Brookhaven Linac Isotope Producer status and Pre/Post-irradiation characterization and analysis capabilities at BNL

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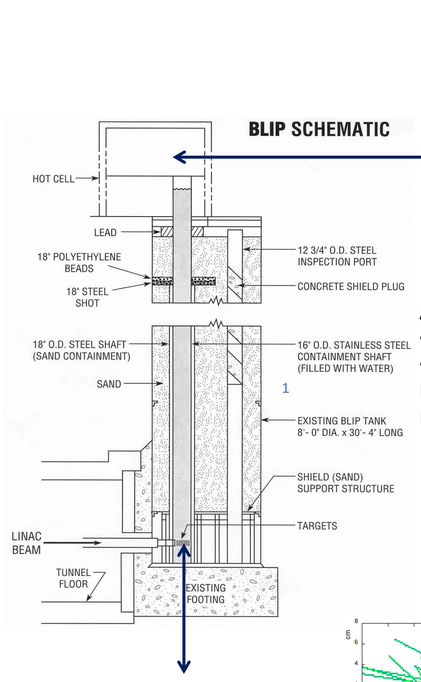
Abstract

The Brookhaven Linac Isotope Producer (BLIP) operations have been ongoing for over fifty years for isotope production augmented with proton and spallation-based fast neutron irradiation studies of particle accelerator and nuclear materials. The program has maintained the handling and characterization capabilities of highly radioactive materials. Specifically, capabilities within the BNL hot cell laboratory, essential for nuclear material studies, include photon spectra and isotopic analysis using high-sensitivity detectors, radioactivity measurements and high precision weight loss or gain assessment. Also, the program is supporting the RaDIATE collaboration and the U.S.-Japan Science and Technology Cooperation Program in High Energy Physics. In the very near future an intensity upgrade will be under way at BNL to increase the 200 MeV Linac up to 320 μA peak current it can deliver after its upgrade.

The Center of Functional Nanomaterials (CFN) has hosted a broad range of research investigations in nanoscience since its inception in diverse research areas, such as efficient catalysts, fuel cell chemistries and architectures, and photovoltaic (solar cell) components. Characterization of the microstructure under extreme temperatures (currently on unirradiated materials) is provided.

The National Synchrotron Light Source II (NSLS-II) has developed at delivering world-class x-ray capabilities for studying complex and heterogeneous materials, including robotics, that allow it to work with radioactive materials with dose rates up to 100 mrem/h at the XPD beamline. Furthermore, BNL is working with DOE-Nuclear Energy on a concept for a beamline with an end station separated from the ring building, controlled access, special capabilities to receive and study radioactive materials with higher dose limits than at any synchrotron beam line within the DOE complex. The initial scope of this special beam line facility will be on structural analysis and tomography but will have the ability to be upgraded to include chemical imaging.

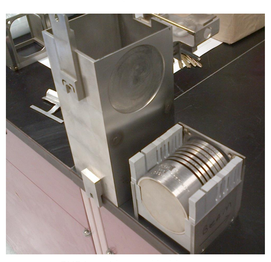
Brookhaven Linac Isotope Producer



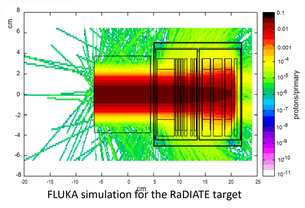
Accelerator Improvement Project (AIP)
- Phase 1 complete: Current improved to 165uA in 2016
- Phase 2 pending: Increase current to 250 uA (SAD mod covers up to 320 uA)

BLIP Raster Project

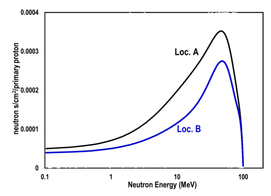
BLIP cooling and target drive system upgrade

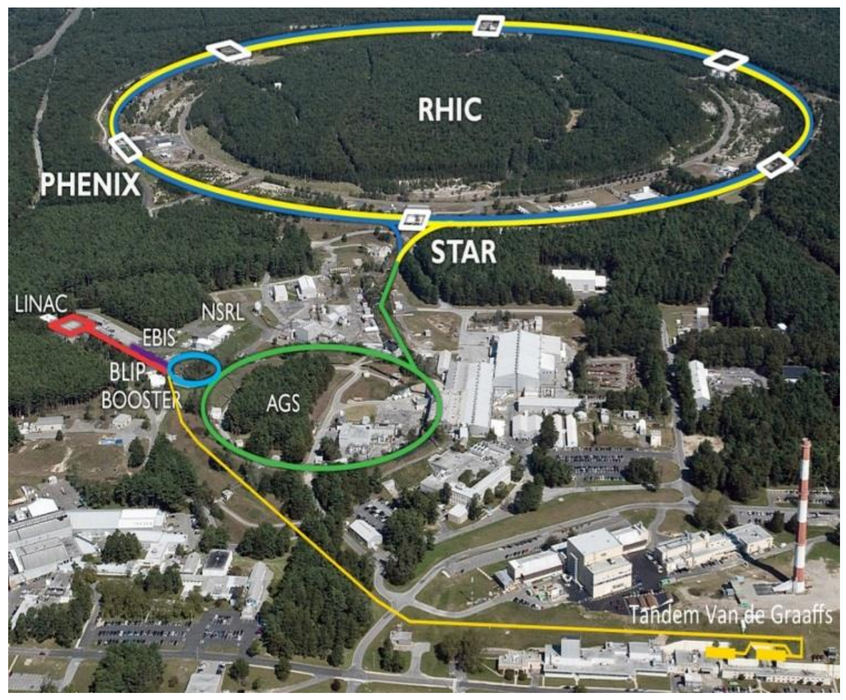


BLIP target box and holder



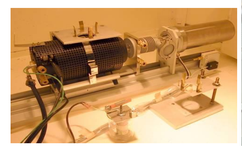
FLUKA simulation for the RaDIATE target



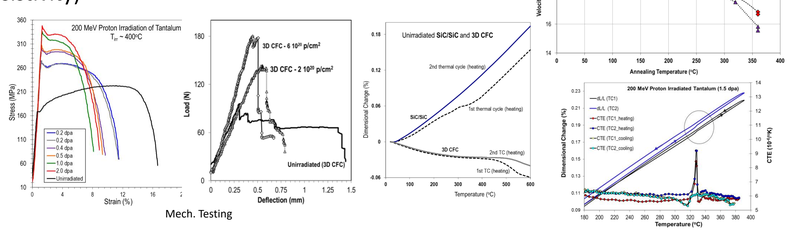


Target Processing Lab

- Experimental Facility occupies 2 hot cells and a HEPA-filtered fume hood
- Photon spectra and isotopic analysis
- Activity measurements
- Weight loss or gain

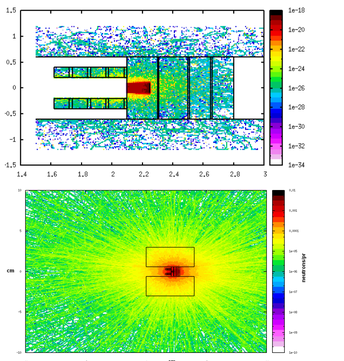


Macroscopic PIE analyses performed are:
- Stress-strain (tension, 3-point and 4-point bending)
- Thermal Expansion and annealing (sensitive dilatometer, Linseis)
- Thermal Conductivity (electrical resistivity)
- Magnetic Whole probe
- Ultrasonic measurements

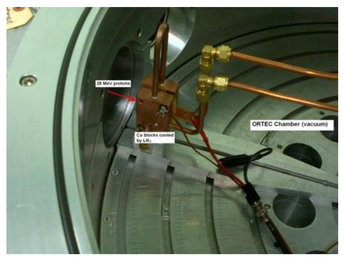


Mech. Testing

Tandem van De Graff: Ion Irradiation



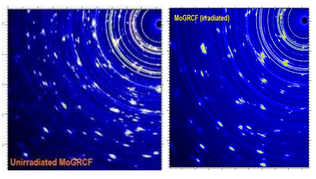
28 MeV irrad. at sub-zero temp.

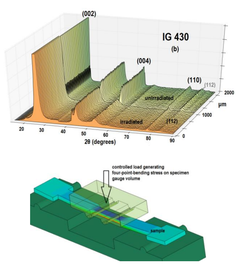


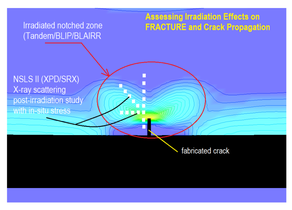
Z	Symbol	Mass AMU	Max Energy MeV	Max Energy MeV/AMU	Surface LET MeV/mg/cm²	Range Microns	Surface LET MeV/mg/cm²	Range Microns
1	^{1}H	1.0079	28.75	28.52	0.0153	4550	0.0118	2610
3	^{7}Li	7.0160	57.2	8.15	0.369	390	0.273	240
5	^{11}B	11.0093	85.5	7.77	1.08	206.13	0.754	132.55
6	^{12}C	12.0000	99.6	8.30	1.46	180.43	1.03	115.82
8	^{16}O	15.9994	128	8.00	2.61	137.78	1.83	88.9
9	^{19}F	18.9954	142	7.48	3.51	118.88	2.45	77.12
12	^{24}Mg	23.9927	161	6.71	6.01	84.16	4.17	55.13
14	^{28}Si	28.0855	187	6.66	7.81	77.16	5.42	50.66
17	^{35}Cl	34.9688	212	6.06	11.5	64.41	7.93	42.71
20	^{40}Ca	39.9753	221	5.53	15.8	51.89	10.9	34.7
22	^{48}Ti	47.9479	232	4.84	19.6	47.8	13.4	32.36
24	^{52}Cr	51.9405	245	4.72	22.3	45.86	15.3	31.06
26	^{56}Fe	55.9349	259	4.63	25.1	44.24	17.2	30.09
28	^{58}Ni	57.9353	270	4.66	27.9	44.56	19.1	30.47
29	^{63}Cu	62.9296	277	4.40	30.1	42.06	20.6	28.79
32	^{72}Ge	71.9221	273	3.80	35.9	37.94	24.4	26.25
35	^{81}Br	80.9163	287	3.55	41.3	37.50	28.0	26.11
41	^{93}Nb	92.9060	300	3.23	47.5	36.32	32.1	25.4
47	^{107}Ag	106.9051	313	2.93	59.2	32.48	39.9	22.89
53	^{127}I	126.9045	322	2.54	66.9	32.54	45.0	23.17
79	^{197}Au	196.9665	337	1.71	84.6	29.21	56.2	21.18

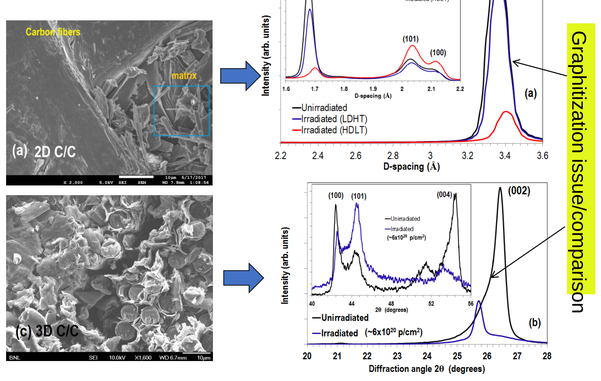
National Synchrotron Light Source II & Center for Functional Nanomaterials

XPD Beamline
- XRD
- PDF
- X-Ray Tomography









N. Simos, et al., "Radiation damage and thermal shock response of carbon-fiber-reinforced materials to intense high-energy proton beams," Phys. Rev. Accel. Beams 19, 2016

Summary

BNL, stemming from its history as a nuclear materials lab (1st graphite research reactor at BNL) has over the decades-maintained infrastructure for macroscopic characterization (hot cells, etc.)

Availability of the NSLS-II synchrotron with high energy X-rays and the commissioned techniques at the beamlines provide an excellent means of micro-characterizing the Linac/BLIP irradiated materials.

While currently Electron Microscopy has been integrated into the characterization process only for unirradiated materials under extremes (at Center of Functional Nanomaterials facility), plans are under way to add the capability at the BNL Hot Cell Laboratory

Protons and other ions as surrogates to emulate the damaging effects of fast neutrons (an ongoing debate) have been used at BNL in that regard. Also, BNL Linac/BLIP has provided to-date modest means to increase the availability of fast neutrons to test materials for fast reactors

A feasibility study under way at BNL to utilize the up to 200 MeV Linac and the 320 μA peak current it can deliver after its upgrade (peak current achieved to-date 200+ μA) for usable fast neutron spectra for fission and fusion materials

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