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AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING

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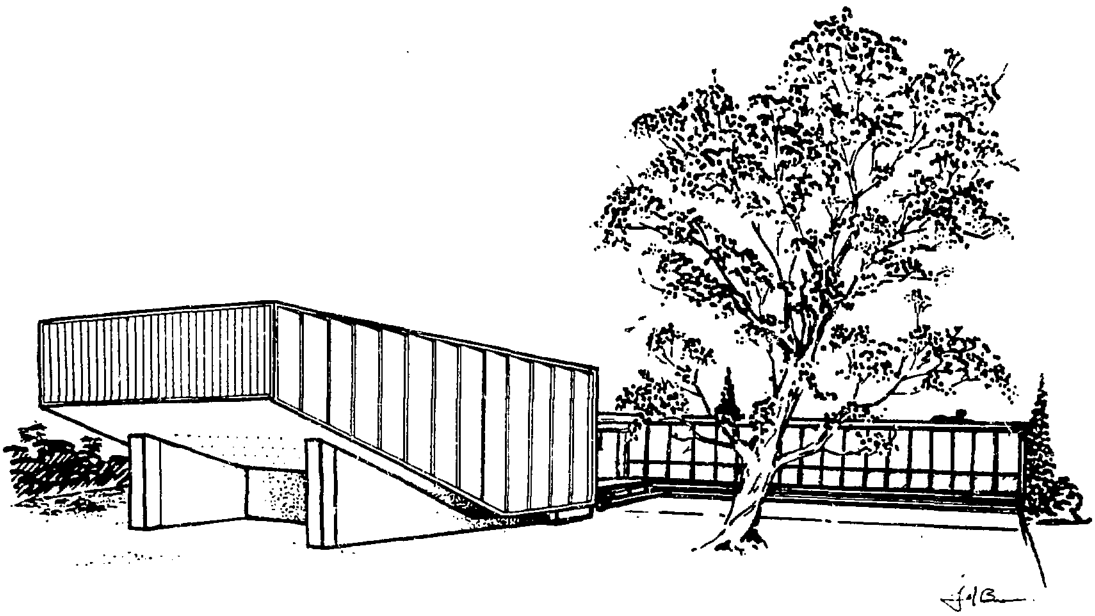
17th AINSE PLASMA PHYSICS CONFERENCE

6th - 8th FEBRUARY, 1989

LUCAS HEIGHTS - AINSE THEATRE



CONFERENCE HANDBOOK

(Programme, Abstracts and General Information)

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AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING

17TH AINSE PLASMA PHYSICS CONFERENCE, 1989

LUCAS HEIGHTS N.S.W.

Monday 6th February, 1989	Commencing	10.30 a.m.
	Conference Luncheon	12.30 - 1.30 p.m.
	Forum	8.00 p.m.
Tuesday 7th February, 1989	Commencing	9.00 a.m.
	Concluding	6.40 p.m.
	Conference Dinner	6.40 p.m.
Wednesday 8th February, 1989	Commencing	9.00 a.m.
	Concluding	4.10 p.m.

Conference President

Professor S.C. Haydon	University of New England

Conference Committee

Professor S.C. Haydon	University of New England
Professor M.H. Brennan AO	University of Sydney
Dr. J.W. Boldeman	ANSTO
Dr. I.J. Donnelly	ANSTO
Professor S.M. Hamberger	Australian National University
Professor I.R. Jones	Flinders University of S.A.
Dr. B. Luther-Davies	Australian National University
Dr. R.B. Gammon	AINSE

Conference Secretary

Ms J. Watson	AINSE

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Professor R.C. Collins
Professor M.H. Brennan
Professor I.R. Jones
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ABSTRACTS

THE GREAT STELLARATOR REVIVAL

by

S.M.Hamberger

Plasma Research Laboratory
Research School of Physical Sciences
The Australian National University
Canberra, Australia

Abstract

The clear demonstration in the 1970's that properly built stellarators confine plasma at least as well as tokamaks of comparable size, but without their inherent problems, led to renewed interest in building larger and better equipped devices capable of achieving stable equilibria at significantly higher β. Two new fairly advanced devices of roughly similar scale (R ~ 2 m), but based on greatly different confinement philosophies have recently been commissioned (ATF at ORNL, WVII-AS at Garching). A third, somewhat smaller one (R ~ 1 m) built very quickly by Japanese industry (CHS at Nagoya) also started up during 1988.

Accompanying this has been much experimental and theoretical activity directed towards selecting the best features of current-free toroidal systems from the enormous range possible, e.g. to examine the roles of transform, shear, magnetic well, by varying the helical harmonic content of the confining magnetic fields. Specially designed experiments include the two flexible heliacs, H-1 in Canberra and TJ-II in Madrid (with SHEILA as the prototype).

Plans are already at an advanced stage for two very large superconducting devices: LHS (Japan, R ~ 5m) an 'optimized' planar axis torsatron, will form the centrepiece for the main Japanese university-based fusion effort, while WVI-X (R ~ 6m) planned for Garching is based on a sophisticated variant of the heliac. Both are expected to demonstrate $\langle\beta\rangle > 5\%$.

Closely associated with all this work have been significant developments in theoretical and computational methods for modelling the inherently 3-D plasma behaviour. These all make extensive use of supercomputers.

FAST ALFVEN EIGENMODES IN THE TORTUS TOKAMAK

by

Mark Ballico

Plasma Physics Department, University of Sydney

Abstract

Fast Alfven cavity modes have been observed in tokamak devices for many years, but mode identification has not been easy. A large number of probes is required to identify unambiguously both the toroidal (n) and poloidal (m) mode numbers. Probe arrays are commonly used to identify low frequency MHD modes, but have not yet been used to identify high frequency Alfven modes. Recent theoretical results [1,2] show that almost all fast wave cavity modes, previously observed in small tokamak devices, are surface waves. These modes are confined to propagate in the plasma edge region, and are therefore prime suspects for edge heating in ICRF heating experiments.

An attempt is being made in TORTUS to identify the spectrum of high Q, fast Alfven modes which are observed at frequencies above the ion cyclotron frequency. A multichannel probe array has been installed, together with a wide band, multichannel phase detector to measure the n and m mode numbers. The array will also provide information on toroidal effects and effects of mode splitting due to the plasma current. An interesting theoretical prediction [2] is that high m modes are so widely split that they propagate in only one direction around the torus.

References

[1] M.J. Ballico and R.C. Cross (1989) Fast Alfven eigenmodes in a cylindrical, inhomogeneous plasma *Plas. Phys. Contr. Fusion* in press.

[2] M.J. Ballico and R.C. Cross (1989) ICRF spectrum of fast Alfven eigenmodes in a cylindrical, current-carrying plasma, *Phys. Fluids* in press.

ELECTRON-BEAM MEASUREMENTS OF THE MAGNETIC SURFACES IN SHEILA

by

T. Y. Tou, B. D. Blackwell, and L. E. Sharp,

Plasma Research Laboratory,
Research School of Physical Sciences,
The Australian National University,
Canberra, Australia.

Abstract

A simple, cost-effective image-intensifying fluorescent probe and subminiature two-element electron gun have been developed and used in the heliac SHEILA to map its magnetic surfaces. A CCD imaging camera, with 128x128 pixel arrays, is employed to record the visible electron-beam image as the probe is scanned over a fixed minor cross sectional plane, at $\phi = 120^o$. For the results presented, the spatial resolution is about 0.75mm and as many as 35 images, which correspond to 35 toroidal transits, can be obtained to produce a Poincaré plot of the magnetic surface. A great advantage of being able to enhance the image-brightness with our fluorescent probe lies in the lowering of the electron-beam energy ($\leq$ 10eV) which is neccesary for minimizing the deviation of the measured magnetic surface from its true one.

Time-of-flight measurements are also carried out with some slight variations to the experimental setup. The time-resolved information, together with the spatial distribution of the visible electron-beam images, enables calculation of the rotational transform of the magnetic field line.

Owing to a small horizontal displacement of the center conductor and the helical winding, error fields are produced which have detrimental effects on the he magnetic surfaces[1]. The measured magnetic surfaces are shown to agree reasonably well with the computed results.

References

[1] X. H. Shi, S. M. Hamberger, and B. D. Blackwell, Nucl. Fusion 28, 859(1988).

DRIFT WAVE STUDY IN SHEILA HELIAC

by

X.H. Shi, B.D. Blackwell, and S.M. Hamberger

Plasma Rerearch Laboratory
Research School of Physical Sciences
Australian National University

Abstract

An experimental study of the density fluctuations in a new type of helical axis stellarator known as a heliac is reported. The experiments are conducted in the prototype heliac 'SHEILA' [1], (major radius 0.19 m, average minor radius 0.03 m), at modest plasma density and temperature and in various gases. This study is based mainly on the use of Langmuir probes, mostly under conditions where the fluctuations are coherent.

The measured parameter dependence of the fluctuations, e.g. upon the magnetic field and the electron collision frequency, suggests that the modes are collisional drift waves. Detailed harmonic analysis of the probe data is performed in a magnetic coordinate system and shows close correspondence between the dominant mode number (m,n) and the rotational transform over a wide range of configurations. An analytic dispersion relation for global modes derived from a linearized two-fluid theory [2] is used to compare with the experimental results. To enable this comparison, the complicated geometry of the heliac configuration is approximated as a periodic cylinder with an average radius defined for each flux surface. A remarkable agreement has been found between the theoretical predictions and the experimental results measured for all configurations studied.

It has also been noted that there is considerable degradation in particle confinement with the appearance of the coherent fluctuations. The estimated particle loss rate due to fluctuations is about one fouth of the total particle loss rate.

References

[1] Blackwell, B.D., Hamberger, S.M., Sharp, L.E., and Shi, X.H.,
To be published in Australian Physics Journal, 1 (1989).
[2] Fredrickson, E.D., and Bellan, P.M.,
Phys. Fluids. **28** (1985) 1866.

ECRH EXPERIMENTS ON THE SHEILA HELIAC

by

G.D.Conway, B.D.Blackwell, and S.M.Hamberger

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Research School of Physical Sciences
Australian National University
Canberra, Australia

Abstract

Recent theoretical studies [1] have predicted good ECRH absorption profiles in a flexible heliac which are independent of the density profile.

We have applied 2kW (10ms pulse) of ECR power at 2.45GHz to both hydrogen and argon plasmas confined in the SHEILA heliac [2]. Strong absorption has been observed at both the fundamental and the second harmonic under a variety of operational conditions. Depending on the position of the resonant field layer and other parameters, either peaked or hollow density profiles are observed.

Densities up to cutoff (7.4 x 10^{10} cm^{-3}) are easily obtained with a helical launching antenna positioned on the low field side. Employing conforming profile dipole antennae in contact with the plasma can produce overdense plasmas ≈2 orders of magnitude above cutoff.

The injection of ECR power in conjunction with the existing ohmic/RF breakdown (400W at 96kHz) has extended the operational range of the machine, including field configurations previously inaccessible to the RF alone.

References

[1] Alejaldre C. & Guasp J. ; Nucl. Fusion, 27 (1987) pp.2153-2160
[2] Conway G.D. (1988), Design report, ANU-PRL-TR 88/2; See also accompanying paper this conference.

ALFVEN WAVES IN TORTUS

by

R. C. Cross

Plasma Physics Department, University of Sydney

Abstract

Alfven waves have been used with spectacular success in large tokamak devices to heat plasmas to temperatures exceeding 5 keV. The waves are usually heavily damped and deposit most of their energy in cyclotron or ion-ion hybrid resonance layers near the centre of the plasma. TORTUS is a much more modest device and the emphasis to date has been on the physics of wave propagation rather than heating.

A wide variety of Alfven wave modes has been observed in TORTUS. This review summarises results obtained at frequencies above and below the ion cyclotron frequency, in single and two ion species plasmas [1-7]. Attention has been focussed mainly on (i) Alfven wave resonance damping of the fast wave, (ii) guided propagation of the shear and ion-ion hybrid waves, (iii) fast wave cavity modes and (iv) shear wave cavity modes.

References

[1] M.J. Ballico, M.H. Brennan, R.C. Cross, J.A. Lehane and M.L. Sawley (1988) A comparison of shielded and unshielded antennas for Alfven wave heating in a tokamak, *Plas. Phys. Contr. Fusion* **30**, 1331.

[2] M.J. Ballico and R.C. Cross (1989) ICRF spectrum of fast Alfven eigenmodes in a cylindrical, current-carrying plasma, *Phys. Fluids* in press.

[3] G.G. Borg and R.C. Cross (1987) Guided propagation of Alfven and ion-ion hybrid waves in a plasma with two ion species, *Plas. Phys. Contr. Fusion* **29**, 681.

[4] R.C. Cross (1988) Propagation of torsional Alfven waves in an inhomogeneous plasma, *Plas. Phys. Contr. Fusion* **30**, 1213.

[5] R.C. Cross (1989) Torsional Alfven modes in dipole and toroidal magnetospheres, *Planet. Space Science* in press.

[6] R.C. Cross (1988) *An introduction to Alfven waves*, Adam-Hilger, Bristol.

[7] A.B. Murphy (1989) Direct excitation of the torsional Alfven wave in a tokamak scrape-off plasma by a Faraday shielded antenna, *Plas. Phys. Contr. Fusion* in press.

Submillimetre laser scattering from TORTUS

by

M.D.Bowden, B.W.James and M.J.Ballico

Plasma Physics Department, School of Physics, University of Sydney, NSW 2006, Australia.

ABSTRACT

A submillimetre laser scattering diagnostic has been set up on the TORTUS tokamak using an optically pumped HCOOH laser operating at 433 μm as the radiation source. The system is designed to study electron density perturbations in the plasma, with emphasis on those density perturbations associated with Alfven wave heating.

Preliminary observations of scattering from these density fluctuations have been made. The scattering system allows the probing laser beam to be moved across the minor radius of the tokamak and results showing laser scattering from different radial locations have been obtained.

These results can be compared with the theory of Alfven wave propagation in a tokamak plasma.

SCATTERING FROM ALFVÉN WAVES USING A GYROTRON

by

G.F. Brand, P.W. Fekete, and K.J. Moore

Plasma Physics Department
School of Physics
University of Sydney, N.S.W., 2006

Abstract

A scattering system using millimetre waves has been developed to investigate density perturbations associated with RF heating of the TORTUS tokamak plasma. The source used was Gyrtron III (1) and provides about 10W of cw power over the frequency range 75 to 330 GHz (4.0 to 0.9 mm).

A quasi-optical, or Vlasov, antenna consisting of a step launcher and a parabolic reflector is used to produce a well collimated, linearly-polarized beam to pass through the tokamak plasma (2). A detection system employing a crystal diode detector and quadrature RF mixing techniques is used. The amplitude A and phase θ of the detected signal at the radio frequency are calculated.

A 60 kW RF pulse (launched at 3.2 MHz) is applied to three pairs of antennas located at different toroidal positions on the tokamak. A fast Alfvén wave is excited in the plasma and mode conversion to a kinetic Alfvén wave occurs at a resonance surface (3).

A strong scattered signal has been observed when the RF is turned on and correlates well with magnetic probes positioned at various toroidal locations. This paper presents some of those results.

References

[1] G. F. Brand 'Tunable Gyrotrons' in INFRARED AND MILLIMETER WAVES (ed. K. J. Button, Academic Press) Vol. 14, pp 371-408 (1985).

[2] S. N. Vlasov and I. M. Orlova, Radiophysics and Quantum Electronics, 17, 115-119 (1974).

[3] D. W. Ross, G. L. Chen and S. M. Mahajan, Phys. Fluids, **25**, 652 (1982).

Experimental Studies of Parametric Decay Instability in the WOMBAT Apparatus

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Abstract

Experimental results on the resonant decay of a fundamental Bernstein wave into a daughter Bernstein and whistler waves are presented. The experiments are carried out in the WOMBAT apparatus which is a large linear system with base pressure around 10^{-6} Torr and working pressure p_0 around 5×10^{-4} Torr. The uniform magnetic field along the axial direction has a standard value of 36 G. The plasma is generated in hydrogen using RF at 72 MHz and has $T_e \sim 3$ eV and $n_e \sim 5 \times 10^8$ cm^{-3}. The electron-neutral collision frequency is $\nu_{en} \sim 10^5$ Hz. Both the transmitter and the receiver antennas are cylindrical probes parallel to the external magnetic field.

The resonant decay process is observed when the pump frequency is near 1.3 ω_{ce} and the plasma frequency is between 2 to 3 ω_{ce}. The pump power at threshold is measured under different, well-controlled conditions. For the standard conditions (p_0=5 $\times 10^{-4}$ Torr, $\omega_{ce}/2\pi$=100 MHz and $\omega_{pe} \sim 2.2\ \omega_{ce}$), the threshold power is $P_{th} \sim 50$ mW. Increase of fast electron (E $\geq$ 30 eV) current is also detected by an electron energy analyser when the pump power is above the decay threshold. The electron acceleration is possibly caused by damping of the whistler wave, since its phase velocity may be close to the electron thermal velocity ($\omega/k \sim v_{th}$).

Antenna Coupling Calculations for BASIL II

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Abstract

BASIL II is a 1.5 m long, 50 mm diameter argon plasma in a uniform magnetic field. The plasma is generated by inductively coupling rf power through a 250 mm long helicon antenna. Landau damping, of the excited $m = 1$ whistler/helicon waves, heats the electrons. Experimentally, enhanced coupling occurs when the driving frequency is around the lower-hybrid frequency.

Conventional methods treating the antenna by a finite element method and solving the fourth order differential equation numerically, are complicated and tedious. We solve the antenna coupling problem in Fourier space. This allows us to take advantage of the symmetry of the system and the natural modes of the plasma column. Our method can solve the antenna coupling problem for any arbitrary antenna in a cylindrical plasma column.

We have modelled the interaction of the actual antenna used in BASIL II with a uniform plasma column. The power deposition profiles are calculated as functions of azimuthal mode number.

ROTAMAK RESEARCH 1987/88

by

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Abstract

This talk will concentrate on two experimental investigations which have been completed during the period under review.

1. A set of scaling experiments which were made using the ANSTO rotamak. These experiments identified the dominant role played by the toroidal current in determining the plasma confinement properties and, most importantly, they showed that these properties are not grossly affected by the presence of the rotating magnetic field.

2. An experiment in which the rotating magnetic field method of driving current was used to produce and maintain a highly prolate compact torus configuration. The observed equilibrium could be described by the Solov'ev solution of the Grad-Shafranov equation. The opportunity was taken to investigate the current drive mechanism which was operative in the experiment. Results showed that the standard theoretical model of rotating field current drive was capable of providing a quantitative description of the situation.

CURRENT DRIVE AND CONFINEMENT IN THE ANSTO LARGE GLASS VESSEL

by

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Abstract

Prior to the termination of the rotamak program at ANSTO, experiments were commenced in a large glass cylindrical vessel (diameter 60 cm, length 80 cm) using the existing rf amplifiers (maximum total power of 200 kW). Typical parameters of the hydrogen plasmas produced are $I_{tor} < 1.5$ kA, $n_e \approx 5 \times 10^{11}$ cm^{-3}, $T_e \approx 22$ eV.

Even allowing for the reduced rotating magnetic field amplitude (typically 4-6 G without plasma) and significantly lower rf power density, marked differences have been observed between this experiment and previous rotamak devices. In particular, the strong linear dependence of driven current on the applied vertical field is no longer evident. The presence of aluminium end-plates with a relatively long time-constant (43 ms for the fundamental mode, as compared to an rf pulse length of 35 ms) disturbs the shape of the applied vertical field and has a remarkable effect on the discharges. In some conditions, current drive can be completely suppressed, and although this is not a desirable state, it allows a direct comparison to be made of the confinement properties of discharges with and without toroidal current.

We attribute our observations to the excitation of low-order whistler waves which have eigenfrequencies close to the rf frequency (1 MHz) in the low density plasmas produced in the large vessel. These whistler modes have a strong influence on the distribution of the rf fields and the time-averaged force that drives the toroidal current. Unlike previous rotamak devices without toroidal field, the rf fields and driven current are not confined to the edge of the plasma. Given the small magnitude of the steady magnetic fields (20 G maximum), the wave excitation problem is highly non-linear and also complicated by the conducting end-plates. Under these conditions, the radial confining force resulting from the interaction of the rf fields is significant and may explain some of the peculiarities of the configurations produced.

LOCALISED CO-INTERCHANGE INSTABILITIES IN A ROTAMAK PLASMA

by

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Abstract

Ideal MHD theory predicts that a field reversed configuration (FRC) is unstable to local modes with very short wavelengths in the toroidal direction. The fastest growing modes are the high m modes (m is the toroidal mode number) investigated by Newcomb [1]. These instabilities correspond to helical deformations of the flux tubes in the vicinity of the magnetic axis and have been referred to in the literature [2] as localised co-interchange modes.

The rotamak is basically an FRC in which the steady toroidal current is maintained by a rotating magnetic field and which for its theoretical description relies on the inclusion of the Hall term $\underline{J}\times\underline{B}$, in Ohm's law.

In this paper we investigate the effect of including this term in the ideal MHD analysis of the co-interchange modes. It is shown that for a typical rotamak plasma the Hall term cannot be simply ignored. Its inclusion leads to a stability criterion for the high m co-interchange modes. Using plasma parameters from past rotamak experiments, the stability criterion indicates that all experimental rotamak plasmas used up to now are stable to the short wavelength co-interchange modes.

[1] W.A.Newcomb, Phys. Fluids 23, 2296 (1980)

[2] J.L.Schwartzmeier et al. Phys. Fluids 26, 1295 (1983)

RMF CURRENT DRIVE IN CYLINDRICAL PLASMAS - THE SAGA CONTINUES

by

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Abstract

Analytical results are presented for the current driven in a cylindrical plasma by a rotating magnetic field (RMF). All but the first harmonic are neglected for oscillating quantities. The number density n is assumed to be either uniform or determined by the radial pressure balance equation (assuming uniform temperature), including the ponderomotive term.

For uniform n, Hugrass (*Aust. J. Phys.* 38 (1985) 157) found numerically that for $\lambda = R(\mu_0\omega/2\eta)^{1/2} \gtrsim 6$, multiple solutions exist for $\gamma = B_w/ne\eta \approx \lambda$, where a rapid transition from low to high current drive occurs. The nature of this multiplicity is explored, and the transition is shown to occur at $\gamma = 3^{1/4}\lambda$ for high λ. For arbitrary λ and γ, it is shown that the power P_n and current α_s, normalised by their values for an azimuthal current synchronous with the RMF, satisfy $\alpha_s \lesssim P_n \lesssim \alpha_s(2 - \alpha_s)$.

For non-uniform n, the limits of large and small γ can be solved analytically. For large γ, when near-synchronous current is driven, n depends exponentially on the axial flux and has a peak at $2^{-1/2}$ times the separatrix radius. For small γ and large λ, equilibria exist with the plasma contained solely by the RMF.

Electron inertia is shown to significantly reduce current drive for $\gamma < \lambda$ when ω/ν_{ei} is large.

A THEORETICAL STUDY OF RF CURRENT DRIVE IN THE ROTAMAK

by

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Abstract

We will discuss the two forms of RF current drive employed to date in Rotamak experiments, namely rotating magnetic field (RMF) and oscillating magnetic field (OMF) current drive. Results will be presented of a detailed analytical investigation, using an immobile ion model and spherical geometry, of the RMF scheme in the small RF field limit. We will show how the toroidal plasma current arises and in addition how poloidal currents generate a bi-directional toroidal field and why the plasma forms a poloidal flux doublet under some circumstances.

It will be shown that OMF current drive can be understood in terms of the results of RMF current drive in the limit of small applied RF field. In particular we will discuss the generation of a toroidal plasma current and a bi-directional toroidal field using the OMF scheme.

PLASMA DRIVEN MHD POWER PLANT

by

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Abstract

Magnetohydrodynamic power generation is a process where fluid flow energy is converted directly into electricity by applying a magnetic field and electricity is extracted by inserting electrodes. Various fluid media and geometrical arrangements may be used. The most advanced system involves a linear flow channel.

Technical feasibility for large-scale power generation has been established and commercialisation is being considered using a fossil fuel fired open-cycle linear channel geometry. However, alternative approaches offer various advantages. This includes indirectly fired closed-cycle MHD operation using noble gases as drivers. Disk generators have emerged as possible economical alternatives.

A major problem facing the eventual application and use of MHD plant in power systems is the need to satisfy operating requirements set by normal power systems. These cover steady-state and transient performance, as well as the response under fault conditions. Another critical factor is the reliability and availability of MHD plant if it is to be used to provide continuous base load. Since MHD generators, as envisaged now, generate d.c. power, it is necessary also to include inverter systems in any detailed analysis. The paper discusses the operating requirements imposed on MHD plant and its present status.

References

[1] M. Petrick et al., (Editors). A joint USA/USSR publication. Published by Argonne National Laboratory, Argonne, Illinois (1978), pp. 707.
[2] Proceedings of the Specialist Meeting on Coal-Fired MHD Power Generation, National Conf. Publ. No. 81/13, Inst. of Engineers, Australia (1981), pp. 1.1.1-7.6.7.
[3] Proceedings of the 8th International Conference on MHD Electrical Power Generation, Vol. I to VII, Moscow (1983).
[4] H.K. Messerle et al., Proceedings of the 26th Symposium on Engineering Aspects of Magnetohydrodynamics, Nashville, Tennessee (1988), pp. 7.3.1-7.3.5.

LASER DOPPLER MEASUREMENTS OF CORONA WIND VELOCITY

by

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Abstract

In corona discharges generated in point-plane electrode geometry, ions accelerating away from the point electrode in the region of high electric field transfer their momentum to the gas molecules. As a consequence, an axial corona wind is generated with a velocity of a few metres per second.

We have assembled a differential laser Doppler system for measuring corona wind velocities and have used it to study open air positive and negative coronas. Details of the system will be described including the method whereby the coronas are seeded with light scattering particles. Profiles of corona wind velocity will be presented and discussed.

THE STREAMER TO GLOW TRANSITION IN THE POSITIVE AIR CORONA

by

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Abstract

In atmospheric air, positive coronas, as generated by a standard point-plane electrode configuration, may occur in the form of repetitive filamentary discharges extending from the anode toward the cathode and carrying currents of the order of tens of mA. Such discharges are called positive streamers and are found to occur with a frequency of kHz. Alternatively, under some discharge conditions, a diffuse glow may occur adjacent to the anode tip providing a dc current of the order of 10 μA: this discharge is called a glow corona. The occurence of these two types of corona under differing gap conditions has been well documented.

Closer examination reveals that under conditions favouring the existence of a glow corona, the formation of the glow is always preceded by the occurence of a single streamer. The delay between the conclusion of the streamer and the establishment of the glow is around 200 μs.

We are undertaking an examination of the conditions which determine whether continuing streamers or a streamer-to-glow transition is obtained. The study involves time-resolved measurements of discharge current and luminosity, and includes the development of a schlieren technique to examine the movement of positive ions away from the point anode after a streamer pulse.

Preliminary results indicate that point geometry and humidity play significant roles in controlling the streamer-to-glow transition.

VIBRATIONAL AND PENNING-TYPE INFLUENCES OF IMPURITIES ON EXCITATION AND IONIZATION IN NITROGEN

by

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Abstract

Following extensive examination of the influence of carbon monoxide on ionization growth in N_2, further studies have been undertaken with trace impurities of O_2, CO_2 and Ne.

Each of these studies has provided new information on the possible role of vibrationally excited long-lived metastable states on both the magnitude and temporal characteristics of ionization in the principal gas.

Evidence of the importance of Penning processes appeared with increasing amounts of neon.

These results will be presented and the potential importance of the observations for future applications will be discussed.

References

(1) M. Elford et al., Contributed to Joint Symposium on Swarm Studies, Granlibakken, Lake Tahoe, U.S.A., July 19-23, 1985.
(2) A. Ernest et al., Aust. J. Phys. 39: 479-96 (1986)
(3) A. Ernest et al., Proc. XVIII Inth Conf. Phenomena in Ionized Gases, Swansea, 82-83 (1987)

SPECTROSCOPIC MEASUREMENTS OF THE ENERGY OF SPUTTERED COPPER ATOMS

by

G.M.Turner, I.S.Falconer, B.W.James, and D.R.McKenzie

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Abstract

Magnetron sputtering discharges are widely used in the manufacture of thin films for solar collector tubes and semiconducter devices (including solar cells). The energy of the condensing atoms at the substrate surface is important in determining the structure, and thus the properties, of these deposited films.

We have performed Monte Carlo simulations of the thermalisation process of sputtered atoms and calculated the velocity distributions of these sputtered atoms at various filling gas pressures[1]. The average energy calculated form these distributions duplicates the trend observed in previous experimental measurements of the average energy of sputtered atoms as a function of gas pressure[2]. However, direct comparison is limited due to the scatter and uncertainties in the experimental data.

The line profile of the 510.6 nm emission from neutral Cu atoms sputtered in a cylindrical magnetron discharge has been measured using a modification of the spectroscopic technique employed in the previous work. A high resolution Fabry-Perot scanning interferometer has been used to obtain line profiles, which were recorded on a computer and averaged to increase the signal to noise ratio. The distribution of velocity component of sputtered atoms in the direction of observation was deduced from the deconvolution of the hyperfine structure of this spectral line and the instrumental function of the interferometer from the measured line profile. These distributions and the average energy estimated from them are compared with those calculated using the Monte Carlo code.

References

1. G.M.Turner, I.S.Falconer, B.W.James, and D.R.McKenzie, *J. Appl. Phys.*, to be published.

2. L.T.Ball, I.S.Falconer, D.R.McKenzie, and J.M.Smelt, *J. Appl. Phys.* **59**, 720 (1986).

Recent Advances in Plasma Processing

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Abstract

In the processing of thin films, a plasma serves two roles. The first is to dissociate a molecular gas into active radicals which can either etch or deposit a thin film. The second is to act as a source of ions which can be attracted to the substrate and change the character of the etched or deposited film.

The production of submicron circuits in the mid 1990's requires precise and independent control of plasma and substrate parameters. A new generation of plasma processing systems is being developed which have these characteristics – one of them originating from the ANU.

The characteristics of these systems will be described and their advantages over present systems discussed. The plasma physics problems in plasma processing such as plasma-wall interactions and the possibility of modelling will be mentioned.

EFFECTS OF PLASMA CONFINEMENT ON DEPOSITION AND ETCH RATES

by

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Abstract

Film formation and etching is often performed in radio-frequency discharges using "plasma" or "reactive sputter etching" processes. In such processes, often system voltages must be held low (e.g., in electronic device fabrication steps). In addition, input power densities must be constrained to avoid substrate overheating. Hence process rate often must be traded off against target voltage and input power to obtain a useable process. A final constraint on discharge operation is the patterning accuracy required; fine patterns typically require low-pressure operation, which results in yet lower rates in typical radio-frequency sputtering ("diode") discharges.

In this paper we present results from this commonly used diode configuration, and compare its behaviour with more confined systems using CF_4 gas. Such confinement is obtained with both mechanical (1) and electronic (2) barriers to the escape of active discharge components. Step-by-step discharge confinement results in progressive improvements in its operating characteristics. The best performance is obtained with a target-confined hollow cathode, which yields (at 2.2 Pa CF_4 pressure) an etch rate at least 3 times higher than that of a diode, for a given input power density. At a fixed target voltage, the etch rate is 10 times higher than in the simple diode. At lower pressures, yet larger improvements are obtained.

We also present data from silane deposition discharges, demonstrating the general applicability of these findings.

References

[1] K.E. Davies, Diode and Hollow-Cathode Etching in CF_4, J.Vac.Sci.Technol. (submitted).

[2] C.M. Horwitz, Silicon Deposition in Diode and Hollow-Cathode Discharges, J.Vac.Sci.Technol. (to be published).

ION BOMBARDMENT IN RADIO-FREQUENCY GLOW DISCHARGES

by

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Abstract

Radio-frequency discharges are widely used for the deposition and etching of thin films. Consequently rf discharge behaviour is of great interest; in particular, knowledge of the ion current density and ion energy at a bombarded target would permit meaningful calculations of target processes to be made. Quantitative ion current density measurement is difficult due to the long ion path lengths in typical ion energy analysis systems, which limit the acceptance angle and so exclude a portion of the incident ion flux. In addition, such analysis is difficult on a high-potential radio-frequency electrode. Consequently ion analyses are typically made at a grounded less-heavily bombarded electrode (e.g., ref.1). There has been no data taken on ionic fluxes at target electrodes.

Here we report on results from a short path-length retarding analyser which is capable of excellent quantitative ion current measurements. This analyser has been attached to an inverted radio-frequency discharge chamber in which the target is grounded. Our apparatus has low errors from secondary particle generation, and permits analysis of both the electron and ion energy distributions. Comparison with known dc discharge distributions gives good agreement, and our apparatus is not affected by sampling orifice size variation, as is often the case.

We have found that the current density in a 4 Pa Ar discharge exhibits good agreement with Child-Langmuir space-charge limited predictions for sheath size. The ion energy distribution is more uniform than in the dc discharge case, implying far fewer resonant charge-exchange collisions. We have also tested hollow cathode behaviour, and found that the smaller sheath sizes correlate with higher ion current densities, for a given input voltage, than in the diode. Pressure and voltage dependencies are also in agreement with measured etch rate dependences.

References

(1) J.W. Coburn, E.Kay, J. Appl.Phys. 43, 4965 (1972).

Simulation of a RF Parallel Plate Discharge

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Abstract

The electrostatic low-pressure parallel-plate rf discharge is studied by solving Poisson's equation

$$\frac{d^2\phi}{dx^2} = \frac{e}{\varepsilon_0}(n_e - n_i)$$

and Newton's equation

$$m_s\frac{d^2x}{dt^2} = e_sE$$

self-consistently using the particle-in-cell technique with non-periodic boundary conditions [1]. The boundaries are perfectly absorbing although secondary electron emission due to ion or electron impact can be included without difficulty. Since the ions are allowed to move and can be lost at the boundaries, ionizing collisions must be included so that a steady-state can be achieved.

The plasma in this simulation is maintained by a process known as 'sheath heating' [2] which occurs when electrons are acclerated by the moving rf sheath. We have studied the details of the interaction between the electrons and the sheath and the power dissipated in the discharge as the rf voltage on the boundary is varied. A simple scaling of the dissipated power

$$P \propto V_{rf}^2$$

is obtained and its relationship to the electron-sheath interaction is discussed.

References

[1] R. W. Boswell and I. J. Morey, *Appl. Phys. Lett.* **52** 21 (1988)

[2] V. A. Godyak, *Sov. Phys. Tech. Phys.* **16** 1073 (1972)

REVIEW OF TECHNIQUES FOR FLUCTUATION MEASUREMENTS

by

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Abstract

It is now widely accepted that collective plasma fluctuations affect confinement: this has led to a world-wide revival of interest in improving and extending the range of experimental techniques proposed for their study, and to some confusion over their relative merits and interpretation. By considering the general problem of forward scattering from an inhomogeneous medium we have been able to obtain a unified description which covers the wide variety of techniques used and known by many names. These include Bragg-angle scattering, light-beating spectroscopy, shadowgraphy, far-forward scattering (based on fourier optics) and the various derivatives of interferometry including phase-scintillation and phase-contrast methods. The different detection and signal processing methods have also been investigated.

The principal conclusion of this study is that for detailed three-dimensional reconstruction of the scattering medium it is necessary to use tomographic techniques (i.e. measurement of the medium at many viewing planes) with the measurement performed either in the ultra-near field, where a contact phase-image of the medium can be obtained, or in the far field where the wavenumber spectrum is directly measured in the detector plane. For random media which are characterized by their spectral properties, the preferred measurement uses the far-field approach, while for coherent structures the contact-image method provides the best information. This description is, of course, not limited to plasma but is applicable to any media whose fluctuating properties impress phase changes on a probing beam.

A COMPARISON OF MULTI- AND SINGLE-MODE C.W. LASER-INDUCED PERTURBATIONS OF THE 1S5 STATES IN NEON

by

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Abstract

Multi-mode perturbation techniques revealed the quenching action of highly-tuned laser radiation on the 1S5 metastable level of neon. These preliminary results have now been supplemented with a single-mode investigation of the same perturbation, enabling a comparison to be made of the responses of each mode-configuration to changes in the power output level of the laser. These investigations have highlighted the need for further studies with an appropriate single-mode facility.

References

(1) Wang Yumin et al., Proc. XVIIIth Int. Conf. Phenomena in Ionized Gases Swansea, U.K., (1987) p.214.

LASER INDUCED FLUORESCENCE ON THE TORTUS TOKAMAK

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Abstract

The result of an extensive series of measurements of laser induced fluorescence on the TORTUS tokamak will be presented.

A flashlamp pumped dye laser tuned to the H_α transition was used to excite the fluorescence, and the absolute intensity of the H_α emission measured as a function of plasma radius. From these measurements and concurrent submillimetre laser interferometer measurements of the electron density profile the neutral density profile was calculated from a collisional-radiative model.

Measurements of the fluorescence lineshape with a pressure scanned Fabry-Perot interferometer suggested that the atom temperature was significantly lower than the value obtained from emission lineshape measurements.

An investigation was also made of emission at the H_β wavelength as a function of radius when the atoms were excited at the H_α wavelength.

Session VII Tuesday 2.20 - 2.40 p.m.

MULTI-VIEW SCANNING INTERFEROMETER FOR THE H-1 HELIAC

by

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Abstract

A novel scanning far infrared interferometer, proposed for installation on the H-1 heliac, is presented and described. Using three detectors, the device will be capable of producing up to 20 chordal measurements (multiplexed in time) in each of at least two orthogonal views of the plasma.

TOMOGRAPHY OF SOFT X-RAY EMISSION ON LT-4

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Abstract

Certain a priori constraints strongly stabilize the inversion of chord averaged soft X-ray emission on the LT-4 tokamak to enable time and space resolved measurements of the emission to be obtained. Reconstructions show clearly strong and coupled MHD activity prior to, and throughout density limit minor disruptions and sawtoothing discharges.

A film depicting the time evolution of a discharge exhibiting a sequence of minor disruptions will be presented.

A REVIEW OF RF CURRENT DRIVE

by

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Abstract

Radiofrequency current drive can proceed either by an interaction of the wave fields with a resonant group of electrons, as exemplified by lower hybrid current drive, or by the wave fields exerting a force on the electron fluid as a whole, as occurs in the <jxb> current drive mechanism. Both approaches have been used successfully, the former in tokamaks and the latter in both tokamaks and rotamaks. In this review I will outline and compare the physics of each process, and summarise recent advances.

GENERALIZATION OF THE NEWCOMB EQUATION TO HAMILTONIAN FORM

by

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Abstract

The importance of the resistive modes which are often responsible for major disruptions in fusion devices, leads us to extend the PEST2 code [1] to the treatment of resistive instabilities.

According to the small resistivity limit [2], the ideal marginal MHD equation for linearized displacements is obtained outside narrow inner layers at the rational surfaces. The so called generalized Newcomb equation is a generalization to two-dimensional geometries [3,4] of Newcomb's [5] form of the Euler-Lagrange equations in a cylindrical plasma. By defining a momentum-like quantity, it becomes possible to write the generalized Newcomb equation into Hamiltonian form [6]. The Hamiltonian form generates a whole class of equivalent equations related to each other by symplectic transformations.

An application of the symplectic transformation is the reduction of the generalized Newcomb equation to Newcomb's form in cylindrical geometry. Symplectic transformations can also simplify the Frobenius expansion of the solution, leading to the Mercier criterion which appears at the zeroth order of the expansion.

References

[1] R.C. Grimm, R.L. Dewar and J. Manickam, J. Comput. Phys. 49 (1982) p.94.

[2] H.P. Furth, J. Killeen and M.N. Rosenbluth, Phys. Fluids, 6 (1963) p. 459.

[3] M. Bineau, Fusion Nucléaire, 2 (1962) p. 130.

[4] R.L. Dewar, D.A.Monticello and W.N.-C. Sy, Phys. Fluids 27 (1984) p. 1723.

[5] W.A. Newcomb, Annals of Physics 10 (1960) p. 203.

[6] R.L. Dewar, Annual Controlled Fusion Theory Conference (Sherwood Theory Meeting), Arlington, Virginia, Paper 1R24 (1983).

NONLINEAR SIMULATIONS OF WALL LOCKING AND TOKAMAK DISRUPTIONS

by

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Abstract

Stabilization of the m=2/n=1 tearing mode by resistive walls is effective in tokamaks operated at low q when the mode rotates fast compared with the timescale of the wall and the resonant surface of the mode is in the highly conducting plasma. The sharp stability limit at $q_a \cong 2$ observed in many tokamaks can be understood to be a result of the loss of wall stabilization when the q = 2 surface moves out of the plasma [1-2]. An overview of the present understanding of the q-limit is given as well as a discussion of the influence of wall locking on high-q discharges.

References

[1] M. Persson, A. Bondeson, in Theory of Fusion Plasmas, Eds. A. Bondeson, E. Sindoni, and F. Troyon (Editrici Compositori Bologna, 1988) p. 325.

[2] A. Bondeson, M. Persson, Nucl. Fusion 28 (1988)p. 1887.

RESISTIVE MAGNETOHYDRODYNAMIC SPECTRA

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Abstract

This talk will discuss the development of a toroidal, resistive magnetohydrodynamic spectral code, including the modifications necessary to include compressible effects. An exactly soluble model which has been used to test this code has been extended to include viscosity. It is of interest to see the additional stabilizing effect of the combination of resistivity and viscosity.

SPECTROSCOPIC AND IMAGE INTENSIFIED INVESTIGATIONS OF LOW TEMPERATURE DC AND RF PLASMA IN N_2

by

H. Itoh†

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Abstract

Low pressure investigations of DC plasma using plane parallel electrode geometry in nitrogen will be discussed in detail. These plasmas are examined by using spectroscopic image-intensified methods together with computer graphic techniques. Spectroscopic records are obtained as functions of current and pressure over a wavelength range from 300 to 400 nm and ratios of the intensities of the spectral lines $N_2^+(0,0)/N_2(0,0)$ are deduced. The recorded spatial emission lines and ratios associated with the fundamental electron processes, namely excitation and ionization, show clearly the structure of the DC plasma. Measured shapes of the spatial variation of ratios of the intensities obtained in the cathode fall region agree with those calculated by Monte Carlo simulation. Furthermore, the present results are compared with those of previous RF investigations and the difference in the structure of DC and RF plasmas is discussed.

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A THOMSON SCATTERING SYSTEM FOR TORTUS TOKOMAK

by

N Finn

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An ultra-high throughput Thomson Scattering system for measuring plasma electron temperature and density profiles has been constructed. The light source is a 10J in 20ns Ruby laser and the 90° scattered light is collected and spectrally resolved with very high efficiency using a series of unblocked interference filters. Each filter is tilt timed to transmit a narrow band of wavelengths to a PM tube reflecting the rest of the spectrum to the following channels. The pass bands of the filters and the angles of incidence of the Thomson scattered light are chosen to resolve spectra scattered from plasmas with electron temperatures ranging from 20eV to 350eV.

The two main sources of noise: background plasma light and spuriously scattered laser light from vessel windows and walls are reduced by various means. Since typically only 1 in 10^{14} photons is Thomson scattered a small amount of stray light is disastrous. In our apparatus it is minimised by means of light baffles and beam viewing dumps and that which remains is removed by line rejection filters. The Thomson scattered light is polarised while the background plasma light is not and so inclusion of a polariser reduces plasma light by a factor of two. The Thomson scattered signal is integrated for a period equal to the FWHM of the laser pulse only, thus minimising the relative contribution of the plasma light. Another period of integration measures the plasma light alone for later subtraction but the shot noise from this signal remains. The system will be used to diagnose a variety of plasmas on TORTUS tokamak.

ALFVEN WAVE HEATING IN THE TORTUS TOKAMAK

by

Mark Ballico

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Abstract

The Alfven wave heating scheme is being studied in TORTUS using an array of 6 antennas to fix the toroidal (n) and poloidal (m) mode numbers. In this scheme, the fast (compressional) Alfven wave is generated directly by the antennas and the wavelengths in the toroidal and poloidal directions are fixed by appropriate phasing of the antennas. Wave energy propagates from the antennas towards the plasma centre, but mode converts to a shear (or torsional) wave at an Alfven resonance layer where the local wavelength of the shear wave matches the wavelength imposed by the external antennas. The location of the resonance layer can be adjusted to lie anywhere between the centre of the plasma and the edge by appropriate choice of wave frequency or plasma density. At the resonance layer,

$$\omega = k_{\|}v_A = (n + m/q)v_A/R$$

where R is the major radius of the torus, and v_A is the Alfven speed. Wave heating results from Landau damping of the shear wave.

In TORTUS, the antennas are driven at a frequency $f \sim 3$ MHz and at a power level up to 60kW. The power input is determined from measurements of the antenna resistance and the effects of wave heating are determined from measurements of line broadening and by means of a thin film bolometer.

SPECTROSCOPIC MEASUREMENT OF ION AND ATOM TEMPERATURES IN A METAL VAPOUR VACUUM ARC

A Studer B W James and I S Falconer

Wills Plasma Physics Department
School of Physics
University of Sydney NSW 2006 Australia

and

Ian G Brown

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The ion and atom temperatures in the vicinity of the cathode spot of a metal vapour vacuum arc may be determined from measurement of the lineshape of the Doppler broadened spectral emission lines. The lineshape must be accurately measured in order that hyperfine splitting and nuclear shift, and the instrumental function may be deconvolved from the measured lineshape to give the contribution of Doppler broadening to the lineshape. Previous measurements using a scanning Fabry-Perot interferometer [1,2] have not given satisfactory results as the arc characteristics change with time and, in particular, the viewing windows become covered with sputtered material.

We have overcome this problem by using a Fizeau interferometer to spectrally resolve the line of interest, coupled to a PAR Model 1430 Optical Multichannel Analyser to record intensity data in parallel. The design and testing of this instrument will be described and preliminary results of lineshape measurement on a pulsed aluminium arc presented.

[1] P J Martin, R P Netterfield, D R McKenzie, I S Falconer, C G Pacey, P Tomas, W G Sainty J Vac Sci Technol A5, 22 (1987)

[2] P J Martin, D R McKenzie, R P Netterfield, P Swift, S W Filipczuk, K H Muller, C G Pacey, B James Thin Solid Films 153, 91 (1987)

CATHODE SPOT PHENOMENA IN CONTINUOUS AND PULSED VACUUM ARCS

P Swift, I S Falconer, B W James and D R McKenzie

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and

Ian G Brown

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Abstract

Results of an experimental study of cathode spot behaviour in both continuous and pulsed arcs will be presented.

The spot velocity for a continuous arc has been measured photoelectrically as a function of magnetic field and filling gas pressure and type. These measurements have been supplemented by image converter camera studies of the number of cathode spots present as a function of current, the formation and decay of cathode spots and cathode spot structure.

Image converter camera and spectroscopic measurements have been used to study the initial stages of the pulsed arc, and the variation of spot number during the current pulse.

 Session IX Tuesday 5.10 - 6.40 p.m.

ROTATING MAGNETIC FIELD CURRENT DRIVE IN HOT PLASMAS

by

I.J. Donnelly and P.A. Watterson*

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Abstract

The theory of current drive using rotating magnetic fields has been extensively developed for plasmas with temperatures such that the RMF frequency ω is less than the collision frequency ν_{ei}. The force that drives the electron current comes from the time-averaged interaction between the oscillating current $\underline{j}$ and magnetic field $\underline{b}$, viz $\eta J_\theta = -\langle \underline{j} \times \underline{b} \rangle_\theta / ne$. As the RMF amplitude B_ω increases, the driven current first increases quadratically with the parameter ω_{ce}/ν_{ei}, where $\omega_{ce} = eB_\omega/m_e$, and then rises very rapidly to its saturation value at which the electron fluid rotates synchronously with the RMF.

Provided that the condition $\nu_{ei} >> \omega$ is satisfied, electron inertia plays no part in the equations that determine $\underline{j}$ and $\underline{b}$. However, in warm to hot plasmas, electron inertia can affect the amplitude and phase of these terms and thereby change the current driven. We have shown that this results in a reduction in the size of J_θ for small values of ω_{ce}/ν_{ei}. However, the current saturation still occurs at a value of ω_{ce}/ν_{ei} similar to that predicted in the absence of electron inertia.

It is also of interest to examine the effects of the RMF on the ion fluid as $\omega \to \omega_{ci}$. In this limit it is expected that the RMF will generate a steady poloidal ion current due to the $ne\langle \underline{v} \times \underline{b} \rangle_\theta$ force. We have found that the size of this effect has a sensitive dependence on the form of the ion momentum relaxation processes that hold.

* AINSE Research Fellow

Optical Gain in BASIL II at the Lower Hybrid Resonance

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Abstract

Optical gain of 488 nm has been measured in RF generated plasmas with 3.1 cm and 4.5 cm inner tube diameters. The plasma is thought to be generated by Landau damping of the whistler waves excited by the antenna. The optical gain as a function of the magnetic field was measured with different RF frequencies and tube diameters. The results show the peak gain appears near the lower hybrid frequency. This implies the lower hybrid resonance may play an important role in the coupling of energy to the plasma.

A New 1D-3V Spherically Symmetric PIC Code

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Abstract

Although 1D particle in cell (PIC) codes with non-periodic boundary conditions can effectively simulate a symmetric capacitive RF discharge, there are obvious problems in treating even simple collisional phenomena. In addition it is not possible to study the effects of different electrode areas on parameters such as self bias. In order to get over some of these problems, a PIC code has been developed with 1D, 3V in a spherically symmetric system. Ion and electron motion have been included using different time scales to reduce computation time along with a variable spatial step so that the high fields generated in the sheath region can be properly modelled. Initial results of the simulation will be presented using a simple model for ionization and secondary emission processes.

Plasma Diffusion in an Inductively Coupled RF Plasma Etching System

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Research School of Physical Sciences
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Abstract

The move within the semiconductor industry towards the use of large diameter substrates (up to 20cm) has required the parallel development of plasma reactors capable of producing high density plasmas, uniform over large areas. In this poster we describe how a large volume of high density plasma - average densities up to 10^{12} cm^{-3} - can be created in an etching system.

By operating at pressures for which typical mean free paths are comparable to the dimensions of the machine, the plasma electrons can be confined using surface magnetic fields or a solenoidal field. We will examine the important differences between these two confinement techniques.

Fast Anisotropic Etching of Silicon by SF_6 in an Inductively Coupled Plasma Reactor

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Research School of Physical Sciences
Australian National University
GPO Box 4 ACT 2601

Abstract

A plasma etching reactor based on a resonant inductively coupled 13.56 MHz source has been shown to perform very well for etching both silicon and quartz. In this reactor up to 1 kW of rf is coupled into the 15 cm source tube and the resulting plasma allowed to diffuse into a larger reactor chamber in which the substrate table is situated. Either multipole or solenoidal confinement may be used around the reactor chamber, with higher density and a smaller region of uniform plasma resulting from the latter.

In a pure SF_6 plasma at 0.5 mTorr etch rates of 0.5 μm/min are achieved with a modest substrate bias of -1[illegible]0 V ensuring an anisotropy of 1.0. By increasing the magnitude of this bias to -160 V it is possible to increase the etch rate to 0.7 μm/min at 1 mTorr whilst maintaining the anistropic etch profile. The selectivity to SiO_2 is always better then 5. The etch rate of SiO_2 in a CHF_3 plasma at 4 mTorr was 0.45 μm/min with selectivity against Si of 4.

A NEW LARGE ROTAMAK EXPERIMENT AT FLINDERS UNIVERSITY

by

G. Besson, G. Cottrell, M. Dutch,
I.R. Jones and G. Staines

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The Flinders University of South Australia
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Abstract

A new large rotamak experiment which is nearing the end of its construction will be described. The RF system is capable of delivering pulses of RF power (40 msec duration, 0.5 MHz) at a total power level of 800 kW from two channels. The new rotamak vessel which will be powered by the RF system consists of a large pyrex vessel (0.6m diam; 1.0m length) with the rotating field coils located on the outside i.e. a larger version of the original rotamak apparatus. In the first instance, we wish to bypass the twin problems of eddy-currents and current generation in the outer regions which characterized experiments in a metal-walled vacuum chamber.

It is anticipated that at least half the available RF power (i.e. about 400 kW) will be dissipated in the plasma thus raising the level of ionization to a point where we can expect much higher electron temperatures than are attained in the present generation of rotamak experiments. The amount of driven current should also increase at this power level thus significantly improving the confinement properties of the rotamak configuration.

STUDIES OF "NEAR-SPHERICAL" PLASMA DISCHARGES IN AN INEXPENSIVE ROTAMAK

by

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Abstract

"Near-spherical" compact torus configurations in Argon discharges utilising the rotating magnetic field (RMF) technique have been produced using low-cost MOSFET RF generators (~ 2.5 kW). Typically, the configuration is sustained for 40 ms and is highly reproducible. The steady and time-varying magnetic field configuration, the configuration of bi-directional toroidal magnetic fields, the current density doublet and the electron temperature and number density have been determined by a variety of diagnostics including various magnetic probes, Langmuir probes and a microwave interferometer. A comparison with theoretical models has also been undertaken.

Session IX Tuesday 5.10 - 6.40 p.m.

THE PAST TWO YEARS OF LASER FUSION

by

B. Luther-Davies

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Australian National University
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Abstract

The last two years have seen a number of exciting developments in the field of inertial confinement fusion. The recently declassified Centurion-Halite experiment has demonstrated the possibility of inertial microfusion on a scale similar to that envisaged for laser driven experiments. As a result a lot of effort is now being directed towards the development of very large lasers in the 10 to 100 megajoule region that are now believed necessary to demonstrate a significant gain from laser fusion. On a smaller scale the benefits of induced spacial incoherence for obtaining high compression have been demonstrated in the University of Rochester whilst the first high resolution images of thermonuclear neutrons generated within a compressed target have been obtained at the Lawrence Livermore Laboratory. Neutron imaging is regarded as an essential diagnostic for future work.

46R Session X Wednesday 9.00 - 9.30 a.m.

PHASE-MODULATION AND THE FUNDAMENTAL AND SECOND HARMONIC EMISSION SPECTRA FROM LASER-PRODUCED PLASMAS

by

R. A. M. Maddever, R. Dragila and B. Luther-Davies

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Abstract

In my PhD thesis, just completed, phase-modulation has been suggested as the mechanism responsible for the fine-structure which can be seen in the fundamental and second harmonic emission spectra from laser-produced plasmas, when narrow collection optics are used. While we have presented the details of the time-integrated spectra, and tentatively suggested the phase-modulation mechanism, with the support of computer-simulations, at previous AINSE conferences (1985 & 1987), we have not yet presented the details of our highly informative time-resolved spectra which are crucial in proving the theory. It is the aim of this talk to do so, and also to outline the possible physical mechanisms which we believe may be driving the phase-modulation process, while at the same time tying all of the previous observations together.

GYROTRON IV - A NEW TUNABLE GYROTRON FOR PLASMA DIAGNOSTICS

G F Brand

School of Physics
University of Sydney NSW 2006

Abstract

Gyrotron IV is the latest in a series of tunable gyrotrons designed and constructed at the University of Sydney. Like Gyroton III [1], it is tuned by raising the field of a superconducting magnet. One cavity resonance after another is excited. It will provide more than 10 W of CW power over the frequency range 75 to 330 GHz.

Design changes to improve the quality of the output include (i) sine-squared transitions at either end of the cavity and a step transition at the output end so that all of the mode conversion takes place at the step, and (ii) replacing the profiled output window by a plane window to further eliminate the production of unwanted modes.

The output is converted into a well-collimated, linearly-polarised beam by means of a quasi-optical antenna.

[1] G F Brand and M Gross. Int. J. Infrared Millimeter Wares 10/1 (1989)

ISOTOPE SEPARATION IN THE VACUUM ARC CENTRIFUGE

by

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Abstract

In the vacuum arc centrifuge (VAC), high speed rotation of a fully ionised, near neutral plasma leads to radially dependent mass separation. The use of this technique was first demonstrated by Krishnan and co-workers who reported separation in Cu/Ni and pure Cu plasmas [1,2]. For the latter system, significant isotopic separation was observed under the most favourable conditions. This suggested that the VAC may provide a useful and cost-effective method of producing small quantities (10g-1kg) of moderately enriched, stable isotopes. The present study was undertaken in order to investigate this possibility.

This paper describes recent VAC experiments with copper plasmas. The $^{65}Cu/^{63}Cu$ isotope ratio in plasma deposited samples was determined by inductively coupled plasma-mass spectrometry. The degree of separation was found to depend on the conditions associated with the vacuum arc discharge. Possible reasons for this behaviour will be discussed together with several problems encountered during the course of this study.

References

[1] M. Krishnan, M. Geva and J.L. Hirshfield, Phys. Rev. Lett. 46, 36 (1981).

[2] M. Geva, M. Krishnan and J.L. Hirshfield, J. Appl. Phys. 56 (5) 1398 (1984).

MUON CATALYZED FUSION: EFFECT OF AN ELECTRIC FIELD

by

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Abstract

Recent interest in muon-catalyzed fusion[1] as an energy source has followed the prediction and later experimental verification that a single muon can catalyse 100 or more fusions in a mixture of deuterium and tritium. Kinetic theoretical methods of swarm physics can be readily adapted to muon swarms in hydrogen, and we thus analyze the first step in the cycle, muonic atom formation, using an established and highly accurate procedure for solving Boltzmann's equation. The next (and perhaps most crucial) step in the cycle is the resonant formation of the mesomolecule due to interactions between hydrogen molecules and the muonic atoms. Cohen and Leon [2] proposed an epithermal model to explain the temperature dependence of the mesomolecule formation rate, in which the more energetic muonic atoms lead to faster formation rates. Rather than enhancing the available energy in the centre of mass by increasing the gas temperature (and therefore also the pressure, thereby adding to containment problems) we consider here the possiblity of achieving the same result using an electric field E instead to increase the steady state temperature of muons with a view to raising the average recoil energy of the muonic atoms formed following capture. For density $\lesssim$ 0.1 liquid hydrogen density, a significant fraction of "hot", recoiling muonic atoms, produced initially in a highly excited state (n $\gtrsim$ 14) can be expected to reach the ground state and subsequently participate in mesomolecular formation. Furthermore, as the capture cross section is energy-dependent, the capture rate itself will vary with E and hence, the rate of formation of muonic atoms, in addition to their recoil energy, can be controlled, at least in principle, by the electric field. We also believe that, apart from this potential application, the theoretical calculation of muon transport properties, as presented here, is of interest in its own right, since the possibility may soon arise, as is indeed already the case with positrons, of performing muon swarm experiments in order to determine low-energy muon-matter cross sections.

References

[1] S.E. Jones, Nature 321, 127 (1986)
[2] J.S. Cohen and M.Leon, Phys. Rev. Lett. 55, 52 (1985)

HIGH POWER ION CYCLOTRON RESONANCE HEATING IN JET

The JET Radio Frequency Division and
The JET Team

presented by

A.L.McCarthy
(Visiting Scientist Sept. 1987 - Sept. 1988)

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Abstract

Ion Cyclotron Resonance Heating (ICRH) powers up to 17 MW have been coupled to JET limiter plasmas. Minority ICRH heating experiments exploiting the specialised features of highly localised heating and fast ion production have produced stored energies of 7 MJ with 13 MW of RF in 5 MA discharges with $Z_{eff} \approx 2$. Transient sawtooth stabilisation (up to 3s) and significant energy content in the minority particles accelerated by the RF (up to 30% of the total stored energy) give confinement improved by 50% over Goldston L mode scaling when $I_p/B_\phi \approx 1$ MA/T. The He^3-D fusion reaction experiments with energetic He^3 minority ions have produced 60 kW of Fusion power, at a fusion rate of 2×10^{16} s^{-1} ($Q \sim 0.005$). For the corresponding D(T) scenario, Q is predicted to be between 0.2 and 0.8 using plasma parameters already achieved. Peaked density profiles generated by pellet injection have been reheated by ICRH producing a configuration remarkable in that the heat transport is reduced by a factor 2 or 3 despite the exceptionally high pressure gradient. For high current discharges ($I_p \geqslant 5$ MA), on-axis ICRH during the current rise has achieved central electron temperatures and D-D reaction rates up to twice as high as those obtained with heating in the current flat top, but the improvement in ion heating is much less than with the pellet fueled discharge.

EFFECT OF SMALL-SCALE INHOMOGENEITIES ON THE PROPERTIES OF WAVES IN PLASMAS

by

D. B. Melrose

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Abstract

Inhomogeneities with scale lengths shorter than the wavelength of waves in a medium need to be taken into account in calculating the linear response tensor (e.g. the equivalent dielectric tensor) for the medium. It is shown how the response tensor may be calculated for an arbitrary spectrum of inhomogeneities. Two applications are discussed briefly: (i) the effect of such inhomogeneities on the cutoff frequencies and on the coupling across associated stop bands, and (ii) the effect of structured "ripples" in causing an otherwise isotropic plasma to become birefringent.

 Session XI Wednesday 11.40 - 12.00 noon

OBSERVATION OF m = ±1 MHD SURFACE WAVES AND SHEAR ALFVEN WAVES CONVERTED FROM THE SURFACE WAVES

by

Y. Amagishi

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Abstract

Experimental results are presented which show that MHD surface waves (fast waves with poloidal wavenumber m = ±1) have been excited in the range of frequency less than the ion cyclotron frequency using a helical antenna in a finite β, cylindrical plasma. Their dispersion relation and spatial structure were successfully confirmed after the wave signals were separated from those of the local shear Alfven waves that propagated together with the surface waves. In order to obtain the dispersion relations from the signals, we used three different techniques: (1) conventional cross-power spectrum density using the fast Fourier transform, (2) the maximum entropy method, and (3) direct estimation of the phase velocities of the wave packets.

Next, using not the helical antenna but a special one, we have tried to excite the m = ±1 fast waves locally on the surface of the plasma column with a constant parallel wavenumber. When the dispersion relation of the m = -1 wave approaches the merging point, the azimuthal component b_θ of the magnetic field, which the fast wave scarcely includes in the vacuum, is observed to be strongly enhanced near the plasma center, whereas the parallel component b_z is not so changed either with or without plasma. The field b_θ is believed to be that of the shear Alfven wave converted from the m = -1 MHD surface wave.

QUASILINEAR RELAXATION OF ELECTRON DISTRIBUTION FUNCTION

by

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Abstract

Electron-cyclotron instabilities, which are inherently relativistic in nature, occur in laboratory and astrophysical plasmas. The theory of the linear growth of these instabilities has been successfully applied to the Earth's auroral kilometric radiation, solar microwave spike bursts and bursts from flare stars, among others, particularly by Melrose and his collaborators for a loss-cone type distribution. Electromagnetic waves near the electron cyclotron frequency can be amplified if the electron distribution function has a population inversion with respect to the velocities perpendicular to the magnetic field, i.e. a maser instability occurs. Many different distribution functions have now been investigated, and also many parameter ranges, such as cold and hot background plasma. However, not much work has been done so far on the nonlinear evolution of the distribution function during the instability, i.e. the saturation of the maser, and it is this problem that we address in this paper.

The approach used is to numerically calculate the evolution of the loss-cone distribution function using the quasilinear kinetic equation, i.e. calculate the diffusion of the electrons in velocity space due to their scattering off the electromagnetic wave fields that the nonthermal distribution itself produces. Under the quasilinear approximation, the result is a kinetic equation for the electron distribution coupled to an evolution equation for the wave energy density. For azimuthal symmetry about the magnetic field, and for a spatially uniform system, two velocity space variables and two wavenumber space variables are involved. The diffusion coefficients have recently been calculated by Aschwanden and Benz (1988). A convenient model for the distribution function is to assume that it is Maxwellian in v, the magnitude of velocity, but to solve numerically for the pitch-angle dependence, each pitch-angle having a different temperature for v associated with it, on the assumption that the loss-cone distribution relaxes primarily by diffusion in the pitch-angle. This sort of model has been used by Muschietti et al. (1981) to calculate the relaxation of an electron beam, and is referred to by them as a 1½ dimensional model. The numerical method uses finite elements, and we have compared results of the 1½ D model with the more exact, although slower, 2-D model. When our code is found to be working efficiently, it should be applicable to other quasilinear relaxation problems, such as r.f. heating and current drive.

References

[1] M.J. Aschwanden and A.O. Benz (1988) Ap. J., 332, 447.

[2] L. Muschietti, K. Appert and J. Vaclavik (1981) Phys. Fluids, 24, 151.

PLASMA ETCHING OF PHOTORESIST MATERIALS FOR MICROELECTRONIC APPLICATIONS

by

M. Gross and C.M. Horwitz

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Abstract

The patterning of masking layers in submicrometer scale integrated circuit technology usually involves the exposure and development of a photosensitive polymer followed by reactive ion sputter etching of the polymer in an oxygen-containing rf discharge (1,2). The ion flux during this etching process must be highly anisotropic in order to preserve the original pattern line widths. This means that low gas pressures (typically less than 1 Pa) are required in order to minimise collisional randomisation of the ions in the sheath region, and to minimise the proportion of active neutral species which have isotropic etching characteristics. However, in the conventional rf diode etching systems commonly used, low pressure operation leads to low etching rates unless some discharge enhancing mechanism is employed.

In our laboratory we have been investigating the advantages of the rf hollow-cathode for reactive sputter etching of various materials used in microelectronics (3). In this poster we show some results of etching fine patterns in photoresist in an rf hollow-cathode oxygen plasma. We have found that the hollow-cathode geometry with mechanical discharge confinement is capable of achieving high accuracy patterning of photoresist layers at rates exceeding 15 times that in a diode system. This is achieved without using higher target self-bias voltages and at input powers densities which do not cause overheating of the photoresist. The smaller sheath height in a hollow-cathode under similar conditions to a diode system results in increased directionality of the incident ions due to the smaller distance available for randomising collisions. This leads to reduced bowing of the sidewalls of the photoresist patterns.

References

[1] B.R.Soller and R.F. Shuman, J.Electrochem.Soc., 131, p1353, 1984.
[2] H. Namatsu, Y.Ozaki and K.Hirata, J.Vac.Sci.Tech., 21(2), p.672, 1982.
[3] C.M. Horwitz, S.Boronkay, M.Gross and K.E. Davies, J.Vac. Sci.Tech., A6(3), p1837, 1987.

IONISATION PROCESSES IN LOW PRESSURE N_2 PLASMAS

by

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Abstract

The population densities of N_2^+, N^+, N^{++} etc. ions that can be obtained by applying RF energy to N_2 gas at pressures of about 1 mtorr are of particular interest for plasma immersion ion implantation. A cross-section library for the electron ionisation of nitrogen molecules, atoms and ions has been assembled and used for the derivation of reaction rates assuming a Maxwellian distribution of electron energies. For a range of fixed electron temperatures and filling pressures, the time-evolution of the ionised states and their final steady-state values have been calculated for conditions appropriate to glow discharge plasmas in which the dominant recombination mechanism occurs via the plasma-wall interaction.

We have found that there is zero steady-state ionisation below a certain electron temperature T_{c1}. Between T_{c1} and a higher temperature T_{c2} there are two steady-state solutions possible, one with low and one with high electron density, and above T_{c2} only the high density solution exists. The temperatures T_{c1} and T_{c2} are functions of filling pressure and the plasma confinement time. In typical glow discharge plasmas,only the lower density branch is accessible because of RF power constraints. This limits the electron temperature in such plasmas to the range $T_{c1} < T_e < T_{c2}$.

RF GENERATED PLASMAS FOR PLASMA IMMERSION ION IMPLANTATION

by

J.Tendys and G.A.Collins

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Abstract

Ion implantation by biasing a target immersed in a plasma is being developed at ANSTO as an alternative to traditional accelerator-based techniques of implantation. This paper will describe experimental studies that are attempting to characterise the electron density and ionisation state required, with a view to the development of a rf plasma device optimised for the implantation process. The behaviour of the plasma when a large negative bias is applied to the target is extremely important, and efforts are being made to understand the dynamics of the sheath that is formed.

A LINEAR SYSTEMS DESCRIPTION OF FORWARD SCATTERING EXPERIMENTS

by

J. Howard, R.Nazikian and L.E.Sharp

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Abstract

The Fourier diffraction projection theorem relates the angular spectrum of scattered radiation to the wave-number space properties of the scattering medium. This very powerful result is applied to the general problem of radiation forward scattered from a plasma under both plane wave and Gaussian beam illumination. A simple unifying picture of experimental techniques ranging from imaging interferometry to Bragg angle scattering is presented.

ECRH EXPERIMENTS USING A 2.45GHz DOMESTIC MICROWAVE OVEN MAGNETRON

by

G.D.Conway and B.D.Blackwell

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Abstract

We have adapted a 650W average / 2kW peak domestic microwave oven magnetron (2.45GHz) to the production and heating of plasma in the SHEILA heliac via electron cyclotron absorption [1]. The magnetron is matched by a tunable cavity directly into a coaxial transmission line before entering the vacuum vessel. A coaxial line was chosen in preference to the usual waveguide because of the restricted access to the plasma column imposed by the toroidal field coils.

A selection of antennae have been evaluated, including dipoles and helical antennas, and their launching efficiencies investigated. The system was developed initially on a cylindrical test chamber (with an extended mirror confining/resonant field) before being installed on the SHEILA heliac.

This paper complements an accompanying paper in which fuller results from the SHEILA heliac are presented. Here we concentrate on the technical aspects of the system, including the design performances of matching components.

References

[1] Conway G.D. (1988), Design report, ANU-PRL-TR 88/2

FREE BOUNDARY STABILITY OF HELICAL PLASMAS USING PEST25

by

G. Cooper

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Abstract

The PEST25 code is a modification of PEST2 for testing the stability of fixed boundary helical plasmas. I have modified the code for free boundary stability by the installation of subroutines which calculate the potential energy matrix contribution δW_v due to a vacuum. This vacuum contribution is calculated using a Green's function method similar to that used by HERA. The main difference is that the scalar potential, Φ is expanded in terms of complex exponentials $\exp(i\ell\Phi)$, rather than finite elements, so it is well represented by a small number of expansion functions.

The newly installed vacuum subroutines will be verified by comparison of the eigenvalues given by PEST25 with analytic results for fixed and free boundary stability of a constant current cylindrical plasma. The code will be further verified by comparisons with HERA using a straight helical plasma equilibrium.

BETA LIMIT OF HELIAC PLASMAS

by

R.L. Dewar and W.A. Cooper*

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*Centre de Recherches en Physique des Plasmas
Ecole Polytechnique Fédérale de Lausanne
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Abstract

The VMEC three dimensional equilibrium code [1] and associated mapping, Mercier and ballooning stability codes have been installed on the ANU VP-100 supercomputer. Pressure profile optimization studies aimed at determining the maximum beta for Mercier and ballooning stability of the H-1 heliac will be presented.

References

[1] S.P. Hirshman, W.I.van Rij and P. Merkel
Computer Physics Communications 43 (1986) 143-155.

NONLINEAR HYBRID TE-TM WAVES IN A FLOWING PLASMA

by

S. Vukovic

Laser Physics Centre,
The Research School of Physical Sciences,
The Australian National University,
Canberra

Abstract

Analytical studies of the electromagnetic field structure in subsonic and supersonic regimes of the plasma flow have been based upon *a priori* assumptions about the state of polarization of light [1-2]. While this is correct in the linear theory when the Maxwell's equations decouple into TE and TM modes, in the nonlinear electrodynamics these modes become coupled via intrinsic nonlilearities due to electrostriction.

Recently, the first integral of the complete set of nonlinear Maxwell's equations has been found [3]. This general result for hybrid TE-TM waves allows for further analytical studies of the field structure within the model of stationary, one-dimensional stream of nonisothermal collisionless plasma. In the present work, the plasma density and velocity structures are investigated in both subsonic and supersonic regimes. It is demonstrated that in addition to the well known density steepening near the plasma resonance, high stream velocities allow for other type of discontinuous solutions.

[1] N.E.Andreev, V.P.Silin and P.V.Silin, Zh. Eksp. Teor. Fiz. 79,1293(1980) [Sov. Phys. JETP 52, 653 (1980)].
[2] V.B. Gil'denburg, A.V. Kochetov, A.G. Litvak and A.M. Feigin, Zh. Eksp.Teor.Fiz. 84, 48 (1983) [Sov.Phys.JETP 57, 28 (1983)].
[3] S. Vukovic and R. Dragila, J.Opt. Soc. Am. B, January (1989).

ON THE SOLUTION OF THE ROTAMAK CURRENT DRIVE EQUATIONS BY EXPANSION IN VECTOR SPHERICAL HARMONICS

by

D. Brotherton-Ratcliffe and S. Xu

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Abstract

Vector spherical harmonic expansion provides a useful and efficient technique for the solution of non-linear problems in a spherical geometry. Here, we apply this technique to the rotamak current drive equations describing 'rotating magnetic field' current drive in a spherical plasma bounded by an insulating wall.

We solve the harmonic equations by a perturbation method, valid for small RF field or high plasma resistivity. We present the derivation of explicit expressions for the steady toroidal current driven, the bi-directional toroidal magnetic field and the toroidal current density doublet harmonic. We also show how helicon modes are excited when a 'vertical' equilibrium field is applied and we discuss the role of these modes in the current drive.

Session XII Wednesday 1.00 - 2.30 p.m.

TRANSVERSE OSCILLATING FIELD CURRENT DRIVE IN SPHERICAL PLASMAS

by

D. Brotherton-Ratcliffe and R.G. Storer

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Abstract

The technique of driving steady Hall currents in plasmas using a transverse oscillating magnetic field is studied numerically under the approximation of negligible ion flow. We model a uniformly dense and resistive spherical plasma bounded by an insulating wall and immersed in a uniform magnetic field which has both an oscillating component (of frequency Ω) and an orthogonal constant 'vertical' component. We formulate the (3-D time dependent) problem in terms of a spatial expansion in vector spherical harmonics and a temporal expansion in Fourier harmonics.

THE JUPITER TORUS AS A PLASMA AND ELECTROMAGNETIC WAVEGUIDE

The Jupiter Torus as a plasma and electromagnetic waveguide and a consequent explanation of the influence of the satellite IO on the form of the Jupiter decametric emissions received on earth.

W.S. Boundy

School of Physics, South Australian Institute of Technology (Retired)

Abstract

In some earlier work, Boundy (1986) on the diffraction of 20MHz radiation by the moon at the time of a total eclipse established the integrity of the Lommel diffraction relations, Hufford and Davis (1929), over distances comparable with the diameter of the earth orbit. It is known, Bigg (1964), that experimental evidence relates the orbital position of the Jupiter Satellite IO with the occurrence of maxima in the Jupiter decametric emissions received on earth. The eclipse results suggested the possibility of detecting evidence of Lommel patterns within the peaky records found for many Jupiter emission records at about 20MHz which Jennison (1966) calls dirty little clusters of spikes. Such patterns can possibly be attributed to an occultation-diffraction process involving IO and a Jovian decametric source. Gardner and Shain (1958) expressed the opinion that the most probable source of Jovian bursts is plasma waves excited by some means and subsequently transformed into electromagnetic waves. It is known that the satellite IO moves about Jupiter in an orbit which is slightly inclined to a doughnut shaped plasma torus. The satellite is also linked to the parent planet by a flux-tube which carries a very large current of about one million amperes between Jupiter and IO.

The paper explores the suggestion that the magnetised plasma structure together with the large current injection at IO provide conditions in which Alfven waves are produced in the neighbourhood of IO. These waves it is suggested are guided around the torus in opposite directions and meet at a point in the plasma torus where there occurs non linear interaction and conversion into 20MHz electromagnetic radiation. This radiation is then guided around the plasma torus until it is diffracted by the immersed IO and a diffraction pattern produced where fine structure is detected by the moving antenna on earth. Some records which have been cited in support of a beaming theory, Maeda and Carr (1984), can be fitted to the diffraction concept.

References

BOUNDY (1986) Lommel at Large, Optics Workshop, AIP 7th National Congress 1986
BIGG (1964) Nature 263,1008
JENNISON (1966) Introduction to Radio-Astronomy, Newnes, London 1966
GARDNER and SHAIN (1958) Aust.J.Phys.11,55
HUFFORD and DAVIS (1929) Phys.Rev.33,589
MAEDA and CARR (1984) Nature 308,166

The Effect of Symmetry Breaking Errors on the H-1 Plasma Configuration.

B.D. Blackwell and T.Y. Tou

Plasma Research Laboratory
Research School of Physical Sciences
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Canberra, Australia

Abstract

The presence of errors in a magnetic configuration will in general cause small deviations from the ideal shape and position of the flux surfaces, and introduce small magnetic islands on resonant surfaces ($\iota \sim n/m$). Numerical studies of the effect of errors have been performed on the ANU Fujitsu VP-100 supercomputer, with a version of the Princeton University HELIAC computer code. The most troublesome (and computationally expensive) errors are those which do not have the same symmetry as the H-1 magnetic configuration. If the up/down symmetry or the 3-period symmetry is broken, then there is less restriction on allowed values of n and m, and many more island chains appear, in places where there were previously none.

Two cases have been studied in detail. To simulate the effect of remanent magnetization in iron reinforcements in the floor of the H-1 experimental area, a magnetic dipole was positioned 2 m below the midplane of the coil set, at various distances radially and at various angles in the plane of the floor. Small errors (~1 mm) in the position and orientation of the circular ring conductor were studied as a representative construction tolerance error.

The rate of growth of island size with the error field magnitude δB is found to increase from the expected $(\delta B)^{1/2}$ scaling to δB scaling within the range of errors to be expected for H-1. Possible explanations will be discussed. By concentrating on the dimensional requirements that are found to be most critical, it is expected that the island size in the central 75% of the plasma volume can be limited to 10 mm. We are presently investigating compensation of the toroidal coil position errors by adjustment of the position of the ring conductor, with promising initial results, and an investigation of the non-linear interaction of two sources of error is in progress.

THE USE OF ELECTROSTATIC PROBES IN R.F. PLASMAS FOR MATERIALS PROCESSING

N.M.P. Benjamin*

Department of Engineering Science, University of Oxford, Parks Road, Oxford, U.K.

Abstract

Some of the theory and practice for the operation of Electrostatic Langmuir probe diagnostics in plasmas used for materials processing are considered. Such plasmas are often generated by R.F. excitation in the intermediate regime, $w_{pi} \ll w_{RF} \ll w_{pe}$, which can result in an R.F. voltage component between probe and plasma. Beside giving rise to displacement currents, R.F. bias can influence the collection or loss by a surface of the various species of particle present, even including neutrals. The modification of charged particle fluxes, in turn, gives rise to the "d.c. self bias" observed in such systems. These effects are vital in the application of plasmas to surface modification, but complicate the interpretation of diagnostic probe results. In order to recover a quasi-d.c. measurement, a bootstrap technique, which has been developed at Oxford is described, and its application in typical scenarios is discussed.

* presently at Plasma Research Laboratory, Research School of Physical Sciences, The Australian National University, Canberra, Australia

RF PLASMAS AND IMPURITY EFFECTS

by

S.C. Haydon

Physics Department
University of New England
Armidale, NSW, Australia

Abstract

RF Plasmas provide one of a number of options for achieving modifications to electrode surfaces through dry etching procedures or by film deposition. Typical gas pressures are usually $\lesssim$ 1 torr and plane-parallel electrodes are conventionally employed in practical devices.

Some years ago we began investigations of r.f. plasma phenomena using point-plane geometry as part of a programme to understand the onset of arc-plumes at atmospheric pressure at high power aerial arrays. Techniques have been developed to record and analyse highly time-resolved intensified images of r.f. plasmas at selected phase positions within a single r.f. cycle and at various stages in the development of the r.f. discharge. Linked with such intensified plasma images is a capability to observe the corresponding highly time-resolved spectroscopic emissions originating from different regions of the r.f. plasma at various times.

This paper will review, briefly, some of the salient features of the investigations undertaken in N_2. It will then address the problems of extending these observations to H_2 and mixtures of H_2 with CH_4. Such mixtures are known to yield deposits of diamond-quality carbon and some of the parameters that appear to control both the production and quality of the deposits will be identified. The possible advantages of using point-plane electrode geometry as a means of improving our basic understanding of the complexities of r.f. phenomena will be discussed and brief reference will be made to potential influences of trace impurities on the behaviour of low temperature plasmas in certain gases and gas mixtures.

PROSPECTS for FUSION POWER: RECENT REPORTS in EUROPE

by Mr.G.W.K.Ford

(Part of UNSW Mech.& Ind.Eng. AINSE Project on Nuclear Power)

An outline is presented of the recent evolution of ideas and the current development of technologies which may lead to a practical magnetic-confinement fusion reactor with a toroidal plasma geometry. The review is mainly based upon the material reported in some 319 papers presented at the 15th Symposium on Fusion Technology convened in Utrecht, September 19-23, 1988, in which nearly all the presentations related principally to tokamaks or allied toroidal devices. Reported research spanned plasma engineering, nuclear engineering and materials cycles; and embraced devices ranging from 'small' (eg RTP, AIF, Compass etc) and medium (eg JFT-2M, Textor, Asdex, RFX etc), through the large tokamaks (JET, TFTR, JT-60, Tore Supra & T15) to 'Next Step' concepts (eg CIT, ETA, NET, ITER & JIT), and thence to 'Demo' & 'Commercial' schemes (eg.Titan, Navigator etc).

Major present efforts for today's machines relate to plasma heating (& effects on confinement times), plasma position control & stabilisation, disruptions, and protection of plasma-facing components. Much effort for JET & TFTR now has to be devoted to considerations of tritium handling, neutron radioactivation, and remote manipulation for all operations on the fusion core components. Plans, and alreday-built equipment, for all these purposes are at an advanced stage of development or prototype testing, and are also in process of extrapolation to Next Step machines. Refuelling methods (eg pellet injection) are under development.

Concepts for the Next Step range from the newly-announced JET-based JIT 'Thermonuclear Furnace', planned to demonstrate ignition and primarily aimed at plasma engineering investigations (cf CIT), without need to resort to superconducting magnets, to reactor-like schemes such as NET, ITER & FER, involving not only considerable advances in plasma engineering (eg 15 to 30 MA plasma currents), but also demanding very extensive nuclear engineering (eg tritium breeding blankets, heat transport etc).

Much emphasis is now being placed on safety and environmental analysis, and on the requirements for radwaste disposal. Unlike fission reactors, which are intrinsic producers of fission products, for fusion reactors there is considerable scope for design ingenuity and materials choice (including eg 'isotopic tailoring' of alloy additives) to minimise radioactivation.

Extrapolation of tokamak principles to power reactors seems to lead to low power densities (hence high fusion core specific mass), and to superconducting magnets. Hope for economic toroidal reactors may have to rely on more advanced concepts such as the reversed field pinch with normal-temperature copper coils.

MAGNETIC CONFINEMENT -STATUS AND PROSPECTS

by

M H Brennan

Wills Plasma Physics Department
University of Sydney NSW 2006 Australia

The advances in magnetic confinement fusion research that were reported at the 1988 IAEA Conference on Plasma Physics and Controlled Nuclear Fusion will be presented and discussed.

GENERAL INFORMATION

GENERAL INFORMATION

CONFERENCE VENUE

The Conference will be held in the AINSE Theatre (Institute Building), Lucas Heights see map page 83, from Monday 6th February to Wednesday 8th February, 1989.

PAPERS

Timing

Green light shows for presentation of paper,
Warning lights show when 5 & 2 minutes are remaining,
Red light shows when presentation time has expired,
Discussion time of 5 minutes is then allowed by the Chairman.

Slides

Authors using 35 mm slides in conjunction with their talk are requested to place their slides in the projector magazine during the break preceding the sesssion in which the paper is scheduled.

Poster Sessions

The Poster Sessions will be held in the ANSTO Amenities Centre adjacent to the Swimming Pool, see map p.83, at the scheduled times (see programme). Posters should be set up before the Poster Session commences and removed after the final session that day. Posters should be prepared before arrival at the Conference in accordance with the guidelines previously provided.
Authors are expected to be in attendance by their posters throughout the poster session.
Materials for setting up posters are available from any member of the AINSE staff.

ACCOMMODATION

For out of Sydney participants whose nominations have been previously accepted, accommodation has been arranged in accordance with advised requirements, at Stevens Hall, Lucas Heights (adjacent to the Institute Building, outside the Main Gate) - see map p.83, or at the Sapphire Motel, 408 Princes Highway, Sylvania Heights. The Institute will make payment directly to the management for room only charges at Stevens Hall or the Sapphire Motel. Participants should make personal arrangements to pay cash for breakfast charges at Lucas Heights and the Sapphire Motel. Participants are requested to vacate Stevens Hall rooms by 9.00 a.m. Wednesday, and to leave their luggage in the room marked 'luggage' adjacent to the Theatre Foyer. Room keys to be left in the Stevens Hall Reception Office.

MEALS

Breakfast

For Stevens Hall residents, breakfast is served in the ANSTO Canteen from 7.30 a.m.
For Sapphire Motel residents, breakfast served when required, in dining room or own room.
Participants should make arrangements to pay cash for breakfast charges at Lucas Heights and at the Sapphire Motel.

Conference Lunch - Monday 6th February, 1989

Lunch for all participants will be held in the Stevens Hall Dining Room during the scheduled lunch period (ref. programme). The cost has been included with the Conference Dinner payment.

Lunches - Tuesday and Wednesday, 7th and 8th February, 1989

Lunches may be purchased from the ANSTO Canteen.

BBQ Evening Meal - Monday 6th February, 1989

5.30 - 7.00 p.m. Gather by ANSTO Swimming Pool

Conference Dinner - Tuesday 7th February, 1989

Pre-Dinner Drinks - Amenities Centre with Poster Session
6.40 p.m. Buffet Dinner - Bamboo Room, ANSTO Canteen
Speaker - Mr. E.A. Palmer

Note: No other meal service will be available at Lucas Heights on this evening.

Evening Meal - Sunday 5th February

Please advise the Conference Secretary prior to the Conference if you require an evening meal on this evening.

TRANSPORT

Transport from Sydney Airport - Monday 6th February, 1989

An ANSTO bus will leave the Australian Airlines Terminal (Sydney Airport) for Lucas Heights at 9.25 a.m. Kindly give your name to the driver when entering the bus. If any difficulty is experienced in locating the bus, the Australian Airlines Commonwealth Car Desk will advise details of its precise location.

Request to Participants Arriving on ANSTO Bus from Airport

As time will be limited, participants are asked to go directly to the AINSE Theatre and not to Stevens Hall. Luggage may be left in a room adjoining the Theatre Foyer marked 'luggage'. Keys may be picked up from Stevens Hall Reception at any time during the day.

Transport from Sydney Airport (excluding Special Arrangements for Monday 6th February, 1989)

Taxis are available from the airport to:-

Lucas Heights,
Sydenham Railway Station - then train to Sutherland Station,
Sutherland Railway Station - then bus to Lucas Heights, or taxi
(ref. bus timetable below)

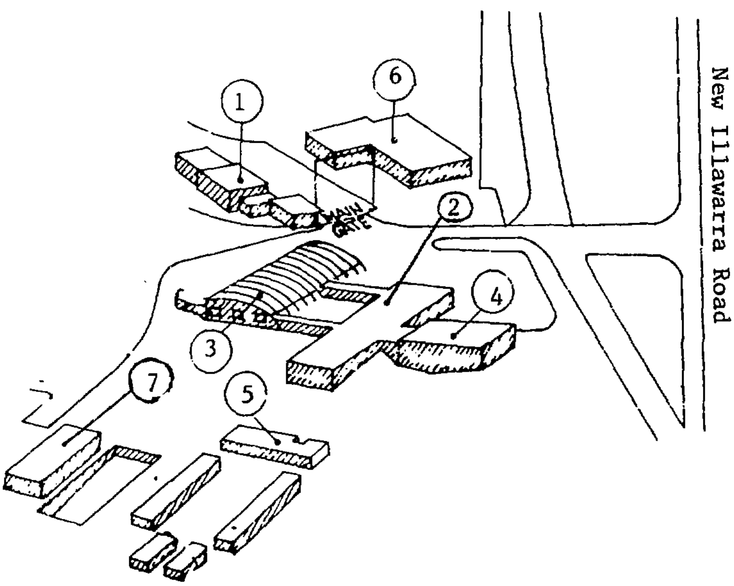
Note: Bookings must be made for all transport listed below - through AINSE, as transport is only provided if demand exists.

Monday - Friday	
Depart Lucas Hts. for Sutherland	Depart Sutherland for Lucas Hts.
6.15 a.m.	6.50 a.m.
7.35 a.m.	7.55 a.m.
8.30 a.m.	8.15 a.m.
9.35 a.m.	9.05 a.m.
10.35 a.m.	10.05 a.m
11.30 a.m.	11.10 a.m.
12.30 p.m.	12.00 p.m.
1.00 p.m.	1.10 p.m.
2.15 p.m.	1.30 p.m.
3.35 p.m.	2.45 p.m.
4.50 p.m.	
6.00 p.m.	
8.30 p.m..	

Buses from Lucas Heights leave from outside ANSTO Main Gate

Buses from Sutherland leave from outside Post Office, Flora Street.

LUCAS HEIGHTS N.S.W.



1. Main Gate
2. AINSE Building
3. Canteen
4. AINSE Theatre
5. Stevens Hall
6. Reception
7. Amenities Centre

TRANSPORT

Transport from Sapphire Motel to Lucas Heights

Transport will be arranged for participants. Please wait outside the Motel Reception Office for pick-up at 8.20 a.m. It would be appreciated if participants with their own transport could drive to Lucas Heights and assist by transporting others if possible.

Transport from Lucas Heights to Sydney Airport - Wednesday 8th February, 1989

Transport will be arranged to take participants to Sydney Airport after the Conference concludes. Please place your name on the list provided, on the noticeboard outside the Theatre, if you require this service.

Participants leaving Stevens Hall - Wednesday 8th February, 1989

Participants are requested to vacate their rooms by 9.00 a.m. Luggage may be left in the room marked 'luggage' adjacent to the AINSE Theatre Foyer. Room keys may be left in the Stevens Hall Reception Office.

TELEPHONE MESSAGES

Telephone messages will be taken for conference participants on:-

543-3436 (AINSE)	543-3411 (AINSE)	543-3111 (Switchboard)

All enquiries concerning the Conference arrangements should be directed to:-

Joan Watson,
Conference Secretary,
A.I.N.S.E.,
Private Mail Bag 1,
MENAI NSW 2234

Phone: 543-3436 or 543-3411

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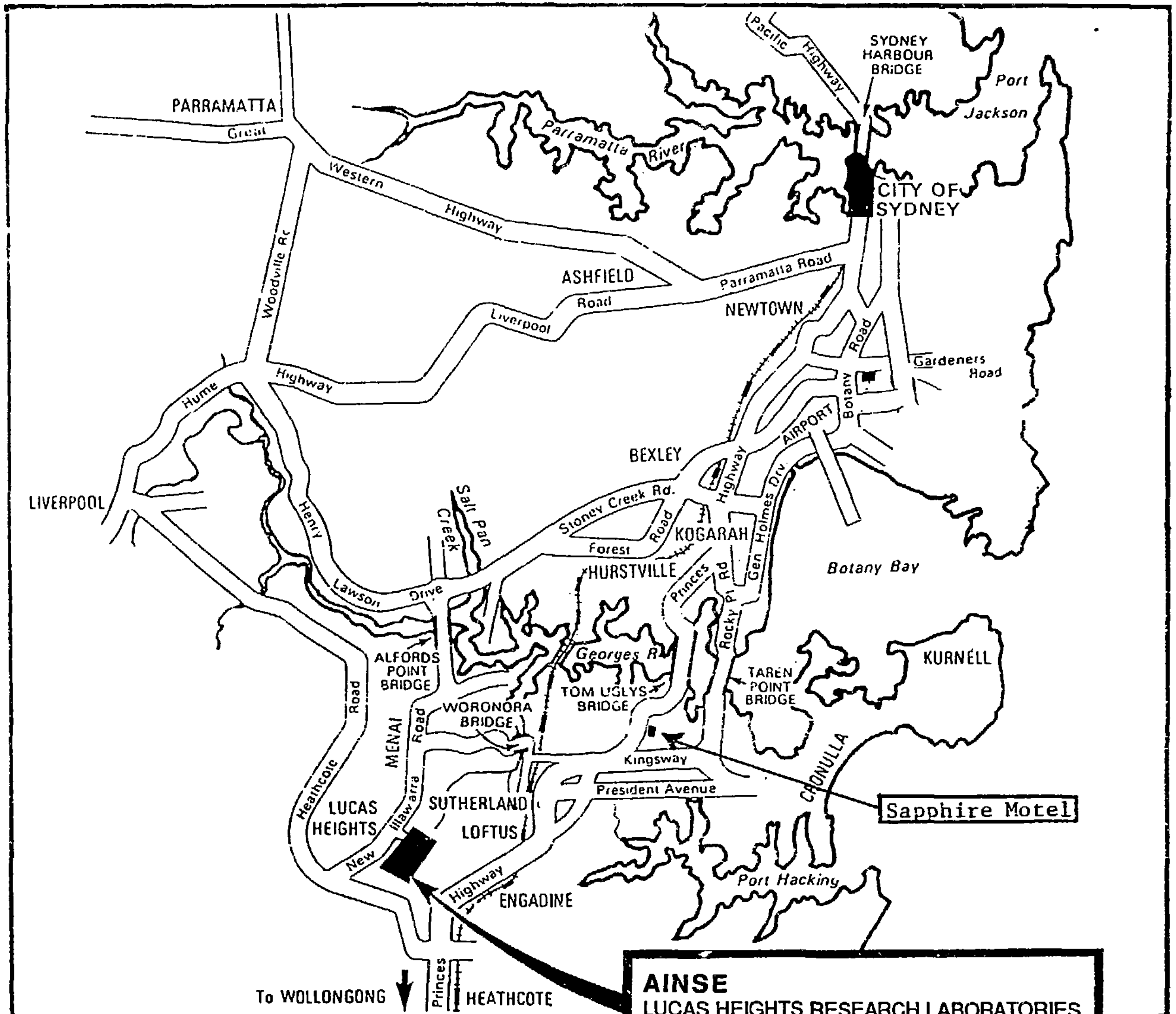

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