RECENT ADVANCES IN IEC PHYSICS AND TECHNOLOGY AT THE UNIVERSITY OF WISCONSIN


October 15, 2012
Outline of Presentation

• Brief History of IEC Program.
• New Insight and Results at the Univ. of Wisconsin
  – Advances on Helios (Becerra) Session 2.
  – Upgrade to VICTER code-Added negative ions and He^{++} (Emmert) Session 3.
  – Efficiency of neutron production in 6-gun device (Michalak) Session 5.
  – 300 kV Power Supply (Bonomo) Session 5.
  – Exploration of Core Physics (Santarius) Session 6.
  – Analysis of negative ions in jets of gridded IEC devices (Alderson).
  – New data on interaction of high energy He and W at high temperature (Garrison, Hall).
Inertial Electrostatic Confinement Devices First Introduced by Lavrentyev and Farnsworth in the Late 1950’s
Robert Hirsch Reported High Neutron Production Rates in the First Ion IEC Device in 1968 at ITT-Farnsworth in Fort Wayne, IN

20 cm
There Have Been at Least 27 IEC Research Programs in 10 Countries Around the World in the Last 55 Years

- United States (14)
- Canada
- Netherlands
- Germany
- Soviet Union
- Japan (5)
- South Korea
- India
- Iran
- Australia
There Have Been 14 IEC Research Programs in the U. S. in the Last 45 Years
Location of 14 US-Japan IEC Workshops

5th & 11th Wisconsin 2002, 2009

1st & 7th LANL, 1998, 2005

3rd MSFC 2001

9th ANL 2007

14th U of MD 2012

2nd, 8th, 12th Kansai Univ. 2000, 2006, 2010

6th Tokyo-IT 2003


13th Sydney Univ. 2011
There are Currently Four Different IEC Chambers in Operation at the University of Wisconsin

- HOMER-Gridded Device
- HELIOS-Ion Injected Gridded Device
- SIGFE-6 Ion Gun Device
- MITE-E Ion Gun Device
Two New Pulsed Neutron Sources Under Development

- The STOROID
- The PING
The University of Wisconsin IEC program is 18 years Old

- 1st steady-state D-³He fusion: 1999
- 1st published UW results (Thorson): 1995
- Steady State DD neutron rate $10^7$ n/s
- 75-200kV capability
- 1st UW IEC device constructed
- Fusion source regions identified: 2003
- Helicon ion source: 2005
- Demonstrated $^3$He-$^3$He fusion
- Explosive detection studies initiated: 2005
- Initial pulsed operation
- SIGFE Installed
- Fusion Ion Doppler diagnostic
- Hirsch results replicated in SIGFE
- Integral transport theory published
- First Time of Flight fusion spatial profile
- Negative ions in jets analyzed
- Upgraded VICTER code with He⁺, D⁻
- Negative ion modeling: 2011
- Discovery of tungsten "grass": 2011
- 300 kV power supply operational: 2009
- Negative ions identified: 2009
- Demonstrated HEU detection with $5 \times 10^9$ n/s pulses: 2007
- LANL/UW DNDO collab.
- Studies of ion implantation in materials at high temperature initiated
- 2001
- Medical isotopes produced
- 1999
- 1995
- 2013
Becerra Studying the Discrepancy Between Predicted and Measured Helium Ion Current from Helicon Sources (session 2)
Emmert is modifying the VICTER code to include He\(^+\) and He\(^{++}\)-Session 3
Michalak is Upgrading the 6-Gun SIGFE to Balance Individual Gun Output - Session 5

Ion beams
Bonomo is Addressing the Issues Associated With Coupling to a 300 kV Power Supply - Session 5

CAD Drawing of 300 kV Switch

Installation of Final Assembly
Santarius is Investigating IEC Core Physics-Session 6

- Electrostatic potential created by discrete wires in cylindrical geometry
  - Channels formed between grid wires, and
  - Potential peak near origin due to converging ion space charge.
McEvoy is Reassessing the Spatial Distribution of Fusion Events in a Gridded IEC-Session 6

- Raw DD Fusion Spatial Profile

Additional Information on Energy of Reactants

Chord Through Center of Chamber-$z$

Counts

Energy 0-40 keV

Left Wing | Core | Right Wing

- $r_w$
- $r_a$
- $r_c$

Counts

z-Position [cm]

- $r_w$
- $r_a$
- $r_c$

Energy 0-40 keV
Jets are a fundamental phenomenon in the IEC device

Univ of Wisconsin

Courtesy of G.H. Miley
Alderson Analyzed the Negative Ion Current in IEC Jets

- The IEC device cathode produces a rippled potential near the cathode, more negative at the wires, less negative in the spaces between the wires.
- These dips in potential produce jets that negatively charged particles preferentially pass through.

Vacuum potential for cathode diameter of 20 cm, anode diameter of 30 cm, 90 kV applied to the cathode.
The enclosed electrodes and small size allow the Faraday cup to be used to produce spatial profiles—Alderson 2012.

- Azimuthal positioning
The jet produced by a 20 cm dia. cathode at -60 kV and 30 mA with a 30 cm dia. anode produces a jet, which extrapolations suggest contains ~100 μA of negative ions.

“Grass” Morphology in W is Highly Dependent on the Orientation of the Grains to the Ion Beam-Garrison and Zenobia

$\phi_L = 3.6 \times 10^{18} \text{ He}^+/\text{cm}^2, T = 900\,^\circ\text{C}$
Fusion for energy and medicine:
Long-term goal: clean, abundant and affordable power

\(^{99}\text{Mo}/^{99m}\text{Tc} \text{ Diagnostic}
The Wisconsin IEC Team

Questions?