Progress in Inertial Electrostatic Confinement at the University of Sydney

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IEC 2014
Madison
• The Polywell
• Reverse polarity IEC
• Embedded fusion
• Spacecraft propulsion
The Polywell is used to create a virtual cathode

Magnetic field lines through a central plane

Trapped electrons form a virtual cathode

Matthew Carr, Phys. Plasmas 18, 112501 (2011)
Reducing the electron loss rate with point cusps

Setting the coil spacing leads to point cusps

Point cusps produce minimal electron loss rate.

Matthew Carr, Phys. Plasmas 18, 112501 (2011)
Polywell Mark I

- Teflon construction
- Presence of background gas (~ 15 mTorr)
- Electron gun made from an IEC microchannel.

Matthew Carr, Phys. Plasmas 17, 052510 (2010)
The shell was positively biased.

A fast scanning Langmuir probe was used to obtain I-V measurements.

Electron energy distributions were obtained.
This Polywell was for the study of

- the effect of coils spacing.
- the dependence of potential well depth on electron current
- the applicability of capacitive probes in a magnetic field
To study

- Electron confinement time
- Electron energy distribution function
- the effects of high electron current.

Construction of 1A electron gun in progress.
The floating potential on a single ended Langmuir Probe showed a drop in potential with the application of a magnetic field in the presence of a background gas.

Potential wells can exist in an ionized background gas.

Matthew Carr, Phys. Plasmas 17, 052510 (2010)
Electron energy distribution function deduced from probe measurements

Non-Maxwellian distribution

Matthew Carr, Phys. Plasmas 20, 052504 (2013)
The dependence of Potential well depth on electron current

250 eV electron energy

Scott Cornish, Physics of Plasmas 21, 092502 (2014)
Adiabatic and non-adiabatic regions

Matthew Carr, Phys. Plasmas 18, 112501 (2011)
Operating region for a Polywell

David Gummersall, Physics of Plasmas 20, 102701 (2013)
Electron confinement time low beta

Number of electrons within the device.

\[ N(t) = \exp \left[ -(2.0 \pm 0.6) \times 10^6 \times \frac{K^3}{\sqrt{Ia^2}} t \right] \]

Confinement time

\[ t_n = 5 \times 10^{-7} \times \frac{\sqrt{Ia^2}}{K^{3/4}} \]

Kinetic energy

Coil current

Coil radius

High beta confinement time calculations are in progress.

David Gummersall, Physics of Plasmas 20, 102701 (2013)
Relativistic treatment of electrons in a Polywell

• 10 keV electron travel at 20% the speed of light, c.

• 100 keV electrons travel at 60% c.

• The latter is the most likely energy for a Polywell aimed at energy generation. So a relativistic treatment is needed.

• See the talk by Dr. John Hedditch about the relativistic treatment at this workshop.
Reverse polarity IEC

Experiment proposed by Elmore, Tuck and Watson. Apply positive voltage to the inner grid to produce a virtual cathode from the convergent electron focus.

Electrons form a virtual cathode

Elmore, Tuck and Watson, Phys. Fluids, 2, 239 (1959)
Reverse polarity IEC

Negative polarity IEC in star mode.

Reverse polarity pulsed IEC.

The discharge is mostly contained within the positively biased grid.
Oscillations in plasma potential occur after the pulse.
A two stream instability, known as the Buneman instability has been identified as the cause of the oscillations.

This causes electron bunching, which subsequently pass energy onto the ions.

200 eV ion energy have been measured in this discharge.

See Rehan Bandara’s talk at this workshop for further details.
Electron screening enhancement of fusion cross-section

Assume 3 keV deuterium ions striking deuterium embedded in the following metals:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Increase in fusion cross-section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pd</td>
<td>14</td>
</tr>
<tr>
<td>Pt</td>
<td>10</td>
</tr>
<tr>
<td>Fe</td>
<td>5</td>
</tr>
</tbody>
</table>

We will investigate enhancement in fusion rates for low energy IEC using different materials.

The exiting neutrals from the cathode were applied to producing a thruster for electric propulsion of space-craft.
SUMMARY

- Polywell
  - Coil spacing
  - Electron energy distribution functions
  - Scaling laws for low beta confinement
  - Dependence of potential well on electron current
  - Relativistic treatment of electrons

- Reverse polarity IEC
  - Buneman instability
  - Production of energetic ions a virtual cathode

- Investigating enhancement of cross-section using embedded fusion

- IEC microchannels being developed for spacecraft propulsion