The Design of A Neutron Generator Using The Inertial Electrostatic Confinement of A Deuterium Plasma

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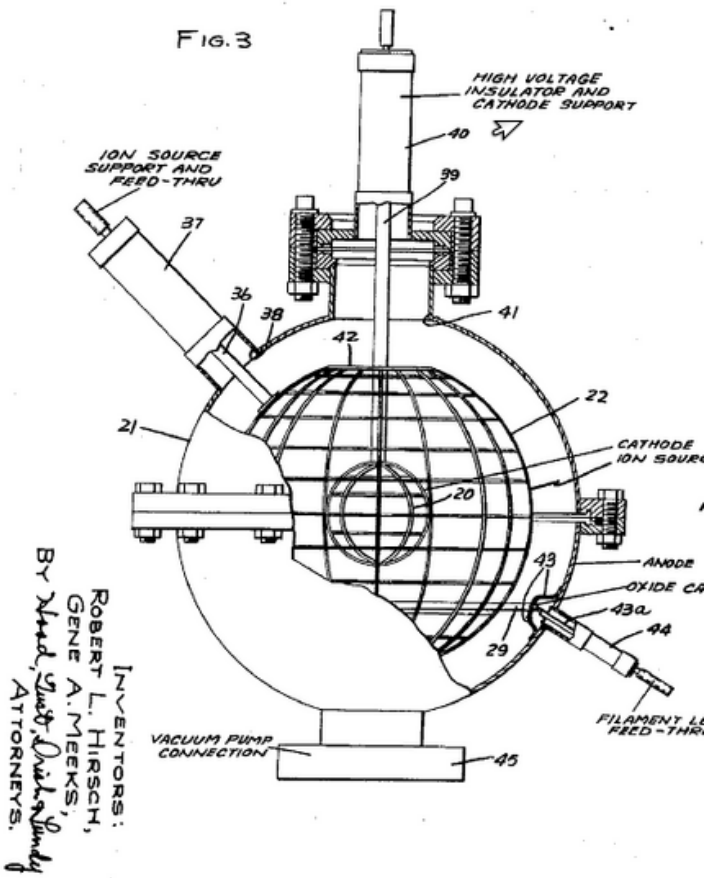
UOIT

CHALLENGE INNOVATE CONNECT

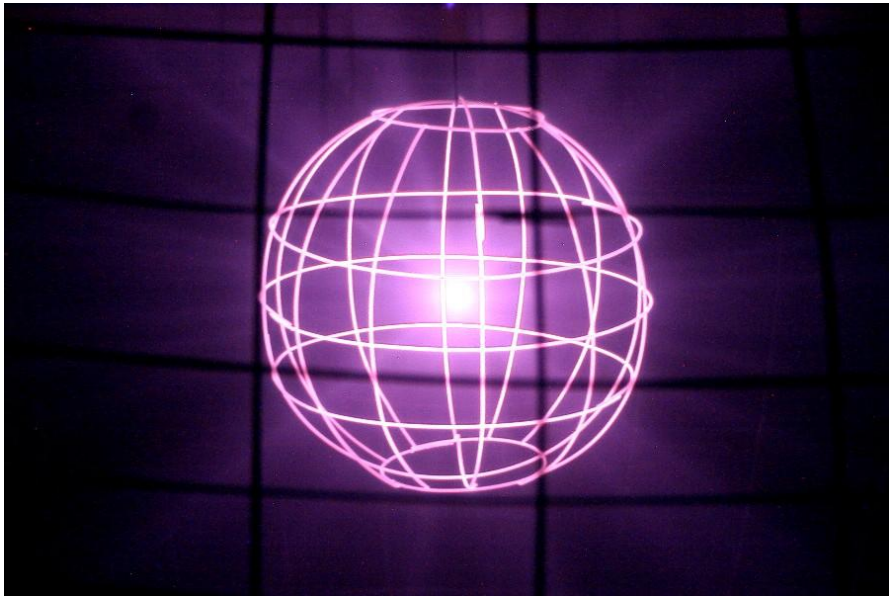
Overview of IEC and Project

- Inertial Electrostatic Confinement (IEC) is a method to generate fusion reactions
  - Dates back early 1950s
  - Widely used in commercial neutron generators
  - Best known design is probably the Farnsworth-Hirsch Fusor Device
- At the start of the project, UOIT had only a small radioisotope neutron generator.
- I've been wanting to build one for years, and I needed a thesis project.

What an IEC Device Looks Like

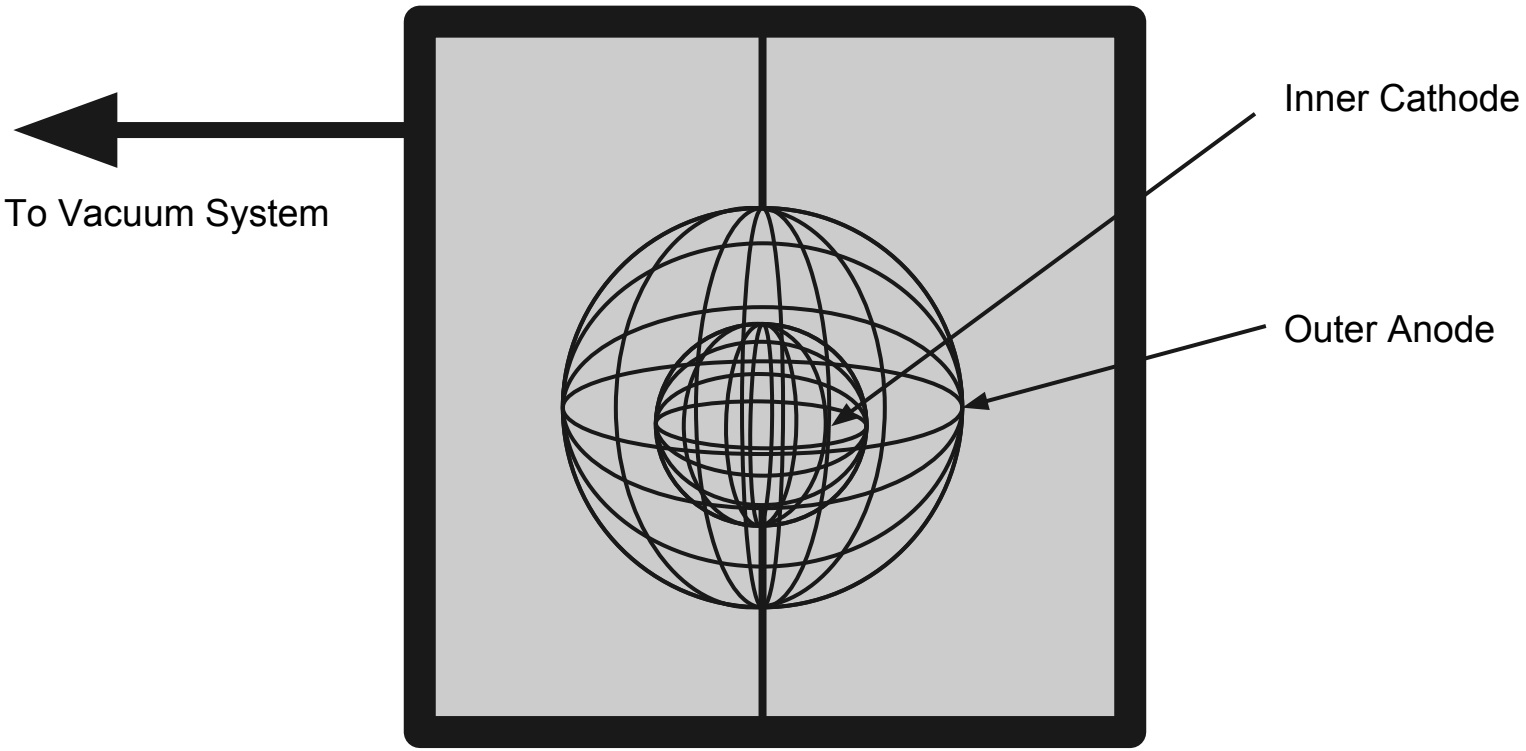


An IEC Device from the Hirsch-Meeks Patent [1]



The HOMER Device at UW [2]

Theory on How IEC Works



$^{2}D + {}^{2}D \rightarrow {}^{3}He + {}^{1}n$ (2.45 MeV)

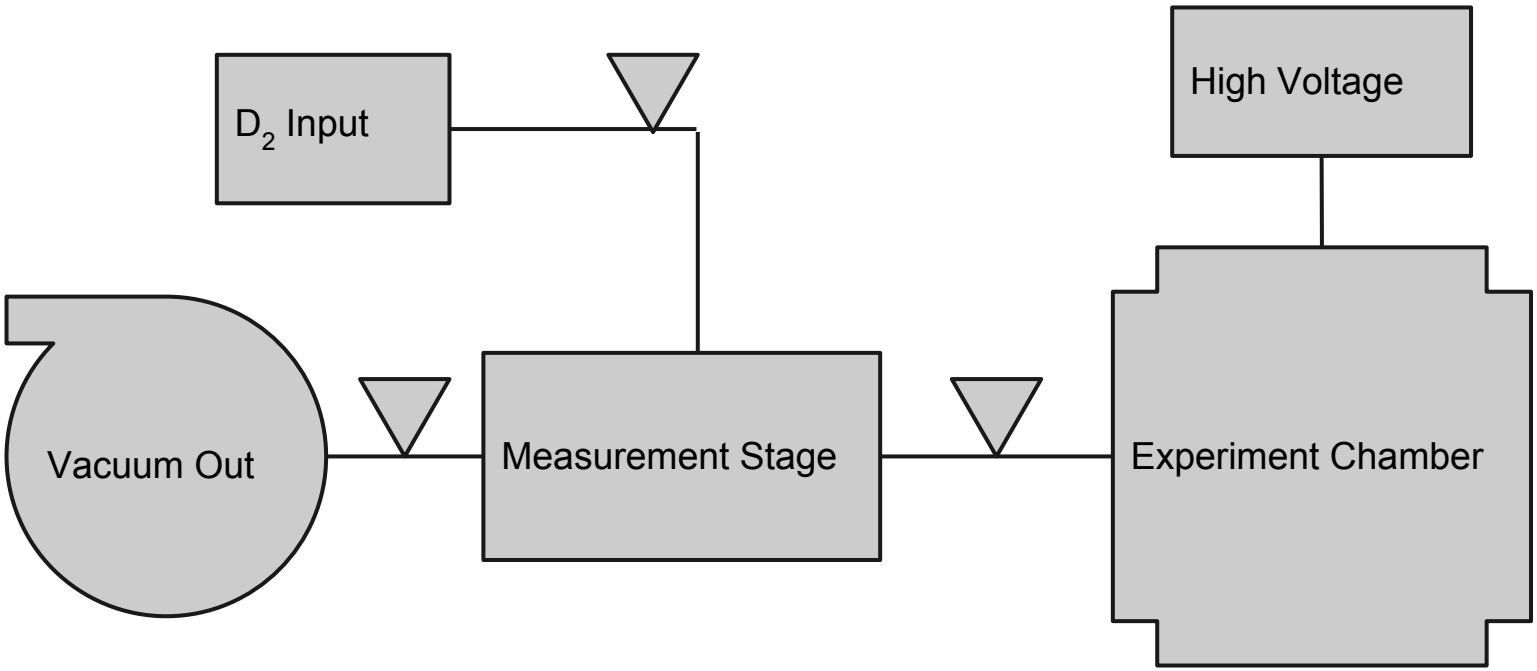
Project Goal

Build a working IEC device on a budget.

Components to be Designed and Built

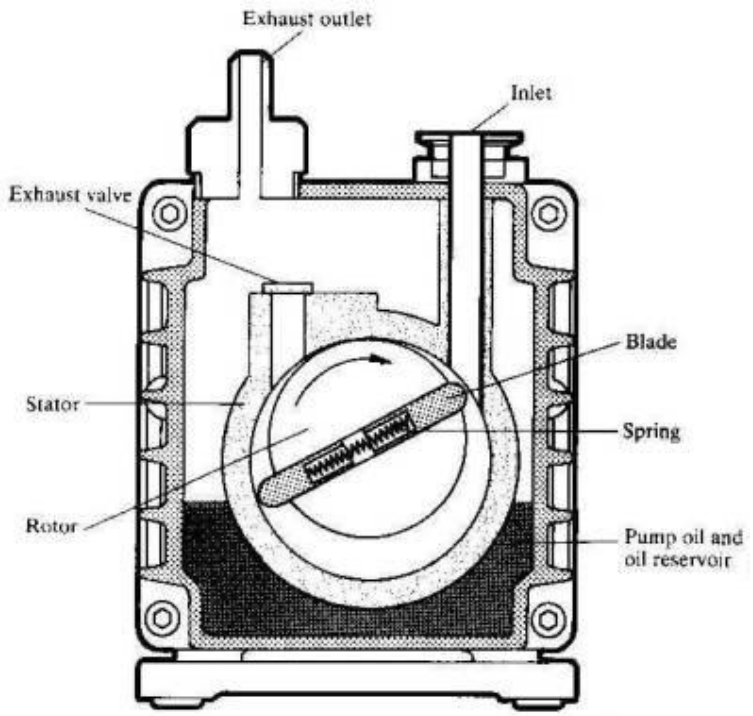
- High Vacuum System
  - Two Stage Pumping
  - Two Stage Measurement
- High Voltage System
  - Cathode power supply
  - Anode power supply
- Gas Fill System
- Neutron Detection System
- Other Components

System Layout



Vacuum Pumps

- Requirements:
  - At minimum reach molecular flow regime (Kn > 10)
    - Kn = MFP / L
  - Remove as much air (impurities) as possible
- Dual stage pumping
  - Two stage rotary vane pump - 10^{-2} torr
  - Turbomolecular pump - ultimate vacuum of 10^{-9} torr



Rotary Vane Pump [4]

Turbomolecular Pump

- Imparts directed kinetic energy onto gas molecules
- Runs at thousands of RPM
- Can only start-up at low pressures (~0.1 torr)

Turbomolecular Pump [5]

Vacuum Measurement

- Dual stage measurement
  - Pirani gauge - atm to 10^{-4} torr
  - Ionization gauge - 10^{-4} to 10^{-8} torr
- Signal stages
  - MCU to read everything out

Pirani Gauge[6]

Deuterium Injection System

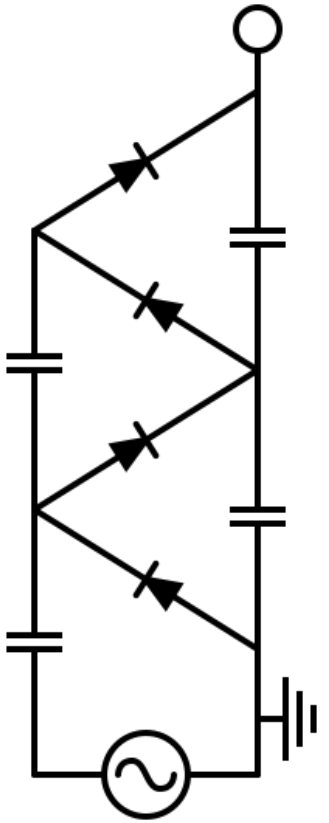
- Measure out D_2 to be injected into the system with pressure gauges
- High accuracy, low pressure regulator on gas inlet

High Voltage System

- Requirement:
  - Tens of kilovolts negative on cathode
  - Hundreds of volts positive of anode
- Implementation
  - Cockcroft-Walton voltage multiplier for cathode
  - off-the-shelf HV power supply for anode
  - high voltage feedthroughs

Cockcroft-Walton Voltage Multiplier

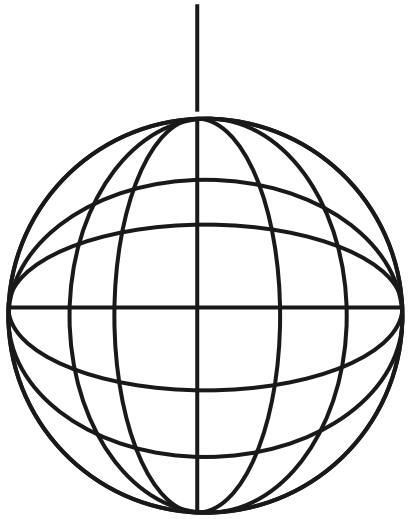
- Generates extremely high DC voltages
- Each stage multiplies the voltage by 2
- No need for extremely high voltage parts, voltage across each stage is that of the supply voltage
- Positive or Negative out



Cockcroft-Walton Voltage Multiplier Circuit [3]

Electrodes

- Spherical shape
- Stainless steel for heat resistance
- Tungsten Inert Gas (TIG) weld
- Larger anode hangs from top
- Smaller cathode supported from bottom
- Hole at bottom of anode to let cathode pass through



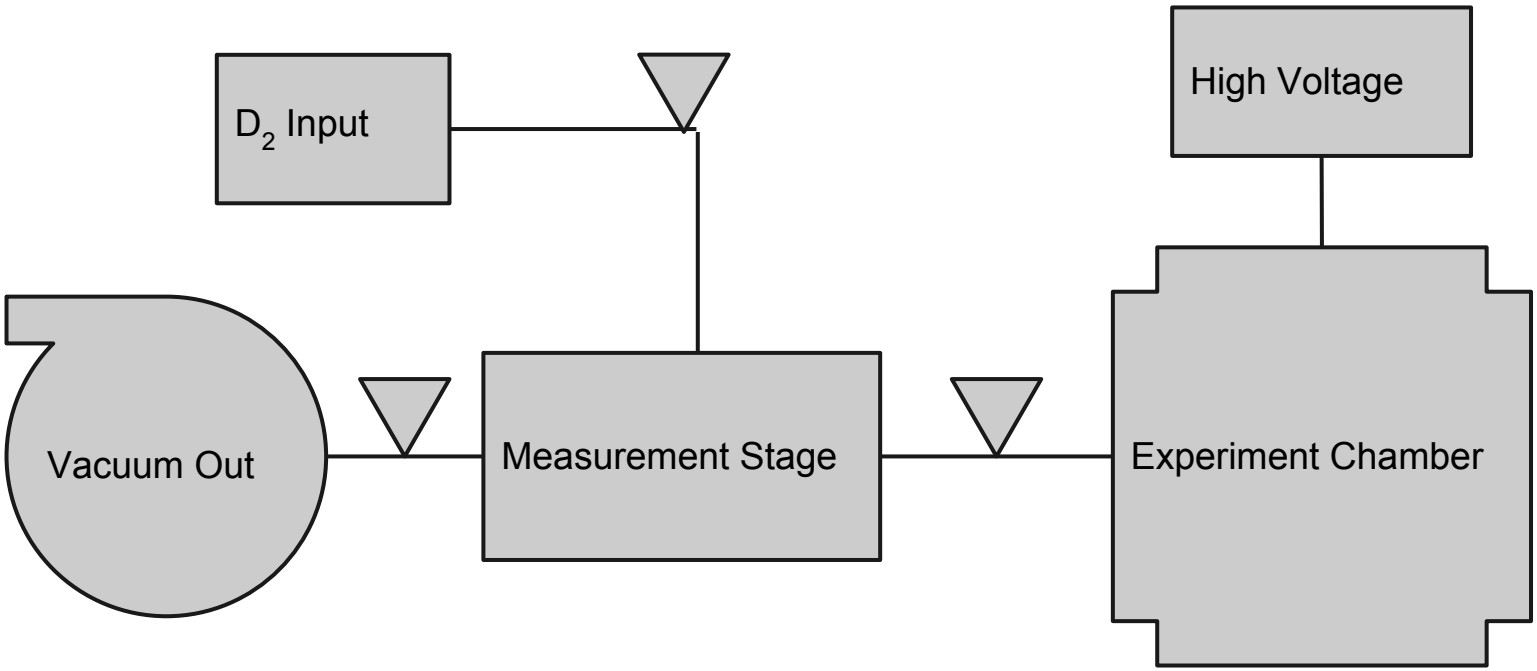
Neutron Detection System

- Neutrons born fast at 2.45 MeV
- Need to thermalize the neutrons
  - use paraffin
- Helium 3 detector
- Pulse Corona Boron tubes
  - USSR era army surplus

Other Components

- Something to build the thing on
- Water cooling for turbomolecular pump
- Radiation protection and safety

IEC Device Operation



Testing

- Helium for initial tests
- Hydrogen to test confinement
- Deuterium to generate neutrons

Project Milestones

- April 2012: First asked if I could take on this project
- June 2012: Met Blair Bromley
- July 2012: Procured voltage multiplier
- August 2012: Got lab space
- September 2012: Surplus Vacuum Chamber from NRCan
- October 2012: Shipment of surplus high vacuum equipment from CRL

Project Milestones

- January 2013: Procured various HV components
- February 2013: More lab space
- April 2013: CNS Undergraduate research scholarship
- May 2013-Present: More HV equipment procurement

Works Cited

[1] R. Hirsch, G. Meeks "Apparatus for Generating Fusion Reactions" US Patent 3530497, 1968

[2] University of Wisconsin (online) "Inertial Electrostatic Confinement Fusion" http://iec.neep.wisc.edu/ May 25, 2013

[3] Wikimedia "Cockcroft-Walton Voltage Multiplier" (online) May 26, 2013 http://commons.wikimedia.org/wiki/File:Cockcroft_Walton_Voltage_multiplier.svg

[4] ETA Film Technology Inc. "Optical Thin Film Deposition Technology History" (online) May 26, 2013 http://www.etafilm.com.tw/Thinfilm_filter_Deposition_History.html

[5] Wikimedia "Turbomolecular Pump" (online) May 26, 2013 http://commons.wikimedia.org/wiki/File:Cut_through_turbomolecular_pump.jpg

[6] Brooks Automation "Convectron 275 Pirani Gauge" http://www.brooks.com/products/gauges-modules-controllers/vacuum-gauges/275-convectron-gauges (online) May 26, 2013