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LASER PROFILE MEASUREMENTS OF AN H$^-$ BEAM*

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Abstract

A non-intercepting beam profile monitor for H$^-$ beams is being developed at Brookhaven National Lab. An H$^-$ ion has a first ionization potential of 0.75eV. Electrons can be removed from an H$^-$ beam by passing light from a near-infrared laser through it. Experiments have been performed on the BNL linac to measure the transverse profile of a 750keV beam by using a Nd:YAG laser to photoneutralize narrow slices of the beam. The laser beam is scanned across the ion beam neutralizing the portion of the beam struck by the laser. The electrons are removed from the ion beam and the beam current notch is measured.

1. INTRODUCTION

The Spallation Neutron Source (SNS) under construction at Oak Ridge National Lab consists of a 1GeV H$^-$ linear accelerator (linac), a storage ring, target, and connecting beam-transport lines [1]. The linac delivers a 1.04 ms macropulse which is chopped into about 10^3 pulses of 10^{11} protons each. As this pulse enters the storage ring from the linac each chopped pulse lines up longitudinally with all proceeding pulses forming a single 550-ns bunch and a 250-ns gap. After stacking beam in the storage ring for 1000 turns the proton beam is dumped onto a metal target producing a 550 ns pulse of neutrons.

Beam profiles will be measured in the medium energy transport line (MEBT) between the radio frequency quadrupole (rfq) and the linac entrance, along the linac, and in the linac-ring transport line. Stepped carbon-wire scanners will be the primary profile diagnostic. However beam heating will limit wire scanners to tuning and matching applications with either the beam pulses shortened or the current reduced. There are also concerns about placing wires near the superconducting cavities where wire failure can cause cavity damage.

We are developing a laser beam profile monitor (LPM) which is non-invasive and suitable for continuous profile monitoring. The technique selects a transverse slice of an H$^-$ beam by photoneutralization by a laser beam [2,3]. An H$^-$ ion has a first ionization potential of 0.75eV and can be neutralized by interacting with a photon with wavelength<1500 nm, fig.1. The 1064-nm light from a Nd:YAG laser is very near the peak of the cross section.

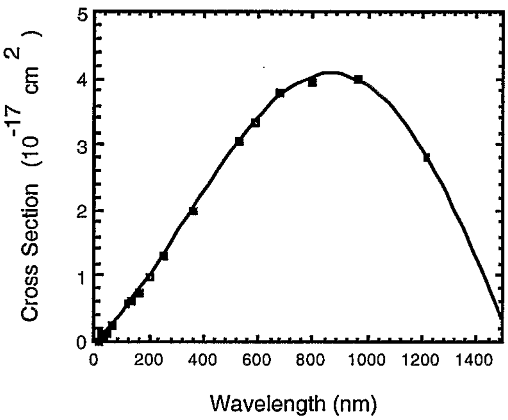

Figure 1: Calculated cross section for H$^-$ photoneutralization as a function of photon wavelength. Data are from a table in ref. [4].

2. LINAC EXPERIMENT

Figure 2 shows the experiment on the BNL linac. A light pulse from a Q-switched Nd:YAG passes through the 750 keV H- beam from the linac rfq neutralizing the portion of the beam the light passes through. A downstream current transformer measures a dip in the beam current which is proportional to the fraction of the beam hit with the light, fig. 3. The laser beam is stepped across the ion beam and the profile is constructed by plotting the depth of the current notch vs. laser beam position.

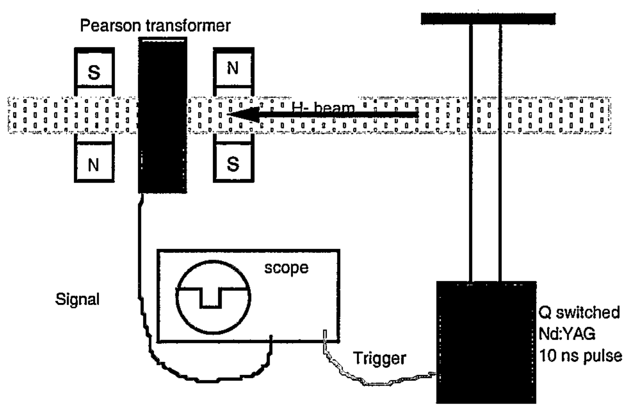

Figure 2: Laser scanner experiment on BNL linac. The first of two 10 Gm dipole magnets removes the free electrons from the beam and the second straightens the beam.

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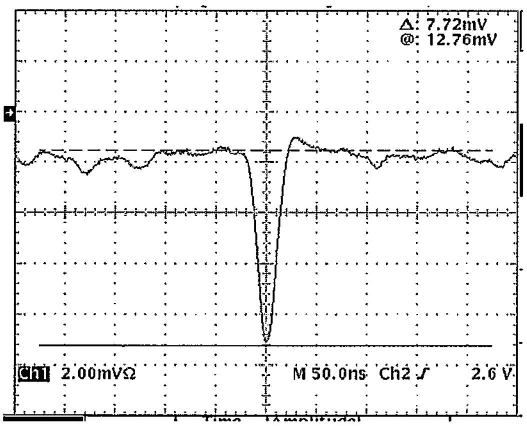

Figure 3: Scope trace of the current transformer signal showing notch created by the laser pulse.

The arrangement of the laser and optics on the linac beamline is shown in fig. 4. A CFR200 laser from Big Sky Laser [5] is mounted on a shelf at the top left. Three 45° mirrors are mounted inside the vacuum on linear motion feedthroughs. The top-left mirror is used to switch between vertical and horizontal scans and the other two do the scanning. The top-right mirror scans horizontally and the bottom-left mirror scans vertically. Both scanning mirrors are shown with arms to hold lenses. In this experiment the lenses were not installed.

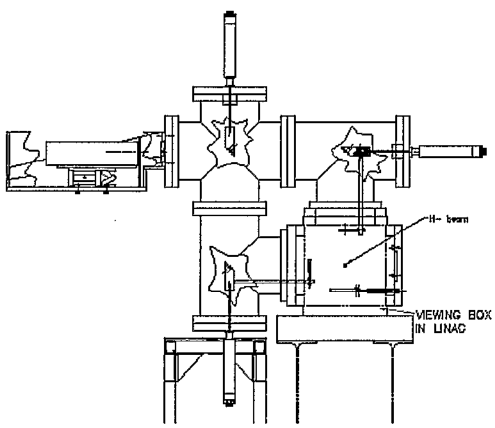

Figure 4: Laser scanning assembly installed on linac beamline. View is looking up beamline.

The CFR200 puts out 200 mJ pulses that are about 10 ns long. Without lenses the beam diameter is about 0.6 cm giving a photon flux of 3.5 x $10^{26}/cm^2s$. The neutralization fraction f_{neut} is calculated from,

$$f_{neut} = 1 - e^{-\sigma(E)Ft} \tag{1}$$

where $\sigma(E)$=3.7 x $10^{-17}cm^2$ is the cross section from fig. 1, F is the photon flux and t is the flight time of the ion beam through the laser beam. The flight time of 750keV ions through the 0.6cm diameter beam is 420ps. Using these numbers we calculate that over 99% of the ions passing through the center of the laser beam were neutralized.

When an ion is neutralized the free electron continues to move along with the beam. These electrons have to be removed from the beam to measure a current drop. In an accelerator installation this is accomplished by either rf cavities or quadrupoles but in the experiment the current transformer had to be placed in the same vacuum chamber as the laser optics. For this reason we placed two weak permanent-magnet dipoles on either side of the transformer. The pole tips are 2.5cm square and 5cm apart and the field is about 400 G. The first magnet deflects the electrons from the beam and the second one straightens out the beam.

3. MEASURED PROFILES

Figure 5 shows the measured horizontal and vertical profiles. In each plot the measured points are indicated by markers and the curve is a gaussian fit to the data.

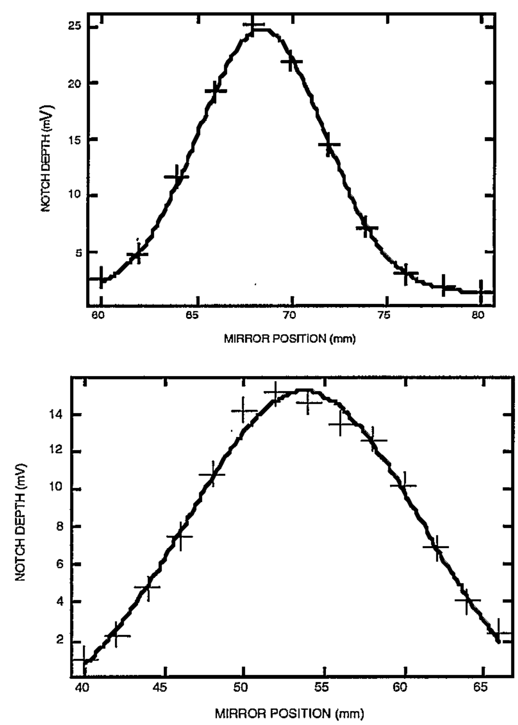

Figure 5: Measured horizontal (top) and vertical beam profiles.

The rms widths of the two fitted curves are σ_x=3.32±0.05 mm and σ_y=7.3±0.6 mm. These values agree with expectations from previous measurements at this location, however for this experiment there was no profile measurement by another method.

These data were taken by moving the mirrors manually and measuring the notch depth on an oscilloscope set to average 15 shots. We measured a maximum notch depth of about 40% on the horizontal scan. If the laser beam power was uniformly distributed over the spot the maximum notch depth should have been closer to 60%. Based on this we conclude the laser power is not uniform over the spot.

4. DISCUSSION

Beam profiles of an H- beam can be measured by laser photodetachment followed by current measurement. To automate the data collection we are going to use a gated boxcar integrator triggered by the Q-switch timing output of the laser. The output of the integrator will be digitized and averaged over several laser bursts to accommodate shot-to-shot variations in the laser power output and the ion beam current.

A compact laser scanning station, fig. 6, is being built for measuring profiles in the SNS medium energy transport line between the rfq and the linac entrance. This will use a 50mJ/pulse laser and all of the optical components will be mounted on a 35x20 cm plate. The plate will attach to tapped holes on the viewports of the wire-scanner chamber.

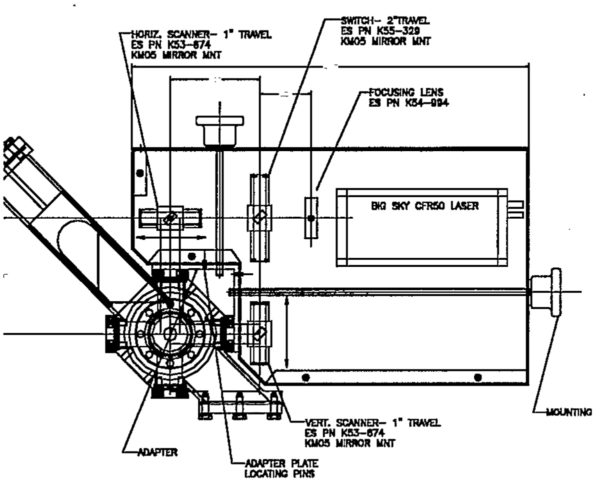

Figure 6: Laser profile scanner plate that will be tested on the SNS beamline between the rfq and linac entrance. It is shown mounted to the wire-scanner chamber.

ACKNOWLEDGEMENTS

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