UNIBEAM - BEAM PROFILER FOR BEAM CHARACTERIZATION AND POSITION FEEDBACK

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Abstract

A beam profiler called UniBEaM is based on passing 200 micron cerium-doped optical fibers through a charged particle beam and measuring the scintillation light. In order to characterize UniBEaM over its entire kinetic energy range: keV to GeV; current range: pA to mA; and particle type range: light ions to heavy ions, and electrons, an Early Adopter Programme (EAP) was established to test UniBEaM's performance. EAP's: Australia National University (ANU) and Michigan Ion Beam Laboratory (MIBL) report on their use of UniBEaM at their facilities.

INTRODUCTION

A beam profiler based on doped SiO_2 optical fibers was designed and tested at the Albert Einstein Center for Fundamental Physics (AEC), Laboratory for High Energy Physics (LHEP), University of Bern, Switzerland [1]. This beam profiler, called the Universal Beam Monitor (UniBEaM™) was licensed and commercialized by D-Pace Inc., Canada. This paper provides example measurements made by two early adopters of this device: the Department of Nuclear Physics of the Australian National University (ANU), and the Michigan Ion Beam Laboratory (MIBL).

SYSTEM DESCRIPTION

D-Pace's commercial version of UniBEaM was described in detail by Potkins et al. [2].

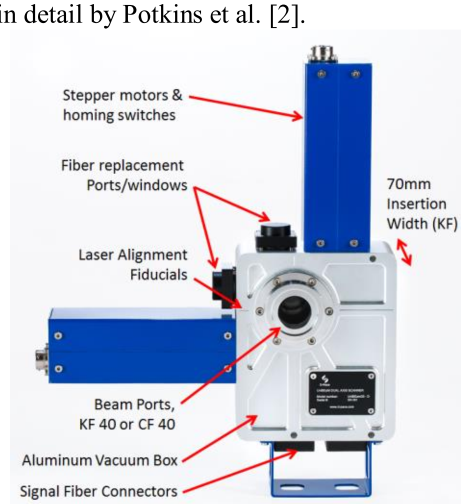

Figure 1: UniBEaM Probe.

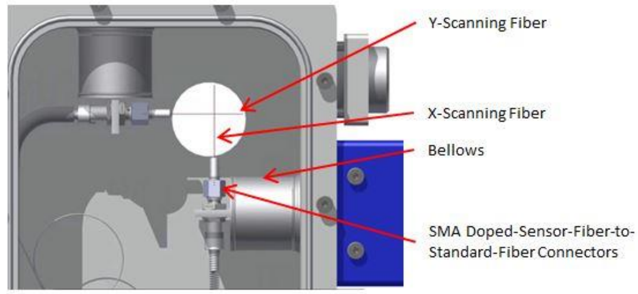

Figure 2: Internal view of UniBEaM showing the X & Y scintillating sensor fibers and fiber connector

The UniBEaM probe [Figs. 1 & 2] has two sensing fibers; one for X-profiles and one for Y-profiles. The sensor fibers are moved through the beam by stepper motor actuators. The sensor fibers are made from SiO_2 doped with Ce^{+3} ions, and have a diameter of 200µm. Silicon photo multipliers (SiPMs), located in the UniBEaM controller 10's of meters from the probe, measure the scintillation light, and subsequently amplify and digitize the signal. The UniBEaM software controls the scan resolution, and start and stop positions. X and Y beam profiles may be scanned separately or simultaneously. The software also calculates the beam centroid and the integral of the intensity profile.

The UniBEaM25 probe measures nominal 25mm diameter beams, has a 35mm aperture, and is provided with KF40 or CF40 flanges.

TESTING

Signal to Noise Assessment with 1MeV 16O^{+1}

ANU installed UniBEaM on the beam line of a high energy ion implanter. The implanter utilizes an NEC 1.7 MV tandem accelerator able to reach energies up to 10 MeV. The BPM provides the feedback required for the operator to produce a well-focused and aligned beam on the target, and to measure the beam response to beam steering devices.

ANU utilized UniBEaM to measure beam profiles of a $16O^{+1}$, 1 MeV beam at low beam currents to investigate the noise floor of UniBEaM and compare the results with profiles acquired using an NEC BPM 80 helical wire scanner.

UniBEaM plots separate profiles for the orthogonal X and Y scans. The X and Y profiles may be scanned and displayed individually, or in the same plot. The horizontal axis of the UniBEaM plots are in mm. Figure 3 shows a scan of a $16O^{+1}$, 1 MeV, 80pA beam to evaluate the noise floor of UniBEaM for this beam.

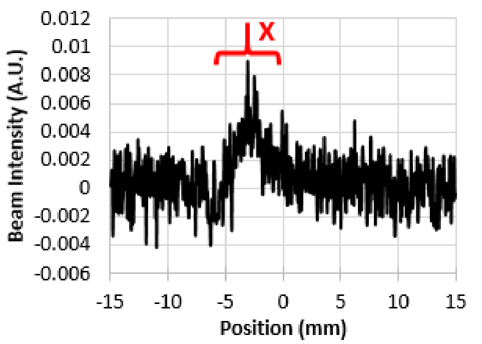

Figure 3: UniBEaM X profile, 16O^{+1} 1 MeV 80pA

The NEC helical wire scanner uses a rotating wire helix to collect secondary electrons from the grounded scanning wire. It has a nominal beam pipe diameter 10 cm with a 2.54 cm molybdenum beam entrance aperture. It produces a single plot representing pseudo-orthogonal X & Y profiles in a single oscilloscope trace, along with a second trace to allow the user to calibrate the horizontal axis time units displayed on the scope into approximate distance units [Fig. 4].

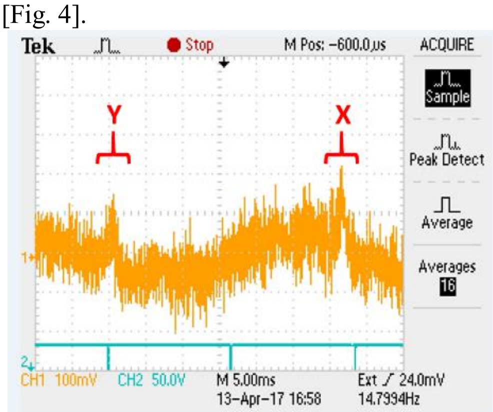

Figure 4: BPM 80 X & Y profiles, 16O^{+1} 1 MeV 80pA

Comparing the two scans shown in Fig. 3 and Fig. 4, the UniBEaM and helical wire scanners have similar signal-to-noise ratios for the 16O^{+1} beam. Figures 5 and 6 show profiles for the same 16O^{+1} 1MeV beam when the beam current was increased to 2.6nA.

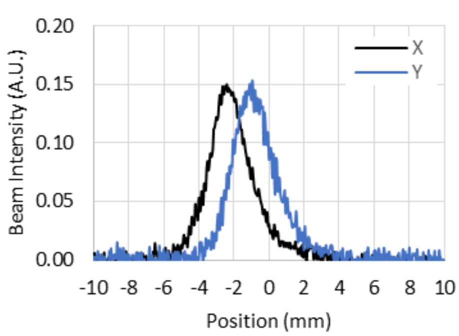

Figure 5: UniBEaM X & Y profiles. 16O^{+1} 1 MeV 2.

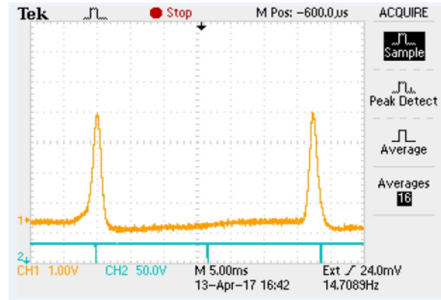

Figure 6: NEC BPM 80 X & Y profiles with 16x averaging. 16O^{+1} 1 MeV 2.6nA beam.

Low Energy Beams

ANU also utilized UniBEaM on low energy beams after the inflection magnet, before injection into their 14UD electrostatic pelletron accelerator. Negative beams of H, Ni, O, Al_2O_3 and S were tested.

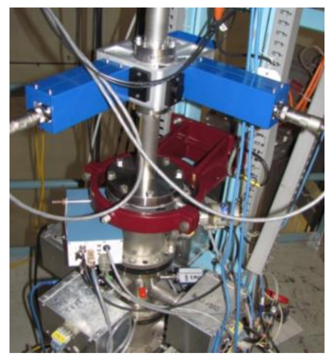

Figure 7: UniBEaM installed at the entrance to pelletron accelerator

Since the UniBEaM system utilizes two separate signal paths for the X & Y channels, gain and offset adjustments are required to account for the different dark currents and gains of the light sensors for each channel, as well as the variability between X & Y channel optical connectors. These adjustments were made to the profiles shown in Figs 5, and 8.

In the nA current range, the UniBEaM exhibited better signal-to-noise and spatial resolution than the NEC BPM 80 (Fig. 8 & 9).

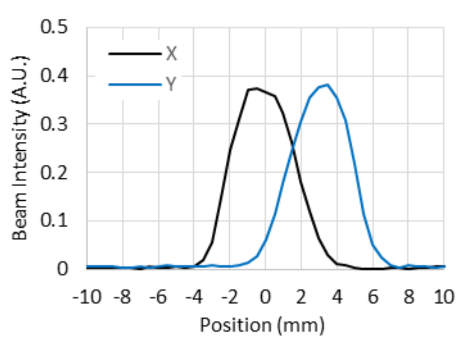

Figure 8: UniBEaM X & Y profiles. 32S^{-1} 150keV 300nA.

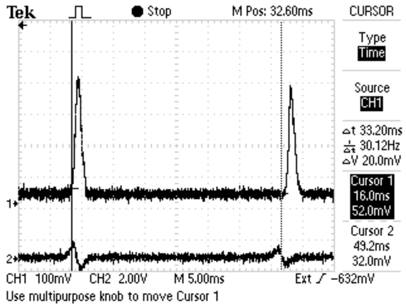

Figure 9: NEC BMP 80 profiles. $32S^{-1}$ 150keV 300nA beam.

Raster Scanning Feedback

The Michigan Ion Beam Laboratory (MIBL) used UniBEaM to profile ion implanter (Ar, Ag, Fe and Ni) beams. Figure 10 shows a UniBEaM scan where 107Ag and 109Ag are resolved in the beam profile.

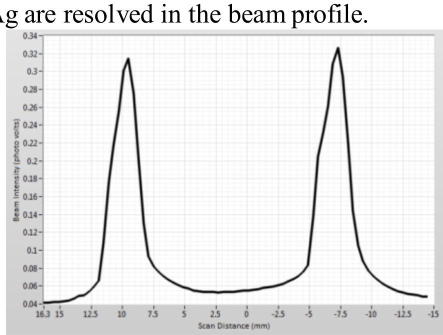

Figure 10: 107Ag and 109Ag, 370keV 3uA. Resolved peaks in Y profile scan of beam.

Figures 11, 12 and 13 show UniBEaM profiles taken for focussed, rastered, and defocussed Argon beams, where UniBEaM was used as a tool to assess beam uniformity for ion implanting.

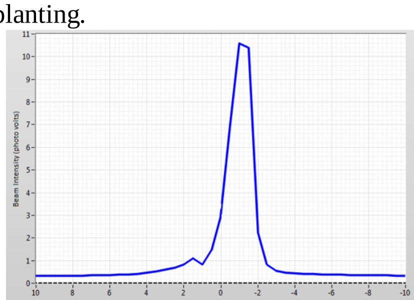

Figure 11: Ar 370keV 3uA, Y profile of focussed beam.

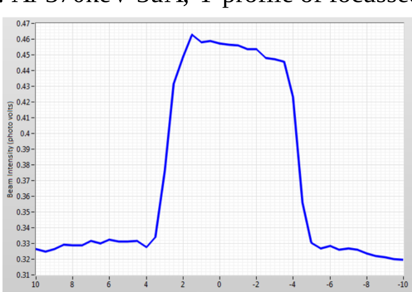

Figure 12: Ar 370keV 3uA, Y profile of rastered beam with 6mm x 6mm aperture.

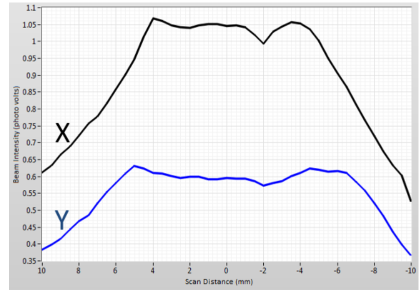

Figure 13: Ar 370keV 3uA, X & Y profiles of rastered beam with no aperture.

FURTHER DEVELOPMENTS

Further investigation will be required to determine if the properties of the sensor fibers change as a result of ion implantation into the sensor fibers themselves, thereby changing their optical or emission properties.

D-Pace will investigate the utility of an optional collimator to limit the exposure of the sensor fibers where beam characteristics allow particles to reach the optical fiber in its parked position.

D-Pace is developing a version of UniBEaM for pulsed beams, where sensor fiber movements and measurements are synchronized with the beam pulses, for pulse rates up to 1000 pulses per minute.

D-Pace is working on a high sensitivity version of UniBEaM where a photon counting approach is used to further improve signal-to-noise for low current beams. The University of Bern utilizes photon counting methods.

CONCLUSION

UniBEaM is an alternative to conventional wire scanners, and offers the particle accelerator industry a compact and cost effective means of measuring charged particle, electron and x-ray beam intensity profiles over a large range of currents and beam energies.

ACKNOWLEDGMENTS

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REFERENCES

[1] M. Auger et al., “A detector based on silica fibers for ion beam monitoring in a wide current range,” *Journal of Instrumentation*, vol. 11, p. 03027, March 2016.

[2] D. Potkins et al., “A Low-Cost Beam Profiler Based On Cerium-Doped Silica Fibers” in *Proc. CAARI 2016*, Fort Worth, Texas, USA, Oct. 2016, un-published.