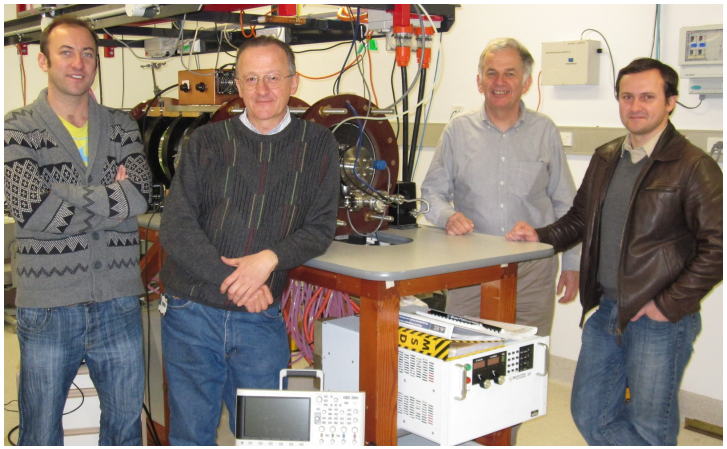
Overview

The MAGnetized Plasma Interaction Experiment (MAGPIE)

- Description
- Plasma characterisation (T_e, n_e, EEPF, Ion flow)
  - Low power (< 500 W)
  - Medium Power (500 W to 2kW)
  - High Power (4 kW to 22 kW)
- Initial material results

- Outlook and concluding remarks

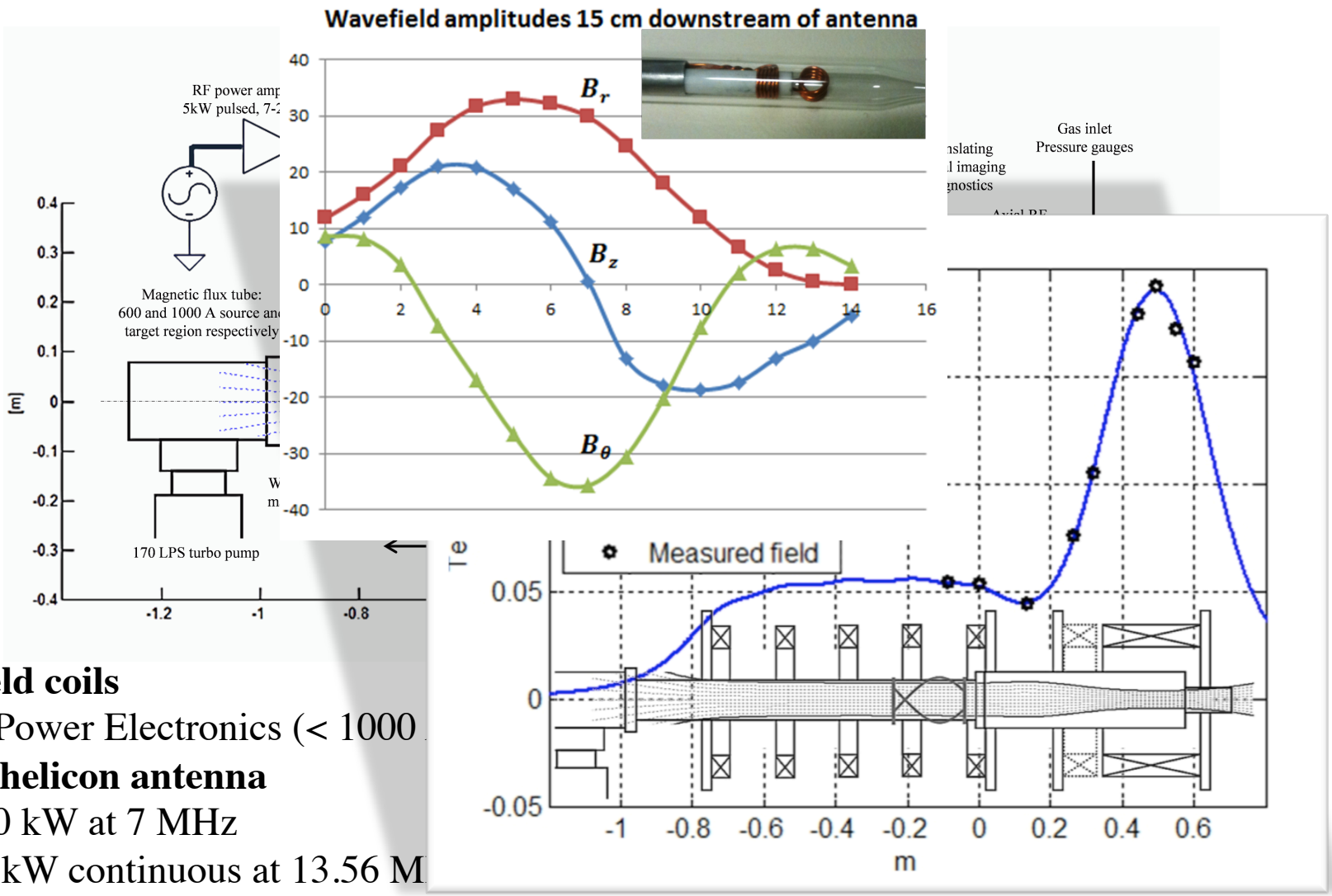


Objectives

Establish a new interdisciplinary research effort, bringing together Australian expertise in plasma physics, atomic and molecular physics, chemistry, materials science and surface physics.

- Create key experimental configurations and plasma conditions to investigate advanced wall material.
- Resolve fundamental physics in the plasma-wall region.
- Develop novel non-intrusive diagnostics to determine properties (density, temperature) of impurities and plasma species.
- Benchmark current (e.g tungsten, carbon-based) and novel materials.
- Validate numerical modelling against experimental data, ultimately predicting and tailoring plasma-surface interactions.

MAGnetised Plasma Interaction Experiment (MAGPIE)



Magnetic field coils

Magna Power Electronics (< 1000

RF power – helicon antenna

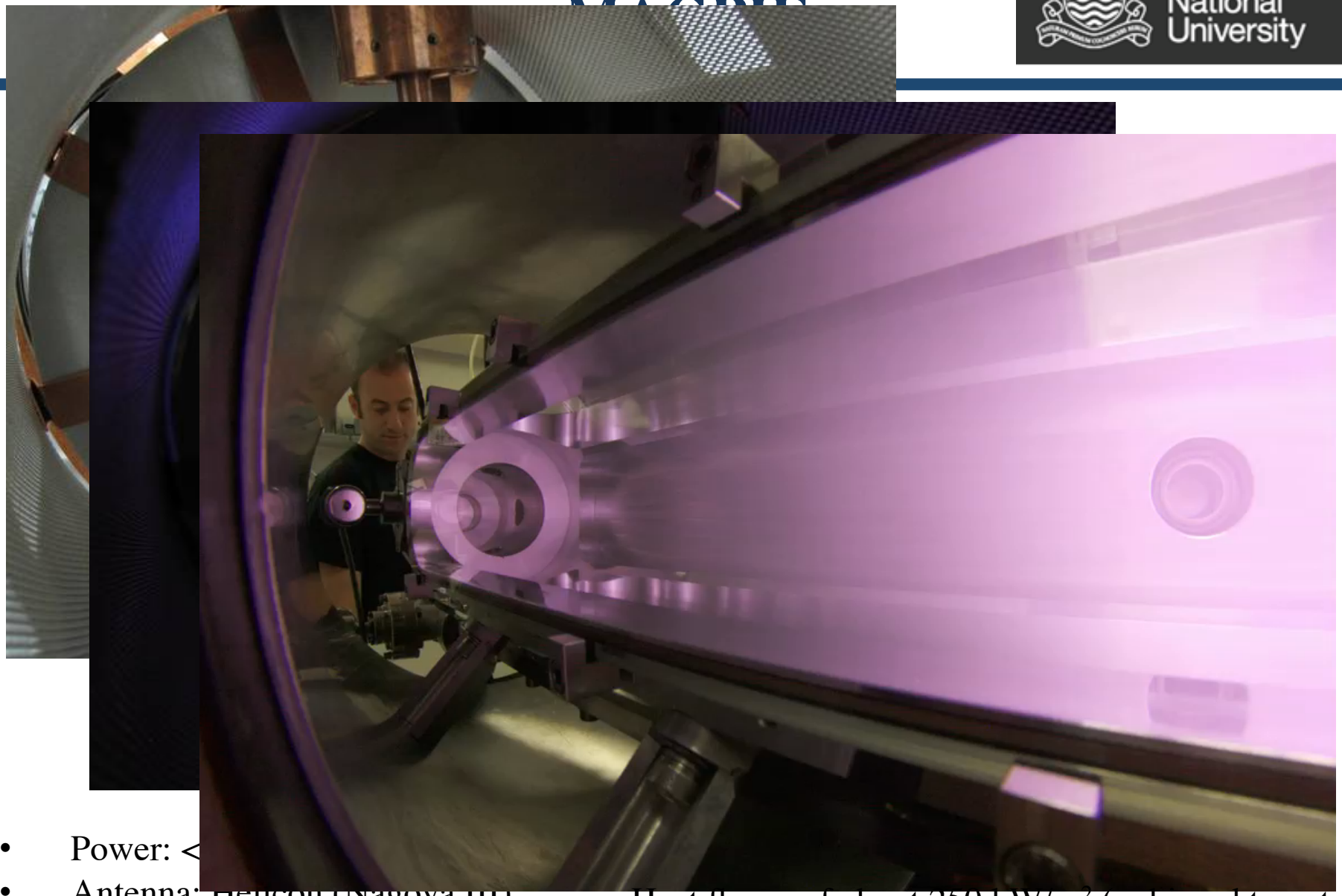
Up to 20 kW at 7 MHz

Up to 3 kW continuous at 13.56 M

Gas

H_2, D_2, He, Ar, N_2

MAGPIE



- Power: <
- Antenna: Helicon (Nagoya III)
- Magnetic Field: < 1900 G peak
- Pressure: < 15mTorr

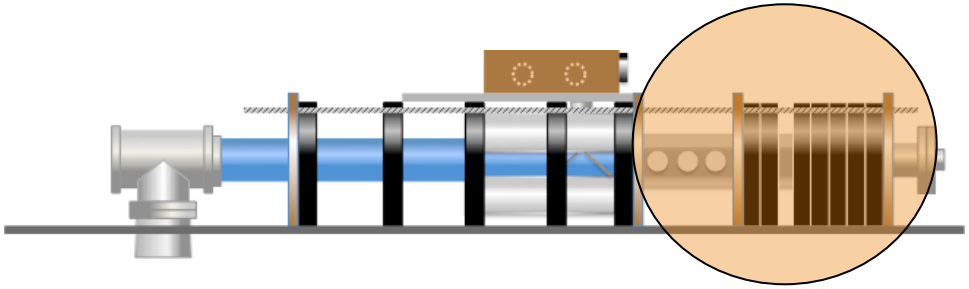
Heat fluxes of about 250 kW/m^2 (unbiased targets)
Heat fluxes in the MW/m^2 range (biased targets)

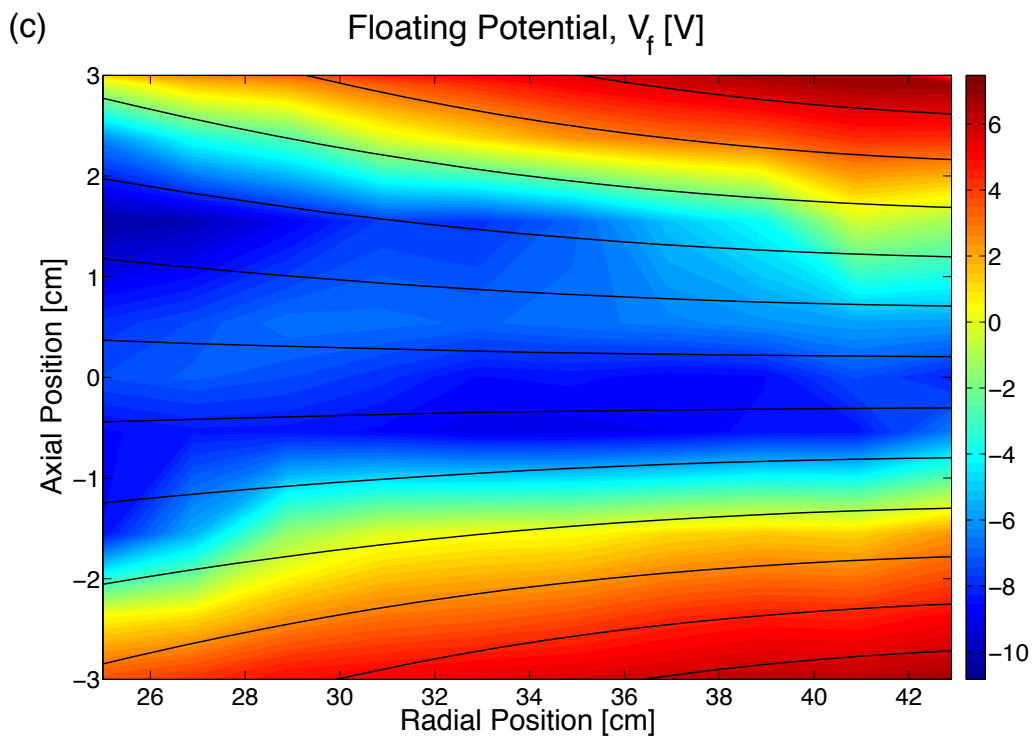
Diagnostic capabilities

- Probes
  - Langmuir, Bdot, RFEA, Double probe
- Optical emission spectroscopy
- Spatial coherence imaging
  - A “snapshot” imaging polarization interferometer that allows local estimates of phase and contrast to reconstruct distribution functions
- Laser based techniques
  - photodetachment, laser induced fluorescence

2D spatial profiles in target region

200 W
1.3 mTorr
500 G

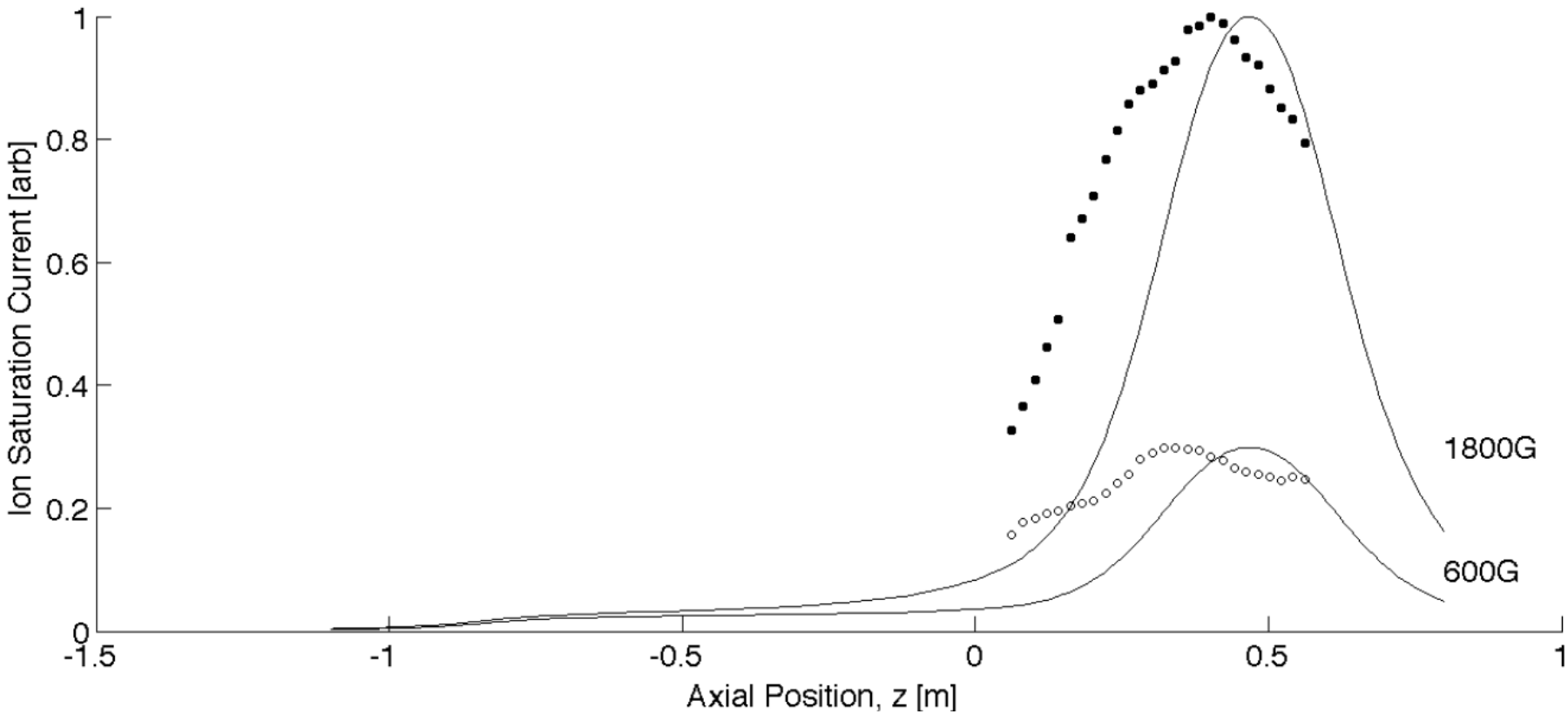




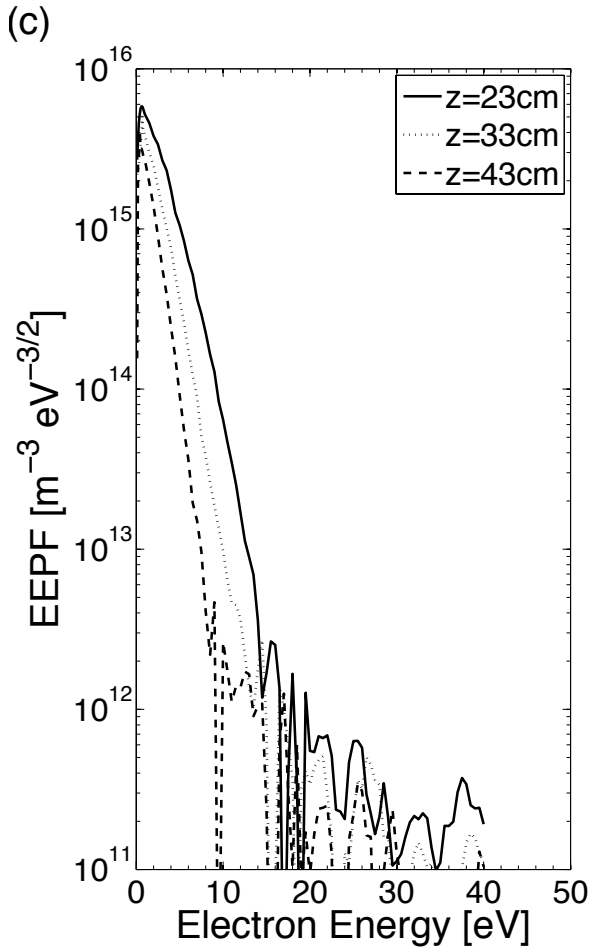
Observations:

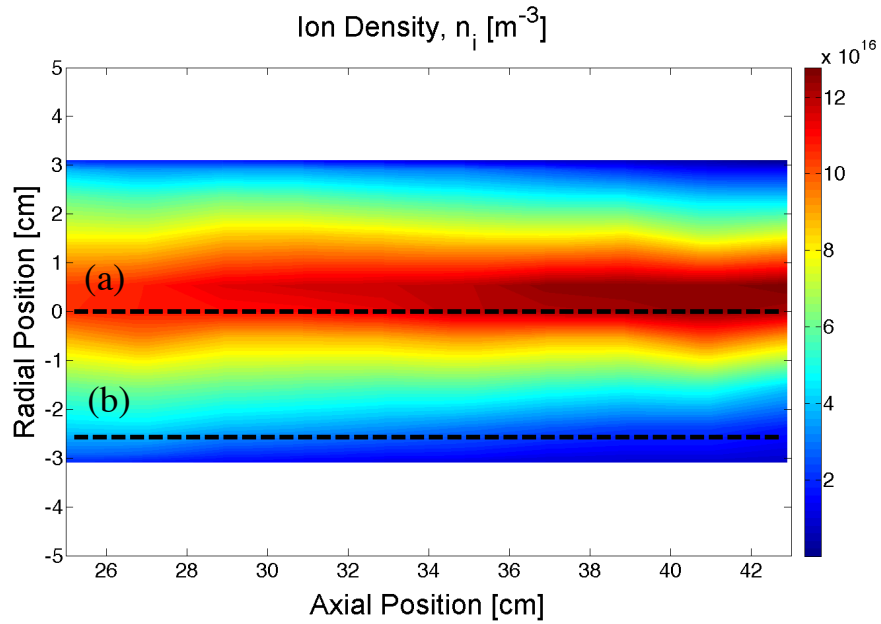
- Electron temperature and floating potential follow magnetic flux tubes
- Increase in plasma density in target region
- Peak density at the peak gradient of magnetic mirror

Density peak near B-field maximum

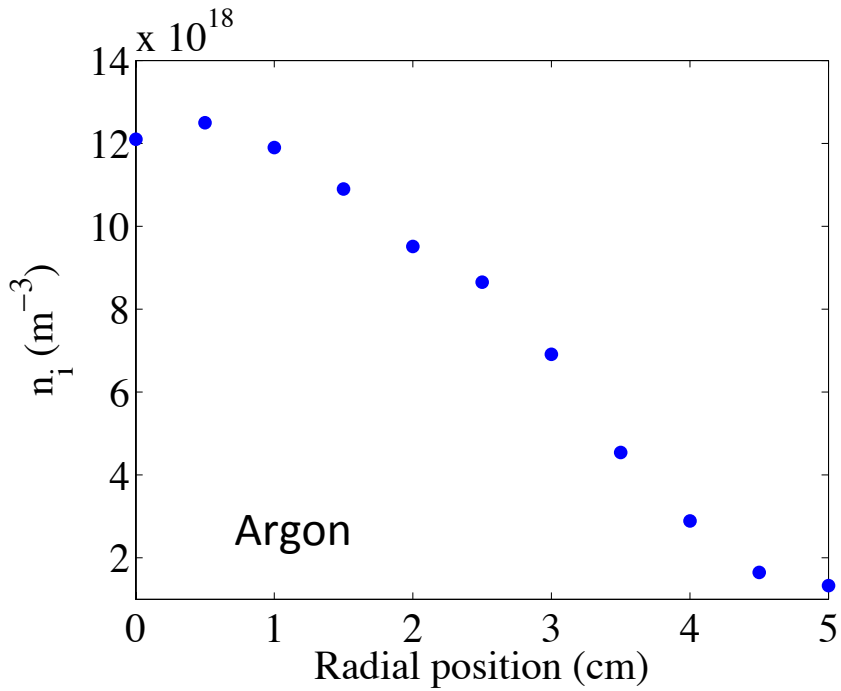


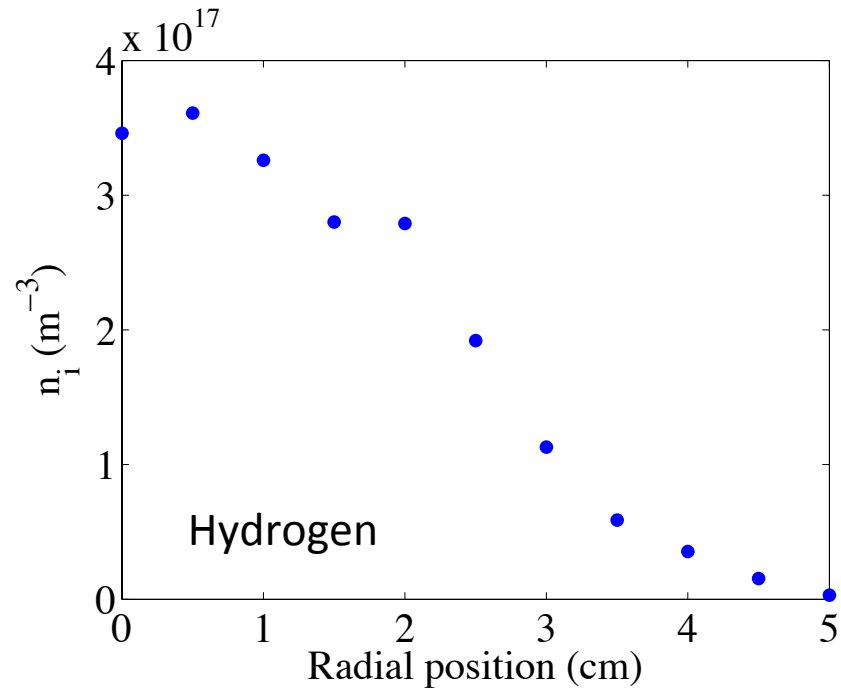
Electron energy distribution function





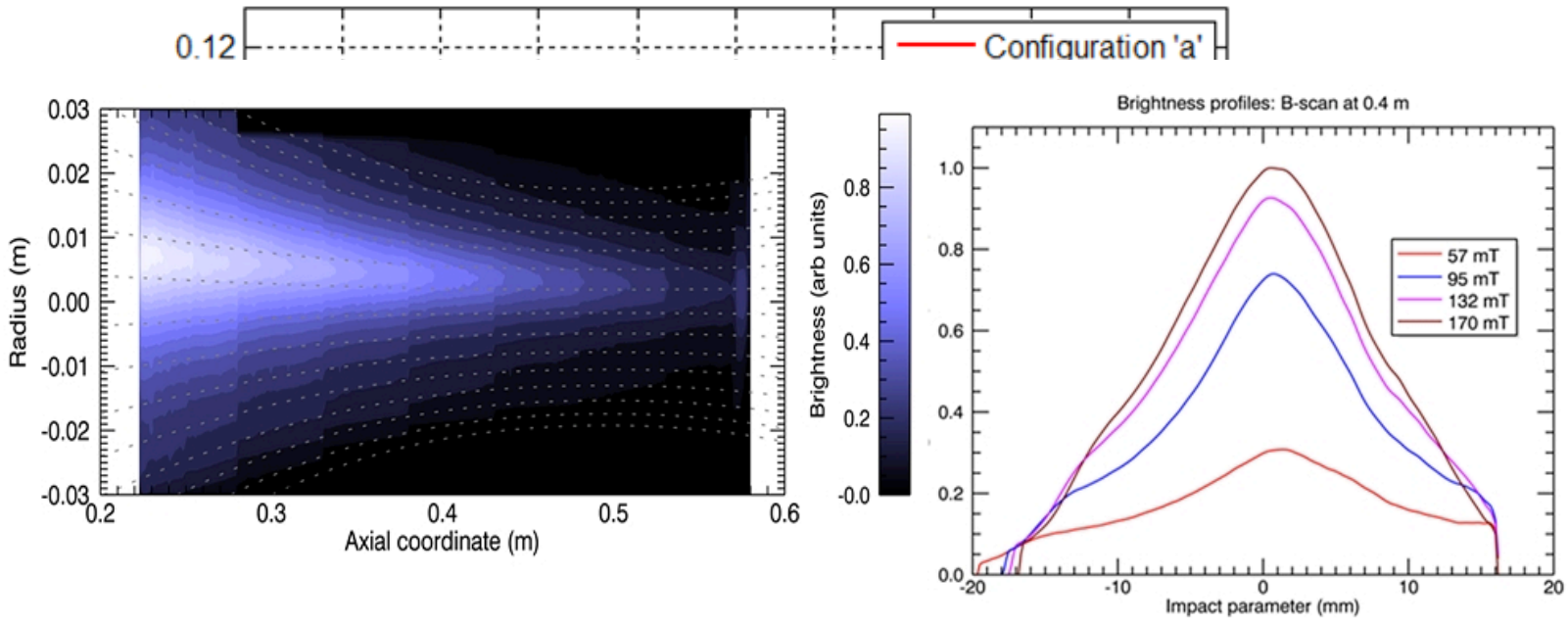
Medium power: < 2kW



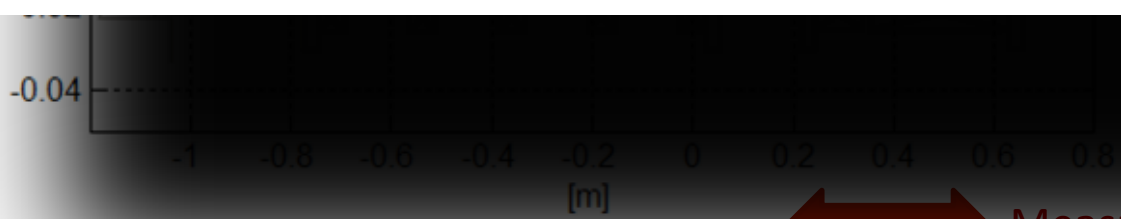


Power : 1.4 kW
Pressure : 5 mTorr
Magnetic field : 0.18 T at peak

2D plasma flow imaging system



mirror

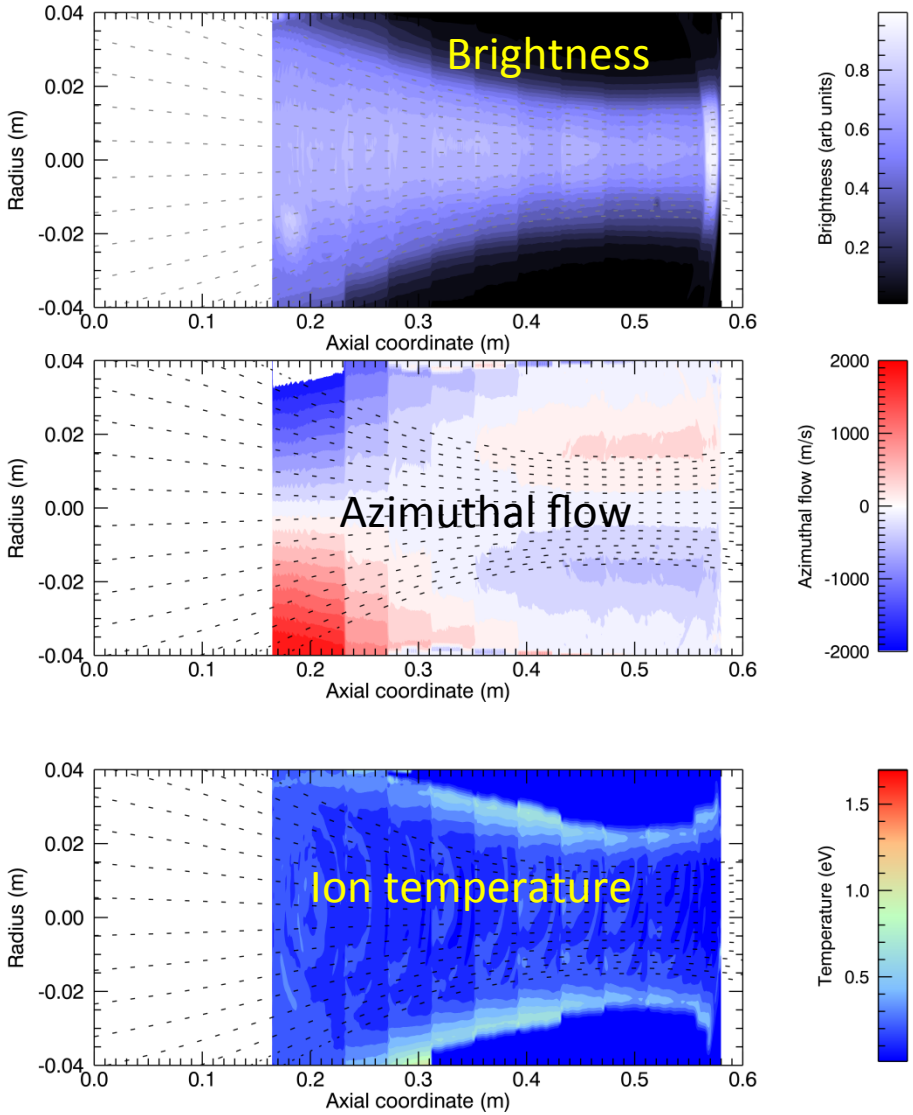


Measurement region

Argon discharge, ~1 kW 13.56MHz
Pressure range 1-5 mTorr,
High mirror ratio configuration, mirror fields 0.05 – 0.15 T

Doppler Coherence Imaging of flow

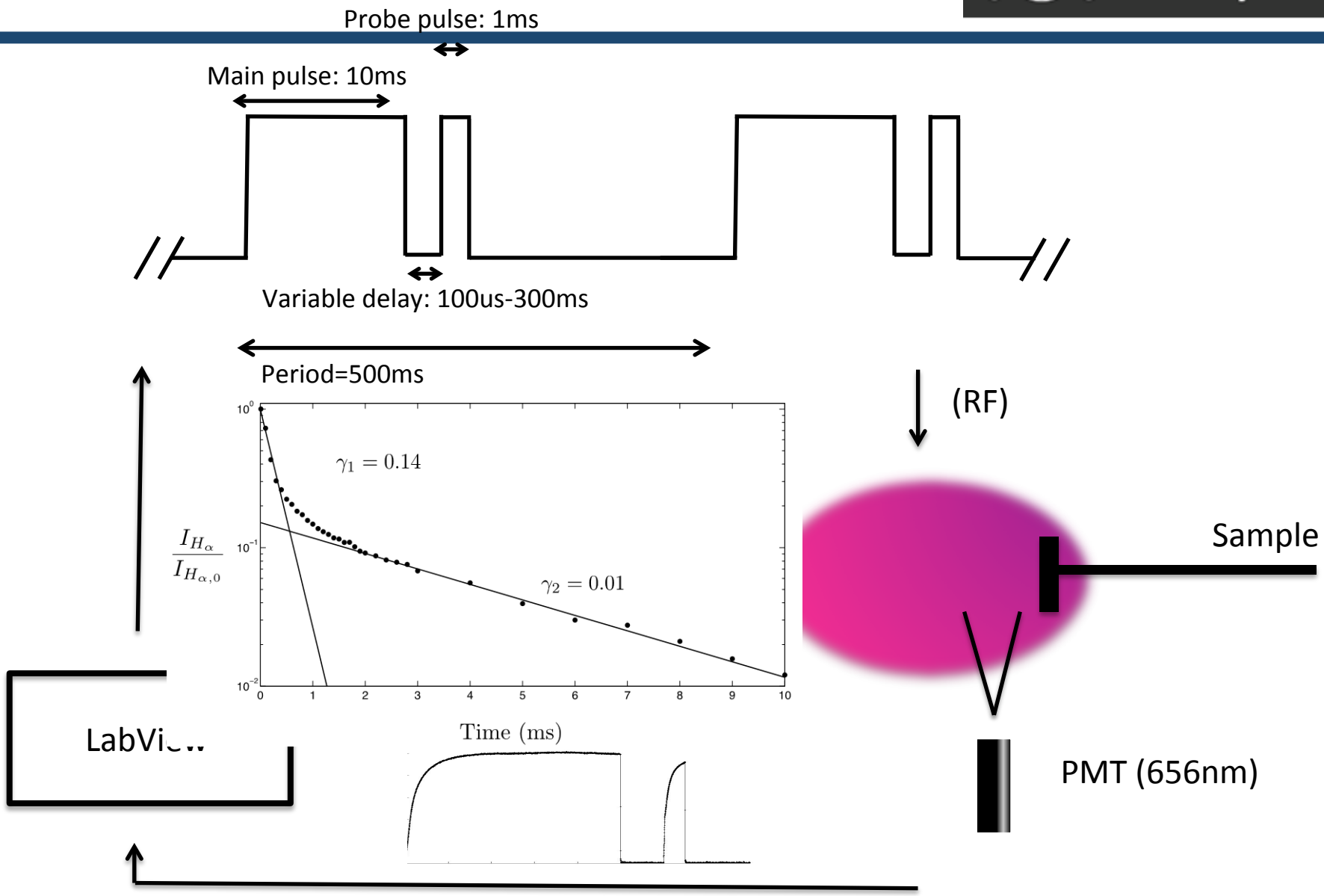
J. Howard, R. Lester



3.0 mTorr Ar, 1kW @13.56MHz

- Composite image composed of demodulated coherence images from independent discharges.
- The phase shift image is decomposed into odd and even parity parts to recover azimuthal and axial flows. Azimuthal flow reverses on propagation into mirror resulting in axial flow acceleration.
- Ion temperature is edge elevated.

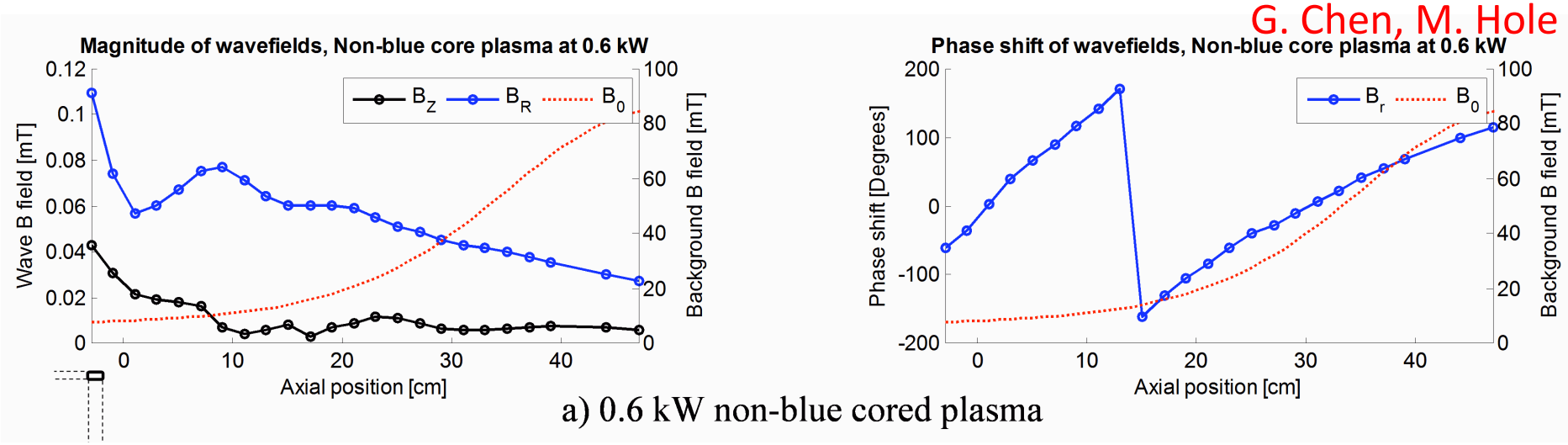
Plasma Induced Fluorescence



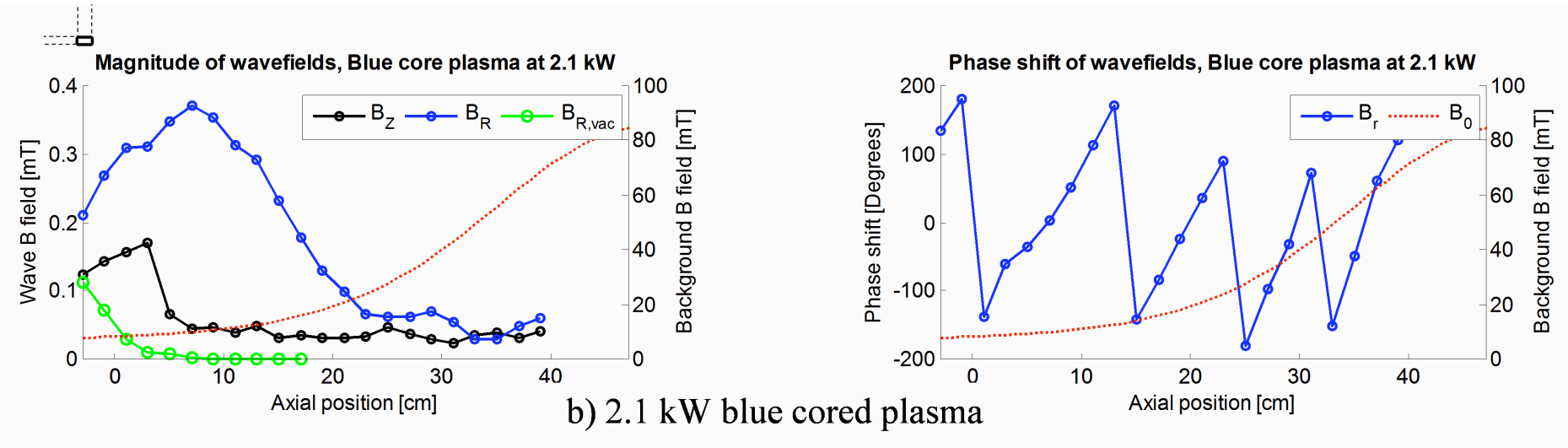
Rousseau, Cartry, Duten, J. Appl. Phys. 2001

Helicon wave propagation in Argon

Juan Caneses, Lei Chang
G. Chen, M. Hole



a) 0.6 kW non-blue cored plasma



b) 2.1 kW blue cored plasma

Comparison with simulation

An RF field solver (ElectroMagnetic Solver, EMS) based on Maxwell's equations and a cold plasma dielectric tensor is employed to interpret the RF waves measured in MAGPIE.

Lei Chang, Juan Caneses,
G. Chen, M. Hole

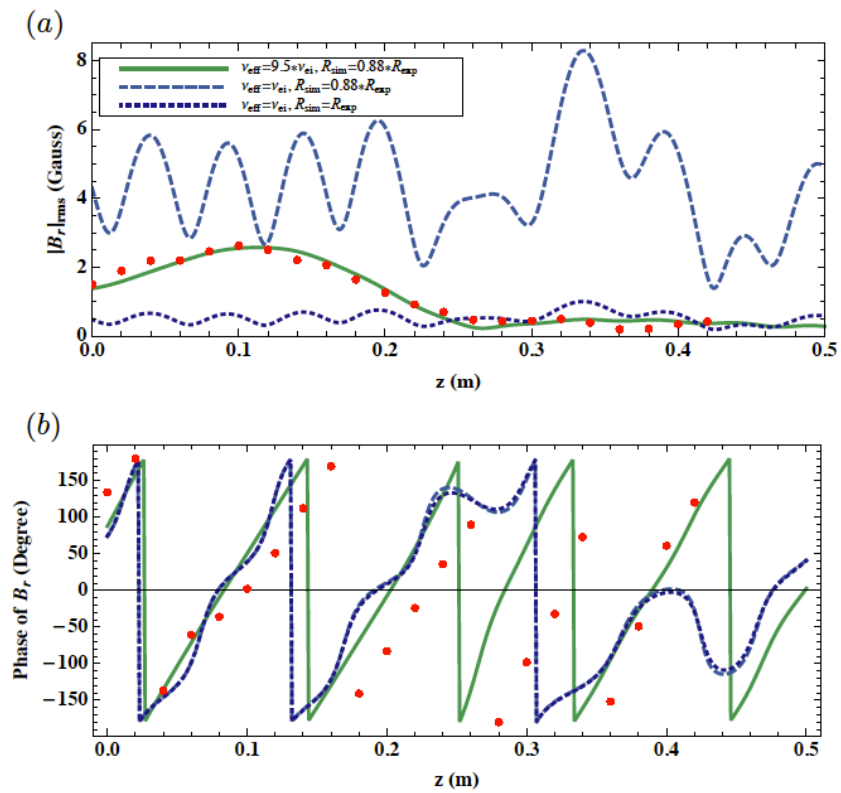
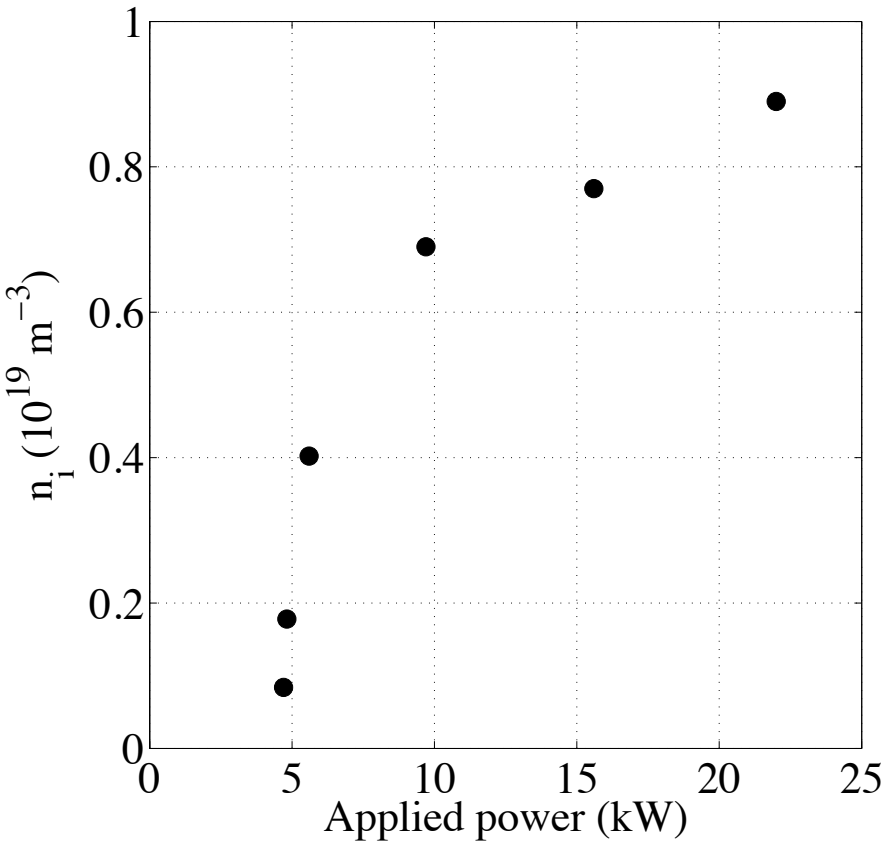
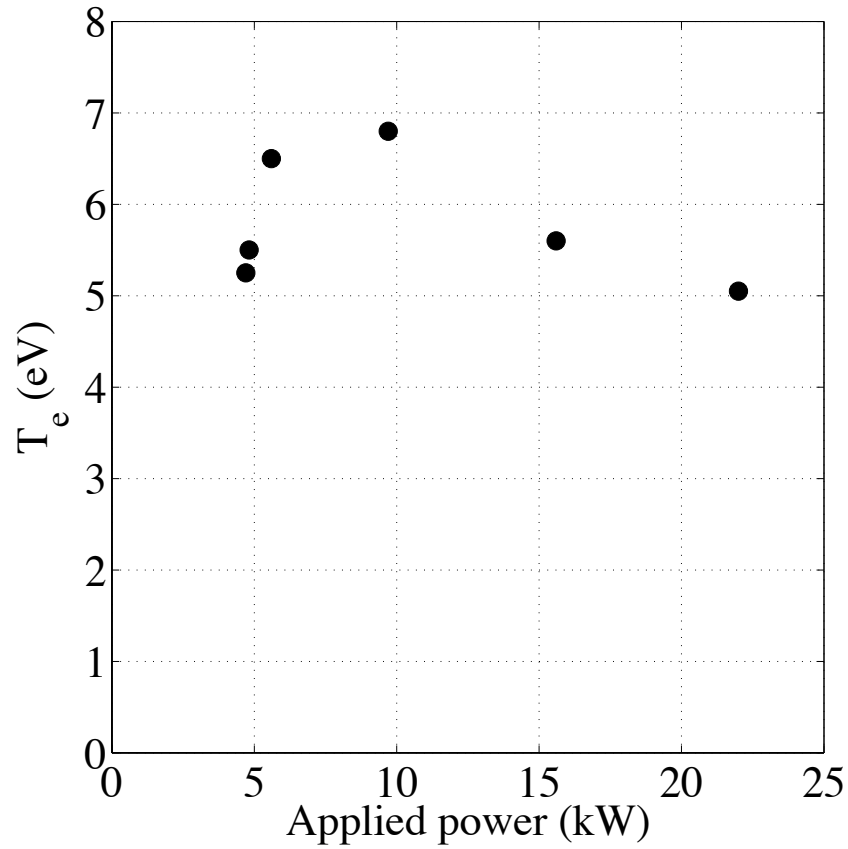


FIG. 4. Variations of magnetic wave field in axial direction (on-axis): (a) $|B_r|_{\rm rms}$, (b) phase of B_r. Computed results (lines: dotted for $\nu_{\rm eff} = \nu_{ei}$ and $R_{\rm sim} = R_{\rm exp}$, dashed for $\nu_{\rm eff} = \nu_{ei}$ and $R_{\rm sim} = 0.88R_{\rm exp}$, and solid for $\nu_{\rm eff} = 9.5\nu_{ei}$ and $R_{\rm sim} = 0.88R_{\rm exp}$) are compared with experimental data (dots).

High power hydrogen plasma: Power dependence (> 4 kw)

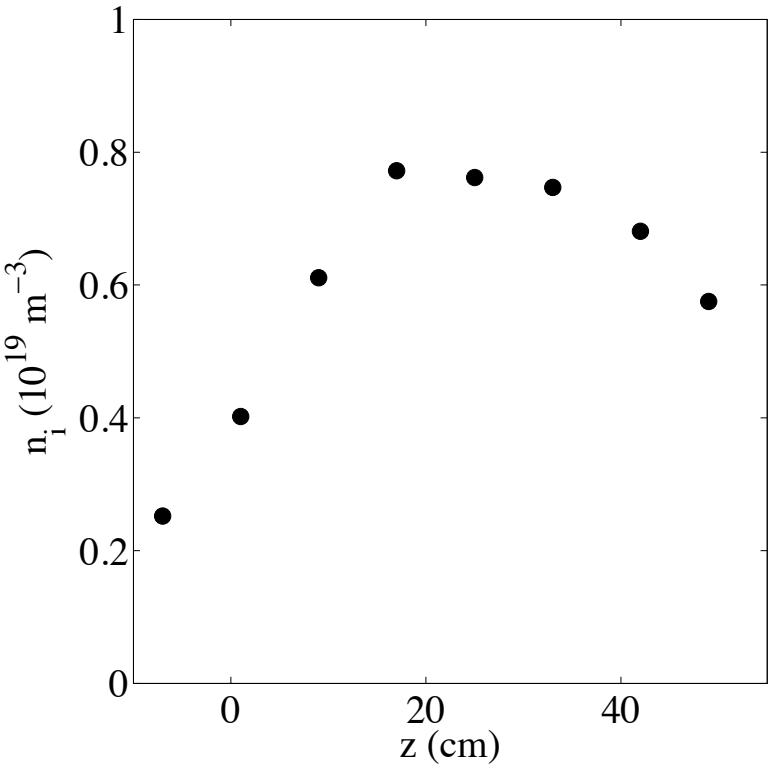
3 mTorr
900 G

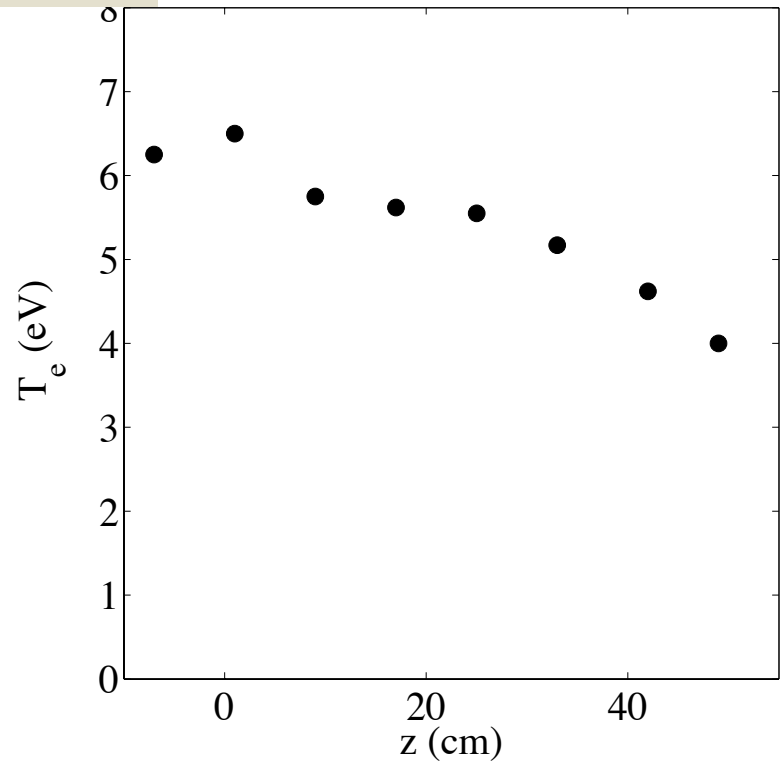


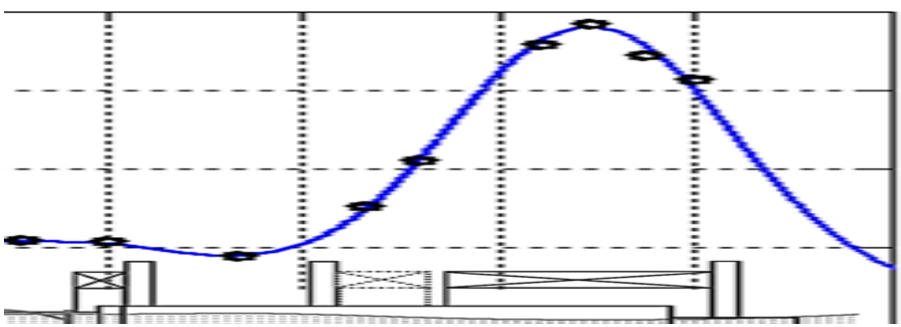


High power hydrogen plasma: Axial profile

3 mTorr
900 G

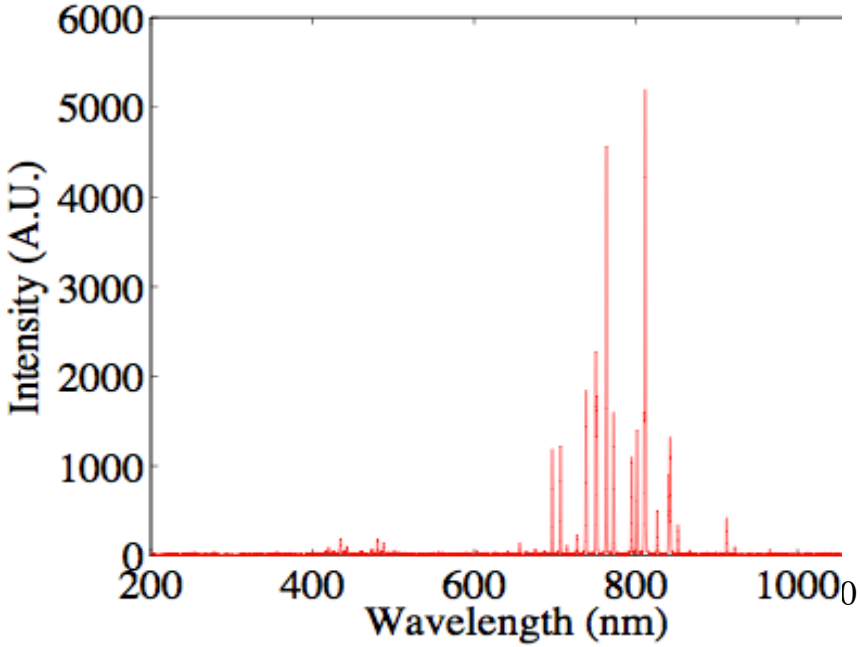


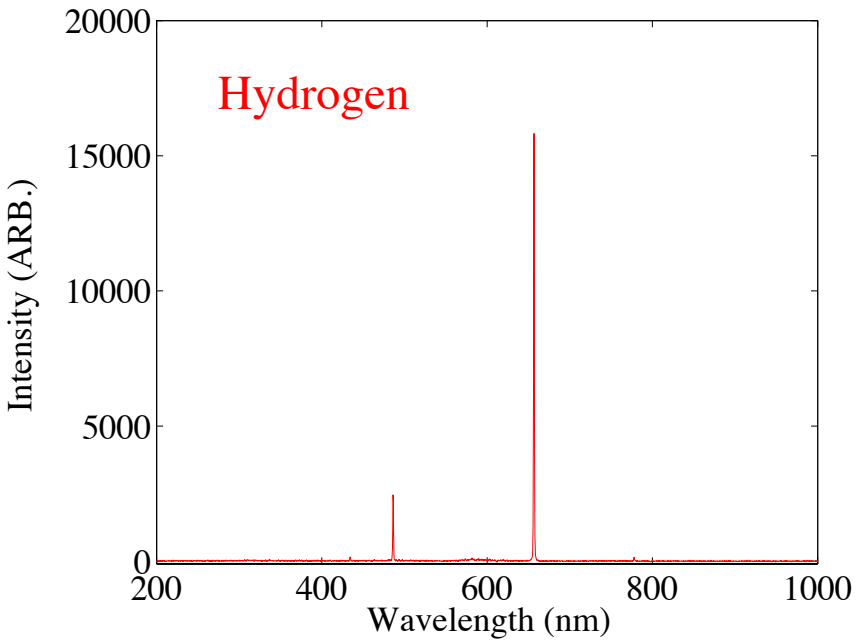




Optical emission spectroscopy

3 mTorr
900 G
18 kW

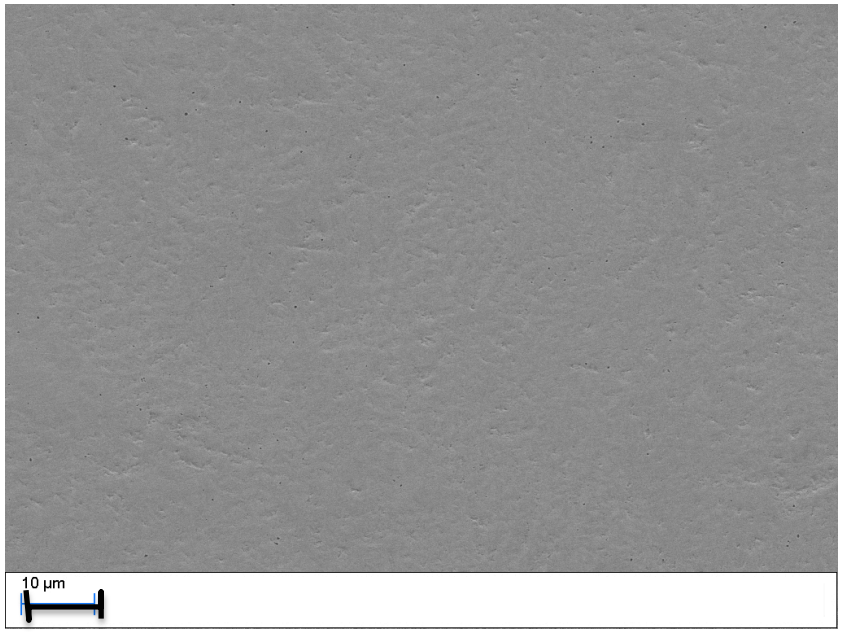




No impurities observed (below detection level)

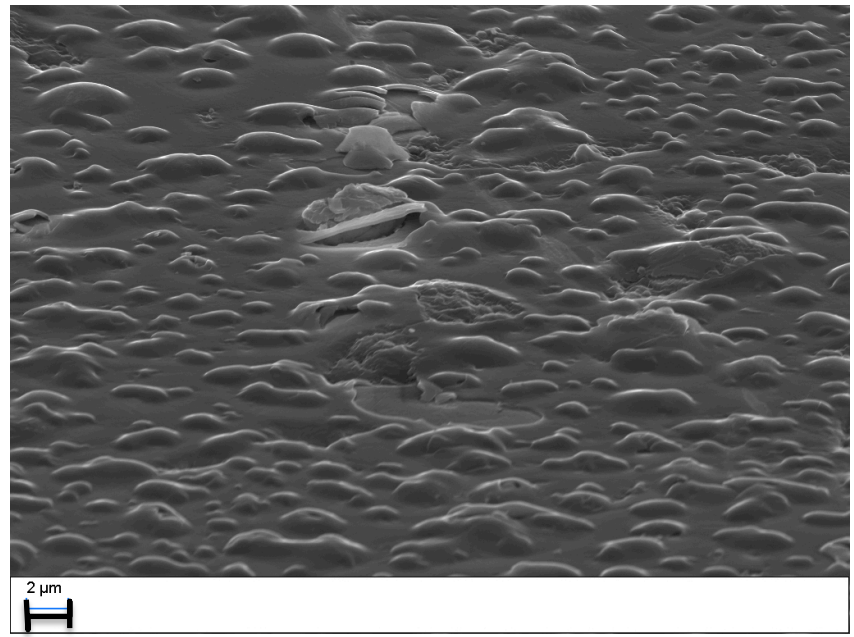
Initial Material Tests

Tungsten



10µm

Tungsten-lanthanum alloy



2µm

Gas: Helium

$p = 4\text{mTorr}$

$P = 500\text{W}$

$|B| \sim 50\text{G}$

$V_{\text{bias}} = -250V$

Ion dose ~ 10^{23} ions/m^2

ANU: Ion irradiation and characterisation

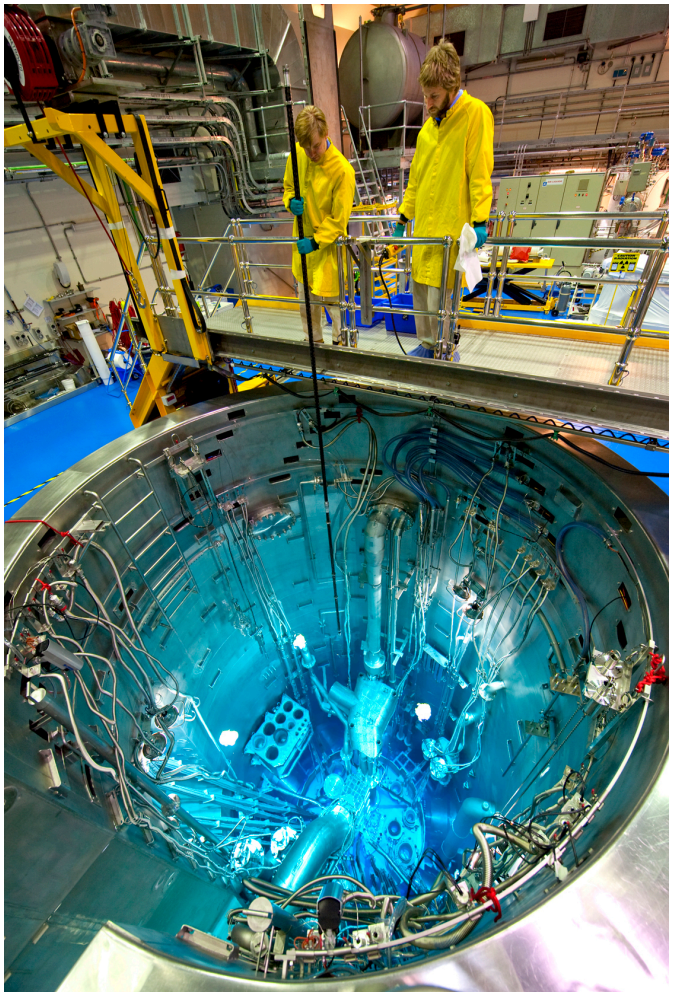
- 150 keV low energy

- 1.7 MeV tandem accelerator

- Radiation effects
  - Ion-irradiation as a proxy for neutron irradiation testing
  - Structure, properties and interactions of irradiation induced defects in materials
  - Effect of irradiation on the physical properties of materials, including swelling, phase separation, radiation enhanced diffusion and intermixing

- Advanced materials characterisation
  - Physical, mechanical, optical and electrical properties of material subjected to extreme environments

ANSTO: Material design and fabrication



- Various neutron and x-ray scattering instruments
- Expertise in material characterisation, synthesis, modification, fabrication and theory/modeling.
- Range of high temperature synthesis, processing and fabrication capabilities to enable the development of novel materials relevant to nuclear applications.

Australian Government

Nuclear-based science benefiting all Australians

The Australian Plasma Fusion Research Facility

Australian National University

Future

H-1

- Use all 3 axes of the Toroidal Mirnov Array → polarisation
- Bayesian MHD Mode Analysis
- Toroidal visible light imaging (Neon, He)
- Correlation of multiple visible light, Mirnov and $\tilde{n}_e$ data
- Spatial and Hybrid Spatial/Temporal Coherence Imaging
- 3rd control param→ Island, chaotic and open field line physics

Materials Diagnostic Facility (MAGPIE prototype)

- Need to understand the plasma first
- Plasma Surface Interaction physics
- Sample holder is currently in development
- Initial material testing is beginning soon…..
- Access to 80 kW RF, magnets and cooling from H-1 Heliac stellarator

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