vessel. Certain classes of waves are driven unstable in the presence of a supra-thermal particle population, such as fusion-born alpha particles. Understanding the physics of these waves is necessary for avoiding or controlling them. In the absence of fast particles we apply harmonic forcing, by way of active antennas, at relevant frequencies to measure the properties of the stable modes.

We subject a one-dimensional electrostatic modified Vlasov-Maxwell (VM) system to harmonic forcing as a heuristic model to study Toroidal Alfvén Eigenmode (TAE) excitation on the Mega-Amp Spherical Tokamak (MAST) device. This model serves as an intermediate step between simple harmonic oscillator models, currently used to derive the system's transfer function, and the wave-particle interaction that occurs in tokamaks.

The equations governing the electrostatic model consist of a modified Vlasov equation with the electric field calculated using a modified displacement current equation. Collisions act on the particle distribution and are incorporated as either a Krook model (close collisions) or a Fokker-Planck (FP) model (distant collisions) or a combination of both. The collision operator is written as

$$\left(\frac{\partial f}{\partial t}\right)_{Coll} = -\nu_a(f - F_0) + \nu_c\frac{\partial}{\partial v}\cdot[(v-u)f + v_{th}^2\frac{\partial f}{\partial v}] \tag{1}$$

with the first and second terms being the Krook and FP operators, respectively. The quantities v_{th} and u are the local thermal and flow velocities, respectively; these are calculated from the first and second velocity moments of the particle distribution. The coefficient ν_a represents particle annihilation/injection rate, and ν_c represents collision frequency.

The steady-state system response is fitted with a linear transfer function, derived from a damped-driven harmonic oscillator model, giving damping rate and resonant frequency of the system's stable modes. Increasing driving amplitude induces a system response that is dominated by nonlinear terms of the governing equations. In simulation, scanning the driving frequency around system resonance with strong forcing can induce shock-jump phenomena, leading to hysteresis in the frequency response function.

Wednesday, 1 April 2009, 13:40-14:20:

Multi-Scale Coupling in Plasmas: Opportunities via Space

Steve Schwartz[1] **on behalf of the Cross-Scale Science Study Team and community**[2]
[1] *Blackett Laboratory, Imperial College London, South Kensington, London SW7 2AZ*
[2] *www.cross-scale.org*

Several universal collisionless plasma processes (shocks, magnetic reconnection and turbulence) mediate the momentum and energy budgets in space, astrophysical, and laboratory plasmas. Cross-Scale is an ESA Cosmic Vision candidate mission to measure simultaneously the multi-scale coupling across electron, ion, and fluid scales with 12 satellites. This contribution will focus on the science questions, mission plan, and invite discussion on how this Cosmic Vision mission can best answer them.

Wednesday, 1 April 2009, 14:20-14:40:

Rotational stabilization of the resistive wall mode in the visco-ideal regime

C.J. Ham, C.G. Gimblett, R.J. Hastie
EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK

Stabilization of the resistive wall mode (RWM) will be important for the operation of advanced tokamaks at high β. Stabilization of the RWM with plasma velocity of $\sim 1\%$ v_A, where v_A is the Alfvén velocity, has been seen experimentally in a number of tokamaks [H Reimerdes et al, Phys. Plasmas **13**, 056107 (2006)]. An analytic model of this stabilization is proposed and analysed here. Gimblett and Hastie [C.G.Gimblett and R.J.Hastie, Phys. Plasmas **7**, 258 (2000)] analysed this problem using a cylindrical model of the plasma equilibrium proposed by Finn [J.M.Finn, Phys. Plasmas **2**, 198 (1995)] combined with a tearing response at the resonant layer. This analysis found that only a very small parameter space exists where stabilization is possible. No stabilization at all is possible within this model if the ideal or visco-resistive layer responses are assumed. A visco-ideal layer response [F. Porcelli, Phys. Fluids **30**, 1734 (1987)] is used in this paper. This assumes that viscosity and inertia dominate within the resonant layer. The visco-ideal response occurs in the transition from the ideal response to the visco-resistive response. This response is justified when $P >> 1$, where $P = \mu/\nu$ is the magnetic Prandtl number, μ is the kinematic viscosity and ν is the resistivity. This can be satisfied if phenomenological viscosity is used rather than classical (Braginskii) viscosity. An analysis similar to Gimblett and Hastie [C.G.Gimblett and R.J.Hastie, Phys. Plasmas **7**, 258 (2000)] indicates that there is a much larger parameter space where stabilization of the RWM with rotation is possible. The velocity required for stabilization in this regime is of the order of ~ 1

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RATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Wednesday, 1 April 2009, 14:40-15:00:

EPSRC Support for Plasma Physics

Amanda Chmura

Engineering and Physical Sciences Research Council

Amanda Chmura manages the plasmas, lasers and fusion portfolio in EPSRC's Physical Sciences and Energy Progammes. This talk will detail current support for this area, mechanisms for obtaining future support and information on upcoming changes and consultations. In addition, Amanda will be available to take questions throughout the day.

Wednesday, 1 April 2009, 15:40-16:20:

Audio reproduction from atmospheric pressure plasmas

H.E. Potts, D.A. Diver

Dept. Physics and Astronomy, University of Glasgow, Glasgow, UK G12 8QQ

In order to reproduce sounds, one has to move a volume of air. Traditionally this is done by moving a lightweight diaphragm using a magnet and coil. This process has its limitations. Real diaphragms have mass and can deform, leading to resonances and limited frequency response. What if somehow the air itself could be persuaded to move, without a mechanical driver?

This idea was first demonstrated in 1899 by William Duddell in the form of the "singing arc". The technology slowly developed over the next 50 years or so, resulting in many patents, a few commercial successes, and many flops.

This talk will review the history of plasma acoustic systems, and bring it up-to-date

by exploring some of the new devices that are currently being developed. These include a corona discharge system which is driven by a tesla coil, which generates a point-like audio source. We will also present results from a novel large area surface discharge system which we have developed at Glasgow, which has a very wide frequency response, and is capable of producing well focussed beams of acoustic energy.

Wednesday, 1 April 2009, 16:20-16:40:

Modulational instabilty of ion-acoustic waves in superthermal plasmas

Nareshpal Singh Saini, Ioannis Kourakis

Centre for Plasma Physics, Department of Physics and Astronomy, Queen's University Belfast, Belfast, BT7 1NN.

The modulational instability of finite amplitude ion-acoustic wavepackets is studied in a plasma containing excess superthermal (non-Maxwellian) electrons, modeled via a kappa distribution. The wave modulation is investigated by using a multiple scale technique, leading to a nonlinear Schrodinger equation (NLSE) for the wavepacket amplitude. The coefficients (nonlinearity and dispersion) of the NLSE are functions of the kappa parameter. It is shown that the superthermality (of electrons) significantly affects the occurrence and characteristics of modulational instability (MI). The critical wave number (beyond which MI occurs) increases/decreases with a change in the value of the spectral index parameter. The occurrence of either bright- or dark-type envelope solitons is shown. The effect of the superthermality on the amplitude and width of envelope solitons is also discussed.

Wednesday, 1 April 2009, 16:40-17:00:

Electron trapping and acceleration on a downward density ramp: a two-stage approach

R. Trines, P. Norreys

Central Laser Facility, Rutherford Appleton Laboratory, Didcot, United Kingdom

In a recent experiment at Lawrence Berkeley National Laboratory [1], electron bunches with about 1 MeV mean energy and small absolute energy spread (about 0.3 MeV) have been produced by plasma wave breaking on a downward density ramp. It was then speculated that such a bunch might be accelerated further in a plasma of low constant density, while mostly preserving its small absolute energy spread. This would then lead to a bunch with a high mean energy and very low relative energy spread. In this paper, the mechanisms behind wave breaking and electron trapping on a downward density ramp will be explored analytically, and the two-stage process of trapping followed by acceleration will be explored through particle-in-cell simulations. Those experimental parameters and properties of the scheme that influence the quality of the final electron bunch will be identified, and the potential of experiments based on this two-stage scheme will be discussed.

[1] C.G.R. Geddes et al., Phys. Rev. Lett. 100, 215004 (2008).

Thursday, 2 April 2009, 9:00-9:40:

Probing the static and dynamic response of warm dense matter

G. Gregori

Department of Physics, University of Oxford, Oxford, UK

Materials under extreme compression, as the one achieved by direct laser illumination, exhibit almost-equal thermal and Coulomb energies and structural properties that are in between those of ideal gases and solids. Their understanding is critical for the calculation of the equation-of-state (EOS) of the interior of giant planets as well as for inertial confinement fusion research. We will provide a detailed introduction to x-ray scattering as powerful technique to measure the microscopic properties of warm and dense matter states. It allows to extract static correlation properties for both the ionic and electronic subsystems; extraction of dynamic properties has been limited to the electrons so far. We will explore possibilities on how to extend the technique to the investigation of ion dynamics. We will also discuss few examples drawn from experiments conducted in low-Z materials (Li, B and C) using high power lasers. Further progresses of the x-ray scattering techniques towards the understanding of isochoric heating in proton heated matter will be discussed.

Thursday, 2 April 2009, 9:40-10:00:

Cold Avalanche Ionisation

P.P. Rajeev[1,2], M. Gertsvolf[1,3], P.B. Corkum[1,3], D.M. Rayner[1]

[1] *Steacie Institute of Molecular Sciences, National Research Council Canada, 100 Sussex Drive, Ottawa, ON, Canada, K1A 0R6*

[2] *Central Laser Facility, Rutherford Appleton Laboratory, Chilton, Didcot, UK, OX11 0QX*

[3] *University of Ottawa, Ottawa, Canada, K1N 6N5*

Intense laser pulses can ionise matter with the process initiated by multiphoton effects. In some cases the electrons, gaining energy from the laser field, can collide with other atoms and ionise them, triggering an avalanche ionisation. It is generally believed that the laser pulse has to be sufficiently long ($>$ 100fs) for the electrons to gain energy required for an avalanche. However, this is still a well-debated issue as some experimental observations suggest that avalanche effects can prevail even for shorter pulses [1]. Recent theoretical work suggests that in the presence of intense fields, even electrons with lower-than-the-bandgap energy can cause ionisation [2]. This field-assisted collisional ionisation or cold avalanche could be present even for few cycle pulses. However, its presence has not yet been experimentally verified as it is difficult to distinguish this from a normal avalanche process.

We show experimental evidence for cold avalanche and demonstrate how it can be distinguished from the traditional avalanche process. We analyse the nonlinear absorption of 800 nm, ultrashort pulses focused inside fused silica glass to study the ionization mechanisms [3]. The light is focused tightly inside the glass using a microscope objective so as to avoid surface damage and self phase modulation. The transmission is monitored as a function of pulse energy and pulse length. The transmission drops at the onset of nonlinear ionisation. Fitting the transmission curves allows us to distinguish the various ionisation mechanisms involved.

We observe that the ionisation threshold (I_{th}) decreases as the pulse length of the incident light is increased. This is a signature of avalanche ionisation; I_{th} will be invariant for purely multiphoton ionisation. The nonlinear absorption is characterised by the generation of free carriers with a rate determined by two contributions: (a) a multiphoton contribution with a cross section and (b) an avalanche contribution. The transmission curves can be fitted with a constant multiphoton cross section but we see that the value of the avalanche coefficient has to be reduced as the pulse length is increased to obtain reasonable fits. We propose that this increase in α with decrease in pulse duration is the signature of cold avalanche. The higher the intensity, the less energy the electron needs to ionise other atoms through field assisted collisions. This makes cold avalanche more probable for short pulses, resulting in an increase in avalanche coefficient as pulse length is reduced. We will show how cold avalanche can be modelled in conjunction with the traditional avalanche process.

[1] M. Lenzner et al., Phys. Rev. Lett. 80, 4076 (1998).
[2] L. N. Gaier et al., J. Mod. Opt. 52, 1019 (2005)
[3] P. P. Rajeev, M. Gertsvolf, P. B. Corkum and D. M. Rayner, Phys. Rev. Lett. (accepted)

Thursday, 2 April 2009, 10:00-10:20:

Fast electron transport in dense plasma diagnosed by ion emission

X.H. Yuan[1], M.N. Quinn[1], D.C. Carroll[1], P. Gallegos[1,2], A.P.L. Robinson[2], R.J. Clarke[2], D. Neely[2], R.G. Evans[2,5], L. Romagnani[3], K. Quinn[3], P.A. Wilson[3], G. Sarri[3], L. Lancia[4], M. Borghesi[3], P. McKenna[1]

[1] *SUPA, Department of Physics, University of Strathclyde, Glasgow, UK*
[2] *Central Laser Facility, Rutherford Appleton Laboratory, Oxfordshire, UK*
[3] *Department of Physics and Astronomy, Queen's University Belfast, Belfast, UK*
[4] *Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, France*
[5] *Department of Physics, Imperial College, London, UK*

The transport of fast electrons in relativistically intense laser irradiation of solid targets is a key issue for the fast ignition approach to inertial fusion energy, and plays a crucial role in the optimization of high power laser-driven ion acceleration and X- and γ-ray production. The fast electrons accelerated at the front irradiated surface transport through the solid target and produce an electrostatic sheath field at the rear nonirradiated surface. This field ionizes the target material and accelerates the resulting protons and ions to multi-MeV energy. Spatial and energy resolved measurements of the accelerated ions provide a diagnostic of the electron sheath at the target rear surface, and hence the electron transport through the target. The maximum proton energy and the laser-to-proton energy conversion efficiency are measured as a function of target material and thickness (up to 1 mm) in the regime of laser intensity (6Á1020 W/cm2) and pulse duration (1ps) that the highest energy protons are presently generated. Both the maximum proton energy and the laser-to-proton energy conversion efficiency are found to decrease linearly with increasing target thickness. The sheath size, determined from proton beam divergence measurements, shows a significantly slower increase than expected from simple ballistic transport of the electrons with a fixed divergence angle. The implications for fast electron transport within the target are presented.

Thursday, 2 April 2009, 11:00-11:40:

The effect of turbulence on magnetic reconnection

N. F. Loureiro

EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK

Magnetic reconnection is a well known plasma process believed to lie at the heart of a variety of phenomena such as sub-storms in the Earth's magnetosphere, solar/stellar and accretion disk flares, sawteeth activity in fusion devices, etc. During magnetic reconnection, the global magnetic field topology changes rapidly, leading to the violent release of magnetic energy. One of the outstanding theoretical challenges in this field is the understanding of the mechanism(s) responsible for such rapid changes.

It is usually believed that in single fluid MHD, magnetic reconnection, well described by Sweet-Parker (SP) theory, is orders of magnitude too slow to explain observations. In many cases of interest, reconnection takes place in plasmas which are fundamentally collisionless, and which cannot, therefore, be described by MHD theory. Indeed, a vast amount of numerical studies suggest that fast reconnection can be obtained when kinetic physics becomes important. However, in many astrophysical situations (e.g., inside stars and accretion disks) the density is so high that the reconnection layer is collisional and resistive MHD should apply. How, then, can reconnection be fast in these environments?

Missing from the SP picture is that most, if not all, environments where reconnection occurs are likely to be turbulent. Theoretical arguments exist [Lazarian & Vishniac, ApJ **517**, 700 (1999)] that suggest that indeed turbulence can significantly enhance the reconnection rate, but only in 3D. Given the significant numerical challenge of modeling this process, the validity of this claim has not yet been satisfactorily demonstrated. Since turbulence permeates both collisional and collisionless plasmas, understanding the effect of background turbulence on MHD magnetic reconnection is of general importance and can drastically change the way we presently understand non-MHD reconnection phenomena such as the sawtooth instability in tokamaks.

In this talk, we present the results of an extensive, high resolution, numerical study of the effect of small-scale background turbulence on 2D magnetic reconnection. We show that, contrary to theoretical expectations, turbulence has a very significant effect in enhancing 2D reconnection, yielding a reconnection rate whose dependence on resistivity (η) is extremely weak and is even consistent with it asymptoting to an η-independent value.

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Thursday, 2 April 2009, 11:40-12:00:

Investigation of electron beam instabilities in dense plasma.

M.N. Quinn[1], X.H. Yuan[1], D.C. Carroll[1], P. Gallegos[1,2], A.P.L. Robinson[2], R.J. Clarke[2], D. Neely[2], R.G. Evans[2,5], L. Romagnani[3], K. Quinn[3], P.A. Wilson[3], G. Sarri[3], L. Lancia[4], M. Borghesi[3], P. McKenna[1]

[1] *SUPA, Department of Physics, University of Strathclyde, Glasgow, UK*

[2] *Central Laser Facility, Rutherford Appleton Laboratory, Oxfordshire, UK*

[3] *Department of Physics and Astronomy, Queen's University Belfast, Belfast, UK*

[4] *Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, France*

[5] *Department of Physics, Imperial College, London, UK*

This work presents on the findings of electron transport instability measurements through dense plasma using the Vulcan Petawatt system.

Electron transport instabilities play a critical role in key applications such as fusion by fast ignition and ion-radiation sources. Measurements regarding the effects that bring about filamentation, scattering and pinching of the fast electron beam through the dense plasma are therefore of great relevance.

A novel approach involving proton emission was used to measure the instability growth and beam breakup size over a range of target properties and materials including lithium, aluminum and plastic. A theoretical study to determine the physical mechanisms of the seeding and development of the instability growth was performed using the LEDA hybrid code.

The experimental and theoretical data show that instability growth is strongly seeded by target resistivity and that there is minimal smoothing from effects relating to target Z-number electron-ion scattering.

Thursday, 2 April 2009, 12:00-12:20:

Developing MAST to explore the Physics of Fusion Power

R.J. Buttery on behalf of the MAST team.

EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB, UK.

The development of fusion power as a viable means of energy production requires advances in the science and technology of plasma physics on many fronts. The spherical tokamak (ST) provides an ideal facility to explore many of the most critical aspects. This is because its unique geometry allows it to access physics and plasma regimes that would otherwise require much larger and higher power devices. For example, because of its efficient use of magnetic field, the ST can operate simultaneously at high plasma current and lower toroidal field than a conventional tokamak. This enables it in the same discharge to confine energetic particles, with distributions akin to the fusion alphas produced in a power plant, at 'Alfvénic' velocities, whilst producing stable plasmas with a high ratio of thermal and magnetic pressures ('beta'). This combination allows the study of how fast particle populations might drive instabilities in a burning plasma device, potentially modifying transport and current distributions in the plasma, and the accompanying role of the high beta damping mechanisms that may stabilise such effects. Based on such considerations various improvements have been designed for the MAST device (Mega Amp Spherical Tokamak) at Culham in Oxfordshire. These pursue a twin track approach, addressing both the critical science of power plant scale devices, as foreseen for the forthcoming ITER facility in France and a successor demonstration power plant, and at providing the physics basis for a future spherical tokamak Component Test Facility. This latter would utilise the ST's properties to compactly confine a D-T fusing plasma, providing an efficient high neutron fluence device that minimises tritium consumption, to accelerate the technology development of fusion. These two tracks have many common issues that can be advanced by exploration and development on MAST. For instance, capabilities to study energetic particle dynamics and their effects can be extended with options to introduce new diagnostics and deploy neutral particle beam heating more flexibly with different positions and directions in the plasma. Development of the 'divertor', through which plasma particle and heat flux is directed onto targets, is key in understanding how to efficiently contain the plasma with low impurities while minimising target erosion. MAST has unique capability to explore the physics and optimisation of this critical element, thanks to its cylindrical tank, which provides regions to expand, cool and diagnose the plasma exhaust. Ideas are proposed to utilise this further with more remote targets and increased connection lengths to help decouple core performance from target interactions. These and other such improvements (eg in magnetic field and pulse length), will help provide the capability to understand how to drive and sustain self consistent long pulse plasma scenarios for the next generation of fusion devices. These and other ways in which MAST can access the challenging physics of fusion power will be explained, with a view to further involvement of collaborative partners in the physics and development of this flexible UK facility.

(This work was jointly funded by the UK Engineering and Physical Sciences Research Council and by the European Commission under the contract of association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.)

Poster

X-ray scattering in multicomponent warm dense matter

K. Wünsch, J. Vorberger, D.O. Gericke

Centre for Fusion, Space and Astrophysics, University of Warwick, Coventry CV4 7AL, UK

In the last few years, it became possible to generate extreme state of matter with solid densities and temperatures of a few electron volts in laboratories. This warm denser matter (WDM), that occurs in astrophysical objects as giant gas planets, has properties common to plasmas, fluids and solids. A theoretical model for this peculiar state is challenging due to the occurrence of strongly coupled ions and quantum degeneracy of the electrons. A deeper understanding of WDM is also required for the progress of the generation of energy in terms of inertial confinement fusion.

In addition to its generation, it is also necessary to analyse WDM and therefore to develop capable diagnostics. It has been shown, that x-ray scattering can be successfully applied to infer plasma parameters from WDM. However, a good understanding of the structural properties in WDM is required as theoretical input. In particular, recent experiments using plasmas consisting of more then one ion species led to the new issue of how multiple components influence theoretical predictions for the interpretation of the x-ray scattering signal.

In this contribution, we will present a generalisation of the Chihara formula suitable for systems with multiple ion species. It splits up the dynamic electronic structure factor into the ion feature and the free electron part as usual. However, the mutual correlation of the several ion species, characterised by the partial structure factors, have to be taken into account. We will compare an approximation for the partial structure factors which uses the single-ion structure factor from an average state of system with results from our multicomponent approach. It is demonstrated, that the one-component treatment with an average charge state becomes inapplicable for strongly coupled ions. Finally, we will apply this method for the description of the ion feature in the scattering process for several mixtures (LiH, CH, ...) and highlight the differences to a single-ion component approach. Again, a multicomponent description is required for systems with strongly coupled ions.

Poster

Chirped pulse amplification based on Raman backscattering in plasma

Xue Yang, Gregory Vieux, Andrey Lyachev, Dino Jaroszynski

Department of Physics John Anderson Building 107 Rottenrow East Glasgow

Raman backscattering (RBS) in plasma is an attractive source of intense, ultrashort laser pulses which has the potential to bring in a new generation of laser amplifiers. Capitalising on the advantages of plasmas, which can withstand extremely high power densities and can offer high efficiencies over short distances, Raman amplification in plasma could lead to significant reductions in both size and cost of high power laser systems.

We are investigating chirped laser pulse amplification through RBS in the linear and non-linear regimes, with experiments aiming to develop an effective way to transfer energy from a long pump pulse to a resonant counterpropagating short probe pulse which is compressed and spectrally broadened in a controlled manner through self-phase modulation. Measurements show a peak gain of 900%, with an energy increase of 32% and an energy transfer efficiency of about 3.5%.

Poster

Space-Charge Limited Cusp Gun for a Gyro-TWA

A.R. Young, C.G. Whyte, C.W. Robertson, K. Ronald, A.W. Cross, A.D.R. Phelps

University of Strathclyde, SUPA, Department of Physics, Glasgow, G4 0NG

The gyro-Travelling Wave Amplifier (gyro-TWA) can be used to generate high power, broad-band microwave radiation with a high efficiency. Gyro-TWAs with a conventional interaction region based on circular waveguide did not fulfil this early potential since to achieve broad-band amplification it was necessary to operate the device far from the cut-off frequency of the waveguide. This made the device sensitive to velocity spread in the electron beam. An idealised dispersion was realised by introducing a helical corrugation on the surface of the interaction. The corrugation couples a near cut-off mode to a far from cut-off mode when the Bragg resonance conditions are satisfied. Experiments conducted using this interaction region have found it to have a significant improvement over the conventional smooth cylindrical waveguide in gyro-amplifier systems by decreasing the sensitivity to electron velocity spread, increasing the stability to parasitic self-oscillations and improving the frequency bandwidth. Due to these properties, such waveguides have been used in a wide range of applications e.g. interaction regions in gyro-TWAs and gyro-BWOs.

The frequency of operation of gyro-devices is dependent on the cyclotron frequency. The physical requirements of producing large magnetic fields make it desirable to operate at a harmonic of the cyclotron frequency. When operating at a harmonic of the cyclotron frequency, the problem of parasitic oscillations can be mitigated by using an axis-encircling or large orbit electron beam. For such a beam there is the mode selectivity condition that the harmonic of the cyclotron frequency must equal the azimuthal number of the interacting mode. Such a beam has been realised in the past by using a ‘kicker’ coil to impart a transverse momentum to a beam from a ‘Pierce-like’ diode.

Research into plasma confinement showed that the presence of a non-adiabatic magnetic field reversal in a diode can give an annular electron beam a ‘kick’ so that it circles the axis with a high pitch alpha (ratio between transverse velocity and axial velocity). This method has the advantages, particularly for CW operation, of requiring no kicker coil and reduced beam power density when performing energy recovery compared with a solid beam. The simplest arrangement of cusp diode is to use two solenoids without any magnetic shaping poles. If the cusp is positioned close to the cathode then the energy of the electrons is relatively low and therefore the amplitude of the cusp can be small. A small cusp amplitude means that the Larmor step is large and therefore the field reversal can happen over a longer distance.

At the University of Strathclyde gyro-TWAs have been successfully operated with a thermionic cathode operated in the temperature-limited regime. The poor quality and consistency of the resultant beam from the temperature-limited thermionic cathode adversely affected the overall performance of the gyro-TWA. The thermionic cusp gun has therefore been redesigned to operate in the space-charge limited regime in order to improve the overall quality of the electron beam emitted and results of these simulations will be presented.

Poster

Effect of defocusing on laser-coupling into gold cones

John Pasley[1,2], Rob Clarke[2], Margaret Notley[2], James Green[2], Toshi Yabuuchi[3], Tammy Ma[3], Andy MacPhee[4], Lauren Gartside[1], Ian Bush[1], Chris Spindloe[2], Hazel Lowe[2], Trevor Winstone[2], Wigen Nazarov[5]

[1] *University of York*

[2] *STFC Rutherford Appleton Laboratory*

[3] *University of California San Diego*

[4] *Lawrence Livermore National Laboratory*

[5] *University of St Andrews*

Results from an experiment to investigate the change in coupling from a high energy picosecond 1.06 μm laser pulse, with various degrees of defocusing, into cone-wire targets are described. The experiment was performed using the Vulcan PetaWatt Laser at the Rutherford Appleton Laboratory. Gold cone targets, with a wall thickness of 20 μm and a tip thickness of 6 μm were used in the experiment. Each cone had a 40 μm diameter, ∼1mm long copper wire attached to its tip. Diagnostics included a quartz crystal imager looking at Cu K-α emission, Highly Oriented Pyrolytic Graphite crystal spectrometers looking at Cu K-α 1 and 2 and a calibrated CCD operating in the single photon counting regime, used for calibration of both the imager and the spectrometers. A short pulse optical probe, delayed 400 ps relative to the main pulse, with shadowgraphy and interferometry channels, was also employed to diagnose the extent of plasma expansion around the wire.

Poster

Microwave Imaging Edge Current Diagnostic Design

S. J. Freethy[1], R. G. L. Vann[1], V.F. Shevchenko[2]

[1] *Department of Physics, University of York, Heslington, York YO10 5DD, U.K.*

[2] *UKAEA/Euratom Fusion Association, Culham Science Centre, Oxon. OX14 3DB, U.K.*

Electron Bernstein Waves (EBWs) are observed in overdense plasmas through Bernstein – Extraordinary – Ordinary (B-X-O) mode conversion. This mode conversion only takes place at critical angles of incidence and forms a mode conversion window, the shape and orientation of which is strongly linked to the pitch angle of the magnetic field. Imaging this mode conversion at several frequencies allows the variation of the mode conversion window in density and therefore spatially. With this measurement it is possible to calculate the poloidal magnetic field at different positions and thus take its curl to calculate the edge current density profile. We discuss a design for imaging the mode conversion window in fusion plasmas using aperture synthesis (the principle behind the Very Large Array radio telescope).

Poster

Efficient Raman amplification into the PetaWatt regime

R.M.G.M. Trines[1], F. Fiuza[3], R. Bingham[1], L.O. Silva[3], R.A. Cairns[2], P.A. Norreys[1]
[1] *STFC Rutherford Appleton Laboratory, Didcot, UK*
[2] *University of St Andrews, St Andrews, UK*
[3] *Instituto Superior Técnico, Lisbon, Portugal*

Raman amplification of a short laser pulse off a long laser beam has been demonstrated successfully for moderate probe intensities ($\sim 10^{16}$W/cm^2) and widths ($\sim$ 50 micron). However, truly competitive intensities can only be reached if the amplification process is carried out at much higher probe intensities ($10^{17} - 10^{18}$W/cm^2 after amplification) and widths ($1 - 10$mm). We examine the opportunities and challenges provided by this regime through the first 2-dimensional particle-in-cell simulations using wide pulses. A parameter window is identified in which a 10 TW, 600μm wide, 25 ps long laser pulse can be efficiently amplified to 2 PW peak intensity. This work is supported by the STFC Accelerator Science and Technology Centre and the STFC Centre for Fundamental Physics.

Poster

Numerical simulation of auroral cyclotron maser processes

D. C. Speirs[1], K.M. Gillespie[1], K. Ronald[1], S.L. McConville[1], A.D.R. Phelps[1], A.W. Cross[1], R. Bingham[1,2], B.J. Kellett[2], R.A. Cairns[3], I. Vorgul[3].
[1] *SUPA, Department of Physics, University of Strathclyde, Glasgow, Scotland, G4 0NG, UK*
[2] *Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, England, OX11 0QX, UK*
[3] *School of Mathematics and Statistics, University of St. Andrews, Fife, Scotland, KY16 9SS, UK*

Auroral Kilometric Radiation (AKR) is a phenomenon that has been the subject of particular interest and debate over the last thirty years. It comprises a spectrum of narrowband ($\sim$1kHz) discrete electromagnetic emissions centred around a frequency of $\sim$300kHz and sourced at high altitudes within the polar terrestrial magnetosphere. Principle characteristics of AKR include a high degree of right-hand extraordinary (R-X) mode polarization and frequencies of emission extending down to the local relativistic electron cyclotron frequency. It is now widely accepted that the emissions are generated by an electron cyclotron maser instability in the precipitating auroral electron flux which develops a horseshoe shaped velocity distribution [1] due to conservation of magnetic moment as it experiences an increasing magnetic field in the auroral magnetosphere. Axial momentum is converted into rotational momentum forming a horseshoe shaped distribution in velocity space. Theory has shown that this distribution is unstable to cyclotron emission in the X-mode [2].

In a scaled laboratory reproduction of this process, a 75-85keV electron beam of 5-40A was magnetically compressed by a system of solenoids and emissions were observed for cyclotron frequencies of 4.42GHz and 11.7GHz resonating with near cut-off $TE_{0,1}$ and $TE_{0,3}$ modes, respectively [3]. In the current context we present a comparison of the experimental measurements with numerical predictions from the 3D PiC code KARAT. The 3D simulations accurately predict the radiation modes and frequencies observed from the experiment

[4], with a predicted RF conversion efficiency of ∼1% which is consistent with geophysical observations and the results of quasi-linear theoretical analysis. We also present the results of unbounded, 2D numerical simulations investigating the horseshoe-maser instability in the presence of a background Maxwellian plasma of variable density. These results show strong RF emission centered around the relativistic electron cyclotron frequency after a larger number of Larmor steps than in the bounded experimental case. A quenching of the instability is also apparent as the ratio ω_{ce}/ω_p is reduced to be < 1. This is consistent with the predictions of theory [2] and satellite observations that suggest AKR emission is localized within a region of plasma depletion where $\omega_{ce}/\omega_p > 1$.

[1] D. Gurnett, "Waves in Space Plasmas ", 50th Annual meeting of the APS Division of Plasma Physics, 2008.

[2] R. Bingham and R. A. Cairns, Physics of Plasmas, **7**, 3089, 2000.

[3] K. Ronald et al, Physics of Plasmas, **15**, 056503, 2008.

[4] K. M. Gillespie et al., Plasma Physics and Controlled Fusion, **50**, 124038, 2008.

Poster

Evolving magnetohydrodynamic turbulence in the quiet fast solar wind

R. M. Nicol[1], S. C. Chapman[1], R. O. Dendy[2,1]

[1] *Centre for Fusion, Space and Astrophysics, Department of Physics, Warwick University, Coventry CV4 7AL, U.K.*

[2] *UKAEA Culham Division, Culham Science Centre, Abingdon, Oxfordshire OX14 3DB, U.K.*

The solar wind provides unique opportunities for long duration in situ studies of magnetohydrodynamic turbulence in a plasma flowing supersonically with high magnetic Reynolds number. Its spectral power density scales approximately as inverse frequency f^{-1} at lower frequencies (≤1 mHz); and as $f^{-5/3}$, reminiscent of Kolmogorov's inertial range, at higher frequencies (∼10–100 mHz). Both the $f^{-5/3}$ and f^{-1} fluctuations are often predominantly shear Alfvénic in character. The frequency at which the transition between power laws occurs (∼1–10 mHz) is observed to decline with increasing heliocentric distance in the plane of the ecliptic, and this extension of the $f^{-5/3}$ range at greater distances can be interpreted as evidence for an evolving turbulent cascade. The f^{-1} range is taken to reflect embedded solar coronal turbulence, convected with the solar wind, while the large-scale magnetic structure of the corona varies with the solar cycle and heliospheric latitude, creating variations in solar wind speed. In the present paper we concentrate on the quiet fast solar wind, where large transient events, such as those associated with coronal mass ejections, are absent. We exploit the unique out-of-ecliptic orbit of the Ulysses satellite, by focusing on its measurements of fluctuations in the three vector components of the magnetic field B, taken above polar solar coronal holes at times of both minimum and maximum solar activity. By applying generalised structure function analysis to this data, combined with extended self-similarity (R. Benzi et al., Phys. Rev. E 48, 29 (1993)), we address (R. M. Nicol et al., Astrophys. J. 679, 862 (2008)) key nonlinear plasma physics and MHD turbulence issues. These include: the extent to which the f^{-1} spectrum contains frozen information about coronal magnetic activity; the interplay between the coronal driver and the evolving inertial range turbulence; the degree to which the fluctuations exhibit self-similarity; and the dependence of the foregoing on heliocentric latitude and radial distance.

Poster

Gyrokinetic studies of the ITG instability in the presence of equilibrium $E \times B$ shear flows

E. Highcock[1], **N. F. Loureiro**[2], **A. Schekochihin**[1], **S. C. Cowley**[2]
[1] *Oxford University*
[2] *UKAEA Culham, Oxfordshire, England*

Sheared toroidal flows are an important feature of some magnetic confinement devices. These flows are known to be beneficia for confinement as they tend to reduce the growth rate of the ITG instability, which is generally considered to be the main cause of anomalous transport. However, many analytic and numerical studies tend to ignore these flows. Whereas this might be a good approximation in low Mach number plasmas, for tokamaks such as MAST, where near sonic plasma flows are observed, a generalisation of these results is required.

In this work, we revisit the extension of the gyrokinetic formalism to include strong equilibrium $E \times B$ sheared flows. For the simple case of a sheared slab, the linear ITG dispersion relation is analytically derived. Our methods are based on the sheared coordinate transformation proposed by Roberts & Taylor [1] (see also Howes et. al. [2]) and differ from previous work by other authors. Our results are benchmarked against the GS2 gyrokinetic flux tube code.

[1] Roberts, K.V. and Taylor, J. B. (1965) *Phys. Fluids*, **8**, 315.
[2] Howes, G.G., Cowley, S.C. and McWilliams, J.C. (2001) *ApJ* **560**, 617 - 629.
[3] Artun, M., Reynders, J.V.W and Tang, W. M. (1993) *Phys. Fluids B*, **5**, 4072-4080.

Poster

Nonlinear plasma dynamics modeling at Queen's University Belfast: an overview of research activities & collaborations

I. Kourakis[1], **N. S. Saini**[1], **A. Sharma**[1], **S. Sultana**[1], **M. Dieckmann**[2], **J. Borhanian**[3]

[1] *Centre for Plasma Physics, Department of Physics and Astronomy, Queen's University Belfast, BT7 1NN*

[2] *Department of Science of Technology, Linköping University, SE-60174 Norrköping, Sweden*

[3] *Department of Atomic and Molecular Physics, Faculty of Physics, University of Tabriz, Iran*

An overview is presented of current theoretical activities in modeling nonlinear plasma dynamics in Centre for Plasma Physics, Queen's University Belfast. Main activities include (yet are not limited to) the following:

(a) Relativistic electromagnetic pulses in laser plasmas. A fluid-Maxwell system of equations is employed for the dynamics of a linearly polarized beam. The evolution of the beam envelope and of density harmonics is investigated analytically via a generalized nonlinear Schrödinger type equation, which is then solved numerically using a split step Fourier method. The investigation is currently extended to a circularly polarized beam in magnetized plasma. A number of preliminary results are presented.

(b) Solitons in superthermal plasmas. The propagation of localized electrostatic (ES) pulses in plasmas in the presence of an excess superthermal electron population in the background, modelled via a kappa nonthermal distribution. A multiple scales method is employed to model modulated wavepackets and test their stability. The occurrence of ES solitons is studied, relying on exact and perturbative nonlinear techniques. The deviation from the Maxwellian distribution is shown to influence solitons dynamics and stability.

(c) EM beam profile dynamics in laser plasmas. The evolution of the profile of an EM beam propagating in a plasma is modeled analytically and numerically. Different regimes are identified, including pulse compression, self-focusing and convergence regions.

(d) Filamentation instability. Two counter-propagating cool and equally dense electron beams are modelled with particle-in-cell (PIC) simulations. The electron beam filamentation instability is examined in one spatial dimension. In particular, the saturation of the electron beam filamentation instability by the self-generated magnetic field and magnetic pressure gradient-driven electric field is studied.

(e) Modelling experiments on localized structures observed. An interpretation of solitary wave structures created during intense laser beam and plasma interaction and observed via a proton imaging technique has been undertaken. The characteristics of these structures qualify for an interpretation in terms electron-holes, i.e. large-amplitude supersonic kinetic structures.

(f) Nonlinear modes in Dusty (Complex) Plasmas. We have investigated the role on plasma modes of the existence of charged massive particulates in the background. Both weakly-coupled and strongly coupled plasmas are focused upon. Novel phenomena predicted include the occurrence of Discrete Breather excitations in dusty plasma crystals, and the influence of dust on modulational instability of low-frequency electrostatic modes in dusty plasmas. (g) Pair-ion plasmas. The nonlinear dynamics of pair-ion plasmas (in particularly focusing on recent fullerene ion experiments in Japan) is investigated via an extensive nonlinear study.

Acnowledgment. The research outlined above has been carried out in collaboration with: a) J. Borhanian (Research Visitor CPP, 2008); b) M. Hellberg, U. Kwa-Zulu Natal, Durban, South Africa; d) M.E. Dieckmann (Honorary Visitor CPP, 2008); e) M. Borghesi and G. Sarri (CPP/QUB); f) P.K. Shukla (Ruhr U. Bochum, Germany); g) F. Verheest (U. Gent, Belgium). Our work is supported by a EPSRC Science and Innovation award.

Poster

Finite Larmor radius effects on test particle transport in drift zonal flow turbulence

J.M. Dewhurst[1], B. Hnat[1], R.O. Dendy[1,2]

[1] *Centre for Fusion, Space and Astrophysics, Department of Physics, Warwick University, Coventry CV4 7AL, UK*

[2] *Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxfordshire OX14 3DB, UK*

It is fundamentally important to the goal of magnetically confined nuclear fusion to understand the transport of particles and energy in turbulent plasmas. In tokamaks the magnitude of the observed transport across confining magnetic fields usually exceeds the collisional ”neoclassical” level. It is generally agreed that drift wave turbulence is a good candidate to explain the observed physical properties from first principles. Drift wave turbulence is dominated by the $E \times B$ drift and involves low frequency waves which are driven unstable by gradients in density or temperature. It is widely recognised that zonal flows play an important role in the self-regulation of drift wave turbulence. The self-generation of such shear flows may lead to the formation of transport barriers by suppressing radial turbulence or reducing its correlation lengthscale.

The response of particles to turbulent fields can greatly differ depending on the Larmor radius. High frequency gyromotion effectively smooths out small fluctuations leading, intuitively, to a lower rate of transport. A reduction in the rate of radial transport with increasing Larmor radius has been shown using the Hasegawa-Mima equation as the turbulence model (G Manfredi and R O Dendy, Phys Rev Lett **76** 4360 (1996)). More recently, however, it was found that, in the limit of large Kubo number, this reduction in transport is less dramatic and in some cases, the rate of transport may actually increase with the Larmor radius (M Vlad and F Spineanu, Plasma Phys Control Fusion **47** 281 (2005)). It was also reported that the zonal flow may have a strong influence on the rate of transport and the Larmor radius dependence (T Hauff and F Jenko, Phys Plasmas **14** 92301 (2007)).

Here, we investigate these effects using a modified form of the Hasegawa-Wakatani model which allows the self-generation of zonal flows. We study the transport of passive test particles which are advected by the $E \times B$ velocity. We compare the case where zonal flows are damped to the case where zonal flows are allowed. When zonal flows are damped the transport is diffusive and the rate of transport decreases with increasing Larmor radius. Once the Larmor radius is larger than the typical radius of the turbulent vortices the rate of transport remains constant. When zonal flows are allowed, radial transport (across the zones) is subdiffusive and decreases with the Larmor radius at a slower rate. Poloidal transport (along the zones), however, is superdiffusive and increases with small values of the Larmor radius. We also study an intermediate state where the kinetic energy is shared equally between the zonal flows and drift wave turbulence.

Poster

E to H-mode transition in an oxygen inductively coupled radio-frequency plasma

Deborah O'Connell, Kari Niemi, Mujahid Zaka-ul-Islam, Timo Gans
Centre for Plasma Physics, Queens University Belfast, Belfast, NI

Inductively coupled radio-frequency plasmas can be operated in two distinct modes. At low power and comparatively low plasma densities the plasma is sustained in E-mode. As the plasma density increases a transition to H-mode is observed. This transition region is of particular interest and governed by non-linear dynamics, which under certain conditions result in structure formation with strong spatial gradients in light emission. The two modes show pronounced differences in various measureable quantities e.g. electron densities, electron energy distribution functions, ion energy distribution functions, dynamics of optical light emission.

The transition from the capacitive to inductive mode in an oxygen ICP is investigated using two-dimensional phase resolved optical emission spectroscopy (PROES). The emission, measured phase resolved, allows investigation of the electron dynamics within the rf cycle, important for understanding the power coupling and ionization mechanisms in the discharge. The temporal variation of the emission reflects the dynamics of relatively high-energy electrons. It is possible to distinguish between E- and H-mode from the intensity and temporal behavior of the emission. The spatio-temporal excitation measured in an oxygen ICP in (a) E-mode and (b) H-mode are shown. In capacitive mode the emission is characterized by one distinct excitation maximum within one RF cycle. This corresponds to energy gain of electrons through the sheath expansion as the planar antenna acts as a capacitive electrode. While, in inductive mode the excitation dynamics exhibits two maxima within the rf cycle. Electrons are accelerated by the induced electric field in the plasma, twice within each RF cycle. By applying Fourier analysis very distinct spatial profiles in each mode can be distinguished, relating to regions of varying power dissipation in the system.

In the transition region between the two modes, excitation structures related to energetic electrons - secondary electrons produced at the surface - can be identified as playing an important role in the discharge dynamics. Figure 1(c), showing the spatio-temporal excitation in the transition regime between E- and H- mode, illustrating the penetration of the energetic electrons far into the plasma bulk.

Poster

Solitary Structures in Multicomponent Plasmas with Superthermal Electrons

N. S. Saini[1], S. Sultana[1], A. Sharma[1], I. Kourakis[1], M. A. Hellberg[2]
[1] *Centre for Plasma Physics, Department of Physics and Astronomy, Queen's University Belfast, BT7 1NN, Northern Ireland, UK*
[2] *School of Physics, University of KwaZulu-Natal, Private Bag X54001, Durban 4000, South Africa*

An excess population of superthermal (non-Maxwellian) particles (electrons/ions) is often present in space and laboratory plasmas due to various physical mechanisms. The kappa-type distribution is used to model a high energy tail in the electron/ion distribution function. We have studied weakly nonlinear ion-acoustic solitons in a plasma consisting of superthermal electrons and ions. A reductive perturbation method was employed, leading to a Korteweg de Vries (KdV) equation. The parametric regime for the existence of different type of solitons is investigated. It is been shown that superthermality significantly modifies the width and amplitudes of ion acoustic solitons. We have also investigated large amplitude solitary structures by means of the Sagdeev pseudo-potential method. It is shown that different types of solitary structures exist, depending on physical parameters (superthermality, ion temperature), in addition to the potential existence of charged dust (or impurities) in the background.

Poster

Modification of current-voltage characteristics for point-to-plate geometry corona discharge

A.A. Azooz, Sabah I. Waysi
Department of Physics, College of Science, Mosul University, Iraq Department of Physics, College of Education, Dohuk University,Iraq

Automatic data acquisition is proposed for determining the corona inception voltage with a point-to-plate geometry discharge. The general empirical formula I=K(V-Vo)n has been modified to limit the scope of exponent n for three inception current (Io= 0.1, 0.5, and 1.0 mA). It was shown that the minimum observed inception current lead to demonstrate more accurate inception voltage Vo. This modification provides a detailed demonstration of n=1.85 as well as the inter electrode separation is changed with same needle tip radius.

Poster

Super-X Divertor Design for MAST Upgrade

M. Istenic[1], R. Buttery[1], G. Cunningham[1], I. Katramados[1], M. Kotschenreuther[2], M. Kovari[1], S. Lisgo[1], S. Mahajan[2], D. Taylor[1], P. Valanju[2], T. Todd[1], G. Voss[1], and the MAST Upgrade Team

[1] *EURATOM/UKAEA Fusion Association Science Centre, Abingdon, OX14 3DB, UK*

[2] *Institute for Fusion Studies, The University of Texas at Austin, Texas, USA*

Successful operation of a fusion reactor tokamak requires careful management of the power exhausted to the target plates, where the power densities at the plates could reach > 20MWm^{-2}.There are essentially two routes to the solution of this problem: one is technological, involving development of actively-cooled high heat-flux elements or of 'flowing' targets of liquid metals or pebbles, the other is physics-based, involving the design of advanced magnetic geometries in the divertor, and physics mechanisms (radiation, charged-particle 'friction') to dissipate the power upstream of the target. Here, we focus on one of the second route concepts, where a relatively simple set of poloidal field coils is used to significantly increase the distance along the magnetic fi

The SXD concept has been detailed by Kotschenreuther et al. [1], offering an innovative approach to the steady state high heat flux problem. Their results, shown for a range of devices, demonstrate that a large increase in divertor target radius requires only small-scale modifications to the poloidal field coil geometry used in a standard divertor An SXD-based concept has been developed as part of a potential upgrade to the MAST Tokamak [2]. A principle feature of this SXD geometry is an extra X point that is typically positioned at a large radius and at about the same height as the poloidal field coil nearest to the main X point. Further reductions of the poloidal field along the leg are necessary to obtain the quasi-poloidal null needed for good flux expansion and long connection lengths. This can be done using two additional low current coils close to the quasi-null region.

The proposed upgrade to the MAST tokamak is intended to explore the physics for ITER, DEMO and the Component Test Facility (CTF). Because of the open design of the MAST vessel, there is a large volume available beyond the main strike point, offering a unique opportunity to test the SXD concept at significant power loads, providing data for extrapolation to DEMO. The initial phase of optimising the magnetic geometry is outlined here using a free boundary equilibrium code called FIESTA. Calculations show that the expected increase in connection length is ∼3 to 4 fold, due to a significantly reduced poloidal field ($B_{pol} \ll B_{tor}$) and the strike point radius has increased from ∼0.8 m to 1.6 m, demonstrating the feasibility of the SXD concept.

[1] M. Kotschenreuther, P. Valanju, S. Mahajan, IAEA meeting IC/P4-7, 13-18 Oct., Geneva, Switzerland, submitted to Nuclear Fusion (2008).

[2] H. Meyer, et al., IAEA meeting OV/3-2, 13-18 Oct., Geneva, Switzerland (2008).

This work was funded jointly by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Poster

Detection of Fast Particle Distribution in MAST via Proton Orbits

A. Lampson, R. Vann

University of York, York, YO10 5DD

Knowing the fast particle distribution in devices such as MAST would be a valuable diagnostic tool. The plasmas in MAST are not of sufficent temperature/pressure to result in many thermal ion-thermal ion fusion events. The vast majority of fusion events come from thermal-beam or beam-beam interactions. These reactions have two possible paths, both equally likely.

$$ {}^2_1D + {}^2_1D \Rightarrow {}^3_1T + p^+ \quad (2) $$

$$ \Rightarrow {}^3_1He + n^0 \quad (3) $$

We can calculate the probability of such a reaction occuring by considering how likely it is that a beam ion will interact with a thermal ion, and how likely each such interaction is to result in a fusion event that produces a proton.

In addition to this, we can calculate the orbit followed by the proton using CUEBIT, as we know that it has an initial energy of ∼3.02 MeV. We do not know the direction that the proton will travel initially, but we can calculate the probability that the proton will arrive at any particular position on the vessel wall by calculating the orbits of many particles, each born in different directions.

We now have, in principle, a method of calculating the distribution of the fast particles within the plasma by detecting the protons born in reactions between the beam and thermal ions at the vessel wall. Wether this can be applied in the real world remains to be seen.

Poster

Gemini: A high-repetition rate, ultra-intense dual beam laser

P. Foster, M. Streeter, J. Green, F. Cameron, C. Spindloe, G. Schumann, M. Tolley, R. Clarke, J. Collier, D. Neely, E. Divall, D. Neville, P. Rice, R. Bickerton, S. Blake, P. Holligan, P. Brummitt, P.P. Rajeev

Central Laser Facility, Rutherford Appleton Laboratory, Chilton Didcot OX11 0QX, UK

We report the latest developments at the Gemini laser system at the Central Laser Facility of the STFC Rutherford Appleton Laboratory. This dual beam facility can deliver 15 J, 30 fs pulses per beam at 0.05Hz and is expected to be fully functional with both beam-lines operating in 2009. We report the developments made in the target area to incorporate complex solid targets at the maximum repetition rate. Gemini will have access to a range of intensities up to 10^{22}Wcm^{-2}. With a 10^7-10^8 contrast level, the ASE and pedestal preceding the main pulse can cause a strong pre-plasma and target damage before the short pulse arrives.

A combination of at least two plasma mirrors is required to prevent this. To this end, we have designed a fully motorised plasma mirror system. The geometry requires a synchronised raster scan of both substrates. The raster routine has been set so that the plasma mirror system takes the maximum number of shots between optic changes. Another challenge is to insert extremely complex targets at a high repetition rate available in Gemini and to position them at the focus within a couple of microns. We have recently acquired a target inserter system developed at the General Atomics. The target inserter system is capable of positioning a target carrier at focus every 30 seconds. The inserter requires manual loading of a carrousel which can hold 49 target carriers which may have multiple targets on each. Manual loading does not require cycling of the main interaction chamber because the inserter has its own vacuum chamber which is isolated by a gate valve. Targets are inserted via a motorized arm with two grippers allowing the new carrier to be loaded while simultaneously unloading the previous carrier. Carriers are snapped to a kinematic mount on a hexapod positioning system which allows accurate target positioning to about 2 microns at the focus. The target coordinates are defined by a metrology system incorporating an off-line hexapod positioning system. The full Gemini system will incorporate F/20 and F/2 geometries using the dual beam capability. This opens up a unique stage to perform groundbreaking ultrafast plasma physics experiments at hitherto inaccessible intensities. These include areas ranging from particle acceleration, ultrashort wavelength sources and high energy density physics to laboratory astrophysics and quantum electrodynamics. The dual beams of Gemini, with a variable delay between them, open up a possibility of doing ultra-intense, ultrafast pump-probe plasma physics measurements with unprecedented temporal accuracy. The details of the latest developments discussed here will be presented.

Poster

Beam transport of ultra-short electron bunches

M.P. Anania[1], S.B. van der Geer[2], M.J. de Loos[2], R. Issac[1], A.J.W. Reitsma[1], S.M. Wiggins[1], D.A. Jaroszynski[1]
[1] *University of Strathclyde, Glasgow, United Kingdom*
[2] *Technische Universiteit Eindhoven, Eindhoven, The Netherlands*

Focussing of short electron bunches from a wakefield accelerator into an undulator requires particular attention to the emittance, electron bunch duration and energy spread. We present a design of a focussing system for the alpha-x transport section, which consists of a triplet of permanent magnet quadrupoles. The design has been carried out using GPT code, which considers the space charge effects and allows us to obtain a realistic estimate of the electron beam properties inside the undulator.

Poster

The Effects of Fluid Drifts on Parallel Transport in the MAST Scrape-off Layer

J Harrison[1,2], S.W. Lisgo[2], K J Gibson[1], G F Counsell[3], P Tamain[2], D Reiter[4]
[1] *University of York, Heslington, York, UK*

[2] *Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, UK*
[3] *Fusion for Energy, Barcelona, Spain*
[4] *Forschungszentrum Jülich, Germany*

Understanding how plasma is transported around the scrape-off layer (SOL) of a tokamak has been the subject of intense study for decades. As a result, theoretical models have been developed to explain experimental observations of phenomena such as divertor asymmetries – where SOL plasma tends to flow preferentially to different regions of the tokamak edge. This can lead to excessive heating of plasma-facing components in a fusion device, placing a greater strain on it's structural components. These theories tend to be highly complex, and great computational effort is required to reproduce experimentally observed consequences of SOL transport. This poster outlines recent experimental and theoretical studies into SOL transport in the MAST tokamak.

MAST is a spherical tokamak located in Culham Science Centre, Oxfordshire and is well-suited to SOL physics studies. The vessel's design and open divertor configuration allow for excellent diagnostic access. Observations of SOL flows parallel to magnetic field lines and divertor asymmetries are well-diagnosed with a range of high-quality diagnostics such as Langmuir probes, Infra-Red cameras, filtered CCD cameras (DivCam) and Doppler flow spectroscopy. From a theoretical perspective, the spherical tokamak design amplifies the effects of magnetic curvature in the SOL, allowing it's effects to be studied in greater detail.

The experimental data collected from this array of diagnostics can be used as input into SOL plasma modelling codes such as the Onion-Skin Model (OSM) to calculate the properties of the plasma in the bulk of the plasma boundary. In this poster we will present results of OSM modelling, including the effects of fluid drifts on parallel SOL transport in MAST.

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Poster

The interchange instability in magnetised plasma

O.A. Power, E. Benilov
Dept. of Mathematics, University of Limerick, Ireland

Conventional MHD theory predicts that the interchange mode is unstable on the outboard side of a simple magnetised torus, where the gradients of the magnetic field strength and plasma pressure are of the same (negative) sign. We show that under drift ordering long-wave disturbances do indeed satisfy the MHD instability condition, but that medium-wave and short-wave disturbances can be unstable even if the pressure gradient is positive (i.e., on the inboard side). Furthermore, we show that when the diamagnetic depression of the toroidal magnetic field is taken into account, an additional instability arises for short-wave disturbances and positive pressure gradients.

Poster

Computational modelling of ballooning instabilities in the presence of flow shear

P. Buxton[1], **J. W. Connor**[2], **J. B. Taylor**[2], **H. R. Wilson**[1]
[1] *Department of Physics, University of York, Heslington, York, YO10 5DD, U.K.*
[2] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB, U.K.*

Ballooning instabilities are driven by pressure gradients and impeded by the energy requirements of bending magnetic field lines. The mode structure adjusts to minimise the stabilising effect of magnetic field line bending by having a long wavelength parallel to the magnetic field line. From stability analyses it has been shown that the most unstable mode has a short wavelength perpendicular to the field line (i.e. large toroidal mode number, n).

Including a Doppler shift in the inertia provides a model for the ballooning mode in a tokamak plasma with toroidal flow shear. This has the result of making the ballooning equation non-hermitian, which complicates the analysis. The perturbation of the plasma is described by a 2D equation in (η, τ), where $\eta \propto$ distance along the magnetic field line and $\tau \propto$ time. This equation has solutions of a Floquet form, i.e. a periodic function of time multiplied by an exponential time dependence with growth rate γ.

The growth rate of the ballooning instability has been numerically calculated. We solve the full 2D ballooning equation, with the boundary conditions that as the distance along the magnetic field line approaches infinity the perturbation of the plasma goes to zero and that the perturbation is periodic in τ (after removing the exponential factor). γ is then determined as an eigenvalue.

By considering the limit where flow shear (s_v) is small, the ballooning equation can be significantly simplified. In particular, by an appropriate separation of variables, the ballooning equation can be separated into two differential equations: one that describes the η variation and the other that describes the τ variation, with an eigenvalue γ_0^2. It has been shown that the eigenvalue γ_0^2 has a weak, periodic τ dependence: $\gamma_0^2(\tau)$. When $\gamma_0^2(\tau) > 0$ these equations have been solved numerically (using appropriate boundary conditions) and show a good correlation to the numerical results of the full 2D ballooning equation.

The periodicity constraint determines the true growth rate, γ, in terms of $\gamma_0(\tau)$:

$$\gamma = \frac{1}{2\pi} \oint \gamma_0(\tau')\, d\tau' + ils_v$$

where l is an integer. This is consistent with the values of the growth rate (γ) that were calculated from the full 2D ballooning equation. There is a subtlety when $\gamma_0^2(\tau) < 0$, requiring a modified approach, which is work in progress.

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Poster

Design and simulation of a 200Ghz micro-klystron driven by a pseudospark electron beam

D. Bowes[1], A. W. Cross[1], H. Yin[1], W. He[1], K. Ronald[1], A. D. R. Phelps[1], D. Li[2], J. Zhou[2], X. Chen[2], J. Protz[3], M. Verdiel[3], M. Reynolds[3], T. Schuhmann[3]

[1] *SUPA, Department of Physics, University of Strathclyde, Glasgow G4 0NG, UK*

[2] *School of Electronic Engineering & Computer Science, Queen Mary University of London, London E1 4NS*

[3] *UK*

[4] *Pratt School of Engineering, Duke University, Durham, NC, 27708-0271, USA*

Research of radiation sources in the terahertz region (0.1 to 10THz) have been greatly promoted in recent years because of demands in plasma diagnostics, imaging and advanced communications applications. Currently, THz radiation is generated by various techniques ranging from solid-state devices to vacuum electronics devices such as free electron lasers, gyrotrons, klystrons and backward wave oscillators. Solid state devices operating in this frequency range are limited by material properties in terms of power, efficiency, and robustness, whilst most vacuum electronics devices involving high power lasers and focusing magnetic fields are bulky, complicated, expensive, not very portable and offer comparatively low power densities. In this regard, the klystron is an ideal choice for THz generation due to its operation mechanism, efficiency and robustness as well as the fact that it may be easily scaled in size in order to achieve higher frequency operation [1]. Due to the decrease in size as the frequency is increased, there is a need for the electron beam current density to increase in order to achieve reasonable output powers. The pseudospark (PS) discharge is an ideal electron beam source because it can produce both a suitably high current density and small diameter (< 1mm) self-focusing electron beam propagating without the need for a guiding magnetic field. A 200 GHz microklystron was designed and simulated using the particle-in-cell (PIC) code MAGIC. MAGIC-2D results revealed a strong amplification signal. Using the knowledge gained from previous PS studies [2,3], a small-scale single gap PS experiment was recently performed and produced a 1mm diameter electron beam of 4 A at 6 kV. This also shows the possibility to further scale down the PS into the micron range to drive a microklystron. The fabrication of the designed microklystron will be achieved by using a microelectromechanical systems (MEMS) based manufacturing process [4].

[1] P. H. Siegel, A. Fung, H. Manohara, J. Xu and B. Chang, 'Nanoklystron: A Monolithic tube approach to Terahertz Power Generation', 12th Int. Conf. on Space THz Tech. Proc., San Diego, CA, Feb. (2001) [2] H. Yin, W. He, A. W. Cross, A. D. R. Phelps and K. Ronald, J. Appl. Phys. 90, 3212 (2001) [3] H. Yin, A. W. Cross, A. D. R. Phelps, D. Zhu, W. He and K. Ronald J. Appl. Phys. 91, 5419 (2002) [4] M. Verdiel and J. Protz, 'A Novel Fabrication Recipe for a 200GHz Klystron', Proceedings of the National Vacuum Electronics Conference 2007 (NVEC 2007), Surrey, UK (2007)
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Poster

The Kadomstev-Petviashvili (KP) equation of ion-acosutic solitary wave in multi-components dusty plasma

A. S. Bains[1], T. S. Gill[1], N. S. Saini[2]
[1] *Department of Physics, Guru Nanak Dev University, Amritsar, India*
[2] *Centre for Plasma Physics, School of Math. and Physics, Queen's University Belfast, Belfast, BT7 1NN*

We have considered a hot dusty plasma system containing ions, electrons, positrons and negatively charged dust to study the solitary potential structures. Using reductive perturbation method, the KP equation has been derived. We have studied the characteristics of ion-acoustic solitary waves associated with negative/positive potential. The nonlinearity and dispersion coefficients are the function of positron to electron density ratio, dust density parameter, ion temperature and ratio of positron to electron temperature. It is observed that the amplitude and width of the solitary potential structures change with the variation of these parameters. We have explored the parametric regime for which the different type of negative/positive solitary potential structures exist.

Poster

A new edge ion temperature measurement diagnostic on the MAST tokamak

T. Morgan[1], H. Meyer[2], D. Temple[3], G. Tallents[4]
[1] *University of York, Heslington, York, YO10 5DD, UK*
[2] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK*
[3] *Department of Physics, Imperial College London, SW7 2AZ, UK*
[4] *University of York, Heslington, York, YO10 5DD, UK*

A good knowledge of ion temperatures and velocities at the edge of the plasma in tokamaks is important in understanding the power balance between ion and electrons, pedestal formation, edge stability and L-H transition, amongst other issues. At present no edge ion temperature measurement exists on the MAST tokamak, as the core charge-exchange diagnostic's resolution is limited by the neutral beam width and cannot resolve the pedestal. Charge-exchange measurements at the edge using the current system however show a response to deuterium gas puffing through a corresponding increase in signal intensity. Theoretical calculations showed that this should be expected as charge-exchange of thermal neutrals (in the n=2 excited state) with C6+ provide a significant fraction of the background signal at the relevant wavelength of 5290 Å (corresponding to the n=8 to n=7 transition in C5+, the most commonly used charge-exchange line). Thus a novel technique using thermal neutral deuterium rather than high energy neutral beam particles to provide an increase in charge-exchange emission, as is usually the case, has been proposed and implemented. A dedicated diagnostic device to utilise this observation using existing hardware and optics was used. This provided up to 64 toroidal chords at the midplane at major radii between ∼1.29 m and ∼1.41 m, corresponding to a range of r/a 0.8 to 1, with a theoretical maximum spatial resolution of 2 mm.

Deuterium gas puffing from a midplane outboard nozzle was used to provide a perturbation in the background (i.e. thermal) neutral population, which numerical modelling shows will be well localized spatially in the plasma and will penetrate far enough to provide a substantial intensity boost at all measured radii. Initial results showing the feasibility of using this technique and measured temperatures and toroidal velocities will be presented, as well as an overview of the diagnostic and the theoretical background and modelling behind it.

Poster

Controlling plasma properties by voltage pulse shaping

V. Samara, M. James, L. Bonova, M. Bowden, N. Braithwaite

Dept. of Physics & Astronomy, The Open University, Milton Keynes, UK

v.samara@open.ac.uk

For plasma applications it is often advantageous to be able to control different plasma properties independently. For example, in low temperature plasma processing of silicon wafers, it is desirable to alter ion flux and ion energy. However, in many cases, plasma properties are coupled strongly and independent control is difficult. Simple methods of control include changing input electrical power and gas pressure, while more complicated methods such as using dual-frequency excitation have been developed.

In this research we investigated a novel method of plasma control, tailoring the magnitude of the applied power. By using a pulsed discharge and altering the shape of the applied voltage pulse, we aimed to selectively control different discharge properties. Pulsed plasmas are particularly interesting for production of negative ions in electronegative plasmas because electron attachment has a maximum at low energies, which are easy accessible in the afterglow.

The research was conducted in a GEC cell. The capacitively coupled discharge was maintained between planar stainless steel electrodes with diameter of 100 mm separated by 25 mm. The discharge gas was argon at pressures in the range 50$\sim$500 mTorr and rf power (13.56 MHz) up to 100 W.

Initial measurements were made when the discharge was pulsed with square pulses, with varying duty cycles. Subsequent measurements were made with specially shaped asymmetric pulses. Plasma properties were measured with a hairpin probe and a Langmuir probe. An ICCD camera for capturing the total plasma emission.

When the discharge was operated with square-shaped pulses, the main observed features was a sharp peak in light emission and electron temperature in the first few microseconds of the pulse. This period of low electron density and high electron energy could be controlled to some extent by varying the duty cycle and pulse frequency. Different combinations of plasma and afterglow durations were investigated, such as changing the afterglow duration (1μs to 100 ms) while keeping plasma period short (50μs). We observed that, for afterglow time shorter than 100μs, changing the afterglow duration had huge impact on ignition of the next plasma pulse.

In second stage measurements, we used tailored pulses. With these pulses, we found that we could obtain the same variation in plasma properties while keeping the pulse duty cycle and pulse frequency constant. This behaviour can be explained by considering the effect of rising and falling voltage amplitudes on the electron behaviour. In the afterglow, electron temperature falls rapidly, electron production stops, and electrons diffuse to the walls. Ignition at the next voltage pulse depends strongly on the density of electrons remaining at the end of afterglow. If the voltage pulse rises steeply, the rf pwer is absorbed by small number of electrons and the electron energy rises rapidly. If the voltage pulse rises slowly, the electron energy will also rise slowly. Similar control can be achieved by varying the rate at which the rf power turns off at the end of the voltage pulse.

Poster

A Co-Harmonic Cyclotron Resonant Maser

D.A. Constable[1], K. Ronald[1], A.D.R. Phelps[1], W. He[1], A.W. Cross[1], A.V. Savilov[2], V.L. Bratman[2], I.V. Bandurkin[2], S.L. McConville[1], I.V. Konoplev[1]

[1] *SUPA, Department of Physics, University of Strathclyde, Glasgow, G4 0NG*

[2] *Institute of Applied Physics, Russian Academy of Science, Nizhny Novgorod, Russia*

Currently, there are few devices delivering output in the sub-millimetre range which exploit the electron cyclotron maser (ECM) instability, due to the expense and technical limitations associated with the current level of magnet technology. Devices operating within this THz regime could fulfill a variety of potential applications, ranging from plasma diagnostics to emerging biochemical diagnostic spectrometry. Therefore, operation at a harmonic, s, of the electron cyclotron frequency, ωc, is an attractive alternative of attaining such frequencies. However, given that the starting current, Ist, of a high harmonic will usually satisfy the starting criteria of a lower harmonic, this can prove problematic.

To that end, a novel resonant cavity has been designed, which realizes co-harmonic generation of second and fourth harmonic resonances. This is achieved through an azimuthal corrugation of the walls of the interaction region, which in turn, allows the frequencies of the two resonances to have an exact integer ratio. Through the use of a specially designed output aperture, the lower harmonic should be effectively trapped within the cavity, facilitating a pure output of the upper harmonic.

The 3-D PIC code MAGIC-3D has been used to examine the proposed geometry. Simulations conducted thus far have displayed the intended co-harmonic generation; however, the second harmonic is seen to undergo mode conversion at the output aperture, which in turn, dominates the emitted radiation. The focus of the current research is therefore to address this problem.

Poster

Measurements of Emission Spectra from Hot, Dense Germanium Plasma in Short Pulse Laser Experiments

B.M. Williams[1], D. J. Hoarty[1], S F James[1], C R D Brown[1], L J Thornton[1], C. C Smith[1], J.W.O. Harris[1], L. Upcraft[1], B.J.B. Crowley[1], R. W. Lee[2], H. K.Chung[3]

[1] *AWE Plasma Physics Department, Building E1.1, Reading, Berkshire RG7 4PR, UK*

[2] *Department of Applied Science, University of California, Davis, Davis, California 95616, USA*

[3] *Lawrence Livermore National Laboratory, P. O. Box 808, L-399, Livermore, CA 94550 USA*

High temperature, high density Germanium emission spectra measurements have been made in the 1.3-2.3keV spectral range covering 2p-3d and 2p-4d transitions in charge states up to 29+. In the experiment Germanium microdot samples, 50μm in diameter, 0.06μm thick, and buried in plastic foils, were irradiated by the HELEN CPA laser at intensities of $10^{17} - 10^{18}$W/cm^2. The measurements included mixed samples of Germanium and Titanium, where the plasma conditions were inferred from the Titanium spectra by comparing the measurements of line ratios and widths to Titanium spectra predicted by the FLY code. The inferred electron temperature and material density were 1 ± 0.1keV, 2 ± 1 g/cc, respectively. The data were recorded time-integrated, on calibrated X-ray film, and time-resolved using an ultra-fast X-ray streak camera with a time resolution of 1ps. Using the measured X-ray pulse lengths and spectrometer calibrations, the germanium emission results were converted to absolute units at source. The experimental data are presented and compared to time-dependent CRE code predictions.

Poster

X-ray generation from laser irradiated low Z gas embedded with high Z atoms

Updesh Verma, A. K. Sharma

C/0 Prof. V. K. Tripathi, MS-532, IIT Delhi, Hauzkhas, New Delhi, India.110016

Plasma of mixture of gases (Hydrogen 95% and Xenon 5%) is impinged by a pre pulse of intensity 10^{14} W/cm^2 ionizes hydrogen atoms fully whereas Xenon atoms are only singly ionizes and create hydrogen plasma with partially ionized Xenon. After first pulse is gone plasma expands in about 1ns to produce a hydrogen plasma channel with minimum density on the axis. A second intense short pulse laser of intensity 10^{17}W/cm^2 self focuses and travel guided in the channel. Due to self focusing intensity of the second pulse enhanced and it tunnel ionizes the remaining Xenon. The Xenon acquires Xe^{8+} charge state after loosing 8 ions and acquires Neon like configuration and emits X-rays.

Poster

Measuring and interpreting RF harmonics from a pulsed discharge

M.D. Bowden, V. Samara, N.St.J. Braithwaite

Dept of Physics & Astronomy, The Open University, Milton Keynes MK7 6AA, UK

When RF power is applied to generate a plasma, harmonics of the RF frequency arise due to the non-linear response of the plasma to the applied RF power. The harmonic signals arise in response to the properties of the discharge, and if there is a correlation between signal magnitudes and specific discharge properties, this could provide a valuable non-intrusive plasma diagnostic method. This possibility has led to various attempts to interpret this information, in a new measurement area often called RF spectroscopy.

In this research, we applied RF spectroscopy to pulsed RF discharges, correlating harmonic signals with measurements of electron density, temperature and plasma emission. The research was conducted in a capacitively coupled discharge, operated with RF power at 13.56 MHz. Measurements were made in Ar, SF_6 and Ar/SF_6 discharges, with pressures in the range 50∼500 mTorr.

Plasma properties were measured with a hairpin probe and a Langmuir probe, to determine electron density and temperature, and an ICCD camera, which was used to image the total plasma emission. RF harmonic signals were measured using an Octiv current sensor, placed between the RF power source and the matching box. The sensor, manufactured by Impedans, was modified to enable measurements to be made in pulsed discharges.

Initial measurements were made in a capacitively coupled discharge. Clear differences were observed in the time dependence of the harmonic signals between discharges operated in argon and discharges operated in SF6. Some of the differences can be attributed to the difference between a plasma composed of single atoms and one composed of a variety of molecular species. Other differences may indicate the presence of negative ions.

Poster

Comparison of the ELM toroidal mode number for spontaneous and pellet triggered events in JET

F.M. Poli[1], **P.T. Lang**[2], **S.E. Sharapov**[3]

[1] *University of Warwick, Coventry CV4 7AL, UK*

[2] *Max-Planck-Institut fur Plasmaphysik, EURATOM Association, Boltzmannstr. 2, 85748 Garching, Germany*

[3] *Euratom/UKAEA Fusion Assoc, Abingdon OX14 3DB,UK*

The high confinement regime mode (H-mode) in tokamaks is accompanied by the occurrence of bursts of MHD activity at the plasma edge, so-called edge localized modes (ELMs), lasting on JET typically 0.2 ms. Since the energy stored and released by an ELM increases with the plasma volume, for future ITER operations it is important to minimize the damaging effect that ELMs may have on plasma-facing components, for example by increasing the ELM repetition rate. One possibility in this direction is the triggering and mitigation of ELMs by pellet injection, which was successfully achieved on ASDEX Upgrade [1]. Experiments on JET have demonstrated that ELM triggering [2] and pacing is possible also in large size tokamaks, thus encouraging further investigation of the ELM triggering mechanism by pellets, for future applications on ITER. We present the results from the analysis of the power spectra of magnetic perturbations measured from edge Mirnov pickup coils, during experiments with pellet injection in JET H-mode plasmas with toroidal rotation driven by unbalanced NBI. Spontaneous type-I ELMs and series of ELMs, the so-called 'compound' ELMs are observed in these discharges both during the pellet-free and the pellet-fuelled phase. Sinusoidal wavelet functions are used to compute the spectra of magnetic perturbations with time resolution comparable to the sampling rate and the toroidal mode number is extracted from the phase shift measured between two toroidally separated pickup coils. The evolution of the toroidal mode number of ELMs is then reconstructed combining wavelet spectral analysis with statistical two-point correlation techniques [3]. The measured n rapidly increases during the phases that immediately precede the burst, suggesting that an ELM is the superposition of many modes with toroidal mode numbers up to $|n| > 15$. Comparison between spontaneous ELMs and ELMs triggered by pellets indicates that they have similar spectral characteristics. Similar ranges of frequencies and toroidal mode numbers are involved in the two cases, indicating that the properties of triggered ELMs do not depend on the pellet mass and velocity, but on the plasma background parameters.

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Poster

Flow associated with sheared rotation

G.J.J. Botha[1], E.A. Evangelidis[2]
[11] *University of Warwick, Coventry, UK*
[22] *Centre for Physics and Mathematics, Volos, Greece*

Differential rotation occurs in astrophysical plasmas like accretion disks and the sun, as well as in laboratory plasmas as manifested in the toroidal rotation of tokamak plasmas. A re-examination of the Lagrangian of the system shows that the inclusion of the angular momentum's radial variation in the derivation of the equations or motion produces a force term that couples the angular velocity gradient with the angular momentum. This force term is a property of the angular velocity field, so that the results are valid wherever differential rotation is present. The interaction between this force term and a magnetic field generates guiding centre drifts, which generates mean flows where differential rotation and a magnetic field exist in the same physical space.

Poster

Single-photon counting diagnostics for laser-plasma experiments

E. Wagenaars[1], A. Higginbotham[2], M. Suggit[2], K. Falk[2], S. White[3], P. Gallegos[4], M.J.V. Streeter[4], F. Cameron[4], J.S. Riddick[1], N. Booth[1], G.J. Tallents[1], D. Neely[4], D. Riley[3], G. Gregori[2], J.S. Wark[2], N.C. Woolsey[1]
[1] *Department of Physics, University of York, York YO10 5DD, UK*
[2] *Department of Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, UK*
[3] *School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, UK*
[4] *Central Laser Facility, Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0QX, UK*

In laser-plasma physics, plasmas are created by focussing a powerful laser on a target material. The resulting plasmas are very hot and dense with temperatures in the range of hundreds of eV and densities close to solid densities. Because of the high temperatures, the radiation (Bremsstrahlung) emitted by these plasmas is mainly in the EUV and X-ray regime. It is well-known that at high laser irradiance, as a result of different laser absorption and heating mechanisms, the plasma can have a bi-Maxwellian electron distribution, with two distinctly different temperatures. The cold electron temperature is typically in the range of tens to hundreds of eV, while part of the electrons are heated to much higher temperatures, up to thousands of eV. Measuring the properties of these hot electrons can give further insight in the details of the mechanisms which are at play in these types of plasmas. We employed the technique of single-photon counting to derive hot electron temperatures from Bremsstrahlung measurements in different laser-plasma experiments. The principle of this diagnostic is to measure the energy of single photons with a CCD camera. The photon-flux from the plasma is attenuated with metal filters to ensure a small exposure of the CCD of typically 1 photon per 10 pixels. The high-energy photons (keVs) will create multiple electron-hole pairs in the CCD, proportional to photon energy. Therefore, the number of 'counts' in a CCD pixel is directly proportional to the energy of the detected photon. By analysing many of these single photon events on different parts of the CCD, an energy spectrum of the X-rays can be recorded and a hot-electron temperature derived. In this contribution we will present two different experiments in which single photon counting diagnostics were used. The first is an experiment on the generation of short-pulse X-rays from copper foil using femtosecond pulses from the ASTRA GEMINI facility at the Rutherford Appleton Laboratory. A single-photon counting diagnostic was used to both measure the copper K-alpha and K-beta emission lines and the continuum Bremsstrahlung spectrum to derive hot electron temperatures. The second experiment is performed in the new laser-plasma laboratory in York using a less intense, longer pulse (170 picoseconds) laser focussed on wire targets. The single photon counting diagnostics for both experiments will be discussed in detail as well as the required analysis of the acquired data. Additionally, preliminary results of hot-electron temperatures as function of laser irradiance are presented.

Poster

Electric arc plasma temperature and parameters in mixture gas-metal vapor atmosphere

G. Raniszewski[1], **Z. Kolacinski**[1], **L. Szymanski**[2]

[1] *Technical University of Lodz, Dept. of Electrical Apparatus, ul. Stefanowskiego 18/22, 90924 Lodz, Poland*

[2] *Academy of Humanities and Economics in Lodz, ul. Rewolucji 1905r. nr 64, 90-222 Lodz, Poland*

The electric arc in gas-metal vapour atmosphere appears in many applications. An example of influence of metals on plasma is the plasma waste destruction. Waste are composed mostly of metal oxides. Over 95% of ash composition are oxides of metals such as: silicon, aluminum, calcium, magnesium, sodium, iron. During plasma waste treatment arc burns in neutral gas e.g. argon. The high temperature of plasma arc leads to decomposition of wastes. Vaporizing metals enter the arc channel changing its parameters. Metal plasma also appears in the circuit breakers. Evaporating electrodes change the plasma conductivity, temperature, electron density etc. Low value of the ionization potential of metallic contacts leads to the

AC arc reignition. Another example of metal-gas atmosphere are metallurgical processes involving plasmas. Metal vapor considerably decreases the effective ionization potential of the plasma medium during welding and cutting. This paper deals with investigations of arc plasma in complex gas – metal vapour mixtures. Experimental techniques in the diagnostics have been shown. Various detecting materials were analyzed and advantages of using copper are discussed. Spectroscopic measurements of electric arc temperature are presented. Plasma composition has been calculated and compared to the measured results.

Poster

Lower-hybrid waves in dusty plasmas and cusp solitons

Z. Ehsan[1], **N. L. Tsintsadze**[2]
[1] *Imperial College London, Blackett Laboratory, London SW7-2AZ, UK*
[2] *Salam Chair and Department of Physics GC University, Lahore*

A theoretical model is presented for the excitation of ultra-low frequency dust-lower hybrid mode (DLH) by employing the decay of a relatively high frequency dust-modified lower-hybrid (DMLH) wave into a relatively lower frequency DMLH and DLH based on 3-wave resonant interaction. A coupled nonlinear Schrödinger (NLS) equation for the DMLH wave and Zakharov equation for the DLH wave are derived. The nonlinear contribution in the NLS equation comes from the DLH density fluctuations. Modulational instabilities of DMLH waves are investigated and its growth rates are studied. Additionally, one-dimensional nonlinear localized structures of bright solitons and nonlinear nonlocal structures like cusp solitons are obtained. It is shown that, when the phase velocity resonates with the dust sound speed the nonlocal nonlinearity leads to the generation of cusp solitons.

Poster

Iron Opacity Measurements Using K-alpha Emission

A.K. Rossall[1], **S. Chaurasia**[2], **G.J. Tallents**[1], **L.M.R. Gartside**[1], **L.J. Dhareshwar**[2]
[1] *Department of Physics, University of York, Heslington, York, YO10 5DD*
[2] *Bhabha Atomic Research Centre, Trombay, Mumbai, 400 085, India.*

Targets comprising iron buried beneath a layer of aluminium have been irradiated with an obliquely incident 500ps pulse length Nd: YAG laser pulse at $1.2-1.5\times10^{14}$Wcm^{-2}. The laser produced Al plasma provides a source of hot electrons as a heating source for the iron layer and K-alpha emission for transmission measurements through the target. Analysis of the He- and Li-like lines in the Al spectra and comparison with spectral modelling code FLYCHK demonstrates a two component plasma of temperatures, T_c=140eV and T_h=1keV, confirmed by silicon x-ray diodes. An increase in transmission of Al K-alpha radiation through the target is observed with laser irradiation due to iron opacity changes as it is heated.

Poster

Studying the effect of magnetic shear on plasma stability

Simon Myers, Ben Dudson, Howard Wilson

Department of Physics, University of York, Heslington, York, YO10 5DD, UK

Edge-localized modes (ELMs) are a class of explosive plasma instability that occur in high confinement mode tokamak plasmas. These ELM events expel a significant proportion of the plasma energy into the containment vessel. In future fusion devices such as ITER this expulsion of energy could lead to unsatisfactory levels of damage to the vessel components. The current accepted model is that ELMs arise when the plasma is close to the peeling-ballooning boundary, and a combination of the peeling and ballooning instabilities leads to the largest ELM events. ELMs manifest themselves as filamentary structures which are forced out of the confined plasma, transporting energy and particles outside the last closed flux surface [1]. Non-linear theory [2] predicts filaments erupt outwards when the current density is high and implode inwards at low current density [3]. High current density corresponds to low magnetic shear. The purpose of this project is to isolate the impact of shear on the plasma eruptions, and identify whether or not it influences the direction of the eruption.

The effect of shear is being investigated by examining a slab of plasma, rather than a torus, to simplify the geometry. A slab of plasma with gravity acting upon it is closely analogous to a tokamak plasma as the inclusion of gravity acts like curvature in a tokamak. A non-linear code [4] numerically solves the full 3D MHD equations for such a system in a zero magnetic shear scenario. This code has been adapted to include shear. An analytical reduction of the linearised MHD equations has also been obtained, producing a pair of coupled differential equations which are being solved numerically to find the growth rate of the instability. This will be compared with the results from the full non-linear code during the linear regime to give some insight into the effect of shear, and to act as a benchmark for both solutions in preparation for full non-linear solutions.

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Poster

Hot electron transport modelling with non-Spitzer resistivity

D. Chapman, D. Swatton, S. Hughes

AWE plc. Aldermaston

Fast Ignition Inertial Confinement Fusion (FI-ICF) schemes, and many laser-driven High Energy Density Physics (HEDP) experiments, rely on the efficient propagation of an energetic electron beam through high density, partially ionised (and possibly strongly degenerate) matter. In the case of FI, this beam must then deposit sufficient energy in the assembled fuel to achieve thermonuclear ignition and gain.

The transport of the electron beam is strongly affected by the resistivity of the target material. This dictates the strength of the resulting return current which results in Ohmic heating, and is itself a function of the background temperature.

Typically the resistivity of the target is assumed to follow the classical Spitzer scaling (i.e. $\eta \sim T_e^{-3/2}$, where T_e is the background temperature) for the whole range of temperatures encountered. This is known to be inappropriate at high densities and/or low temperatures. It has been shown experimentally that the resistivity scales linearly with T_e in the cold regime, and later enters a saturation regime with only weak temperature dependence.

Here we present results of simulations of FI relevant targets using the THOR II fast electron transport code. In particular, the effects of various resistivity models on the heating profiles, degree of electron beam collimation, and electric and magnetic field structure are studied. These results are then compared to the results of the classical Spitzer model. Moreover, the simulated heating profiles of plastic targets containing a buried aluminium layer are compared with experimental results from the 100 TW CPA arm of the HELEN laser system.

Poster

An examination of the linear structure of the CUTIE turbulence code

J. Douglas[1], **A. Thyagaraja**[2], **E. Kim**[1]
[1] *School of Mathematics and Statistics, University of Sheffield, Sheffield, S3 7RH*
[2] *Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB*

The nonlinear, global, electromagnetic, quasi-neutral, two-fluid turbulence code CUTIE has successfully reproduced many features of tokamak physics, for example: internal transport barriers (ITB) in tokamak plasmas, see A. Thyagaraja [Plasma Phys. Cont. Fusion **42**, B255 (2000)]; heat pinches in electron-heated tokamaks, see P. Mantica et al [PRL **95**, 185002 (2005)]; and turbulent transport and MHD phenomona of sawtoothlike events in experiments, see M. de Baar et al [PRL **94**, 035002 (2005)]. These simulations have all been performed using the full nonlinear CUTIE code. To gain a more complete understanding of CUTIE this work focuses on examining the linear structure of CUTIE, by performing linear simulations of the code where prescribed profiles of mean quantities are held fixed and linear instabilities are allowed to grow. To provide a simple linear system to work with, the linearized equations to be solved by the code are the density equation, the two-fluid equations and the (reduced) Maxwells equations. This system of equations has several coupled variables and radially varying coefficients for rather general profiles, making an analytical solution impossible. For a given initial fluctuation profile, simulations are performed for all the poloidal mode numbers m for each toroidal mode number n. For the azimuthal symmetry of tokamak equilibrium used in CUTIE, n is a good quantum number for the system, and resonances occur at $m/n = q(r/a)$. Simulations have been performed for a wide range of spatial grids sizes and time steps to ensure consistency and to examine in detail the spatial stucture of the linear modes. The linear simulations show that instabilities quickly begin to grow at a constant rate, as expected in a linear system. The results also suggest that higher values of n result in higher growth rates of linear modes. As an independent check of the modes, the eigenvalue solution to the set of linear equations is investigated and compared to the simulation results. The results from the investigation of the spatial structure of the linear modes, the effects of diffusivities, and the effect of varying the prescribed, fixed profiles of mean quantities will be presented.

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Poster

VALIS: A split-conservative scheme for the relativistic 2D Vlasov-Maxwell system.

N. J. Sircombe[1,2], T. D. Arber[2]
[1] *AWE plc., Aldermaston, Reading, Berkshire, UK.*
[2] *Centre for Fusion, Space and Astrophysics, University of Warwick, Coventry, U.K.*

The accurate modelling of kinetic plasma physics phenomena is of fundamental importance to a number of problems including: laser absorption and subsequent transport in short-pulse laser-matter interaction; growth and saturation of parametric instabilities in long-pulse laser-plasma interaction; the laser-driven particle accelerator; thermal transport in the solar corona; as well as non-linear effects in magnetically confined fusion devices. We introduce VALIS, a 2D2P (i.e. two spatial dimensions and two momentum dimensions) direct Vlasov solver based on a split Eulerian scheme, demonstrate some of it's strengths and present some preliminary results of direct relevance to short-pulse LPI, fast ignition and high energy density physics in general.

Poster

Bounce-Precessional Drive of Alfvén Casade Modes by Fast Particles

I. G. Abel[1,2], B. Breizman[3], S. E. Sharapov[2]
[1] *Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3NP, UK*
[2] *Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon OX14 3DB, UK*
[3] *Institute for Fusion Studies, The University of Texas, Austin, Texas 78712*

Upward sweeping Alfvén cascade eigenmodes have long been observed in tokamak reverse shear discharges. These upward sweeping modes have been explained as eigenmodes, localized around q_{min} driven by fast ion inhomogeneities in the plasma. However in flat q-profile discharges an accompanying downward sweeping mode, not provided for by the previous work, are occasionally observed.

In this work we extend the previous treatments of these modes to include a detailed numerical calculation of the weak radiative decay of the downward sweeping modes, which we can then compare with the resonant fast particle drive. This analysis provides a robust theoretical explanation for the experimentally observed downward sweeping modes, an exact value for the marginal stability criterion and robust predictions that can be experimentally verified including a radial shift of the mode structure.

In order to calculate the fast particle resonant drive we extend the existing canonical Hamiltonian formalism for energetic ions to explicitly evaluate the resonant response from a drift-kinetic model. This provides us with a general framework for evaluating the resonant drive of any high-m Alfvénic activity due to trapped particles, which we intend in the future to apply to many modes of experimental interest including so-called Tornado modes.

Poster

Alfvén wave acceleration of electrons in low beta plasma

K.G. McClements[1], L. Fletcher[2]
[1] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB*
[2] *University of Glasgow, Department of Physics and Astronomy, Glasgow, G12 8QQ*

Electron acceleration by inertial Alfvén waves in low beta plasma is investigated analytically. The accelerated electron fraction is shown to depend critically on the perturbation amplitude, the temperature, and the transverse wave length scale. This process could contribute significantly to the production of energetic electrons in solar flares and may also play a role in tokamak disruptions.

This work was funded by STFC, EPSRC, and the EC through the SOLAIRE Network (MTRN-CT-2006-035484).

Poster

Negative ion density measurement by eclipse photo-detachment in depositing plasmas

ShaoDong You, Robert Dodd, Paul M. Bryant, James W. Bradley
Department of Electrical Engineering and Electronics, University of Liverpool, Brownlow Hill, Liverpool, UK, L69 3GJ

Reactive magnetron sputtering in the presence of oxygen is an important industrial technique for depositing engineering quality dielectric thin films and coatings. Despite the success of the technique, which often includes pulsed modulation of the applied DC power supply in the kHz regime, there is still a lack of understanding of the role of negative ions in these discharges and their influence on the growth of the deposited films.

Here we present detailed photo-detachment measurements of the negative ion densities (O^-, O_2^-) in both RF and pulsed DC driven magnetron devices. The photo-detachment technique utilizes an Nd: Yag laser operating at 1054 nm and 532 nm, in conjunction with a Langmuir probe data collection system. To eliminate ablation and ionization of material from the probe, an eclipse technique has been used, in which the laser beam is prevented from striking the surface of the probe by an external mask with dimensions close to the probe radius.

Preliminary measurements show that in RF reactive sputtering at powers ¡ 50 W the negative ion (O^-) densities N^- are typically greater than the electron densities, with the former in the range of $1 - 5 \times 10^{14} m^{-3}$.

For DC operation however, in the same pressure regime the negative ion densities were found to be up to about 30
(for instance absolute densities in the region of $1 - 5 \times 10^{15} m^{-3}$ varying with power and O_2 concentration. The eclipse technique is being further developed for high power RF and pulsed DC reactive sputtering to yield time-averaged and time-resolved negative ion densities in the bulk plasma.

Poster

Electromagnetic envelope pulses in relativistic magnetized plasma

J. Borhanian[1,2], I. Kourakis[2], S. Sobhanian[1]

[1]*Department of Atomic and Molecular Physics, Faculty of Physics, University of Tabriz, Iran*

[2] *Centre for Plasma Physics, Department of Physics and Astronomy, Queen's University Belfast, BT7 1NN*

A multiple scales technique is adopted to solve the one-dimensional system of fluid-Maxwell equations describing a weakly nonlinear circularly polarized electromagnetic pulse in magnetized plasma. A nonlinear Schrodinger-type equation is shown to govern the amplitude of the vector potential. The conditions for modulational instability occurrence, on one hand, and for the existence of localized envelope modes (bright-type and dark-type envelope solitons), on the other, are investigated in terms of relevant parameters, and in particular of the magnetic field strength. Right-hand circularly polarized (RCP) waves are shown to be modulationally unstable regardless of the value of the ambient magnetic field and propagate as bright-type solitons (electric field envelope pulses). The same is true for left-hand circularly polarized (LCP) waves in a weakly to moderately magnetized plasma. In other parameter regions, LCP waves are stable in strongly magnetized plasmas and may propagate as dark-type solitons (electric field holes). The evolution of envelope solitons is analyzed numerically, and it is shown that solitons propagate in magnetized plasma without any essential change in amplitude and shape. A Gaussian pulse, not corresponding to a soliton solution of NLS equation, can propagate without changes in the anomalous dispersion region of plasma, though it undergoes broadening in the normal region, while it preserves its symmetry.

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Poster

T-junction atmospheric pressure plasma jet

Q.Th. Algwari, D. O'Connell

Centre for Plasma Physics, Queen's University Belfast, NI

A new design for atmospheric pressure plasma jet is introduced in this letter. This configuration is different to that of a linear plasma jet; it consists of a T-junction dielectric tube, which provides gas flow in two directions opposite to each other. Tubular copper electrodes, with 10 mm length, are assembled around the two arms of the capillary T-junction tube. The distance between the electrodes is 7.5 mm. The powered electrode is driven with a pulse high voltage power supply with frequencies 10 to 40 KHz. Using helium as a discharge gas and 2 slm (1 slm in each side) flow rate, a jet is observed at the grounded electrode side. The length of the jet at the grounded end is about 15 mm.

Time resolved images of the jet were recorded with an intensified charge coupled detector (ICCD) triggered with a 50 nsec gate. To observe reactive plasma species in the jet a spectrometer was used to record emission spectra in the range of 200-1100 nm. The ICCD images show there are plasma bullets in the jet at the grounded side with speed 28 Km/s and it is much higher than the gas flow, 2.35 m/s. The bullet speeds are almost constant for discharge frequencies up to 40 kHz, and the time at which the bullet leaves the end of tube is the same for these frequencies. The bullet always appears during the increasing slope of the applied voltage. The maximum bullet intensity shows that the maximum intensity increases with applied frequencies. The optical emission spectrum shows that the dominate emission lines are from the nitrogen excited species and the intensity of these lines decrease with increasing the applied discharge frequencies.

Poster

Plasma electrical, optical and imaging and polymer property studies of an industrial scale atmospheric pressure glow discharge system.

L. Schaper[1], D. Della Croce[1], W.G. Graham[1], B. Twomey[2], D.P. Dowling[2], L. O'Neill[3], A.M. Hynes[3]

[1] *Centre for Plasma Physics, Queen's University Belfast, Belfast, BT7 1NN, NI*

[2] *Schol of Electrical, Electronic and Mechanical Enigneering, University College Dublin, I*

[3] *Dow corning Plasma Solutions, Midleton, Cork, I*

Large commercial systems are not particularly conducive to detailed experimental measurements, however to fully exploit their potential in processing it is necessary to compare and contrast the physical and chemical environments they create with those in the smaller scale research devices. Here we report time-resolved electrical, optical and ICCD imaging characterisation of a commercial, large scale (1800cm^2) parallel plate DBD atmospheric pressure plasma system along with characterisation of coatings deposited on polymer film substrates. The system is driven by a sinusoidally-varying voltage (max 20kV) at frequencies of around 20 kHz [1]. The power input levels are controlled by variation of the applied voltage and its frequency. Coatings were deposited onto PET film by injecting an aerosol of TEOS into the plasma and the film properties determined using ellipsometry, surface energy and FT-IR measurements

The large system exhibits phenomena and behaviour not previously reported in smaller, lower power, experimental DBD systems. Multiple discharge events occur through most of the applied voltage half cycle [2]. In helium the light emission is found to be homogeneous and the structure and behaviour of each event is consistent with that associated with atmospheric pressure glow discharges. This work was supported by Dow Corning Plasma Solutions and the UK Engineering and Physical Sciences Research Council.

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Poster

Plasma formation in evaporated saline solution

L. Schaper[1], W.G. Graham[1], B. Twomey[2], K.R. Stalder[2],

[1] *Centre for Plasma Physics, Queen's University Belfast, Belfast, BT7 1NN, NI*

[2] *ArthroCare Corp. Sunnyvale, CA, 94085-3523, USA*

Plasma production in liquids has been investigated for various experimental setups and different kinds of liquids. Among those, discharges operating in water have drawn considerable interest and have most recently been reviewed by Malik et al. [1]. The predominant type of setup in this environment is a pin to plate discharge in pulsed operation with applied voltages in between 10 and 100 kV in water of low conductivity. This leads to multiple microchannel breakdown plasmas, similar to the corona plasma in high pressure gas plasmas. Those as well as most of the other discharge setups create highly reactive environments in which radicals, shockwaves and strong UV radiation are observed, leading to a broad field of application which includes water decontamination and purification as well as sterilization and applicability in surgery.

Recently there have been interesting new studies of plasmas created in highly conducting saline solution by applying moderate ($<$ 300V rms) bipolar voltage pulses [2,3] to electrodes. Interest in such plasmas has been prompted by their ability to ablate tissue in electrosurgical applications. They are currently widely used in various surgical procedures. This type of environment appears to be very conducive to the study of plasma production in liquids and in particular in elucidating the relationship between vapour layer formation and discharge formation. We have developed an experimental arrangement to facilitate such studies.

Negative voltage pulses of up to 250V with a typical duration of several milliseconds are applied to a pin electrode in a pin to plate setup. Both electrodes are immersed in an isotonic saline solution (0.9% w/w NaCl in H_2O) of defined temperature. In operation the voltages applied to both electrodes are measured, current is measured at the return electrode. For the analysis of the vapour layer formation a shadowgraph of the device is imaged onto a fast ICCD. Plasma formation is also observed time and wavelength resolved via a fast PMT and a spectrometer, yielding insight into the plasmas main reactive components. It is observed, that vapour formation starts at the contact between the active electrode and the insulator. Once started the vapour layer spreads over the complete electrode until it is completely covered. In this complex dynamic environment analysis on the plasma formation is performed.

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Poster

Optimising plasma injection in field coils

L. Brahms[1], **R. Barclay**[2], **Z. Cochrane**[2], **G. LaForge**[2], **M. O'Brian**[2],
[1] *Polytechnical Institute for Material Sciences, Novosibirsk, Russia*
[2] *Daystrom Institute for Advanced Technological Studies, Honolulu, Hawaii, USA*

In modern field coil technology the problem of plasma injection takes a lot of attention. In recent years this problem was solved by canalising the plasma flow into Dyson tubes, which caused considerable inefficiencies in the power management of the field reactor. New magnetic valve injectors that have been developed during the last four years guarantee a steady and reliable plasma flow in the coils. Together with a new optimised field geometry the closing-reopening cycle of the injectors could easily be varied between 25 and 50 ns. A maximum reliable cycle time of more than 53 ns could be achieved using arkenium duranite instead of conventional duranite in the injectors. Due to sequential firing of the plasma injectors corresponding to the plasma pulse frequency, the warp field sheaths are compressed further. These cumulative field sheath forces lead to a considerable mass reduction and warp speed enhancement of more than 20%. In conclusion, this new technology offers a variety of new possibilities to go where no man has ever gone before.

Poster

Dynamics of radio-frequency driven atmospheric pressure plasmas jets

T. Gans[1], **J. Waskoenig**[1], **K. Niemi**[1], **S. Reuter**[1], **L. Graham**[1], **L. Schaper**[1], **H. Böttner**[2], **N. Knake**[2], **V. Schulz von der Gathen**[2],
[1] *Centre for Plasma Physics, Queen's University Belfast, Belfast BT7 1NN, Northern Ireland, UK*
[2] *Center for Plasma Science and Technology, Ruhr-University Bochum, 44780 Bochum, Germany*

Non-equilibrium atmospheric pressure plasmas, in particular microplasma devices, have tremendous application potential. Radio-frequency driven atmospheric pressure plasma jets (APPJ) can provide high radical concentrations at low gas temperatures, e.g. for modification of sensitive surfaces in biomedicine. The plasma dynamics is a complex multi-scale problem with pronounced electron dynamics within the radio-frequency cycle governing plasma ionization and initiating non-equilibrium plasma chemistry. Of particular interest are power coupling and energy transport processes from the plasma core region into the chemically reactive effluent region which is targeted for technological exploitations.

Diagnostics of atmospheric pressure plasmas are extremely challenging due to small confining structures and the collision dominated high pressure environment demanding exceptionally high spatial and temporal resolution down to microns and pico-seconds. The most promising approach is active combination of advanced optical techniques and numerical simulations. Investigations of the plasma dynamics are carried out in the so-called μ-APPJ. The μ-APPJ is an especially designed microscale version of the APPJ providing excellent access for optical diagnostics, in particular to the core plasma. Employed techniques include: classical optical emission spectroscopy (OES), phase resolved OES (PROES), laser spectroscopy, finite-element numerical simulations, and optical techniques based on coupling with numerical simulations.

Plasma ionization and sustainment are governed by electrons energized through the dynamics of the plasma boundary sheath. Excellent agreement between PROES measurements and numerical simulations reveals mode transitions between different ionization mechanisms during sheath expansion, sheath collapse, and electron acceleration in the high voltage sheath region. Under certain conditions the operation in a He/O_2 gas mixture indicates an electronegative character. This has important consequences for the electron dynamics and plasma ionization mechanisms. Maximum electron density is observed in close vicinity of the electrodes during sheath collapse where quasi neutrality cannot be satisfied through negative ions confined to the time averaged plasma bulk region.

The determination of absolute atomic oxygen densities is of particular interest for the dynamics of plasma chemistry, energy transport mechanisms, and technological applications. A variety of advanced optical and numerical techniques show very good agreement for absolute values and spatial profiles along the plasma channel towards the effluent region.

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Poster

Raman amplification in plasma: thermal effects and damping

J. Farmer, B. Ersfeld, D. Jaroszynski

University of Strathclyde, Department of Physics, 107 Rottenrow East, Glasgow, G4 0NG, UK

Raman amplification in plasma is a potential method for the amplification and compression of ultra-short, ultra-intense laser pulses, without the need for compression gratings, which become large and expensive at high powers. However, while plasma has the ability to withstand very high intensities, the associated thermal effects can have a significant impact on the amplification mechanism.

This work studies the role of these thermal effects, and includes suggestions on how they might best be ameliorated, or how they can be taken advantage of and be beneficial. Both collisional damping and Landau damping will be considered, in addition to the Bohm Gross shift of the plasma resonance at finite temperatures.

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