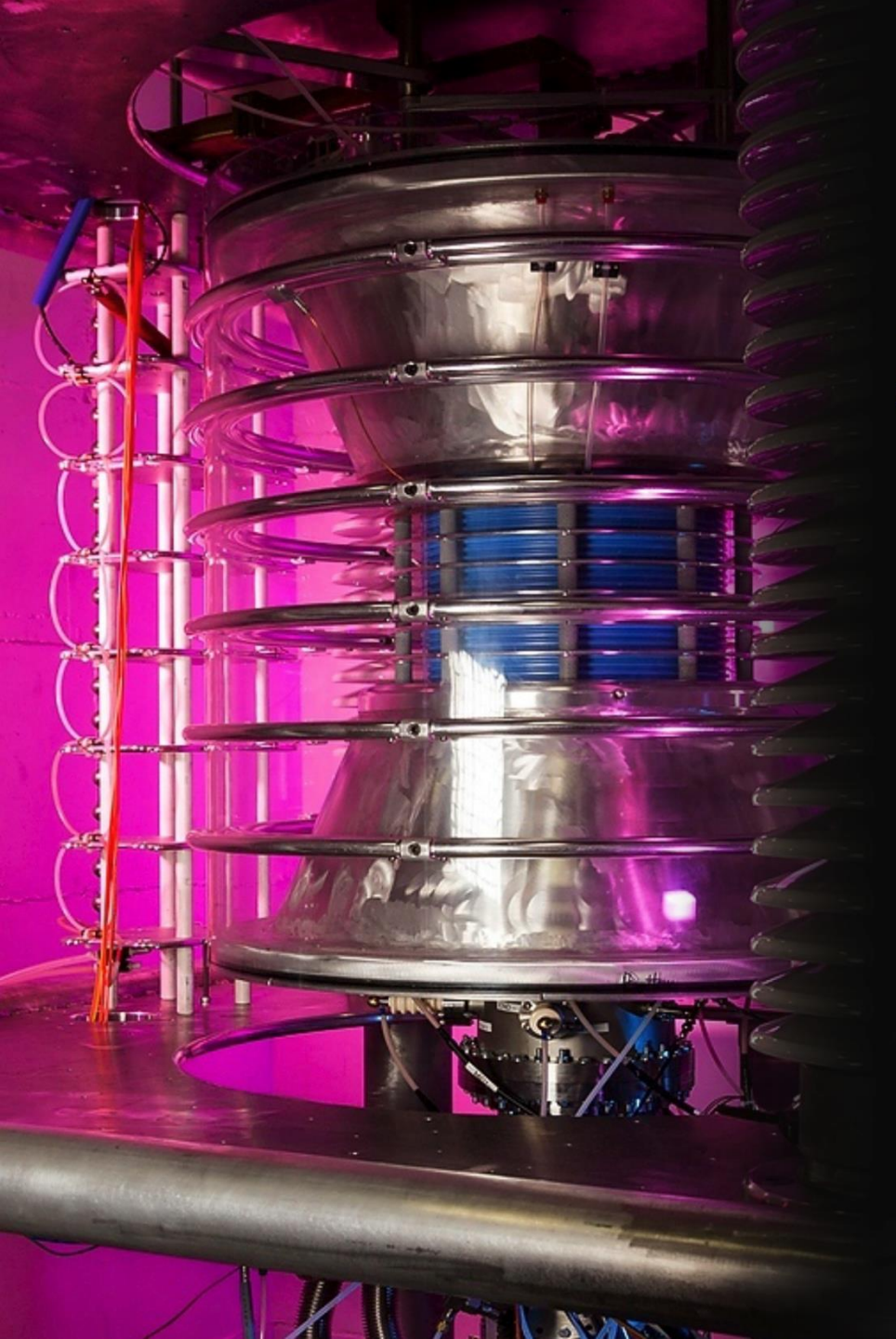

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PROVIDING NUCLEAR TECHNOLOGY FOR THE BETTERMENT OF HUMANITY

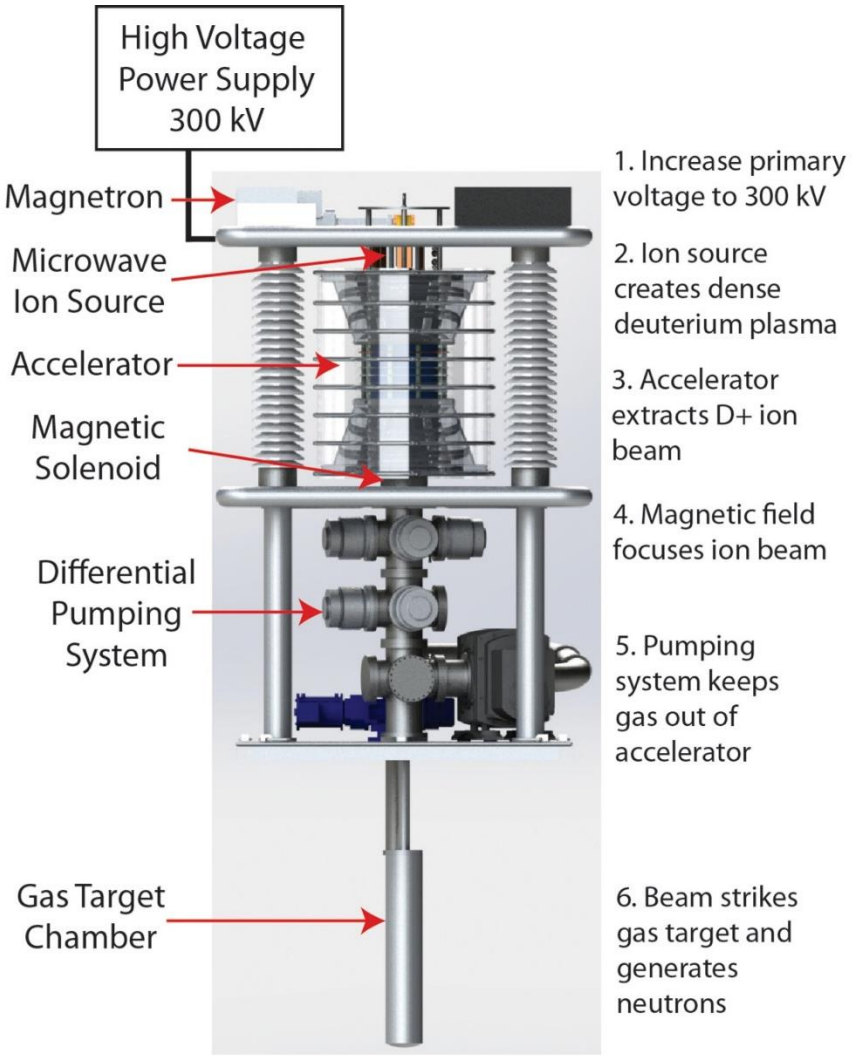
PNL Neutron Generator

Ross Radel, PhD
President, Phoenix Nuclear Labs

PNL Introduction

- Development stage company founded in 2005 with ~30 employees
- PNL has developed high yield, gas target neutron generator
- Measured neutron yield of $3x10^{11}$ DD n/s
- Fundamental technology combines very high current DC ion source, high voltage electrostatic accelerator, and gaseous deuterium or tritium target
- Multiple fielded systems; several more being built in next year

Neutron Source Overview



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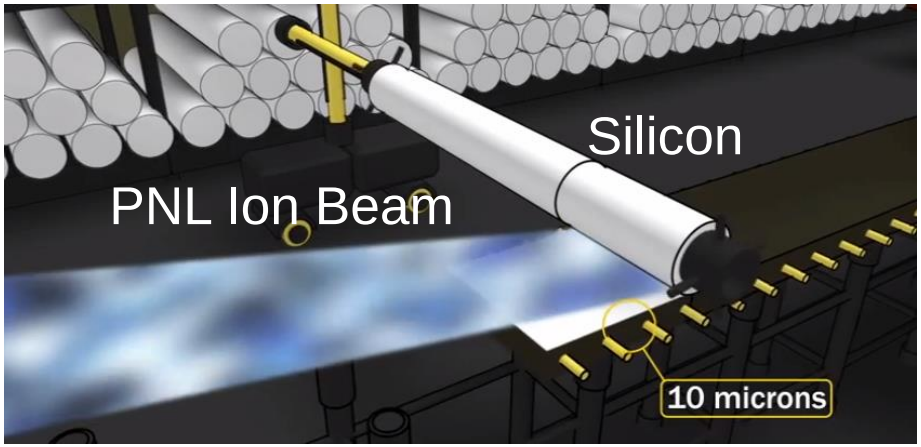
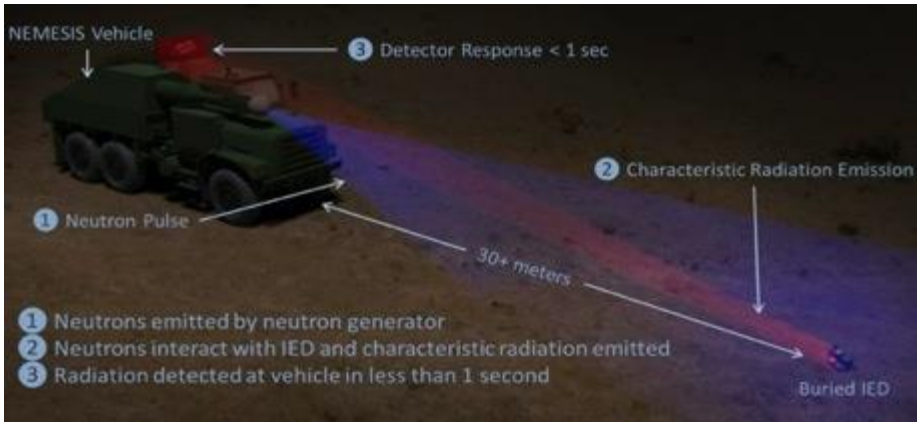
Applications

Semiconductor Processing



Explosives and SNM Detection



Neutron Radiography

Medical Isotope Production

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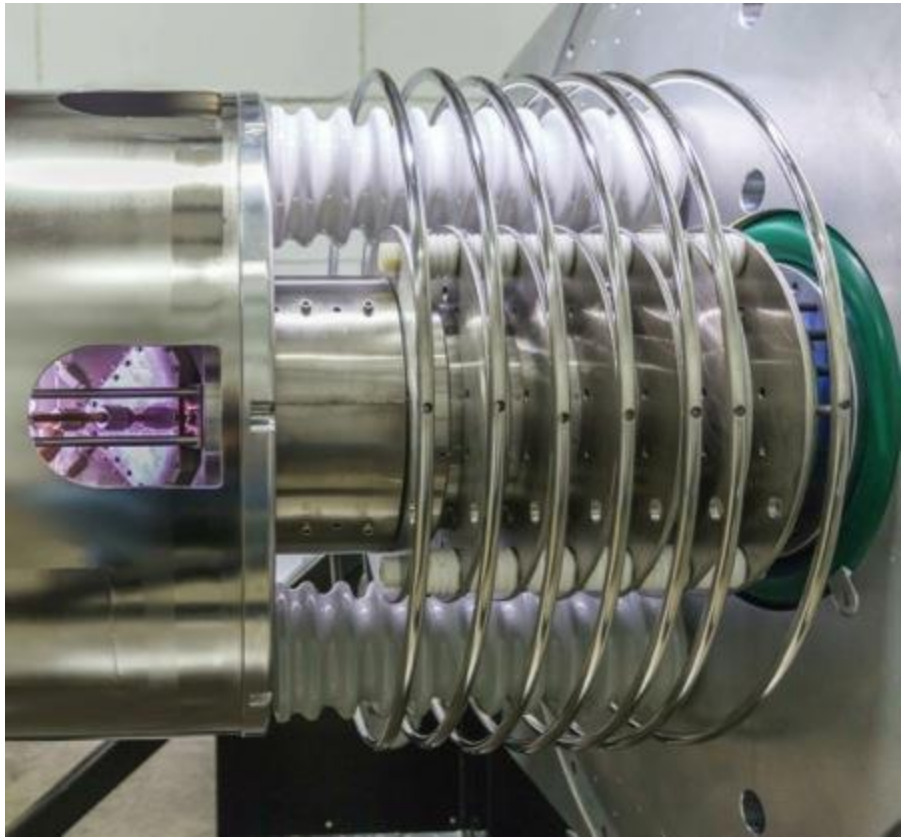
Generation 1: U.S. Army

Generation 2: SHINE Medical

Microwave Ion Source

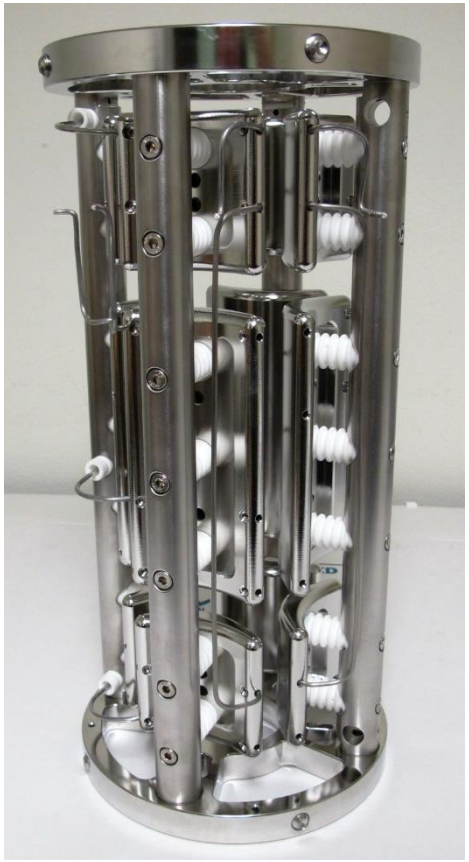
- 2.45GHz microwaves generated by magnetron at ~1kW
- ECR process ionizes gas in plasma chamber
- Beam extraction at 30-60kV
- Current density 40-250 mA/cm^2
- Measured 100mA of extracted D^+ current (CW)
- Very long lifetime (years)
- High atomic ion fraction (~90%)
- High gas efficiency (>25%)

Electrostatic Accelerator



- 300 kV
- Up to 100 mA of deuterium
- Custom lens stack for beam transport
  - Low emittance for gas target
- Both SF6 and dielectric oil have been used as non-vacuum insulator
- Multiple electron suppression elements (magnetic and electrostatic)

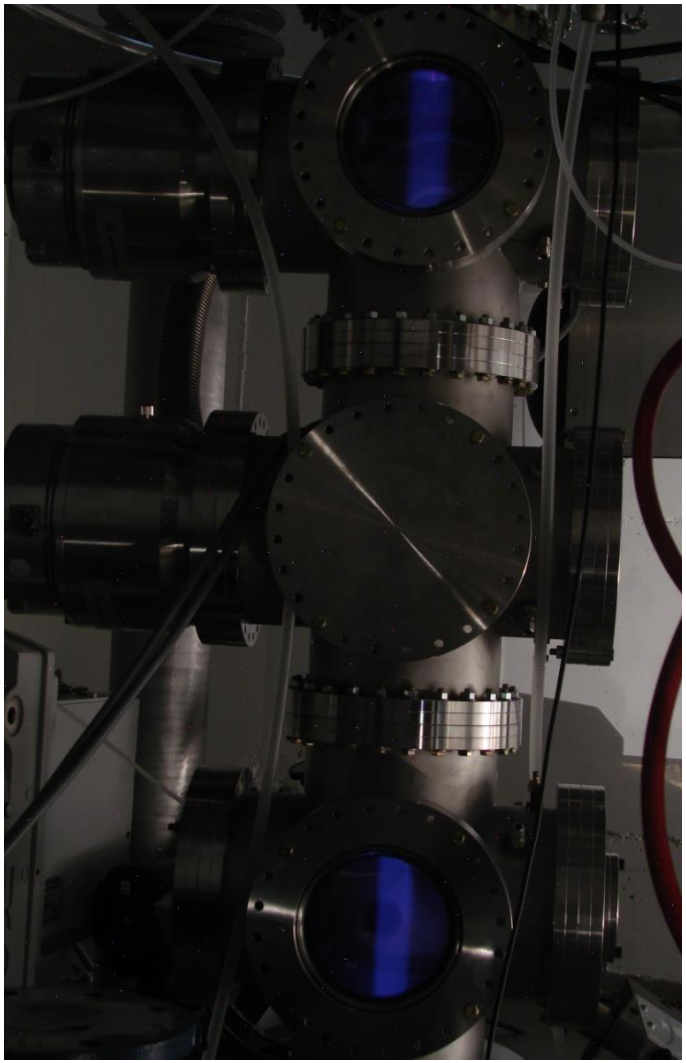
Focus Element



ESQ or Magnetic Solenoid

- Electrostatic Quadrupole
  - Low input power
  - Includes beam steering
  - Transports all ion species
  - Struggles at ion current >25mA
- Magnetic Solenoid
  - High input power
  - No beam steering
  - Only transports single ion species
  - Handles very high current (>100mA)

Differential Pumping

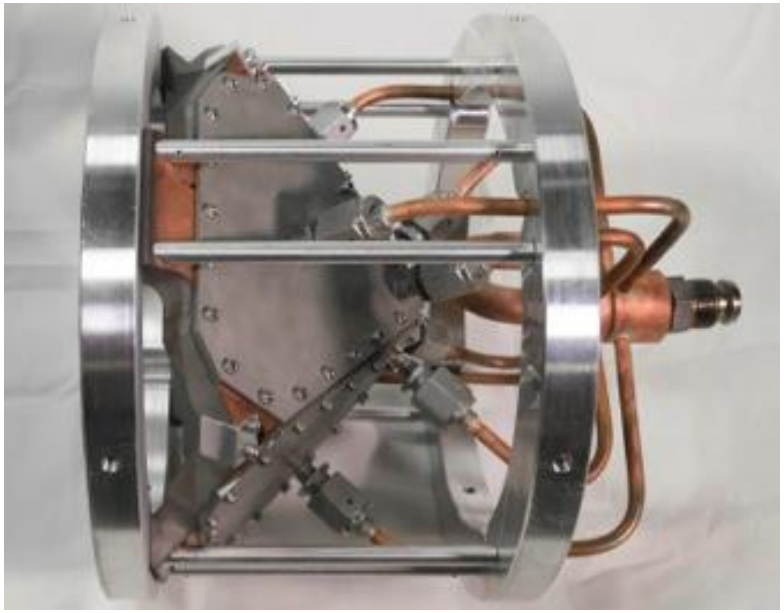


- Accelerator must be kept at low pressure (~uTorr) for voltage standoff and beam transport
- Target must be kept at high pressure for neutron generation (~Torr)
- Million-fold pressure differential achieved by series of pumps and apertures
- Turbopumps, roots blowers, gas jets, etc.

Target

- Cylindrical gas target approximately 1m in length and 15cm in diameter
- Deuterium or tritium gas
- High pressure (10 – 30 Torr) maintained by differential pumping
- Neutron source is effectively a “line source”

Solid Target



- Lower yield, but smaller system
- Copper coated with titanium
  - Higher deuterium concentration
  - Excellent thermal properties
- Targets are self-loading and self-replenishing
  - Proprietary, automated cleaning process for extremely long lifetime
- High beam current and voltage create unique cooling challenges

HV Power Supply

- 300kV, 200mA DC HVPS
- Low stored energy (< 230J)
- Fiber optic arc sensing and very fast automatic shutdown (<50us)

Control Cabinet

Summary and Next Steps

- PNL has developed high yield, gas and solid target neutron generator for several different applications
  - Isotope production
  - Neutron Radiography
  - Explosives and SNM detection
- Measured neutron yield of $3x10^{11}$ DD n/s
- Future development efforts underway
  - Increase voltage/current for higher yield ($5x10^{11}$ DD n/s)
  - Further miniaturization of neutron generator
  - Transition to tritium target ($5x10^{13}$ DT n/s)

Thank You!

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