Office of Nonproliferation and Verification Research and Development

Tagged Neutron Source for API Inspection Systems with Greatly Enhanced Spatial Resolution

Project number (LB11-TagNeutSource-PD03)

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I. Introduction

- Recently developed induced fission and transmission imaging methods with time- and directionally-tagged neutrons offer new capabilities for characterization of fissile material configurations and enhanced detection of special nuclear materials (SNM).
- Advanced Associated Particle Imaging (API) generator with higher angular resolution and neutron yield than existing systems is needed to fully exploit these methods.

II. Goals and Objectives

- The goal is to develop an API generator:
  - Several-fold increase in spatial resolution with 1 mm beam spot size on target
  - Neutron yield of 10^9 neutrons/sec

III. Associated Particle Imaging Generator

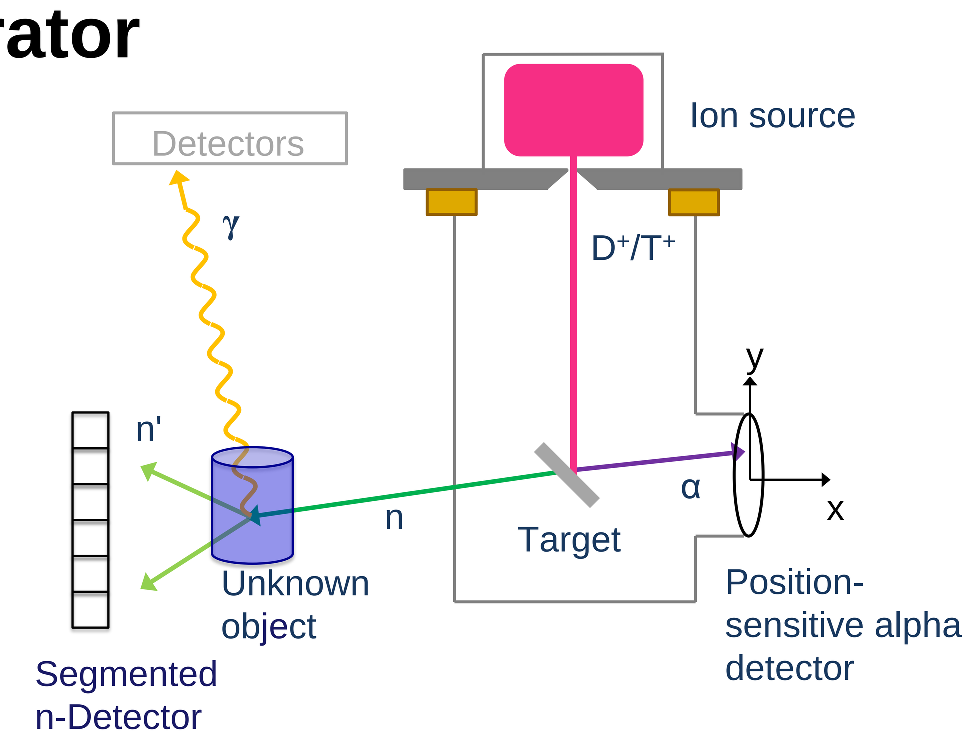
- D-T generator with beam-loaded target
- Fusion reaction: d + T → n (14.1 MeV) + α (3.5 MeV)
- Recording of time and position of alpha particle gives time and direction of associated neutron

For system compactness

- No active focusing – narrow (collimated) beam used

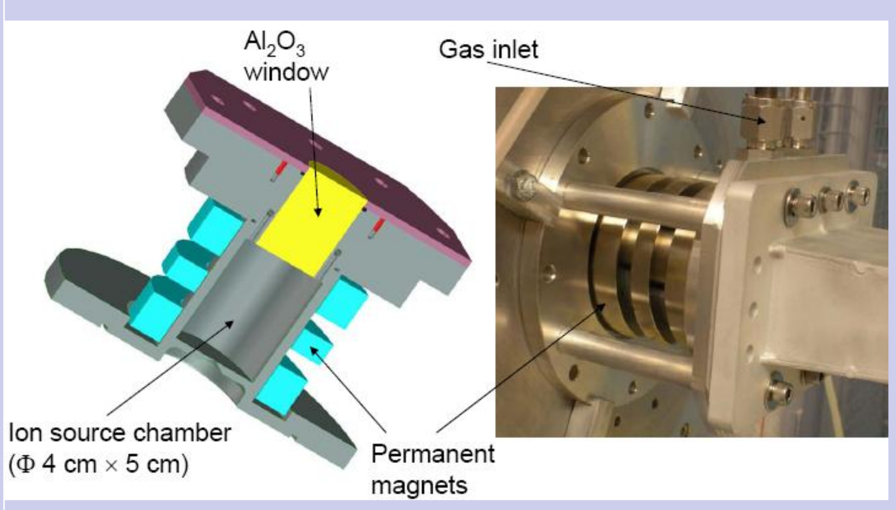
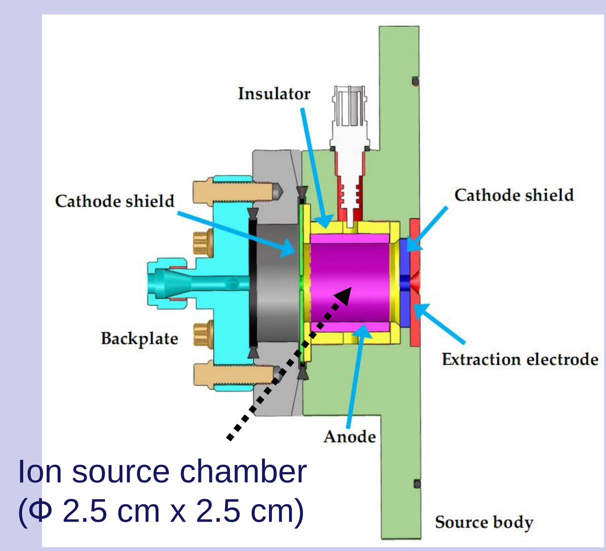
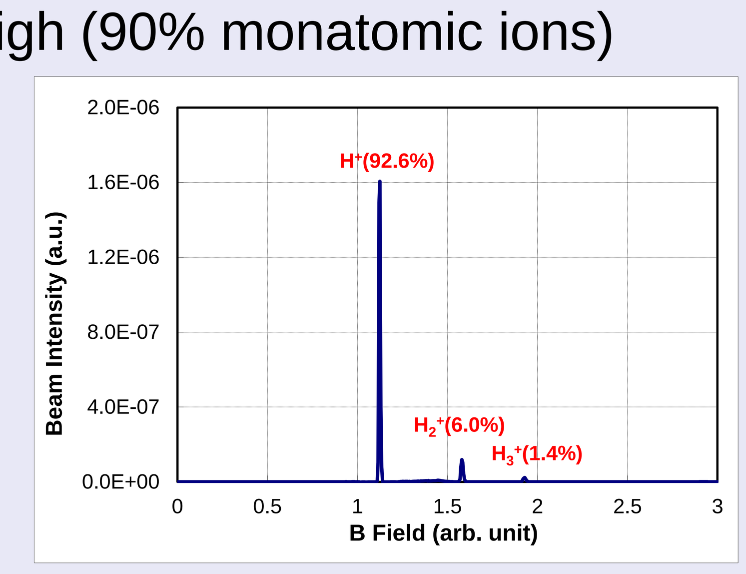
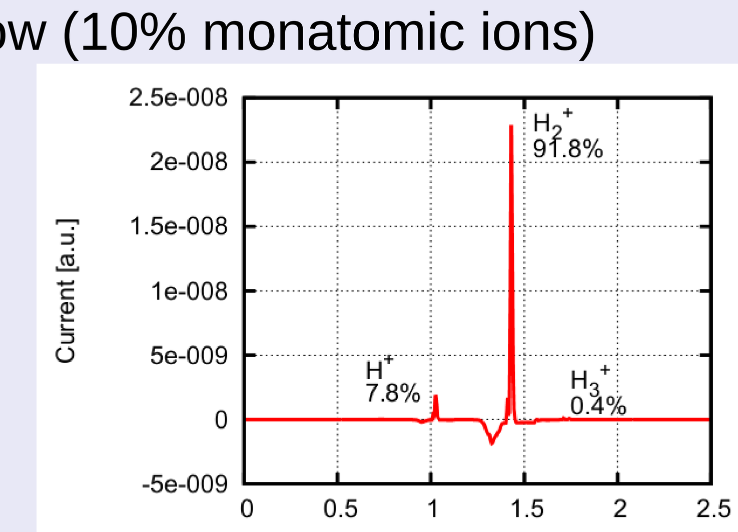
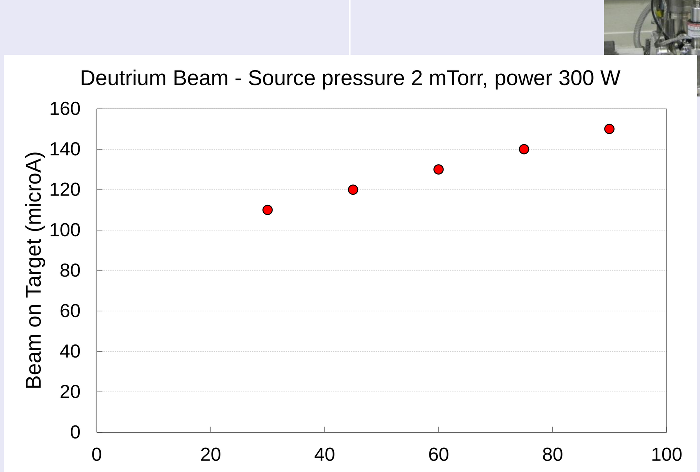
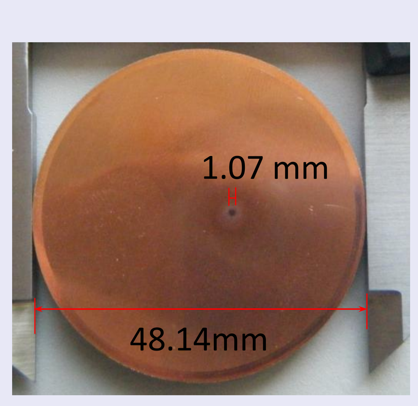
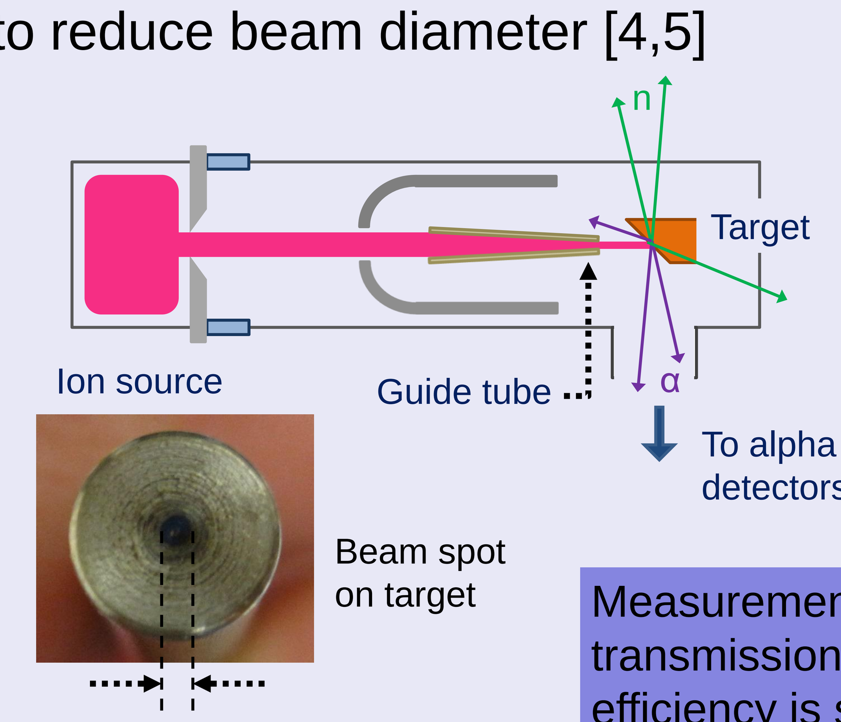
Ion source is key element

- Must produce sufficient beam current density
- High atomic fraction desirable
- Must operate at low gas pressure



IV. Results/Major Findings

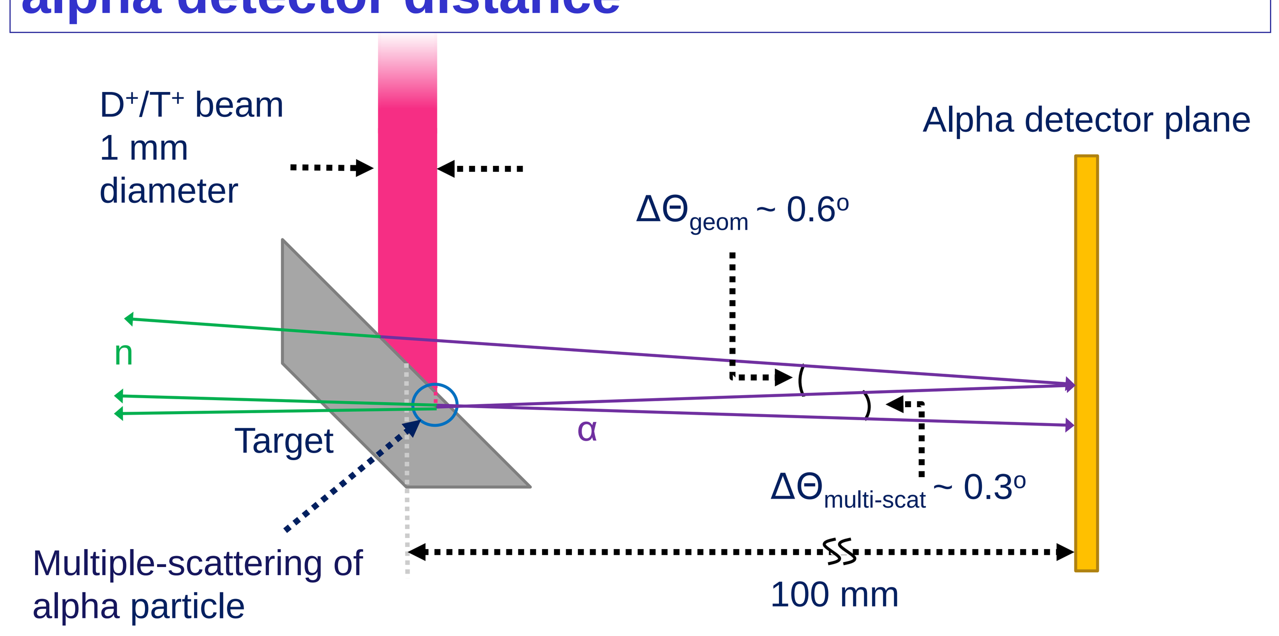
Main task in FY12 ion source R&D - evaluation of both microwave ion source and Penning ion source.

	Microwave Source [1]	Penning Source [2]
		 
Output current density	High (100 mA/cm^2 @ ~300W)	Low (2 mA/cm^2 @ ~10W)
Operating gas pressure	Low (2 mTorr)	Low (< 2 mTorr)
Atomic fraction of the beam	High (90% monatomic ions) 	Low (10% monatomic ions) 
System size	Microwave components add size and weight	Compact, simple
Beam size	High current density allows for collimation [3], ion extraction with reduced apertures for 1 mm beam spot    Beam spot on target Test Results at Adelphi Technology, Inc.	Low current density requires larger extraction aperture; exploration of passive focusing using ion beam guiding to reduce beam diameter [4,5]  Measurement of transmission efficiency is still ongoing

Imaging Resolution

- Contributions to angular uncertainty:
  - Geometry: beam spot size on target, distance to alpha detector
  - Position resolution of alpha detector (ideally << spot size)
  - Multiple-scattering of alpha particle in target
  - Kinematics of D-T reaction (in one dimension)
- Calculated point-spread profiles due to multiple-scattering of alpha:
  - $\Delta\Theta_{multi\text{-}scat}$ ~ 0.3º

Angular resolution dominated by geometry for 1 mm diameter spot size and 100 mm target-to-alpha detector distance



V. Discussion/Next Steps

- Effort is still needed to reduce source power and system size for the microwave-driven neutron generator
- More R&D is needed to demonstrate passive focusing using ion beam guiding; Penning ion source does not yet meet design goal
- Engineering design of microwave-driven neutron generator
- Integration of alpha detector
- System fabrication

VI. Conclusions

- Microwave-driven ion source is capable of delivering over 100 μA of beam current (sufficient to produce 10^9 n/s) onto a 1 mm spot size.
- The API system based on microwave-driven neutron generator will offer new capabilities for characterization of fissile material configurations and enhanced detection of SNM.

References

[1] Q. Ji, *AIP Conf. Proc.* **1336**, 528-532 (2011).
[2] A. Sy, et al., *Rev. Sci. Instrum.* **83** 02B309 (2012).
[3] A. Sy and Q. Ji, *AIP Conf. Proc.* **1336**, 533-537 (2011).
[4] Kreller, et al., *Nucl. Instr. Meth. B* 269(9), 1032-1035 (2011).
[5] Hasegawa, et al., *Nucl. Instr. Meth B* 266(10), 2125-2129 (2008).

Acknowledgements

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