THE ALIGNMENT OF CONVERGENT BEMLINES AT A NEW TRIPLE ION BEAM FACILITY

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Abstract

The Michigan Ion Beam Laboratory (MIBL) at the University of Michigan in Ann Arbor Michigan, USA, has recently upgraded its capabilities from a two accelerator to a three accelerator operation mode. The laboratory, equipped with a 3 MV Tandem, a 400 kV Ion Implanter and a 1.7 MV Tandem, has also increased the number of available beamlines from three to seven with two more in the planning stages. Multiple simultaneous ion beam experiments are already in progress and scientists conduct state of the art experiments involving light and heavy ions. The MIBL staff had to overcome multiple challenges during the physical alignment process of the accelerators, beamlines and experimental end-stages. Not only the position of the accelerators changed, but the target chambers were moved into a different room behind a one meter thick concrete wall. At the same time, a beamline from each accelerator had to converge and connect to a single chamber at a precise angle. This paper focuses on the alignment process of all the equipment involved in triple ion beam experiments and especially on the procedures to align the ion beams on a target.

INTRODUCTION

Ion beam irradiation experiments, if properly conducted, can simulate the radiation damage that occurs in materials inside a nuclear reactor. While radiation effects induced by neutrons can be successfully emulated by protons and heavy ions irradiations in much shorter times, researchers tried to find a way to also simulate the presence of transmutation products in reactors. Building on the successes of other facilities (TIARA-Japan and JANNUS-France), the Michigan Ion Beam Laboratory (Fig. 1.a,b,c) as part of the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan, is now in the position to deliver dual and triple ion beam irradiations experiments.

THE PARTICLE ACCELERATORS

The laboratory is equipped with three accelerators: a 3 MV Tandem, a 1.7 MV Tandem and a 400 kV Implanter. The 3 MV Tandem (model 9SDH-2) high current Pelletron accelerator (Fig. 2a) was built by National Electrostatics Corporation (NEC). The 1.7 MV accelerator (Fig. 2b) is a solid-state, gas insulated, high frequency Tandetron built by General Ionex (now HVEE) that operates in the 0.3 MV to 1.7 MV range delivering very stable DC beams. The 400 kV implanter (Fig. 2c) is an air-insulated device also built by NEC that can deliver ion beams from any element in the periodic table, with beam fluences of 1 mA or more for some gas ions, on an area with a diameter in excess of 6 inches (15 cm). The implantation stage can be cooled to LN temperatures or heated up to 800 ^{0}C.

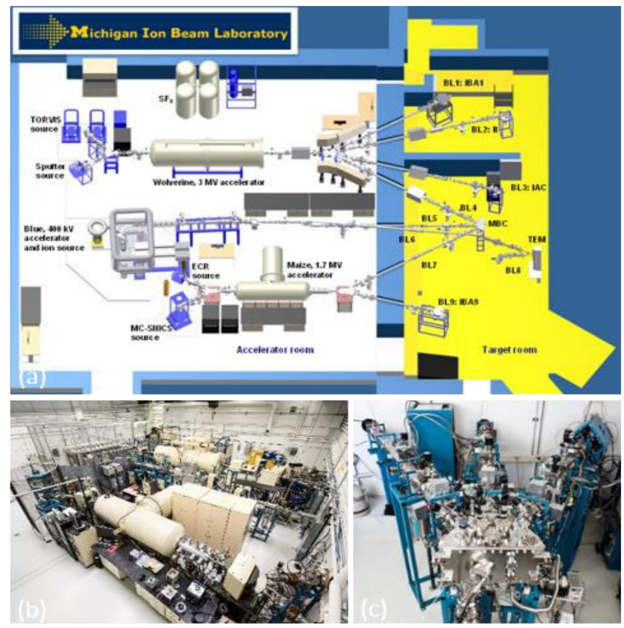

Figure 1: (a) AutoCAD drawing of the lab in the new configuration, (b) Overhead view of the lab (c) View of the multiple ion beam chamber designed to simultaneously accommodate up to three ion beams on a target.

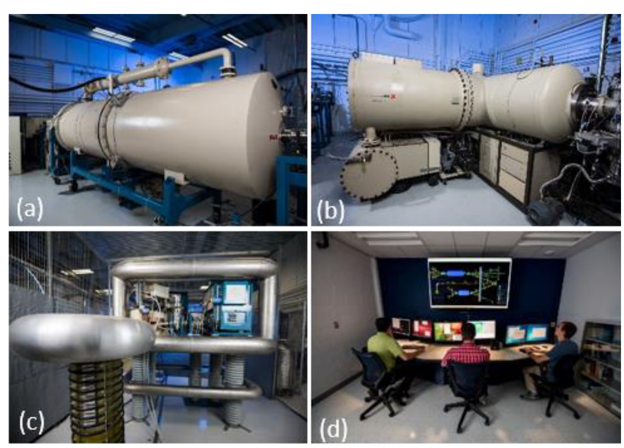

Figure 2: MIBL particle accelerators: (a) 3 MV Tandem – Wolverine (W), (b) 1.7 MV Tandetron – Maize (M), (c) 400 kV ion implanter – Blue (B) and (d) view of the Control Room (CR) of the three accelerators that now operate in remote control mode.

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THE ION SOURCES

The accelerators are equipped with many different types of ion sources. Sources for light ions: TORVIS (NEC), ECR (Pantechnik) and Alphatross (NEC) that are used for the production of protons, alpha particles and deuterium in Fig. 3d, 3b and 3f respectively. The sources for heavy ions are of sputter type: PS120 (Peabody Scientific) and MC SNICS (NEC) in Fig 3a and 3c respectively. These sources work with Cs as a sputtering element. The only positive ion source in MIBL is Danfyzik 921 shown in Fig 3d. installed in the Implanter. This source can operate in gas mode, liquid mode and sputter mode. The sputtering is induced with an Ar beam.

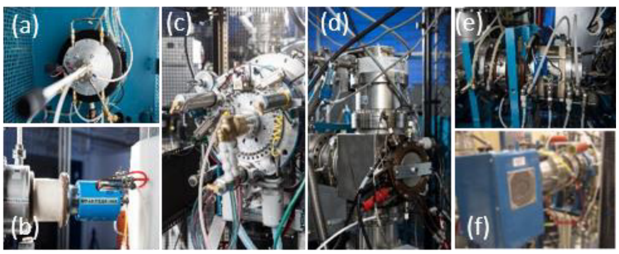

Figure 3: The ion sources: (a) PS 120 (b) ECR (c) SNICS (d) Torvis (e) 921 and (f) Alphatross.

THE BEAMLINES

The laboratory has two experimental rooms and seven active beamlines with two extra beamlines in planning stages (Fig 1a). The North Target Room (NTR) hosts BL1 used for surface analysis experiments (NRA, RBS, ERD and PIXE) and BL2 used in protons and heavy ions irradiation experiments. The South Target Room (STR) hosts BL3 through BL9. BL3 is used in experiments involving simultaneous protons and high temperature, high pressure corrosion experiments. Beamlines 4 (from Wolverine), 5 (from Blue) and 7 (from Maize) are part of a group that can deliver dual and triple ion beams irradiation experiments. The first part of BL5, terminated with a chamber in THE Accelerator Room, is the ion implantation beamline. Future BL6 and BL8 (in planning stages) will interface with a Transmission Electron Microscope (300 kV FEI) for in-situ observation of radiation damage experiments.

THE ALIGNMENT

The alignment (of sources, low energy beamlines, accelerators and high energy beamlines) was a difficult process that presented the lab staff with multiple challenges: (1) three accelerators, nine beamlines, of which three beamlines with one common target, four single ion beamlines and two beamlines still in planning stages; (2) two different center lines, with two accelerators at 56 inches (~1.42m) high and one at 68 inches (~1.72 m) from ground; (3) two different rooms with 12 inch (~30 cm) height difference (target room lower); (4) four feet (~1.2 m) thick wall between rooms, with no direct line of sight or overhead crane to move heavy components. The first step in the alignment process, consisted of mechanically aligning the ion sources, the accelerator and beamlines with a transit scope and overlapping crosshairs. Once the beamlines were under vacuum, a special target or end-station (Fig 4a) was used. A beam fluorescent, ceramic piece was mounted on the surface allowing the visualization of both a laser beam and an ion beam (beam focused in Fig 4b and rastered in Fig 4c). The green laser beam was focused through a quartz port and travelled along the center of each beamline (Fig 4d). Finally, the profile from a BPM (Fig 4e) was used to confirm the shape and size of the ion beam. In order to guarantee that the ion beam hits the desired spot on the experimental stage, the laser beam must perfectly align with the ion beam on the target. During actual experiments the target may not be fluorescent to the ion beam and then the laser spot is used to confirm the location of the beam.

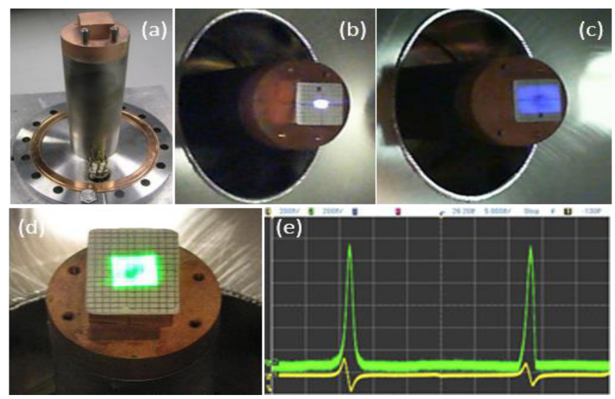

Figure 4: (a) stage, (b) focused beam on the stage, (c) rastered beam on stage, (d) laser light overlap on the ion beam and (e) BPM profile of the focused beam.

The alignment procedure, repeated for each single ion beamline and for the three converging beamlines, consisted in the following steps: (a) centering the focused beam and the focused laser spot on the ceramic piece (separately and overlapped) and (b) rastering the beam and opening the beam apertures to different sizes to confirm that the rastered beam and the defocused laser beam spots coincide. Examples are shown in Figure 5.

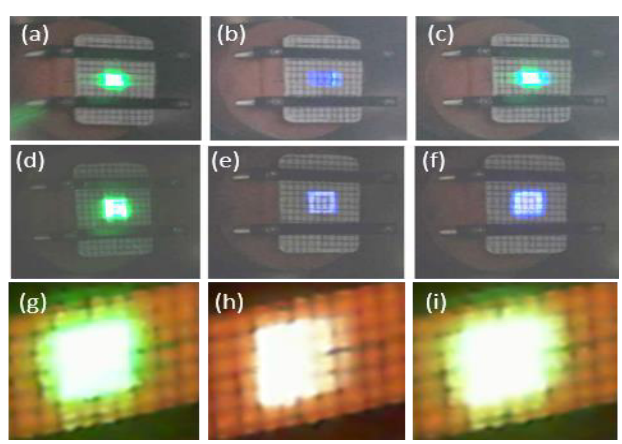

Figure 5: laser beam, ion beam and overlapped laser and ion beams: BL4: (a, b and c), BL7: (d, e and f) and BL2: (g, h and i).

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SUMMARY

Finalizing the new setup at MIBL with 7 beamlines, required extensive work for the alignment of ion sources, low energy beamlines, accelerators and experimental beamlines. During the immediate future (4-8 months) the installation and commissioning of BL6 and BL8 will begin to allow the interface to the FEI TEM to be designed and built. It is expected that the process will take between 2-3 months and the ordering of new equipment is ongoing today. MIBL is now in the position to successfully deliver well aligned ion beams to multiple targets as well as simultaneous ion beams to one target.

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