UW IEC Group 2010: Further Infrastructure Improvements and Preparations for 300 kV Operation

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# now with the NNSA, Washington, D.C. USA
Presentation Outline

1. Current Status
2. Laboratory configuration and basic operation
3. Preparations for 300 kV operation
4. Other infrastructure improvements

Prof. Gerald Kulcinski provided an overview of experiments in progress this morning.
Current Status of Laboratory

• Personnel:
  – 7 graduate students
  – 1 staff engineer/researcher/laboratory manager
  – 1 undergraduate technician/researcher
  – 4 faculty
Current Status of Laboratory (as of October 2010)

• Apparatus
  – 3 operating IEC devices
  – 1 operating materials testing device
  – 1 pulsed device under construction
  – 300 kVDC power supply
  – 2-channel low-ripple filament-heating-and-bias power supply
Laboratory Layout

FTI Primary Laboratory
B151 ERB

Total floor area (incl. brick wall) 730 sq ft / 68 sq m

Experiment cell (12 X 12 ft) / (3.7 X 3.7 m)

14 MeV-n-rated walls
52 in / 132 cm thick
Laboratory Apparatus

HELIOS  HOMER  $^3$HeCTRE / SIGFE  MITE-E
Data Flow (typical)

Experiment → Analog Data → A to D → Labview → Temporal binning and counting → Display → Digital record

Manual keyboard entry Into MySQL database

Data are analyzed using a number of software packages available in the laboratory and at the college computing facility.
300 kVDC Power Supply
installed May 2009
Motivation for Power Supply Upgrade

- Improved access to $^3\text{He}^3\text{He}$ Fusion Regime

Spherical Velocity Distribution, Maximum Charge States

Source: J. F. Santarius

$\sim 500\%$

$\sim 55\%$
Motivation for Power Supply Upgrade

- Neutron flux appears to be monotonically increasing with voltage (greater voltage ==> more neutrons)

Graph courtesy of David Donovan

Neutron Rate = 2500(Voltage[kV])^2 + 34000(Voltage[kV])
Motivation for Power Supply Upgrade

- Neutron flux appears to be monotonically increasing with current (greater current ==> more neutrons)

Graph courtesy of David Donovan
Preparations for 300 kV Operation
Replacement of high-voltage electrical vacuum feed-through

Current System

Metal oil-filled chamber
High-Voltage Connector
Boron Nitride cylinder
Nylon ferrule
Swagelok fitting
Compression nut
Molybdenum rod
Preparations for 300 kV Operation
Replacement of high-voltage electrical vacuum feed-through

Current System

- Metal oil-filled chamber
- Swagelok fitting
- Compression nut
- Boron Nitride cylinder
Preparations for 300 kV Operation

Replacement of high-voltage electrical vacuum feed-through

Failed stalk from a previous year, showing burn-through from arcing
Preparations for 300 kV Operation
Replacement of high-voltage electrical vacuum feed-through

New System: a metal-free feed-through

Quartz chosen for its high purity, tolerance of high temperatures (min 1000°C), and high mechanical strength (1000psi tensile strength)
Preparations for 300 kV Operation
Replacement of high-voltage electrical vacuum feed-through

New System

- HV cable (coaxial)
- PVC elements
- Threaded rod
- Conductor coupling
- Quartz vessel
- Vacuum chamber top cover
- Boron nitride stalk and molybdenum rod

University of Wisconsin -- Madison
Fusion Technology Institute
Inertial Electrostatic Confinement Group

Presented by Richard Bonomo  October 2010
US-Japan IEC Workshop 2010
Preparations for 300 kV Operation

Device Switching

(New) 300 kVDC cable, left, and (current) 200 kVDC cable, right
Preparations for 300 kV Operation

Device Switching

• The current practice is to switch the HV power supply between devices by physically detaching and re-attaching a cable from a junction in an oil-filled barrel.

• The larger and much-less flexible cable which will be used at the higher voltages cannot be used in this way for an extended period.

• Space constraints have also made it much more difficult to switch in the resistor-capacitor network needed to operate the devices in pulse mode.

• The group decided to design and construct a high-voltage switch, to allow the HV PS to be switched (while “off”) between the various experiments without moving cables, and to incorporate the pulse mode network into the design.
Preparations for 300 kV Operation

Device Switching: Proposed HV Switch

Switch specifications:

- Switching at 0 volts (not “live” switching)
- Able to handle 300 kV DC
- Device terminals not in use must be “safed” (grounded)
- Pulse capacitor and resistors to be internal to the enclosure
Preparations for 300 kV Operation

Device Switching

Proposed High-Voltage Switch

- Power input cable
- Device power cable (1 of 4)
- Rotating device selector ("hot")
- Device terminal (1 of 4)
- Raise-able / lower-able contact bridge (1 of 4)
- Pulse-enabling switch
- Pulse-enabling capacitor
Preparations for 300 kV Operation

Device Switching

Proposed High-Voltage Switch

Resistance selector
(0 to 250 kΩ in 50 kΩ increments)

Resistor strings
(5 strings of 250 kΩ each)

Current Status:
• Design studies, including field analysis using Maxwell 3-D complete
• Components and material are being acquired
3He Trapping and Recovery

- Intentions to deploy a trapping system have been advanced.
- Helium-effective turbo-molecular pump, sealed backing pump, and storage cylinder have been obtained.

Motivation

Price of 3He
Richard Bonomo 10/2010

- Price per Liter
- Price per Gram

U.S. $ per Liter

$0 $500 $1,000 $1,500 $2,000 $2,500 $3,000 $3,500

6/26/00 6/26/01 6/26/02 6/26/03 6/26/04 6/26/05 6/26/06 6/26/07 6/26/08 6/26/09 6/26/10

U.S. $ per Gram

$0 $5,000 $10,000 $15,000 $20,000 $25,000

6/26/00 6/26/01 6/26/02 6/26/03 6/26/04 6/26/05 6/26/06 6/26/07 6/26/08 6/26/09 6/26/10

Approx. Date of Quote
HELIOS Helicon Ion Source
Improved ion source with glass-to-metal seal in under construction

Old Configuration
Location of vacuum O-rings (tend to fail due to heating)

New Configuration
(no O-rings)
Additional Infrastructure Improvements

- Additional steps have been made toward establishing a single ground point for the laboratory, with more steps coming

- Ad-hoc facilities to electroform copper parts for the high-voltage switch are being established
Concluding Remarks

• The laboratory should be able to expand the operating regime (cathode voltage to 300 kV) within the next year

• The improved switching system should permit the continued rapid switching between devices and experiments, and greatly reduce the time and effort required to set up pulsed experiments
Questions?
Quartz Vessel

- Quartz chosen for its high purity, high heat capacity (min 1000°C), and high mechanical strength (1000psi Tensile Strength)
- Base is 1” thick
- Ridges on bottom are 0.5” high, provide additional 3” of path length
- All edges are rounded to minimize sharp points
- Height of cylinder above base is 5”
• Primary Breakdown concerns
  – Through materials
  – Along surface

• Minimum 4” radial distance between HV and Ground
  – Minimum 2” PVC, 1”Oil

• At least 4 relevant surface paths
  – Minimum recommended path length for 300kV is 15”, conservatively
  – Minimum achievable in current design is 12.5”

• Two tier design to maximize path length up the HV cable