

The H-1 National Plasma Fusion Research Facility Annual Report 2004

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The National Plasma Fusion Research Facility

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

<http://rsphysse.anu.edu.au/prl/H-1NF.html>

H-1NF

I. INTRODUCTION

The H-1 Major National Research Facility is the Australian focus of basic experimental research on magnetically confined plasma, important in developing fusion energy, the energy source powering the sun and stars. Plasma — ionised gas — makes up 99% of the visible universe, and plasma phenomena are important in everything from stars and space exploration to the processing of electronic materials. Plasma physics is thus a highly interdisciplinary endeavour because of the range of physics areas it encompasses (fluid, atomic, electromagnetic, optical and surface physics) and the diverse technologies employed in plasma experiments (electronics, radio-frequency technologies, magnetics, lasers and microwaves, spectroscopy).

The National Plasma Fusion Research Facility is being developed from the “H-1 heliac” toroidal stellarator experiment in the Research School of Physical Sciences and Engineering in the Institute of Advanced Studies at the Australian National University. The innovative plasma geometry of the H-1 heliac allows investigation of basic plasma physics, and exploration of ideas for improved design of the fusion power stations that will follow the ITER international fusion experiment. The objectives of this project are to provide:

- an experimental Facility with which Australian scientists, technologists and engineers can contribute to the world-wide effort to develop fusion as a future source of energy;
- opportunities for advanced research training for students of science and technology;
- a platform for the development of novel technological ideas that can be spun off for industrial use.

The development of the H-1 National Facility is supported by an \$8.7M grant over five years (1997-2001) from the Department of Industry, Science and Resources. The Facility is operated by the Australian Fusion Research Group (AFRG), which acts under the auspices of the Australian Institute of Nuclear Science and Engineering (AINSE). The AFRG consists of researchers in plasma physics and fusion from the Australian National University, the University of Canberra, the University of Sydney, and

Flinders University of South Australia. International collaborations include work with scientists from Japan, the

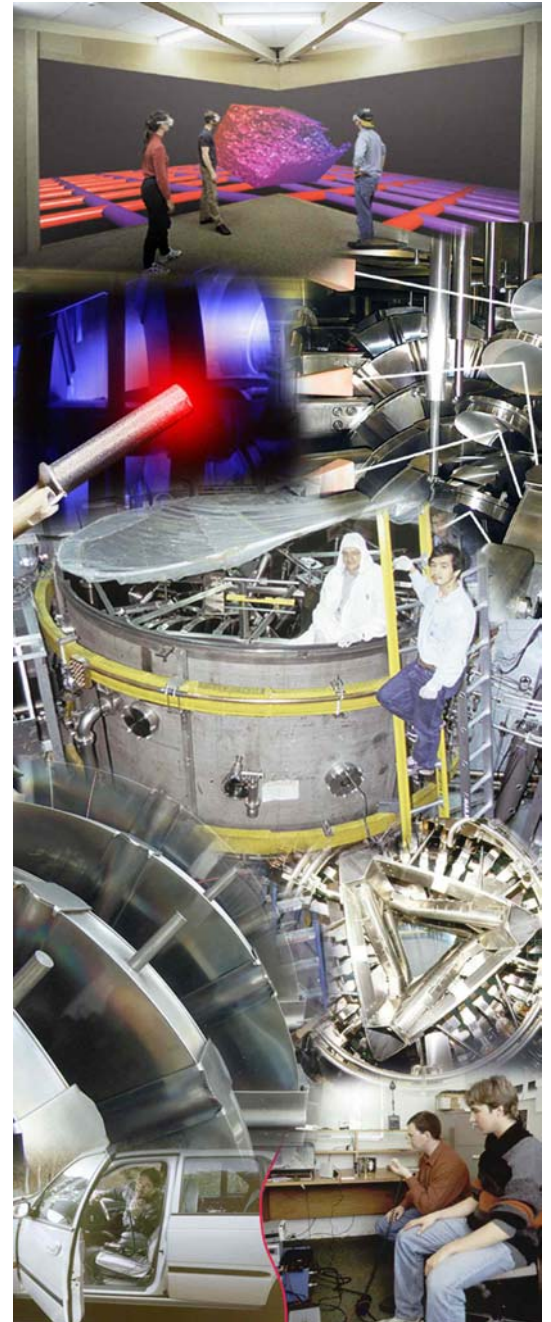


Figure 1: Various aspects of the facility (from top) visualization, plasma, diagnostics, the vacuum vessel, coil set and communications spinoffs.

United States, and Europe, and are elaborated on in section VI.

The H-1 National Facility Helic, operated by the Laboratory's Toroidal Plasma group is a large toroidal helical-axis stellarator device that is used to carry out fundamental research in the physics of plasma confinement. The heliac magnetic field is produced by a precision three-dimensional magnetic system. The plasma is produced by high-power radio and micro-waves, and its properties are measured by electric and magnetic probes, optical and microwave interferometry and scattering instruments. A particular focus of work on the heliac is the study of turbulent transport, flows, instabilities and the effect of magnetic configurations on plasma stability and confinement. Technologies originating in research on the heliac are also being applied to plasma diagnostics for experiments around the world, instruments for industry and defence, and wireless communication and radar.

In addition, the Laboratory also carries research in plasma theory, simulation, and visualisation, in collaboration with staff from the Department of Theoretical Physics and the Department of Computer Sciences in the Faculty of Engineering and Information Technology.

The Laboratory is deeply involved in educating young scientists and engineers, through the supervision of post-graduate research and fourth-year undergraduate research projects. We also regularly host students from around the world who come to take advantage of the Laboratory's special capabilities. Members of the Laboratory staff also contribute to undergraduate lecture and laboratory courses offered by the Department of Physics and the Department of Engineering in the ANU Faculties.

II EXECUTIVE SUMMARY

II.1 Highlights in 2004

2004 was a productive year – the group moved into purpose-built laboratories in the new Weigold wing, work began on recasting the business plan to suit the operational phase of the facility, and the automation of H-1 was largely completed. Automation by the use of programmable logic controllers accelerates data-taking, improves the quality of data by extensive logging of measurements, and reduces the manpower required to operate the H-1 facility. As a result over 3,100 plasma pulses were recorded, amounting to 20 Gigabytes of raw data. New systems included a directional gas injection system (DISH – section III) and an ECRH incident energy monitor.

The heliac is also being used to develop experimental techniques that can be applied on large-scale international fusion experiments. Dr. John Howard and his colleagues in the Advanced Imaging and Inverse Methods Group have developed a series of instruments known as coherence imaging spectrometers. These are novel imaging spectrometers that use electro-optic technology and advanced image and signal processing to determine temperatures and flows in radiating media such as plasmas. This year Dr Howard has expanded the development of novel multi-spectral imaging systems with two recent provisional patents on instruments suitable for industrial colour pyrometry for temperature and emissivity imaging, and for high-speed high-resolution spectroscopic imaging. Cameras similar to those successfully employed on the H-1 heliac, and optimized for high-speed plasma Doppler studies have been sold to Consorzio RFX Italy, Max Planck Institute for Plasma Physics (Germany) and the

Korean Basic Science Institute. Another system is being developed for the University of Sydney with LIEF grant support.

The visible emission tomography system based on a 55 channel fibre coupled coherence imaging spectrometer demonstrated its full potential by imaging intensity, ion temperature and flow in an argon plasma, and by reconstructing both normal surfaces and magnetic islands. The group has seen the recent graduation of three plasma physics PhD scholars (Glass, Michael and Chung).

Ground-breaking experimental studies of plasma turbulence in the heliac by Dr. Michael Shats and his colleagues demonstrated the role of self-organisation, zonal flows and spectral energy transfer in regulating the outward transport of particles and achieving enhanced plasma confinement. This physics is essential to achieving efficient confinement of fusion plasmas, but is also a universal phenomenon in complex dynamical systems, such fluid flows and both Earth and planetary atmospheric physics, and is a rapidly developing research area worldwide. The heliac has been shown to be a uniquely effective experimental environment for precise studies of these phenomena.

.The computer controlled precision magnet power supplies (12,000,000 Watts) together with the above-mentioned automation allow precise adjustment of the complex magnetic geometry. With a large operational range of magnetic fields ($>20:1$), gases, and the variety of heating systems, H-1NF is the most flexible plasma machine in the world. This facilitates detailed investigation of the effect of spatial resonances on the magnetic configuration and confinement. Experiments carried out by Dr. Boyd Blackwell, Prof. Jeffrey Harris and their colleagues demonstrated the sensitivity of confinement and fluctuations to these resonance effects, and a related collaborative experiment on the large D3D tokamak facility in the USA demonstrated the use of spatially-resonant magnetic fields to control the stability of the plasma edge to sudden pulses of heat and particle flux which present control problems for fusion reactors.

III RESEARCH

III.1 Self-Organization of Plasma Turbulence in the H-1 Helic

Results obtained by the Turbulence and Transport Studies group led by Dr. M. Shats suggest that the plasma turbulence in a toroidal magnetic field, such as the plasma in the H-1 heliac, self-organizes into large structures. This makes plasma turbulence similar to the two-dimensional (2D) fluid turbulence observed, for example in planetary atmospheres and oceans. Though intuitively perceived as a more chaotic state (e.g., turbulent versus laminar flows), the 2D turbulence often shows a tendency to *self-organize* leading to a higher degree of order. Zonal flows or poloidally and toroidally symmetric potential structures in plasma are expected to play significant roles in magnetically confined plasma.

The first experimental identification of the finite-frequency zonal flow was presented by M. Shats and W. Solomon based on the data obtained in the H-1 heliac in 2002. In 2003-2004 H. Xia and M. Shats have shown that different waves in plasma turbulence exchange energy in the process of three-wave interactions such that the energy is transferred from smaller scales and higher frequencies towards larger scales and lower frequencies (Physics of Plasmas 11, (2004) 56). This result produced the first experimental evidence of the *inverse energy cascade* in plasma turbulence. It has been proposed that this process leads to accumulation of energy in large structures and may be responsible for the generation of zonal flows. The inverse energy cascade is the basis for the plasma turbulence self-organization.

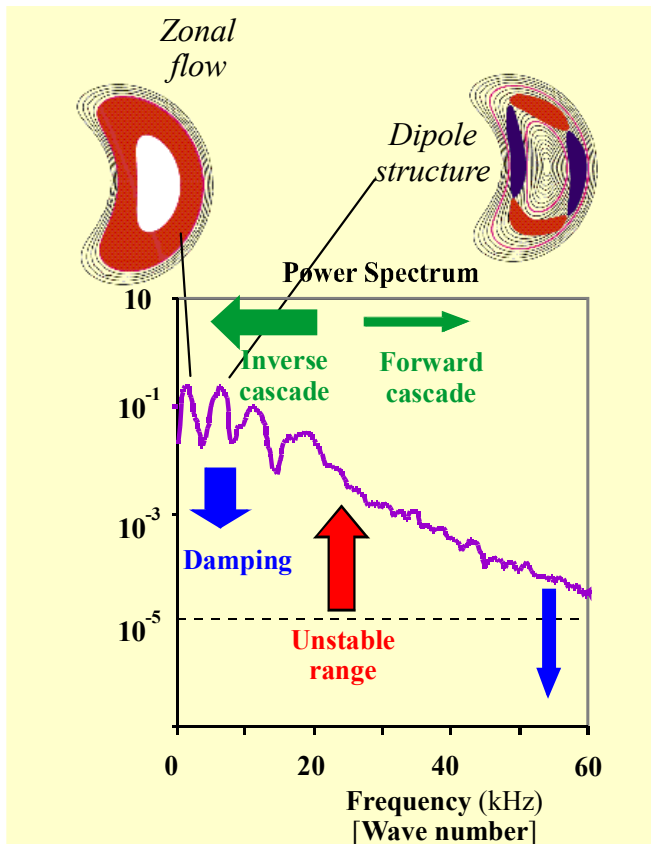


Figure 2: Flow chart of the energy flow within the turbulent spectrum. Inverse energy cascade leads to generation of large structures.

III.2 Studies of Transport Barriers in the H-1 Helic

Since the discovery of the low-to-high (L-H) confinement transitions in H-1 [M. Shats *et al.*, Phys. Rev. Lett. 77 (1996) 4190], intensive experimental studies of this phenomenon has continued. Understanding the physics of improved confinement is crucial for achieving efficient modes of operation in future fusion reactors. The highlight of 2004 was the discovery of the transport barrier and the density pedestal, which form in the plasma during the L-H transition [H. Punzmann and M. Shats, Phys. Rev. Lett. 93 (2004) 125003]. The shape of the electron density profile in the vicinity of the transport barrier was found to be very similar to that in much larger tokamaks at higher magnetic fields. This has also been understood in the frame of a concept of dimensional similarity. In particular it has been shown that low-B large ion mass plasma in H-1 is dimensionally similar to plasma in high-magnetic-field experiments.

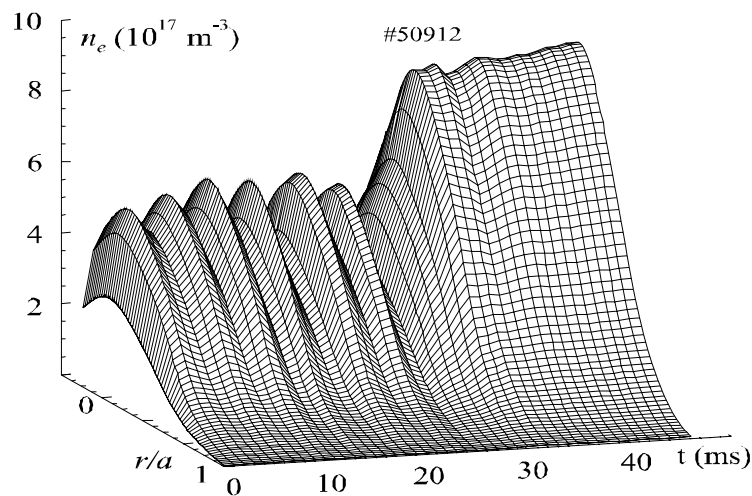


Figure 3 Time evolution of the plasma density during confinement bifurcation from low to high mode. The higher order in the plasma correlates with the turbulence suppression.

Modifications to the electron density observed during L-H transitions are also remarkably similar to those observed in numerical simulations of the bi-stable sand-pile model. The formation of the transport barrier and of the characteristic “kink” in the density profile is observed in sand pile above a certain threshold in the particle deposition. This similarity points to the universal nature of the structural bifurcation in various physical systems [H. Punzmann and M. Shats, Complexity International (12) (2004) 83].

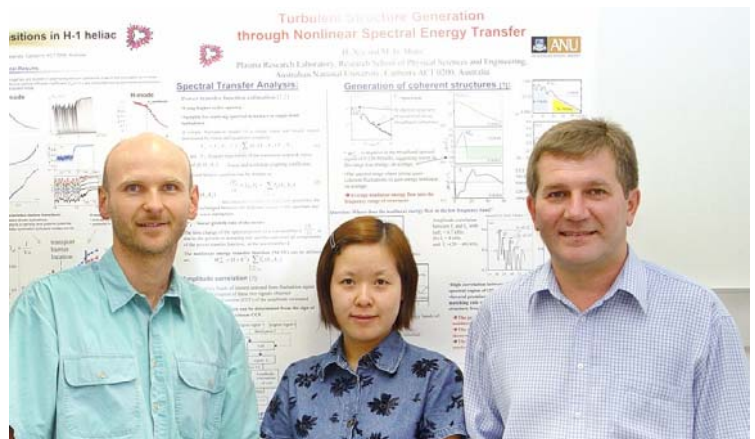


Figure 4: Left to right) Horst Punzmann, Dr. Michael Shats and Hua Xia presenting new results

III.2 Toroidal Plasma Confinement

Magnetic Configuration Studies

In 2004, exploration of the vast configuration space of the H-1NF “flexible heliac” configuration was focussed on determining mode structure of the magneto-hydrodynamic (MHD) instabilities observed. The geometry of the magnetic confinement region can be varied in several dimensions, such as shape, rotational transform (“twist per turn”), and the depth of the minimum in magnetic field (“magnetic well”, related to stability).

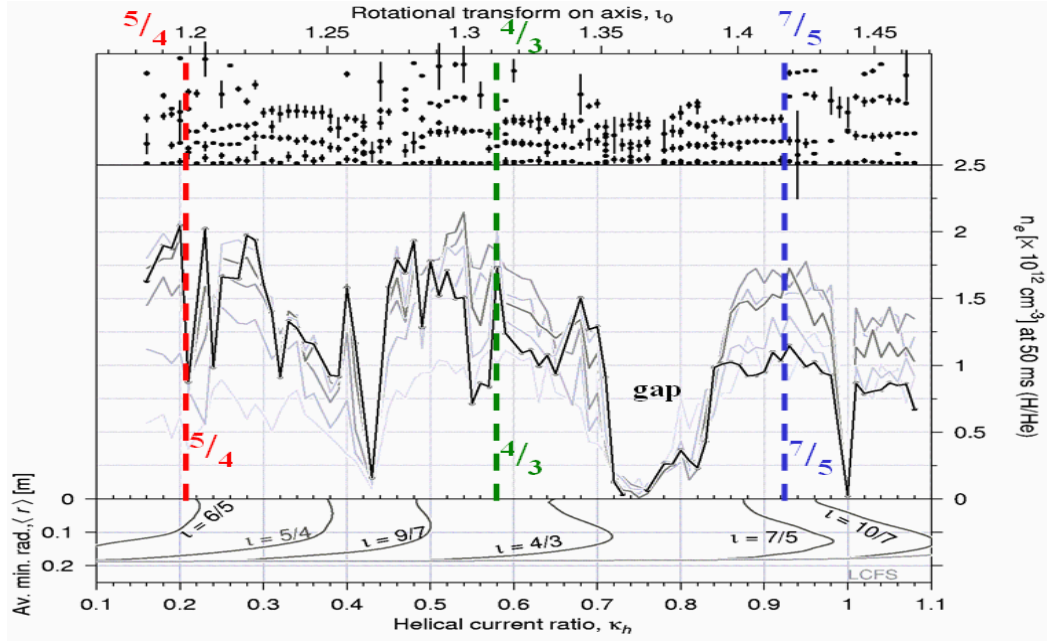


Figure 5 The variation of rotational transform(lower), plasma density and instability frequency (upper, dots) with the ratio of currents in the helical and ring conductors. Significant rational surfaces are marked by dashed lines.

Studies of the confinement of hydrogen-helium plasmas heated with ion-cyclotron waves using very fine scale (steps $< 0.5\%$) scans of the rotational transform show that the density confined in the heliac is very sensitive to the presence of surfaces with rational values of the rotational transform inside the plasma volume. When the rotational transform profile crosses multiple low order rational (e.g., $4/3$) surfaces, the density drops to very low values, as is illustrated in the figure. Fluctuations in the

magnetic field also show a fine structure that changes with rotational transform.

A second 20-coil external magnetic probe (Mirnov array) was installed to obtain toroidal mode numbers and improve poloidal mode data for these fluctuations. The 20 coil positions are shown in the figure, relative to the plasma. Near rational values of rotational transform of the form n/m , where n and m are integers, a predominance of poloidal mode numbers near the value of m is found. For example, near a transform of $3/2$, a poloidal mode number of 2 is clearly seen.

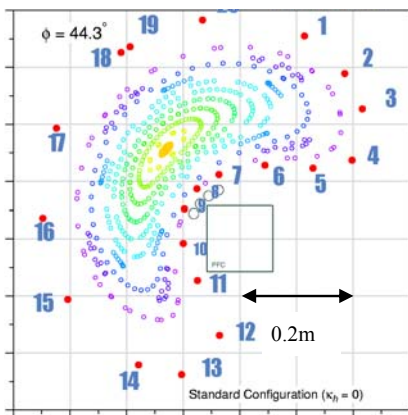


Figure 6: position of the 20 magnetic probes in the bean array

Mode numbers are determined either manually (Figure 7, by fitting phase variation against azimuthal angle, or by various numerical algorithms, such as counting the number of zeros around the periphery.

To understand the variation of plasma density with configuration, experiments were performed with a tubular limiter establishing different last closed flux surfaces. This is an alternative means of varying the rotational transform at the plasma edge, by moving the edge, instead of varying the rotational transform itself. The density variation behaviour was different, and three new small, sharp resonant features were found, at edge transform $4/3$, $7/5$ and $10/7$. However there was no clear link between the broader features and the value of rotational transform at the plasma edge. The present understanding is that the main effect is due to the coincidence of a rational value of transform at a radial location where the spatial variation in rotational transform is low (low “shear”).

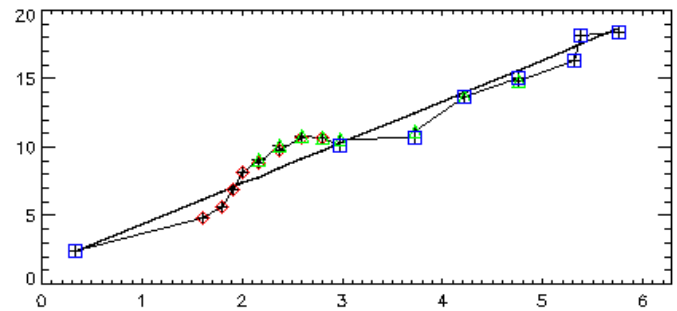


Figure 7: Phase of the MHD instability vs. azimuthal (poloidal) angle around the beam. A mode number of $M=3$ is fitted.

Initial configuration scans were performed with a different plasma heating source – electron cyclotron heating (ECH). The scans were not as detailed, but did not seem to have the fine scale variation with configuration as the RF produced plasma. Further work in this study awaits improvements in ECH power so that the plasma can be formed without any RF assistance.

Data Mining

It has become clear that the sheer volume of data is becoming unmanageable, and manual analysis such as in Figure 6 is too time consuming to apply to even any reasonable fraction of the data. A data mining project, funded by an ARC grant commencing this year will not only be able to deal with such quantities of data, but should extract much more information than possible with manual analysis. As part of this project, the summary database for facility operations will also be upgraded.

D.G. Pretty, B.D. Blackwell, J.H. Harris

III.3 H-1 Systems, Data and Automation

This year, the automation of H-1 was largely completed, and the new laboratories in the Weigold wing became operational. These replace the aging “Roundhouse” constructed for Sir Mark Oliphant in the 1950s. Facilities in these first-rate laboratories include multiple gas lines, closed circuit cooling water, vacuum exhaust and dry nitrogen. The six laboratories and the adjoining workshop will be used for preparation and calibration of instruments prior to installation on H-1, for spin-off developments and associated pursuits.



Figure 8: Ray Kimlin and PLC3, which controls cooling and the machine sequencer.

New systems include a directional gas injection system (DISH – section III) and an ECRH incident energy monitor, based on a sensitive bolometer mounted on the centre of the mirror the final mitre bend of the waveguide. Other gyrotron system improvements included realignment of the high power grooved circular waveguide, and commissioning of the full high voltage capacitor bank, allowing extension of pulses from 10ms to 40ms.

The “JavaScope” data viewer, from the Padua and MIT laboratories has been under further development by Drs. Blackwell and Gardner, mostly through senior student projects in “eScience”. In 2004, Mr. B. Dantuluri’s project was to add real time data capabilities, with a view to exploiting new high performance digitiser hardware for the PCI or CPCI bus (as used in personal computers). As we prepare for migration to the Linux operating system, the Java viewers are becoming an attractive option for everyday use. The increased CPU power makes up for the inefficiency of Java compared to native mode viewers, so that the extra features of the Java viewers can be exploited with very little loss in response time. The image capabilities of JavaScope are illustrated in Figure 13 in the Imaging section.

The fourth and final industrial programmable logic control controller (PLC) was installed for control of diagnostics. This essentially completes the automation of all power systems, cooling systems and the sequence that comprises a plasma pulse, reducing the manpower required to operate the H-1 facility, and improving the quality of data by extensive logging of measurements. Importantly, automation enhances remote participation and collaboration by providing a more complete overview of operational parameters on line, and provides early warning of malfunctions.



Figure 9: Con Costa, Clint Davies and Bob Ball at PLC2, controlling RF, ECH and Motor Generator

Automation upgrades included the second phase of automation of the 200kW gyrotron electron cyclotron heating system including synchronization of the charging supply with H-1 firing, and precision monitoring and feedback control of the magnet currents. These measures greatly improve the long term stability of output power. Other improvements include online water quality monitors, and conversion to PLC control of the 62 point thermocouple temperature measurement system that monitors H-1 coil temperatures and cooling systems. The separation of machine control and diagnostics allow physicists to have free access to the diagnostics, without risk of

compromising machine operation. *B.D.Blackwell, G.C.Davis, R.J.Kimlin, C.M.Costa.*

III.4 Advanced Imaging and Inverse Methods (Still under revision, especially greyed text)

The visible emission tomography system based on a 55 channel fibre coupled coherence imaging spectrometer demonstrated its full potential by imaging intensity, ion temperature and flow in an argon plasma. Implementation of a comprehensive calibration procedure, based on in-situ miniature fluorescent sources allowed successful reconstruction of typical bean-shaped plasma images in a single shot. By accumulation of ~ 10 shots, an unusually shaped pair of magnetic islands were successfully reconstructed, corresponding very well to the shapes observed by vacuum magnetic surface mapping shown in the figure. The group continues its fundamental work on various problems in tomography and has recently established a collaboration with the Singapore Synchrotron Light Source on xray microtomography.

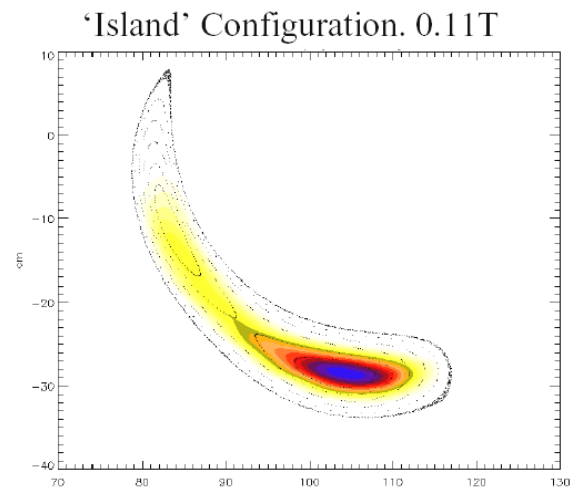


Figure 10: Argon ion emission tomography showing good agreement with computed magnetic surfaces for an island pair near the $3/2$ resonance

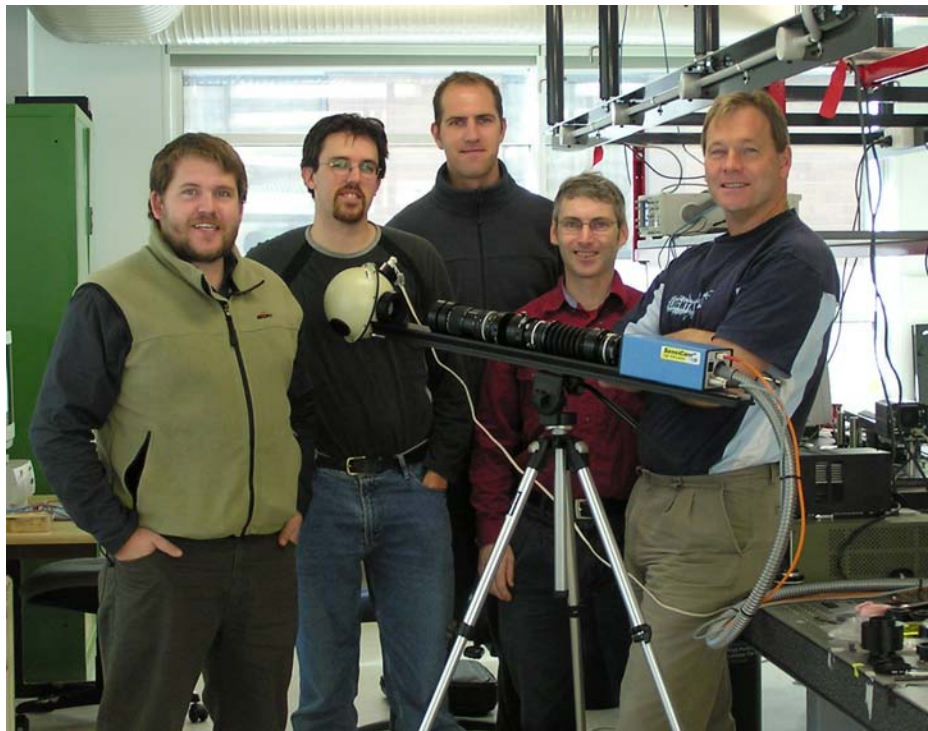


Figure 11: The AIIM group: Scott Collis, Fenton Glass, David Oliver, Dr George Warr, and Dr John Howard. Dr Clive Michael has now graduated and joined the Large Helical Device in Toki, Japan.

Understanding the physics of high temperature plasma confinement relies crucially on non-perturbing remote sensing tools. In recent years, the Advanced Imaging and Inverse Methods group (AIIM), led by Dr John Howard, has pioneered a number of radically new optical measurement systems that are now also being adopted at some of the world's premier fusion laboratories. Related systems are also

finding application in industrial process control. Between 2001-2003 AIIM won in excess of \$500,000 from external funding sources. To fully utilize the new measurement capabilities, the group also continues to develop the inverse mathematical methods that allow the unfolding and interpretation of the coherence data.

Plasma spectroscopic coherence imaging systems

A number of advanced imaging measurement systems based on the recently patented Modulated Coherence Imaging (MCI) spectrometer (US patent #6462826, 2002) are now installed and operating routinely on H-1. The MCI spectrometer is a modulated fixed-delay Fourier transform spectrometer based on solid-state electro-optic birefringent components. It is used for a wide variety of spectroscopic studies (e.g. polarisation and Doppler spectroscopy) of transition radiation from neutral atoms and ions. Growing interest from overseas groups led to invited presentations to the German-Polish EURO Conference on Plasma Diagnostics for Fusion and Applications (*Time-resolved 2-d plasma spectroscopy using coherence imaging techniques* J. Howard, C. Michael, F Glass and A Danielsson, 2002) and to the , International Stellarator Workshop, Greifswald Germany (*Imaging of ion temperature and flows in edge plasma,* 2003). A custom imaging system was sold to the Max Planck Institute for Plasma Physics in Germany, with another multi-channel system being developed for ion temperature and flow measurements on the Italian reversed field pinch experiment.

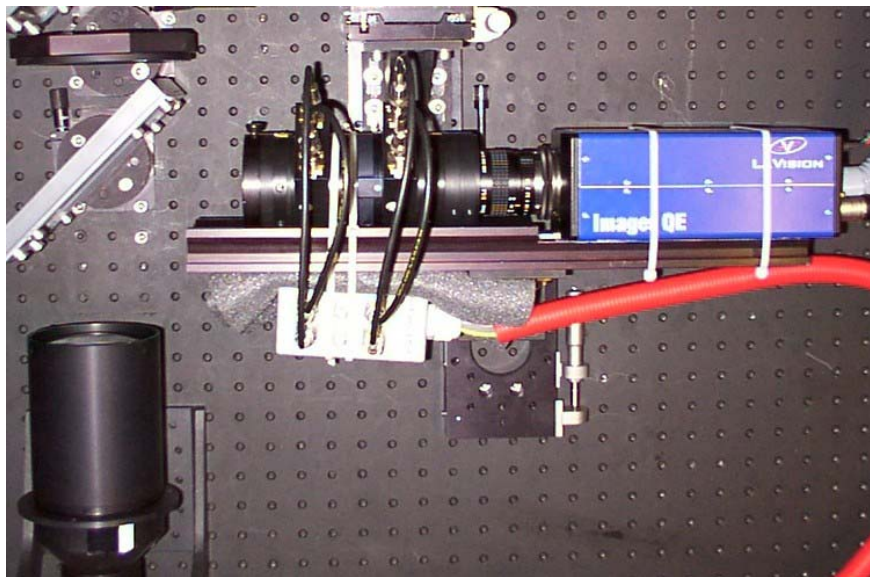
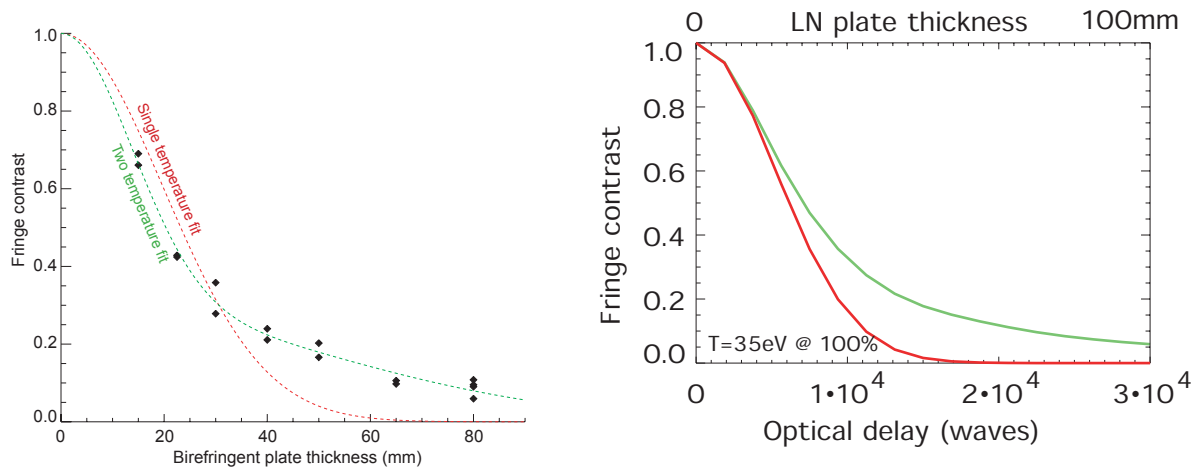


Figure 12: The Figure shows the MCI camera installed on the Wendelstein 7-AS stellarator in the Max Planck Institute for Plasma Physics in Germany.

Plasma heating and fuelling in H-1

The MCI systems have been used for the study of plasma heating and force balance in low-field (0.1T) low-temperature argon discharges (Clive Michael). The discovery of a significant non-thermal (hot) contribution to the ion velocity distribution function, and its localisation primarily to the plasma edge regions, suggests that ions are directly heated in H-1 through stochastic interaction with the radio-frequency sheath attached to the heating-antenna. The measured distribution functions have been

successfully explained in terms of ion-neutral interactions using a kinetic plasma model based on detailed collision cross-sections.



Left: Measured optical coherence variation with optical delay for the 488nm argon ion transition under low field 0.06T (red) and high field 0.12T (green) discharge conditions. The coherence (fringe visibility) is a measure of the Fourier transform of the ion velocity distribution function. Deviations from a Gaussian function indicate a significant role for non-thermal effects. Right: The distortion of the coherence function (distribution function) in the high field case is very well accounted by a kinetic model that includes the collisional interaction between neutral and ion fluids.

Time resolved behaviour of hydrogen and deuterium atom relative densities obtained by MCI imaging spectroscopy have clearly revealed the liberation of hydrogen from plasma-facing wall components as a major particle source. The results in part explain the lower than expected temperatures found in resonantly heated discharges at 0.5T.

Interferometry and particle control

The far-infrared (FIR) rapid-scan interferometer continues to operate reliably and has provided routine electron density profile information for a number of studies. Taken together with data from the MCI spectrometer information, we have been able to establish the need for a calibrated directional gas injection system for particle control. In conjunction with discharge cleaning and wall baking, the supersonic gas injection system, which is being developed by Scott Collis as part of his PhD training, should be able to provide greater control over particle fuelling with consequent access to higher temperature plasma regimes.

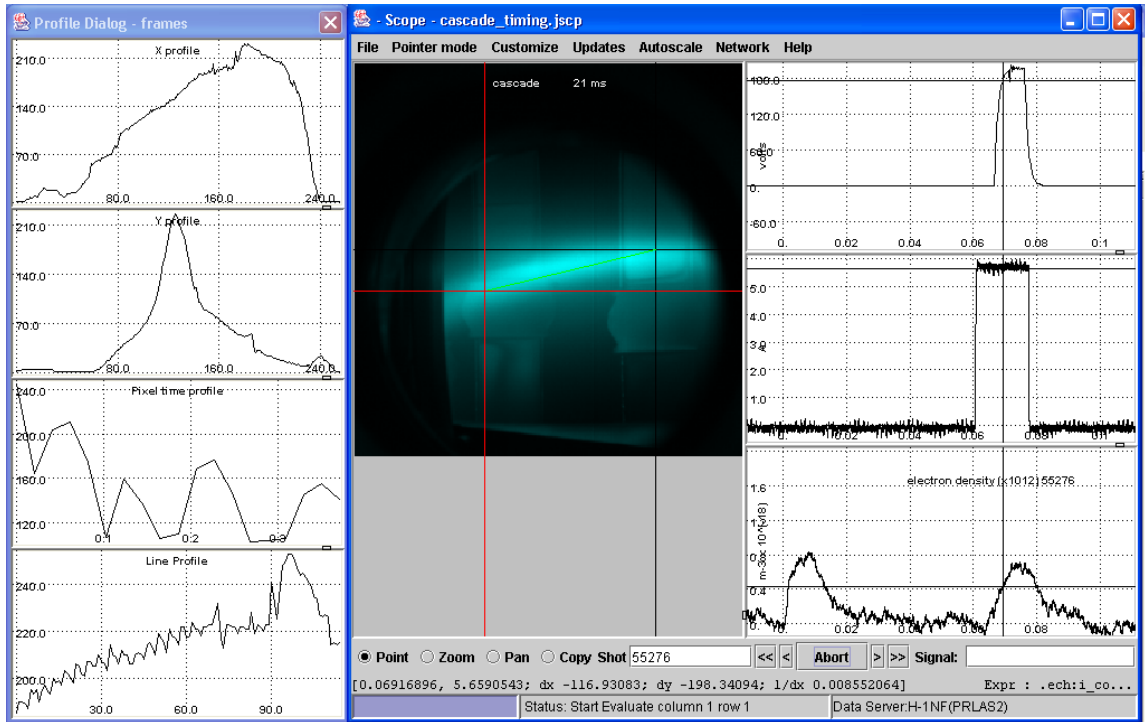


Figure 13: Localised emission from DISH gas puffing during an electron cyclotron heating pulse. This also illustrates the “JavaScope” data viewer being adopted as the standard data viewer for H-1NF.

Following a successful bid to the University Major Equipment Committee, AIIM has been awarded \$110K for the purchase of an electronically tuneable high power microwave source to upgrade the interferometer system. The new system will allow the replacement of the rotating grating, allow higher sweep speeds and give better signal to noise ratio. The development of the new system has been undertaken by Mr David Oliver as part of his PhD course.

Thermal imaging

This year has seen the development of high-throughput, visible-near-infrared interferometric sensors for remote temperature measurement. Related to the MCI spectrometer, the new filters are an attractive alternative to traditional radiometric systems and are also the subject of provisional patent protection. An ACT Knowledge Fund grant (\$40000) has been awarded for the development of an absolute spectro-radiometer based on these new devices for molten steel imaging at BHP-Billiton in Wollongong. The AIIM group has also completed a contract (\$99000) with DSTO for the development of sensors for discrimination of rocket and engine infrared signatures and is working towards next step imaging systems.

Left: The prototype camera installed at the blast furnace taphole. Right: False-colour split-image snapshot of the molten metal stream. The diameter of the stream is approximately 10cm. The cooler blue-green region in the mid lower portion of the image represents molten material in the trough below the metal stream, while the dark blue region at the bottom of the image corresponds to the side of the trough and the casthouse floor. These images have been processed to obtain simultaneous iron temperature and emissivity, the latter being used for the identification of slag.

Doppler tomography and inverse techniques

We have established the conditions under which the inhomogeneous velocity distribution function can be retrieved from Doppler tomographic measurements. Inverse algorithms which confirm these findings have been developed. In addition, new Abel inversion methods based on general splines with non-linear optimization of knot locations have been developed and used for inversion of the brightness, temperature and flow field projections obtained from the interferometer and MCI systems. We are also collaborating with Chalmers University in Sweden on microwave probing systems and associated finite-difference time-domain inverse techniques for detection and localization of human breast lesions.

III.5 Wireless Communications

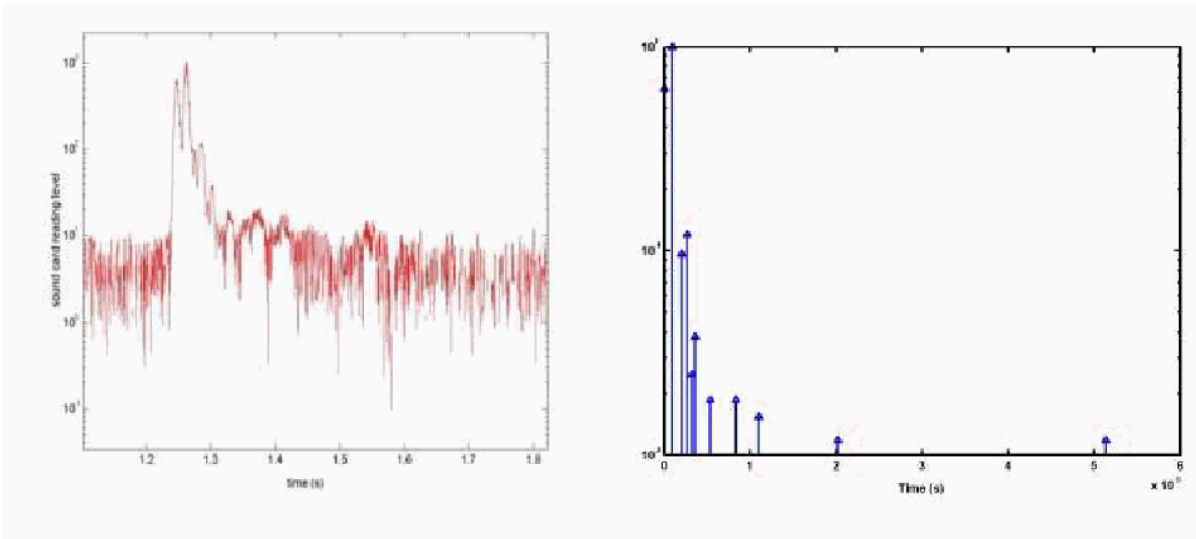
Radio-frequency waves are used throughout PRL to produce and heat plasma. Our interest in rf technology has led to the development of a wireless communications research effort which is headed by Dr. Gerard Borg. The largest part of this program is the Bush Local Area Network (BushLAN) project, which is developing and demonstrating digital VHF (Very High Frequency) wireless technology for use in a novel scheme to provide long-distance (5-50 km) “last-mile” Internet connections to regional Australia on unused VHF TV channel frequencies.

In 2004, following tests in 2003, we began larger-scale deployment of a test network in the ACT and surrounding region. The BushLAN team obtained a three year licence to perform channel measurements and build test data links on 50 - 52 MHz and 56 - 63 MHz in the ACT region. Some basic hardware components have now been developed and a “radio” now exists on which various physical layer platforms can be implemented and tested.



Figure 14: The system employed in tests in the ACT on show at the 2005 ACT Focus on Business Conference.

Link trials and channel sounding measurements were performed using the TV spectrum. An example is the following evidence of multipath in line-of-sight (LOS) and non line-of-sight locations. The figure shows the channel impulse response exhibiting the worst case of observed multipath intersymbol-interference(left) along with the discretised power delay profile (right), which can be interpreted as the main signal followed by a 9 delayed copies, mainly decreasing in amplitude for longer delays.



Test links using this radio have been used to demonstrate data and voice over Internet (VoIP) communications. Some data now exists on link performance and clues are emerging about the challenges to be met by future physical layer platforms. Some interest has also been generated in possible applications of BushLAN to difficult real-world telecommunications problems.

Combining aspects of plasma physics and communications is the development of a broadband miniature plasma switch concept for use in mobile phones, in collaboration with Motorola-USA.

IV. AUSTRALIAN FUSION RESEARCH AND THE H-1NF

Large Device Physics on a University Scale: H-1NF is large enough to permit plasma experiments of fusion interest, but remains a university-scale activity that favours innovative and exploratory experiments. H-1NF thus complements the large national laboratory experiments in Japan, Europe, and the US, which have rigorous technological and scheduling constraints. Recent experiments on H-1NF have explored the details of turbulent particle and energy transport and the transition to improved confinement regimes in low-power plasmas that facilitate diagnostic access, but preserve the essential physics seen in larger, hotter plasmas that are more difficult to study. Novel diagnostic methods using tomography, spectroscopic temperature and flow visualisation, and cross-correlation spectroscopy are being developed on H-1NF for eventual exploitation on larger experiments around the world.

Scientists in Australia have long been active in fusion research, working on small university experiments and as members of international teams on large experiments overseas. The development of H-1NF offers Australian researchers the opportunity to do experiments on a Facility that is large enough to produce hot plasmas with temperatures of the order of 500 eV \sim 5 million degrees C.

IV.1 Australian Fusion Research Group Collaborations

Flinders University: SPECTOR-3D

SPECTOR-3D, a resistive MHD stability and spectral code, has been developed for modelling 3D helical configurations, in particular, to the H-1 heliac. This has been an outcome of collaboration between Flinders University and the ANU, which began in 2000. Results of application to the large helical device(LHD), the largest stellarator currently operating, and other stellarators are very encouraging, but more work, including conversion to parallel processing, are needed to fully apply the code to H-1. The combination of the helical and toroidal curvature of H-1, together with the large indentation makes the Fourier representation difficult, and increases array sizes and execution times.

(B.F. McMillan (ex-ANU, currently at CRPP, Lausanne), R.G. Storer (Flinders University), R.L. Dewar (ANU), H.J. Gardner (ANU))

University of Sydney

Laser Induced Fluorescence

This project received ARC funding for 2000-2003. The aim of the project was to develop techniques for measuring electric fields in plasmas using the laser excitation and fluorescence of metastable helium atoms in a pulsed helium beam. Work undertaken by the Sydney group with collaborators at Hiroshima University (Professors K. Takiyama and T. Oda), focussed on the development of a suitable metastable helium beam injector. A collision rate equation model for helium was used to model the experiment. Dr. Peter Feng joined the group for laser-induced fluorescence measurements of electric fields in the H-1NF plasma edge. His appointment was supported by a large ARC grant held jointly with the University of Sydney.

.A highly directional injector, using a fast valve and a commercial flared conical skimmer was constructed and initial tests were very promising. The injector should also be a valuable localised helium source for helium neutral line ratio estimates of electron temperature and density. (*B.W. James, P. Feng, D. Andruczyk (Univ. Sydney) and J. Howard*)

University of Canberra

A summer student (Kan-John) undertook a project on testing the existing electronics and designing an interchangeable foil version of the 16 channel soft X-ray system. The original system previously installed has been removed for repairs to the electronics, preparatory to being set up as a permanent multi-channel diagnostic to monitor X-ray emission from 0.5Tesla ECH and RF produced plasma. A measurable high-energy X-ray flux is produced even with modest RF powers at 0.5Tesla in hydrogen plasma. (*P. Kan-John, B.D. Blackwell (ANU) and A.D. Cheetham, Univ. Canberra*)

V FACILITY PROMOTION

In 2004, a number of promotional and awareness activities were undertaken by staff to promote the Facility. These include the publishing of recent research results in a number of refereed journals (see Section VI.I) and presentations by researchers at several national and international conferences. A number of collaborative ventures with national and international partners, government and private industry were also undertaken (see Section VII). Visits to the Facility by national and international researchers and by prospective science students were organised, and service was provided by staff to a number of outside organizations.

These activities are summarised below

VI Publications

Evans, T.E.*, Moyer, R.A.*, Thomas, P.R.*, Watkins, J.G.*, Osborne, T.H.*, Boedo, J.A.*, Doyle, E.J.*, Fenstermacher, M.E.*, Finken, K.H.*, Groebner, R.J.*, Groth, M.*, Harris, J.H., La Haye, R.J.*, Lasnier, C.J.*, Masuzaki, S.*, Ohyabu, N.*, Pretty, D.G., Rhodes, T.L.*, Reimerdes, H.*, Rudakov, D.L.*, Schaffer, M.J.*, Wang, G.* and Zeng, L.*

Suppression of Large Edge-localized Modes in High-confinement DIII-D Plasmas with a Stochastic Magnetic Boundary

Physical Review Letters **92** (2004) 235003

Harris, J.H., Shats, M.G., Blackwell, B.D., Solomon, W.M., Pretty, D.G., Collis, S.M., Howard, J., Xia, H., Michael, C.A. and Punzmann, H.

Fluctuations and Stability of Plasmas in the H-INF Helic

Nuclear Fusion **44** (2004) 279-286

Harris, J.H.

Small-to-midsized Stellarator Experiments: Topology, Confinement and Turbulence

Plasma Physics and Controlled Fusion **46** (2004) B77-B90

Michael, C.A. and Howard, J.

Determination of Electron Temperature from Spectral Line Intensity Decay for Radiation Dominated Plasmas

Review of Scientific Instruments **75** (2004) 4180-82

Michael, C.A., Howard, J. and Blackwell, B.D.

Measurements and Modeling of Ion and Neutral Distribution Functions in a Partially Ionized Magnetically Confined Argon Plasma

Physics of Plasmas **11** (2004) 4008-17

Punzmann, H. and Shats, M.G.

Formation and Structure of Transport Barriers during Confinement Transitions in Toroidal Plasma

Physical Review Letters **93** (2004) 125003-1-4

Punzmann H., Shats M.G.

Cellular automata model in particle transport studies in magnetized plasma,

Complexity International, **12** (2004) 83-90

Shats, M.G., Xia, H., Punzmann, H. and Solomon, W.M.

Spectral Energy Transfer, Generation of Zonal Flows and their Role in Confinement Transitions

Fusion Science and Technology **46** (2004) 279-87

Xia, H. and Shats, M.G.

Spectral Energy Transfer and Generation of Turbulent Structures in Toroidal Plasma

Physics of Plasmas **11** (2004) 561-571

Yamada, H.* , Ida, K.* , Murakami, S.* , Watanabe, K.Y.* , Ascasibar, E.* , Brakel, R.* , Dinklage, A.* , Harris, J.H., Okamura, S.* , Sano, F.* , Stroth, U.* , Inagaki, S.* , Tanaka, K.* , Goto, M.* , Nishimura, K.* , Narihara, K.* , Morita, S.* , Sakakibara, S.* , Peterson, B.J.* , Sakamoto, R.* , Miyazawa, J.* , Morisaki, T.* , Osakabe, M.* , Toi, K.* , Tamura, N.* , Ikeda, K.* , Yamazaki, K.* , Kawahata, K.* , Kaneko, O.* , Ohyaabu, N.* , Komori, A.* and Motojima, O.*

Configuration Effect on Energy Confinement and Local Transport in LHD and Contribution to the International Stellarator Database

Fusion Science and Technology **46** (2004) 82-90

V.3 Service to Outside Organisations

Dr B.D. Blackwell

Service to Stellarator Physics Advisory Committee, Princeton Plasma Physics Laboratory, Princeton, USA

Dr G.G. Borg

Editor, *Czech Journal of Physics*

Member, Foreign Relations Committee, ATSE

Professor J.H. Harris

Member, Stellarator Physics Advisory Committee, Princeton Plasma Physics Laboratory, Princeton, USA

Member, Plasma Specialist Committee, AINSE

Member, Executive Committee, International Energy Agency Implementing Agreement for Research on Stellarators

Dr J. Howard

Member, Editorial Board, *Plasma Physics and Controlled Fusion*

Member, 11th International Congress on Plasma Physics Program Committee

Treasurer, Australian Institute of Physics Congress 2005

Dr M.G. Shats

Member, 11th International Congress on Plasma Physics Program Committee

VI COLLABORATION, EDUCATION AND TRAINING

VI.1 Collaborative Ventures

Dr B.D. Blackwell and Dr J. Howard

Project: Soft X-ray Measurements on H-1NF

Partner: A/Professor A.D. Cheetham, University of Canberra

Dr G.G. Borg and Professor J.H. Harris

Project: Plasma Antenna Concept Demonstrator

Partner: Dr N.M. Martin, Defence, Science and Technology Organisation

Project: Infrastructure for Wireless Internet Technology Development for Rural Australia

Partners: Ms H.M. Jones, A/Professor A.D. Cheetham and A/Professor J. Rayner, University of Canberra

Dr G.G. Borg and Mr P. Linardakis

Project: Plasma Switches for Mobile Phones

Partner: Dr R. Scheer, Motorola, USA

Dr G.G. Borg and Mr I. McRobert

Project: VHF Wireless Technologies for Last-mile Internet Access in Regional Australia

Partners: Standard Communications, Sydney; NJH Consulting, Newcastle

Professor J.H. Harris and Mr B. Heslop

Project: VHF Wireless Technologies for Last-mile Internet Access in Regional Australia

Partner: NJH Consulting, Newcastle

Dr J. Howard

Project: Spectroscopic Studies of the Plasma Divertor in W7-AS

Partners: Dr R. Konig and Mr J. Chung, Max Planck Institute for Plasma Physics, Germany

Project: Coherence Imaging on RFX Reversed Field Pinch

Partner: Dr M Valisa, Consorzio RFX, Padova, Italy

Project: Development of Diagnostic Imaging Systems for the Sydney University High Current Pulsed Arc

Partners: Professor M. Bilek, Dr R. Tarrant, Dr G. Warr and Professor D. Mackenzie, University of Sydney

Project: Measurement of Electric Field in H-1NF Using Laser Induced Fluorescence Techniques

Partners: Professor B.W. James and Mr D. Anduczyk, University of Sydney

Dr M.G. Shats

Project: Electron Cyclotron Heating of Plasma in Stellarators

Partner: Dr K. Nagasaki, Kyoto University, Japan

Project: Confinement Studies in Stellarators

Partner: Professor K. Toi, National Institute for Fusion Science, Japan

Project: Turbulent Structures and Transport in Plasmas

Partners: Professor P.H. Diamond and Dr D. Rudakov, University of California, USA

VII CONTRIBUTION TO AUSTRALIAN INDUSTRY

VII.1 Modulated Coherence Imaging System (MCI)

Two MOSS instruments that provide temperature image and other properties of high density plasma streams, were sold during the year –one multi-channel instrument to Max Planck Institute of Physics and one single channel instrument to Associazione Euratom-Eneasulla Fusione.

VII.2 Optical Temperature Measurement

A Knowledge Fund grant was obtained in conjunction with BHP Steel (now Bluescope) to develop an industrial radiation thermometer for the assessment of temperature of streams of molten steel and slag exiting a blast furnace. If successful, it is likely that Bluescope will enter into a Linkage grant for the further development of this technology for high temperature measurements. Dr. Howard has also progressed the technology during the year and has developed a space domain method of measurement of temperature that complements the frequency domain method. A new patent is being considered to protect this technology development.

VII.3 Radiofrequency Research

1) Plasma switch. Motorola is sponsoring a PhD thesis to investigate the use of plasma as a switch. The aim of this work is to investigate plasma as a candidate for a switching medium between antennas in multi-band mobile phones.

2) Novel data transmission techniques. The development of novel techniques for the transmission of high data rates at VHF. This work is aimed at the provision of a flexible long distance network for the provision of Internet services in regional Australia. The system has attracted a lot of interest and

worldwide interest in exploiting the vast amounts of long wavelength bandwidth hitherto only available to television is fast gaining pace.

The research currently associated with each of these areas is described in more detail below.

The Plasma Switch

MOTOROLA Inc., USA has awarded the Plasma Research Laboratory a continuing contract of \$49,500 to develop fast sub-miniature plasma switches for mobile phones. This grant is funding a PhD scholarship for Mr Peter Linardakis. He is performing a comparative investigation of plasma switches with the conventional technologies of PIN diodes and MEMS (micro-electromechanical systems) switches. Several prototype systems are currently being manufactured to test GHz range switching elements and Peter has begun to write his thesis.

Wireless communications

In 2003, five students and two technical officers (Con Costa and Ian McRobert) have been working with Dr Gerard Borg on the BushLAN project. This work is motivated by the need to bring cheap fast Internet to regional Australia and we have just developed a platform using the Band I analog TV spectrum. This system will form the basis of an upgradable research facility for wireless telecommunications in the ACT. The group has obtained a three year licence to utilise channel 1 (56 – 63 MHz) for channel experiments in the ACT region and Channel 0 (50 – 52 MHz) and Channel 1 (61 – 63 MHz) for network implementations within 40 km of Black Mountain ACT.

In the year under review we completed construction of the BushLAN prototype VHF radio. Various units have since been constructed and tested on short links at the University. A photograph of a radio is shown in Fig. 18.

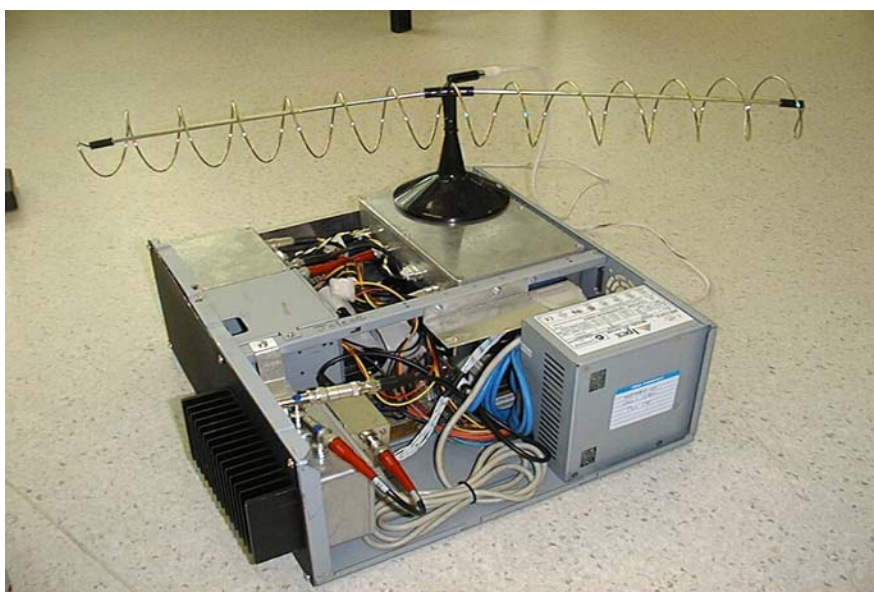


Fig.18. Schematic of BushLAN VHF Radio

At the end of 2003, Michael Anderson commenced PhD studies on BushLAN. He will be developing physical layer coding schemes for the VHF/UHF channel and has spent the initial stage of his thesis working with Mr Rhys Goodwin on VHF channel sounding in the ACT. Jeta VEDI has completed his first year as a PhD student working on networking protocols. Ben Heslop has changed his Master's degree to a PhD in commercialisation.

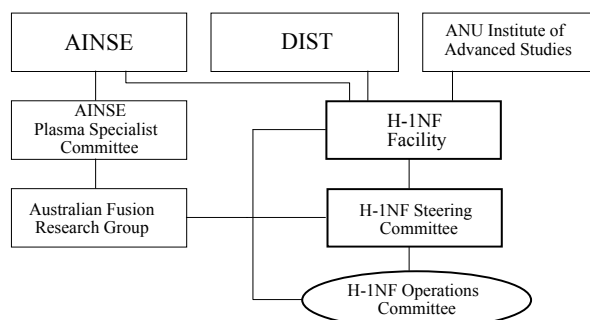
We are now commencing a new project to develop a system to exploit the 300 MHz of bandwidth available in the UHF TV spectrum. This project is part of an ARC linkage project with Standard Communications Pty Ltd in Sydney. This project is the subject of a PhD thesis and will be ultimately aimed at producing a unit economical enough to be attractive to individual users.

The BushLAN team of the Plasma Research laboratory has won \$150,000 towards the prototyping of the above radio through a 2002 ARC LIEF grant. The group also won two Linkage project grants. One for Standard Communications Pty Ltd Sydney to develop UHF BushLAN with PhD student Ian McRobert. A second with NJH Consulting Newcastle to investigate rapid commercialisation of University research with PhD student Ben Heslop.

VIII STAFFING AND ADMINISTRATION

VIII-1 Management Structure of the H-1 National Facility

The management structure of the Facility is shown below. This structure involves three major organisations, namely the Department of Industry, Science and Research, (DISR), the Australian Institute of Nuclear Science and Engineering, (AINSE) and The Australian National University, all of which have input into the decisions made by the H-1NF Board. The Board, and the Steering and Operations Committees, have direct impact on the Facility.



H-1NF Management Structure

The role of AINSE through its Plasma Specialist Committee lies mainly in the facilitation and coordination of Australian collaborations and the allocation of travel funds in support of this. The AFRG has input at all levels as the collaborations with these external bodies is crucial to the objectives and success of the project.

The Steering Committee plans the various programs: construction, installation, commissioning and experiments. The Operations Committee is more or less the shop floor organisation of the actual experimental work, and determines operational plans and schedules.

VIII.2 Membership of the H-1NF Board

As shown in the Table below, the Board is comprised almost entirely of ex officio members from institutions with an interest in the operation of the Facility. The present membership of the H-1NF Board includes representatives of Australian research institutions, government, industry, and overseas fusion research laboratories. The H-1NF Board meets two or three times per year at the ANU, and guides the operation of the Facility as a whole.

Members of the H-1NF Board are:

Chair <i>ex officio</i>	Dr. J. Baker, MSc PhD Qld, OBE, FTSE
Scientific Secretary, AINSE (<i>ex officio</i>)	Dr. D. Mather, BSc PhD UNSW, Dip Ed STC
AFRG Chair (<i>ex officio</i>)	A/Prof. A D Cheetham, BSc PhD Flinders
AINSE Representative (<i>ex officio</i>)	A/Prof. J.O'Connor, BSc PhD DSc ANU
Univ. of Sydney Representative <i>ex officio</i>	Prof. M. Bilek, BSc Syd, PhD Camb
H-1NF Director (<i>ex officio</i>)	Prof. J H Harris, MS MIT, PhD Wisc, FAPS, FAIP
Overseas Fusion Reps.	Prof. A Iiyoshi
	Prof. Fujiwara
Director, RSPHysSE, ANU (<i>ex officio</i>)	Prof. J. Williams, BSc PhD NSW, FAA, FTSE, FAIP, FIEAust
Senior Res. Admin.	Prof. L. Cram, BSc BE PhD Syd, FAIP, FRAS
Industry Representative	Mr. A. Sproule, ME UT Syd, GradDip. OR NSW IT
Member	Em. Prof. S. M. Hamberger, PhD DSc Lond, FAIP
Member	Dr. R. Gammon, Btech PhD Brunel, FinstP, Cphys, MIEAust, CP Eng. FAIE, FAIM
Minutes Secretary	Ms. H.P.Hawes, BA ANU



H-1NF Board meeting, November 2004

(l-r) Prof. S. Buckman, Prof. J.H. Harris, Prof. R. Storer, Dr. I. Falconer (in attendance), Mr. N. Martin (in attendance), Prof. L. Cram, Dr. J. Baker, Ms. H. Hawes, Prof. J. O'Connor, Dr. R. Gammon, Prof. S. Hamberger, Mr. D. Wilson (in attendance)

VIII.3 ANU and AFRG Staff

Academic Staff

Prof. J.H. Harris (ANU), Director, H-1NF
 Dr. B.D. Blackwell, (ANU), H-1NF Facility Manager
 A/Prof. A.D. Cheetham, University of Canberra, Chairman, AFRG
 Dr. J. Howard, (ANU) H-1NF Diagnostics Coordinator
 Dr. G.G. Borg, (ANU)
 A/Prof. R. Cross, University of Sydney
 Prof. R.L. Dewar, (ANU)
 Dr. H.J. Gardner, (ANU)
 A/Prof. B. James, University of Sydney
 Dr. M. Shats, (ANU)
 A/Prof. R. Storer, Flinders University

Adjunct Fellows

Mr. Scott Collis, Bsc Syd
 Mr. Fenton Glass, Bsc Qld
 Mr. Clive Michael, BSc
 Mr. Horst Punzmann, Bsc Polytech Regensburg
 Ms. Hua Xia, Msc Chongqing University, China

Technical Staff

Mr. G.C.J. Davies, Head Technical Officer
 Mr. P. Alexander

Mr. R.J. Kimlin
Mr. J. Wach
Mr. C. Costa

Administrative Staff

Ms. H.P. Hawes

Visiting Fellows

Joe Baker, MSc PhD Qld, OBE, FTSE
Marcela Bilek, BSc Syd, PhD Camb
Andrew Cheetham, BSc PhD Flinders, U Can
Lawrence Cram, BSc BE PhD Syd
Roger Gammon, Btech PhD Brunel, FinstP, Cphys, MIE Aust, CP Eng, FAIE, FAIM
Sydney Hamberger, PhD DSc Lond, FAIP (Emeritus Professor)
Dennis Mather, BSc PhD UNSW, Dip Ed STC
John O'Connor, BSc PhD DSc ANU
Anthony Sproule, ME UT Syd, GradDipOR NSW IT
Robin G. Storer, BSc PhD Flinders
Keith Walshe, MSc Aston (Birmingham) PhD UMIST

Post-graduate Students

Mr Scott Collis, BSc Syd, ANUPS
Mr Fenton Glass, BSc Qld, ANUPS
Mr Ben Heslop, BE, ANUPS
Mr Santhosh Kumar, MSc Pune, ARCDisc
Mr Peter Linardakis, BE /BIT, APA
Mr Liviu Lungu, MSc Polytechnic University, Bucharest, SPIRT
Mr Ben McMillan, BSc Melb, APA (jointly with TP)
Mr Clive Michael, BSc, APA
Mr David Oliver, BSc, UWgong, APA
Mr David Pretty, BSc Melb, ANUPS
Mr Horst Punzmann, BSc Polytech Regensburg, ANUPS
Mr Jeta Vedi, BE BCom, APA
Ms Hua Xia, MSc Chongqing University, China, ANUPTS

Honours Students

Mr Roshan Banan	Faculty of Engineering and IT, ANU
Mr Christopher Brooke	Faculty of Engineering and IT, ANU
Mr Bhaskara Dantuluri	Computer Sciences, ANU
Mr Stefan Foudoulas	Faculty of Engineering and IT, ANU
Mr Rhys Goodwin	Faculty of Engineering and IT, ANU
Mr Phillip Gowlett	University of Sydney
Mr Mark Gwynneth	Faculty of Engineering and IT, ANU
Mr Chris Hollins	Faculty of Engineering and IT, ANU
Mr Robert May	Faculty of Engineering and IT, ANU
Mr Eldad Ohanyon	Faculty of Engineering and IT, ANU
Mr Andrew Vicquaret	University of Sydney

CEA Technologies and Neolite Neon

The Application of Plasma Antennas to Communications and Radar
2000 – 2003, extended to 2004

\$ 63,240

DEST

Innovation Access Programs

Professor J. Harris and Dr M. Shats

*Cross Platform Studies of Fusion Plasma Confinement in Tokamaks
and Stellarators*

June 2003 – April 2004

\$ 50,600

Dr J. Howard

*Studies of High Temperature Edge Plasma Confinement Physics using
New Hyperspectral Imaging Systems*

2004 – 2006

\$ 173,690

DISR

Professor J. Harris *et al.*

National Plasma Fusion Research Facility

April 1997 – May 2005

\$8,700,000

Major Equipment Committee, ANU

Externally led LIEF – University of Sydney

Professor J.H. Harris, Dr J. Howard, Dr B.D. Blackwell, Professor R.W. Boswell,
Dr C. Charles and Dr M.G. Shats (ANU Participants)

Interactive Network for Plasma Surface Analysis

2004

\$72,000

X PROJECT PROGRESS VERSUS MILESTONES

Project Milestones

The Table below lists the 2004 project progress against milestones from the MNRF contract. All but three (light highlights) are complete. Helium line ratio spectroscopy is being evaluated as an alternative to Thomson scattering. Operation at full field (1 Tesla) will be held back as pending results of electromagnetic force tests, and until results with the new ECH and ICH power sources have produced several publications, and until it can be decided if power line compensation should be implemented. The investigation of electromagnetic forces on the H-1 coil set, interrupted by the loss of a staff member, has been resumed as a 4th year engineering project for 2004-2005.

Milestone	Plan	Revised	Achieved	Status/Progress
Magnet Power Supply				
0.5 Tesla	5-1998		2-1999	Achieved
1.0 Tesla	4-2000	7-2006		power supply to full current (11/99)
ECH Plasma Heating				
100 kW into dummy load	3-1998		6-1997	Ahead
150 kW into plasma	6-1998		4-2002	Shot 47355
ICH Plasma Heating				
Demonstrate rf heating at low field (0.1T)	9-1997		9-1997	on time
100 kW into plasma	10-1998		6-1998	Ahead
200 kW into plasma	6-1999		4-2002	Shot 47034 (Argon)
High Power Heating upgrade				
Decide balance of ECH/ICH	6-1999	9-2005		depends on ECH/ICH above
Diagnostics				
Solid state spectrometer for flow and temperature profiles, operational	7-1997		7-1997	on time
Multiple retarding field energy analyzer operational	8-1997			2000: Complete: (Supplanted by advanced probe array and Doppler spectroscopy)
2D tomographic density interferometer operational	4-1998		4-1998	on time
Multiview Thomson scattering operational	9-1998	9-2006		May replace by Helium line ratio installed 9/1999
2D visible Doppler spectroscopy system operational	1-1999		9-2000	
Multiview Soft X-ray diagnostic operational	3-1999	2002		<i>Complete, but offline for repairs</i>
Data system				
Real time experimental participation demonstrated from remote sites—	7-1998		6-1998	Ahead

Milestone completion status for H-1NF Development

XI FINANCIAL STATEMENTS

MNRF CASHFLOW REPORT

NATIONAL PLASMA FUSION RESEARCH FACILITY

Report for the quarter Ended: 31-Mar-04

Name: Sandra Lenarcic

Position: Accountant, Special Purposes Funds
The Australian National University



AUTHORISATION SIGNATURE

		Unused Funds Available for this Period	Next Quarter
Cash Carried over from previous quarter	A1	<u>2,104,011.95</u>	A2 <u>2,070,292.71</u>

RECEIPTS		This Period	Next Quarter
MNRF Program Funds		<u>0.00</u>	<u>0.00</u>
Non-MNRF Program Funds			
Partner Contributions		<u>0.00</u>	<u> </u>
Other Sources		<u>0.00</u>	<u> </u>
Interest		<u>15,779.54</u>	<u>18,474.22</u>
TOTAL RECEIPTS	B1	<u>15,779.54</u>	B2 <u>18,474.22</u>

EXPENDITURE		This Period	Next Quarter
Power Supply		<u>3,860.54</u>	<u>5,000.00</u>
Heating Systems		<u>2,006.93</u>	<u>5,000.00</u>
Plasma Diagnostics		<u>-789.99</u>	<u>30,000.00</u>
Heliac Infrastructure		<u>34,361.73</u>	<u>30,000.00</u>
Other Support Costs		<u>10,059.57</u>	<u>5,000.00</u>
TOTAL EXPENDITURE	C1	<u>49,498.78</u>	C2 <u>75,000.00</u>

CASH BALANCE		This Period	Next Quarter
CASH BALANCE OF ACCOUNT	D1	<u>2,070,292.71</u>	D2 <u>2,013,766.93</u>

MNRF CASHFLOW REPORT

NATIONAL PLASMA FUSION RESEARCH FACILITY

Report for the quarter Ended: 30-Jun-04

Name: Sandra Lenarcic

Position: Accountant, Special Purposes Funds
The Australian National University

AUTHORISATION SIGNATURE

	Unused Funds Available for this Period	Next Quarter
Cash Carried over from previous quarter	A1 <u>2,070,292.71</u>	A2 <u>1,947,378.41</u>

RECEIPTS	This Period	Next Quarter
MNRF Program Funds	<u>0.00</u>	<u>0.00</u>
Non-MNRF Program Funds		
Partner Contributions	<u>0.00</u>	<u> </u>
Other Sources	<u>0.00</u>	<u> </u>
Interest	<u>14,165.40</u>	<u> </u>
TOTAL RECEIPTS	B1 <u>14,165.40</u>	B2 <u>0.00</u>

EXPENDITURE	This Period	Next Quarter
Power Supply	<u>4,281.42</u>	<u>5,000.00</u>
Heating Systems	<u>9,144.90</u>	<u>5,000.00</u>
Plasma Diagnostics	<u>95,254.06</u>	<u>30,000.00</u>
Heliac Infrastructure	<u>19,579.71</u>	<u>10,000.00</u>
Other Support Costs	<u>8,819.61</u>	<u>7,000.00</u>
TOTAL EXPENDITURE	C1 <u>137,079.70</u>	C2 <u>57,000.00</u>

CASH BALANCE	This Period	Next Quarter
CASH BALANCE OF ACCOUNT	D1 <u>1,947,378.41</u>	D2 <u>1,890,378.41</u>

MNRF CASHFLOW REPORT

NATIONAL PLASMA FUSION RESEARCH FACILITY

Report for the quarter Ended: 30-Sep-04

Name: Sandra Lenarcic

Position: Accountant, Special Purposes Funds
The Australian National University

Sandra Lenarcic

AUTHORISATION SIGNATURE

	Unused Funds Available for this Period	Next Quarter
Cash Carried over from previous quarter	A1 <u>1,947,378.41</u>	A2 <u>1,869,394.03</u>

RECEIPTS	This Period	Next Quarter
MNRF Program Funds	<u>0.00</u>	<u>0.00</u>
Non-MNRF Program Funds		
Partner Contributions	<u>0.00</u>	<u> </u>
Other Sources	<u>0.00</u>	<u> </u>
Interest	<u>13,511.60</u>	<u> </u>
TOTAL RECEIPTS	B1 <u>13,511.60</u>	B2 <u>0.00</u>

EXPENDITURE	This Period	Next Quarter
Power Supply	<u>3,885.06</u>	<u>5,000.00</u>
Heating Systems	<u>4,620.13</u>	<u>8,000.00</u>
Plasma Diagnostics	<u>42,352.37</u>	<u>45,000.00</u>
Heliac Infrastructure	<u>34,234.55</u>	<u>25,000.00</u>
Other Support Costs	<u>6,403.87</u>	<u>3,000.00</u>
TOTAL EXPENDITURE	C1 <u>91,495.98</u>	C2 <u>86,000.00</u>

CASH BALANCE	This Period	Next Quarter
CASH BALANCE OF ACCOUNT	D1 <u>1,869,394.03</u>	D2 <u>1,783,394.03</u>

MNRF CASHFLOW REPORT

NATIONAL PLASMA FUSION RESEARCH FACILITY

Report for the quarter Ended: 31-Dec-04

Name: Lorraine Piper

Position: Accountant, Special Purposes Funds
The Australian National University


AUTHORISATION SIGNATURE

	Unused Funds Available for this Period	Next Quarter
Cash Carried over from previous quarter	A1 <u>1,869,394.03</u>	A2 <u>1,834,060.91</u>

RECEIPTS	This Period	Next Quarter
MNRF Program Funds	<u>0.00</u>	<u>0.00</u>
Non-MNRF Program Funds		
Partner Contributions	<u>0.00</u>	<u> </u>
Other Sources	<u>0.00</u>	<u> </u>
Interest	<u>17,068.78</u>	<u> </u>
TOTAL RECEIPTS	B1 <u>17,068.78</u>	B2 <u>0.00</u>

EXPENDITURE	This Period	Next Quarter
Power Supply	<u>2,661.48</u>	<u>4,000.00</u>
Heating Systems	<u>2,073.17</u>	<u>3,000.00</u>
Plasma Diagnostics	<u>36,266.14</u>	<u>30,000.00</u>
Helic Infrastructure	<u>9,605.41</u>	<u>14,000.00</u>
Other Support Costs	<u>1,795.70</u>	<u>2,000.00</u>
TOTAL EXPENDITURE	C1 <u>52,401.90</u>	C2 <u>53,000.00</u>

CASH BALANCE	This Period	Next Quarter
CASH BALANCE OF ACCOUNT	D1 <u>1,834,060.91</u>	D2 <u>1,781,060.91</u>

ACRONYMS

ABC	Australian Broadcasting Commission
AFRG	Australian Fusion Research Group
ANU	Australian National University
AINSE	Australian Institute of Nuclear Science and Engineering
CDX-U	Current Drive Experiment-Upgrade
CQU	Central Queensland University
DC	Direct Current
DISR	Department of Industry, Science and Resources
DSTO	Defence Science and Technology Organisation
DT	Deuterium-Tritium
ECH	Electron Cyclotron Heating
ECRH	Electron Cyclotron Resonance Heating
FEIT	Faculty of Engineering and Information Technology
HARE	Helicon Activated Reactive Etching
H-1NF	Heliac -1 National Facility
IAS	Institute of Advanced Science
JET	Joint European Torus
LCD	Liquid Crystal Display
LHD	Large Helical Device
MEMS	Micro-Electronic Mechanical Switch
MDS	Model Data System
MHD	Magneto-hydrodynamic
MOSS	Modulated Optical Solid State
NIFS	National Institute for Fusion Science
OVMS	Open Virtual Machine Operating System
ORION	Oak Ridge Ion
PIC	Particle-in-Cell
PIN	P-type (intrinsic layer) n-type diode
PC	Personal Computer
RF	Radio-frequency ¹
RIEFP	Research Infrastructure Equipment and Facilities Scheme
SOFT	Spread-Spectrum Optical Fourier Transform
SPIRT	Strategic Partnerships with Industry - Research and Training Scheme
SP3	Space Plasma Processing
TFTR	Tokamak Fusion Test Reactor
TJ-II	Torus de la Junta de l'Energia Nuclear
UC	University of Canberra
VNC	Virtual Network Computer
WKB	Wentzel-Kramers-Brillouin