

IMPLEMENTATION AND DESIGN OF A LASER NEUTRALIZER IN THE LANSCE LEBT

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Abstract

We present the design and installation of a laser wire scanner for H⁻ bunches at the Los Alamos Neutron Science Center (LANSCE) in the low energy beam transport section of the LANSCE beam line. The presented design is modular and supports a variety of input laser options, including diameters, powers and wavelengths. A custom-built laser interaction point, and drift chamber were added to the current beam line to photo-ionize the H⁻ secondary electrons and collect the freed electrons in a custom-built, high-speed Faraday cup detector. Our chamber design is modular and constructed to minimally impact LANSCE production, while also allowing for in-run cycle reconfigurations. This setup will allow testing of a variety of laser system diagnostics configurations at the LANSCE facility.

INTRODUCTION

The LANSCE facility uses a combination of invasive and non-invasive diagnostics to characterize the beam position. While the invasive wire and slit scanners and emittance measurement devices can supply highly accurate data, they cannot be operated during full beam operations. Wire- and slit-scanners for particle beams generate too much radiation spill to be used during production mode in the LANSCE accelerator. The remaining non-invasive diagnostics such as inductive beam position monitors, current monitors, and beam loss monitors cannot provide transverse beam profile or emittance data. We are examining the feasibility of implementing laser wire scanners to mitigate this challenge.

DESIGN

Customized rotating mirror mounts, and COTS optical hardware elements, based on 2" lens tube compatible elements are assembled to provide an enclosed laser transport path to the interaction point (IP) along two orthogonal scanning directions with position monitoring, as illustrated in Fig. 1. The laser wire scanner is built around a standard 6-way cross with 2.75" CF flanges. Thorlabs DDR25 rotating mirror mounts with 60 μ rad rotation repeatability were implemented to control the laser scan angle. The path selection mirror is located at the bottom right corner, as shown in Fig. 1, and is a 45° mounted metallic elliptical mirror (Thorlabs PFE10-G01). Front surface coated, high damage threshold, dual wavelength (532 nm and 1064 nm) prisms (Thorlabs MRA25-K13) are mounted with the front surface centered on the mount rotation center with custom

3D printed mounts (Formlabs Form 4, Tough 2000 resin). Position monitors (Thorlabs S440C/S442C) are mounted before/after the interaction point to calibrate scan motion. Beams are terminated into Thorlabs LB2 beam blocks. Mechanical alignment irises are used at the front and back of the cross ports for initial beam centering, and alignment.

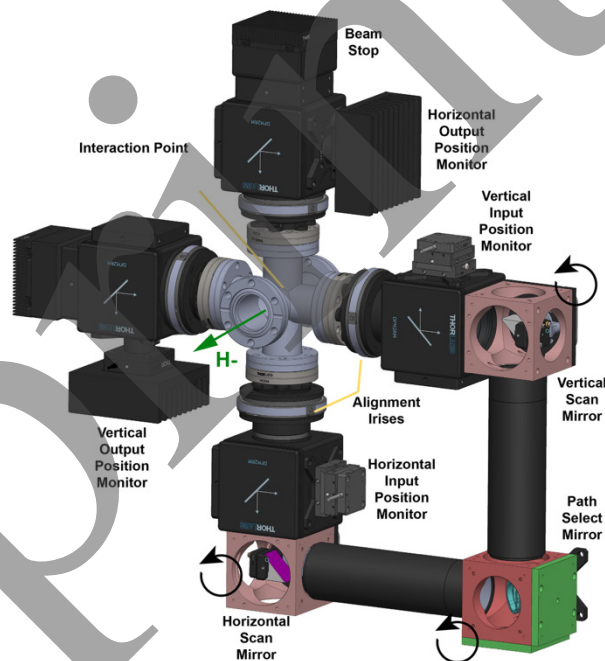


Figure 1: Implemented dual path selector and beam scanner. Rotating mirror mounts at the cube corners allow for the scanning and path selection of the laser beam. Beam sampling positions and motion monitors, and H⁻ bunch flight path is indicated.

EXPERIMENTAL SETUP

LANSCE LEBT Layout

Shown in Fig. 2, the LANSCE Low Energy Beam Transport (LEBT) line turns the post Cockcroft-Walton injector 750keV H⁻ beam 81° before combining with the H⁺ beam near the drift tube linear accelerator (DTL) entrance. The new test stand is positioned downstream of both the H⁻ beam chopper and the 81° bending magnet. When the bending magnet is off, the beam bypasses the bend and is sent to the test stand. An original Faraday cup (FC) monitor diagnostic was displaced to the end of the new test line. The beam chopper was turned off for our initial experiments and deflector set to generate a 300 μ s, 2Hz pulse. Instantaneous current is estimated to be on the order of 10 mA.

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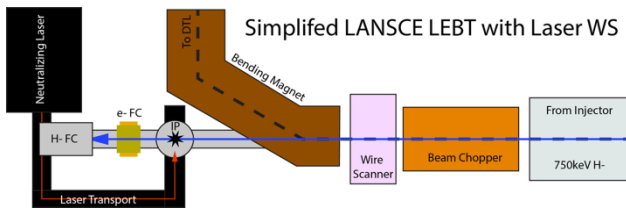


Figure 2: Block diagram of LEBT laser wire test line.

Embedded Class 4 Laser

The LANSCE LEBT is open area which cannot support the free space propagation of high-power laser beams. To use a high energy, pulsed, laser (1064 nm, 180 mJ/pulse, 2 ns) in an uncontrolled area such as the LEBT, we enclosed the laser and aligned a co-propagating class 3R (532 nm 4.5 mW) laser using a harmonic separator/combiner (Thorlabs HBSY12) as shown in Fig. 3. The class 3R laser is used for all alignment and motion calibration procedures. The laser used in this study was the ESL Tempest 20 with the second harmonic module removed, and thus only emitting 1064 nm laser pulses. Due to its large fluence of up to 1.8 J/cm^2 (180 mJ/pulse, 5 mm diameter) care was taken to select optical elements with high damage thresholds. The first two alignment mirrors from the output of the Tempest are V-coated 1064 nm mirrors (Thorlabs NB1-K14). All optics following the harmonic combiner are V-coated for both 1064 nm and 532 nm (Thorlabs NB1-K13) to accommodate both the alignment laser and to allow the option of using a 532 nm laser wire wavelength in future experiments. Only the 1064 nm wavelength was used for laser wire scanning in this initial commissioning study.

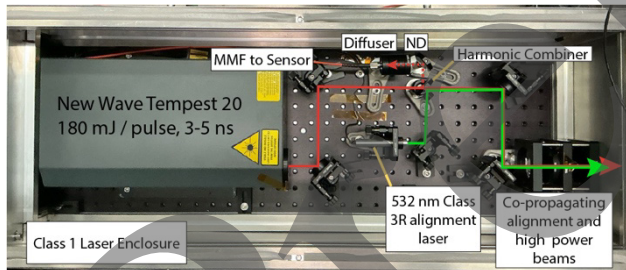


Figure 3: Embedded class 4 laser for use in the uncontrolled LEBT area.

The residual 1064 nm reflection from the harmonic combiner is sent to a ground glass diffuser, with an OD 1 neutral density filter reducing overall intensity. A 400 μm core diameter multi-mode fiber (FT400EMT) collects a fraction the diffused light for external monitoring during experiments. A Thorlabs high bandwidth, 1.2 GHz, photodiode (DET01CFC) is used to monitor the laser pulse shape and relative intensity.

Installed Test Stand

The as-built final setup of the LEBT laser wire diagnostic test stand is shown in Fig. 4. The 81° bending magnet can be seen as the brown box in the background.

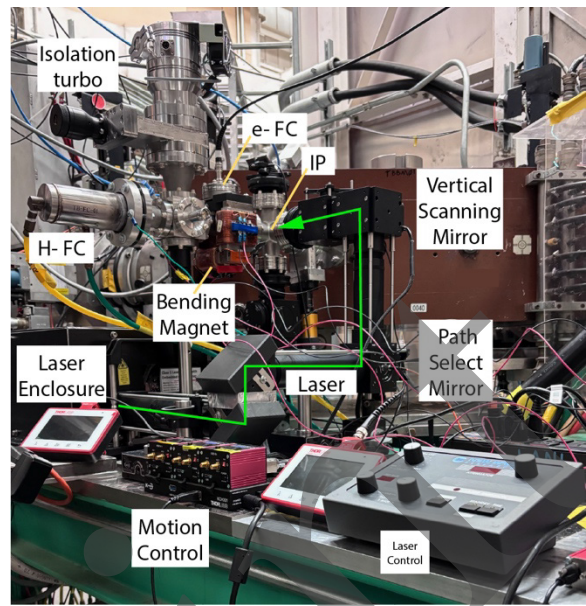


Figure 4: Full layout of the laser wire scanner setup showing installed vacuum chamber laser beam path, motion controllers, laser controller and beam path samplers.

We have highlighted several key elements to the setup including the H- and e- faraday cups, the laser enclosure location and the bending magnet. The basic laser path through the “vertical” scan setup is shown while the “horizontal” laser path is not visible in this image. The isolation turbo pump is used to make the system independent from the LEBT vacuum, enabling reconfigurations of the system using the vacuum valve located between IP and the 81° bending magnet. Laser power control is currently manual using an internal waveplate/polarizer combination.

RESULTS

Detector Design

A copper electrode disk sensor was designed, and a four-coil steering magnet was altered to provide flight path deviation without significant deviation of the H- beam. The H- beam then terminates into a second, inline, Faraday cup, H- FC in Fig. 4. This configuration, and its CAD realization, are shown in Fig. 5, based on a standard 2.75” CF tee.

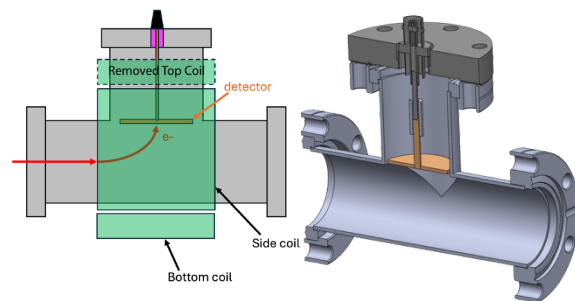


Figure 5: (a) Conceptual design of e- detector with modified steering magnet deflector and a 50 Ω coax feedthrough (IFTMF012033M). (b) CAD rendering of designed and manufactured sensor electrode.

CONCLUSION

We have designed and implemented a laser wire test stand in the LANSCE LEBT. This system has recently been shown to photo-detach the secondary electrons in the LANSCE H⁻ beam. Qualitative inspection of the collected electron detector signal shows a faster, near zero background response, as compared to the loss of H⁻ signal from the legacy H⁻ FC due to reduced current from the photo-conversion of H⁻ to natural hydrogen. Further work on calibration and scanning automation is underway.

ACKNOWLEDGMENTS

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During the detector design phase, an FEA simulation (COMSOL Multiphysics) was used to estimate the sensor bandwidth and to compute local electric potential, V, for applied bias fields. A capacitance for the copper detector and grounded beam tube tee (SS304) system was computed at 1.9 pF. This results in a sensor RC time constant of 145 ps for a 50 Ω load. As shown in Fig. 6, FEA modelling allowed for the computation of the 3D electric field and potential when a bias is applied to the detector electrode. This will be used in future external simulations when computing e⁻ flight paths.

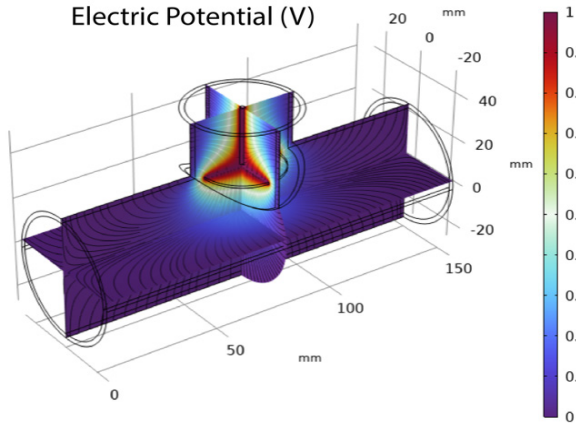


Figure 6: FEA simulation of e⁻ FC detector with a 1kV bias field used to calculate the $C = 1$ pF sensor capacitance.

e⁻ FC and H⁻ FC Signal Response

Initial results, plotted in Fig. 7, show time resolved electron pulses and signal loss in the H⁻ beam at the respective detectors which have close correlation with the monitored laser pulse. The speed response of the designed e⁻ FC is faster than the unaltered original H⁻ FC. The electronic ringing observed in both detectors is evident, but there is much less distortion in the measured e⁻ pulse width. It is interesting to note that there is a correlated signal on the H⁻ FC, indicating the loss of generated current due to neutralization of H⁻ to H⁰. While the H⁻ FC response is broadened, it still represents between 30% and 40% peak signal loss compared to the -300 mV baseline signal.

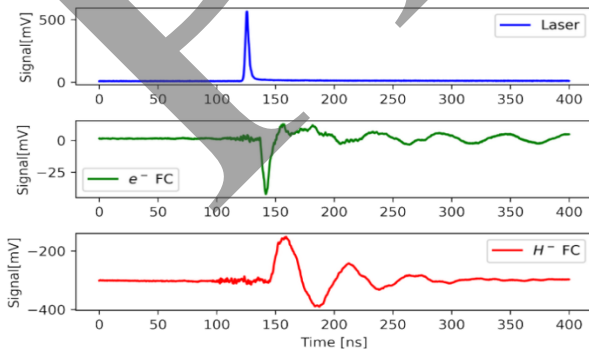


Figure 7: Time resolved incident laser beam pulse (blue), photo-detached electron signal (green), and H⁻ reduced beam signal (red).