The Australian Plasma Fusion Research Facility
NCRIS Progress Report 2: to 30th June 2014

This document is a brief report on the activities within Australian Plasma Fusion Research Facility between Jan 1st 2014 and June 30th 2014 during which time operations and maintenance were supported in part by NCRIS funding. The Facility comprises two devices, the H-1NF heliac and the MAGPIE plasma interaction experiment, and associated instrumentation ('diagnostics'), data accessibility, power, heating and cooling systems. Highlights and activities are summarised below.

Highlights: H-1NF

First optical observation of propagation of radio frequency waves in H-1.

A new re-entrant port on H-1 provides a direct optical view of the plasma in the vicinity of the plasma-heating antenna inside H-1. The simultaneous operation of a newly installed supersonic gas injector at this location offers scientists new opportunities to study the mechanisms of radio frequency heating of plasma. In particular, monitoring the strength of electric fields in the vicinity of the antenna is important in future reactor operation, to avoid sputtering impurities and arcing. Figure 1 shows the arrangement and the first results, a snapshot from a movie of wave propagation away from the antenna. This employed the new synchronous imaging technique implemented on a high speed camera funded by the EIF upgrade, described in Progress report 1. It is the forerunner of a project to obtain detailed measurements of the high electric fields in the vicinity of the antenna.

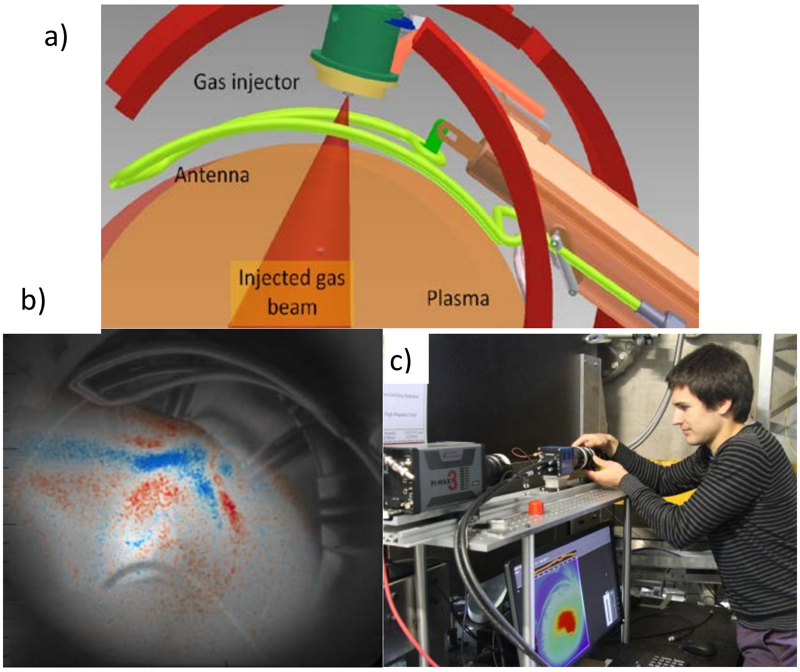

Figure 1: a) arrangement of the gas puff injector (green), RF antenna (lime green) and plasma b) Snapshot of wave structure travelling away from the loop antenna above. Wave crests are red, troughs are blue. c) PhD student Alex Thorman aligns the high speed camera viewing the antenna.

Spectroscopic measurements of density and temperature profiles: Dr von Nessi completed the upgrade of the imaging high resolution spectrometer, with the installation of a new grating designed specifically to observe atomic helium line emissions that he has chosen for electron temperature and density measurements. When used in conjunction with our pulsed helium beam injector (developed in collaboration with the University of Sydney), the spectrometer will be able to provide localised plasma electron density and temperature profiles (not averaged along a line of sight.)

Highlights: MAGPIE

Atomic hydrogen loss measurements in MAGPIE

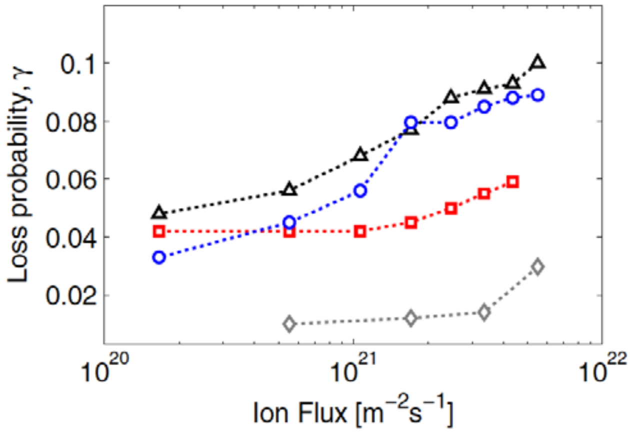

Figure 2: Loss probabilities measured in the early afterglow for tungsten (black triangles), graphite (blue circles), stainless steel (red squares) and for control case (grey diamonds)

Using a new spectroscopic technique PhD student Cameron Samuell and Dr Cormac Corr showed that the loss of hydrogen atoms (loss probability) at the surface of a fusion relevant material is greatly affected by the operating conditions of the plasma. This is related to the probability of absorption of hydrogen into the material. The results show increases as the ion flux increases. Accurate knowledge of this is crucial for modelling materials that will be used for plasma-facing components in next generation fusion reactors, in particular the take-up of radioactive heavy hydrogen (tritium). The research was recently published in Journal of Nuclear Materials.

Gas Temperature Measurements in MAGPIE.

A tuneable diode laser on MAGPIE has enabled the first spectroscopic measurements of the temperature of the neutral hydrogen gas that accompanies the hydrogen plasma. This temperature, found to between 100 and 700 Celsius, plays an important role in the interactions of the plasma with materials. The same process will also allow estimation of the density of energetically excited neutral hydrogen.

Activities: H-1NF

The first demonstration of direct imaging of the propagation of RF waves and of the profiles of helium neutral emission have been described in the highlights section. Other activities included:

Commissioning of the supersonic gas injector and re-entrant viewport.

The supersonic gas injector, funded as part of the EIF upgrade, and show in Figure 1, was successfully commissioned, injecting hydrogen, helium, neon or argon into H-1. The injected gas is localised in the vicinity of the injector, and emits radiation on different spectral lines so that measurements on that part of the plasma can be isolated. Another application is to inject larger quantities of gas provide fuel for increasing the plasma density.

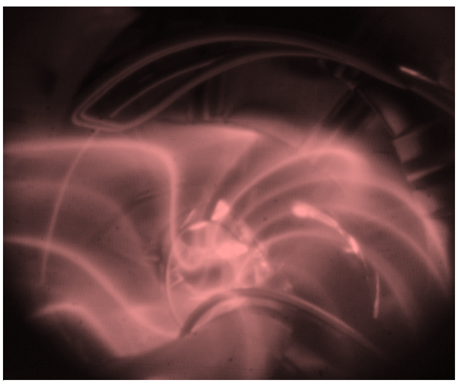
Figure 3: View from re-entrant viewport showing light emitted from electron beams confined on magnetic field lines in H-1NF.

To complement the injector, a re-entrant tube was designed to access a good viewpoint for observing the antenna and injector. Part of the EIF upgrade, an imaging fibre optic bundle and camera provide the images such as in Figures 1b and 3.

Correlations in H-1NF using probes

Langmuir and 'Ball-Pen' probes were used to detect plasma flows and correlations between fluctuations at different points in H-1. High correlations are observed along magnetic field lines, and may be used as a method to experimentally map the magnetic field lines inside a plasma. The magnetic field is very complex and highly twisted, as shown in Figure 3. Figure 4 shows the regions of high correlation which agree reasonably well with the expected paths of magnetic field lines.

The new residual gas analysis system

A mass spectrum analyser and associated vacuum pump system was installed under the EIF upgrade to provide information on plasma purity. To enable usage at the high pressures used for glow discharge cleaning, the flow to the analyser had to be limited. A suitable combination of attenuation and baking, and location away from high magnetic fields was found, enabling the analyser to be used during plasma operation and glow discharge cleaning.

Activities: MAGPIE

Observation of negative ions in MAGPIE.

The first measurements of the density of negative ions are being performed in the MAGPIE device by Dr Cormac Corr and PhD student Jesse Santoso. The technique uses laser photo-detachment to release the electron from the negative ion so that it can be collected by probes embedded in the plasma. The efficient generation of negative ions is an essential element of neutral beam heating systems for fusion reactors.

Synergistic effects of a combination of plasma and simulated neutron bombardment.

In collaboration with ANSTO, Graphite samples were irradiated with high energy (5 million electron volt) carbon ions, which simulate damage created by fusion neutrons. Samples were subsequently exposed to a deuterium plasma in the linear plasma device, MAGPIE. Structural and surface chemistry changes were observed to be greatest for the sample irradiated with the greatest exposure of energetic ions.

Plasma production in MAGPIE

PhD student Juan Caneses has obtained good agreement between the theory of plasma generation by helicon waves and results obtained at high density of hydrogen in MAGPIE. His model is being applied to understanding the production of high density plasma in MAGPIE to provide a basis for designing the next-generation device. This proposed device will be larger and much more flexible to accommodate more users. Discussions with the user community about a joint LEIF application are in progress.

Increasing facility usage

The Australian user base has increased by five in the last six months. This includes researchers from the Australian Defence Force Academy and new students. Collaboration on the analysis of facility data have commenced with Sydney University, Oak Ridge National labs for materials, and CIEMAT, Spain. Highlights of this work will be featured in the next progress report.

Performance

The table below show that all criteria are met (✓) or on target to be met. Note that the Project Plan refers to a two year period, while the figures here are for one year, to be more readily compared with the 12 monthly results (FY 2013-14) to date.

Criterion or KPI	Jan-Jun 2014	FY 13-14	Target	Comment
Refereed Journal Articles:	13	20	15 pa.	✓ Well in excess of target
Student Training	22	22	25 / 2 yrs	✓ On track to exceed target over two years.
H-1 Facility research plasma shot cycles	2050	3696	1000 pA	✓ Based on automated count of shots with significant data recorded
Days of operation of the Materials Facility (MAGPIE)	84	108	100 pA	✓ In excess of target, based on documented days. Actual number is ~50 higher
Increase in Australian user/collaborator base	5	6	3 pA.	✓ Well in excess of target.
Increase in refereed publication output relative to 2010-2013 average.	3	4	2 (10%) pA*	✓ Well in excess of target.
Increased international collaborative activities (MoUs, International Committees, collaborations enabled)	0	1	3 over 2 years	On track to meet target. MoU with IPP Greifswald awaiting signature, negotiations to join the International Tokamak Physics Activity Committees and two more IEA implementing agreements under way.
Increase in organisations benefitting	1	2	2 in total	✓ ADFA has begun using the MAGPIE facility.
Increase in availability for research	1.4x increase	1.9x increase	30% *	✓ Exceeded: Average of total shots over 6 months has increased from 1550 (2010-2013 average) to > 3000 MAGPIE at full capacity
Increase in diagnostic capability beyond EIF commissioning level.	1	2	2 diagnostic systems	✓Gas puff imaging (see highlights)
Increase in parameter range accessible to H-1 (e.g. Deuterium plasma, extend RF heating range to 4-8MHz,)		✓ ✓ ✓	(as listed)	✓ Control of Antenna phasing implemented, providing more flexibility in plasma heating
Design of successor materials device – conceptual design suitable for proposal to a fund provider.				On track— scaling study of density with power on MAGPIE completed, providing guidelines for design of successor device.
Strategic Plan for Fusion Science released.				On track - Completed – Release event with Senator Z. Seselja scheduled for July 2014

** relative to July 2010 - July 2013 average*

Table 1: Performance and KPI estimates: Jan 1st – June 30th

Financial Information ($,000)

Below is a statement up until June 30th. An audited statement in the required form will be supplied as requested in January 2015.

Jan 1st- Jun 30st	**Jan-Jun 2014**	**Budget (2yr)**	**Comment**
Carry Forward	15.3		(actual debit carried forward less than expected due to double counting of some MN items)
Income	-198	900	
Operation, management and governance costs	0.5	5	(recent Board meetings were conducted by teleconference)
Salaries and on-costs for technical staff	139	769	
Infrastructure maintenance + consumables	17.7	96	
Utilities	0	0	
Rent	0	0	
International Collaboration	0	30	4 visitors arranged
Balance as at 30th June	**25.5**		Credit of 25.5k will be absorbed in FY14-15

Table 2: Financial Statement for Jan 1st – June 30th

Boyd Blackwell, Associate Director, Australian Plasma Fusion Research Facility