Progress in IEC Research at the University of Wisconsin Since the 7th US-Japan Workshop

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8th US-Japan Workshop
Kansai University
May 10th, 2006
Outline

- Personnel Update
- Overall Progress Since the 7th US-Japan Workshop-LANL-March, 2005
- Specific Advances from Students Not Attending the 8th US-Japan Workshop
- Future Directions
The **UW-IEC** Group Has Grown to 14
1995
IEC device constructed

1999
1st@LANL

2000
2nd@Kansai Univ.

2001
3rd@MSFC

2002
4th@Kyoto Univ.

2003
5th@U. Of Wisconsin

2004
6th @Tokyo Inst. Tech

2005
7th@LANL

2006

1st Steady State D-³He fusion

10⁷ neutrons / sec steady state

75-200kV Capability

10⁸ D-D neutrons/sec steady state

Medical Isotopes Produced

Explosives Detection Studies Begun

High Temp Materials Studies

Helicon Ion Source

Grid Fabrication Tooling

Fusion source regions identified

1st Published results (Thorsen)
Recent UW IEC History Timeline

- 2005: Finished First Phase of C-4 Explosives Detection
- 7th@LANL

- 2006: Pulsed Operation Begun
- 8th@Kansai
CAD Representation of UW Experimental Setup for Explosives Detection

- IEC Device
- Paraffin
- Borated Polyethylene
- NaI Detector
- Cathode
- Anode
- Explosives
The C-4 Explosive “Signature” is Clearly in Evidence
Recent UW IEC History Timeline

2005

7th@LANL

Initial Cathode Study Completed

Pulsed Operation Begun

2006

8th@Kansai

Finished First Phase of C-4 Explosives Detection
Studies to Determine the Effect of Cathode on Neutron Production Rate

**Cathode Size**
- 10 cm Inner Cathode Grid Diameter
- 20 cm Inner Cathode Grid Diameter

**Cathode Geometry**
- 10 cm Symmetric Inner Cathode Grid
- 10 cm Lat/Long Inner Cathode Grid

**Cathode Material**
- 10 cm Inner Cathode Grid (Re)
- 10 cm Inner Cathode Grid (WRe)

No Significant Difference Seen
Doubling the Cathode Size Increased the Neutron Production Rate by $\approx 20\%$

**Neutron Rate vs Current**

Grid: W-5 (10cm, WRe, Lat/Long) vs W-7 (20cm, WRe, Lat/Long)

[Background Gas Pressure ~2 mtorr]

Constant voltage, background D-D gas pressure, geometry, material, and 50 cm anode diameter
Recent UW IEC History Timeline

- **2005**
  - 7th@LANL
  - Pulsed Operation Begun
  - Cathode Study Completed
- **2006**
  - 8th@Kansai
  - Finished First Phase of C-4 Explosives Detection
  - W Surface Studies Expanded
The First Wall of a Laser Fusion Reactor Will Undergo Significant Helium Bombardment

LASER ENERGETICS
500 kJ on target
2.5 nsec drive pulse

OPTICAL ARCHITECTURE:
20 KrF amplifiers (28 kJ each)
90 beams/amp = 1800 beams
40 beam ports, each 45 beams

OPTICAL TRAIN
< 1.1 J/cm² on optics
GIMM (or dielectric) final mirror
Window shielded from neutrons

CHAMBER
5.5 m inner radius
Optics ~ 2% solid angle
Tungsten armor/steel base (provisional)
No buffer gas in chamber
Blanket for thermal management/breeding

NEUTRON SHIELD
13 m inner radius
New Design Allows Pulsed IEC Operation For Surface Damage Studies

- Currently able to pulse up to 110 kV
- Operation has been performed with pulses as short as 100 µs
- Capable of running D$_2$ and He fuel gas
The Campaign to Assess Ability of W Coatings to Operate in HAPL Environment is Proceeding

Polycrystalline
- He\(^+\) & D\(^+\) Fluence Effect – 800-1200 °C
- Temperature and Voltage Effects
- Simultaneous He\(^+\) & D\(^+\)
- Helium Retention
- W-Re Alloy
- Pulsed Irradiation

Metallic Foams
- Large, medium, & small grain size W on TaC – (He\(^+\)) 800-1200 °C
- Temperature and Voltage Effects
- Simultaneous He\(^+\) & D\(^+\)
- Helium Retention
- Medium grain size W on HfC (He\(^+\) & D\(^+\)) – 800-1200 °C

Single Crystal
- He\(^+\) & D\(^+\) Fluence Effect – 800 °C
- Simultaneous He\(^+\) & D\(^+\)
- Helium Retention
- Completed
- In progress
FIB Analysis Reveals Increased Porous Layer in Pulsed Samples

Pulsed (40 kV)
(1150 °C baseline)

Steady-State (30 kV)
(1150 °C)

$10^{18}$/cm$^2$

$10^{19}$/cm$^2$

$= 300$ nm

$= 90$ nm

$= 700$ nm

$= 290$ nm

2 µm
Pulsed IEC Irradiation Better Simulates HAPL Flux

![Graph showing pulse width versus pulse frequency for different sources: ORNL (Infrared), Current IEC (Ions), Reference HAPL, RHEPP (Ions), XAPPER (X-rays), Dragonfire (Laser).]
Recent UW IEC History Timeline

2005
- 7th@LANL
- Pulsed Operation Begun
- Cathode Study Completed

2006
- 8th@Kansai
- W Surface Studies Expanded
- Finished First Phase of C-4 Explosives Detection
- Cylindrical Third Chamber for Isotope Production Finished
Three IEC Chambers Are Now in Operation at the University of Wisconsin
3rd Chamber Construction

• **Design Features**
  - 75 liter Stainless Steel Cylindrical Vacuum Chamber
  - *Isolated Nut* High Voltage Feed-through design
  - Cylindrical Cathode, Anode, and Filament design

• **Milestones**
  - Vacuum Achieved September 2005
  - New High Voltage Feed-Through installed February 2006. High Pot Tested in March 2006 to 130kV with virgin spherical grid and virgin stalk.
  - First Neutrons produced April 5, 2006 at 30kV and 60mA.
PET Isotopes to be Produced in UW IEC Chamber

Done

In Progress
Recent UW IEC History Timeline

2005

7th@LANL

- Pulsed Operation Begun
- Cathode Study Completed
- Finished First Phase of C-4 Explosives Detection

2006

8th@Kansai

- Direct Conversion Experiments Begun
- W Surface Studies Expanded
- Cylindrical Third Chamber for Isotope Production Finished
- Arc/Noise Suppression Circuitry Installed
- $10^9$ D-D neut/sec pulsed
Activities at the University of Wisconsin Will Continue to Expand in the Future

Wisconsin Advanced Fusion Fuel Project

- IEC Theory
- 3He-3He
- Pulsed Operation
- Direct Conversion
- Clandestine Material Detection
  - Explosives
  - Fissile Material
- Materials Surface Damage
- PET Isotope Production
- Device Optimization

Lead Investigator(s)

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