LANSCE WIRE SCANNING DIAGNOSTICS DEVICE PROTOTYPE

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Abstract

The Accelerator Operations & Technology Division at Los Alamos National Laboratory operates a linear particle accelerator which utilizes 110 wire scanning diagnostics devices to gain position and intensity information of the proton beam. In the upcoming LANSCE improvements, 51 of these wire scanners are to be replaced with a new design, up-to-date technology and off-the-shelf components. This document outlines the requirements for the mechanical design of the LANSCE wire scanner and presents the recently developed linac wire scanner prototype. Additionally, this document presents the design modifications that have been implemented into the fabrication and assembly of this first linac wire scanner prototype. Also, this document will present the design for the second, third, and fourth wire scanner prototypes being developed. Prototypes 2 and 3 belong to a different section of the particle accelerator and therefore have slightly different design specifications. Prototype 4 is a modification of a previously used wire scanner in our facility. Lastly, the paper concludes with a plan for future work on the wire scanner development.

INTRODUCTION

A wire scanner is a device used to obtain intensity and position information on a particle beam. This device consists of at least two signal wires that are typically made from Silicon Carbide fibers or Tungsten fibers. In our wire scanners, these signal wires are mounted at 90 degrees from each other and 45 degrees from the horizontal plane. With this orientation we are able to mount the wire scanner at 45 degrees and have each wire take an X-projection or Y-Projection of the beam. Figure 1 shows a simple representation of a wire scanner.

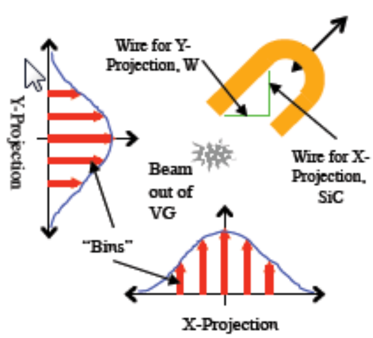

Figure 1: wire scanner basics diagram.

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DESIGN CRITERIA

The first design criterion is that the wire scanner should be constructed with as many commercially available off-the-shelf components as possible. This will facilitate having spare parts that can fit multiple wire scanners. The second criterion is that the wire scanner should be capable of 1mm movements at 4Hz (1mm in 250ms) with a triangular velocity profile as illustrated in Figure 2. Notice that for the area under the curve to be 1mm, the peak velocity must be 8mm/s half way through the motion. This yields an acceleration of 64mm/s² (Note: 1g = 9807mm/s^2). Third, the position of the wires at the end of the "fork" must be known within ±1mm with respect to an external monument. Also, the repeatability of the system must be within ±0.1mm. Fourth, the motor must be powered off while taking a measurement at each bin location. Lastly, the wire scanner should be designed to accommodate as many existing beam structures as possible.

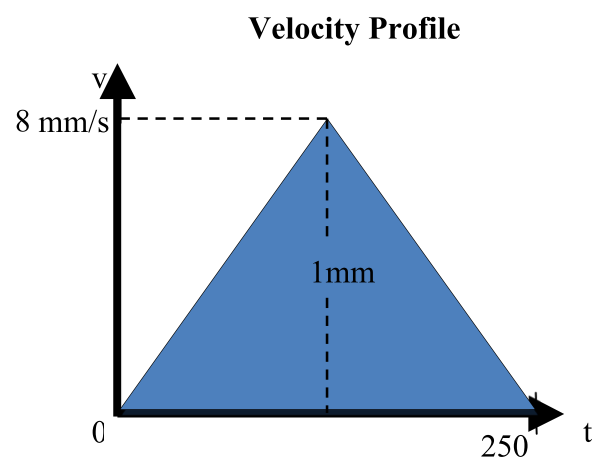

Figure 2: Velocity profile for the wire scanner.

PROTOTYPE 1

The first prototype model is shown in Figure 3.

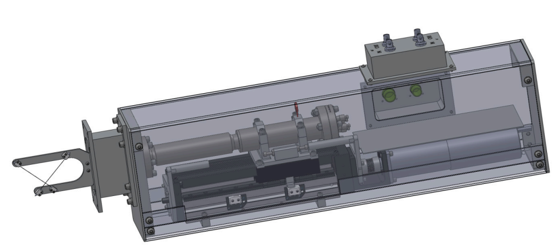

Figure 3: Prototype 1 model.

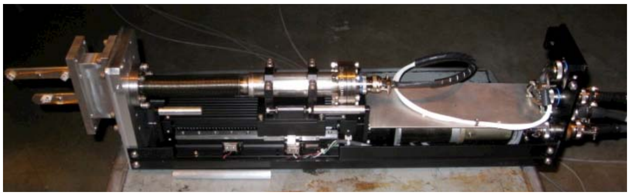

Figure 4: Built Prototype 1.

As can be seen from Figure 4, the built prototype has had some design changes. The most obvious change visible from Figure 4 compared to Figure 3 is that the connectors have all been moved to the back plate from the connector panels on the top and side of the frame. This allows for the top of the plate to be removed without having to disconnect anything. This change removes the use of the connector panels. Other changes seen in this figure but not as obvious are the vacuum feedthrough, the BNC connectors, and the ceramic piece on the fork. The vacuum feedthrough has been changed from a four-SMA double-ended feedthrough to a single MS connector feedthrough. This leads to the change of the four BNC connectors on the top panel to a single MS connector on the back plate. The two bottom ceramic pieces that are seen on the model have been changed to a single ceramic piece that accommodates two signal wires. This was done to space the wires in a way that only one wire will be inside the beam aperture at a time.

When this first prototype was built, one thing that was tested was its repeatability. For this test each limit was tested individually. When testing the in-limit switch the position only varied from a maximum error of -0.025mm. When testing the out-limit switch, the position varied a 0.06mm max. Testing each limit 30 times the results were satisfying since the repeatability requirement calls for ±0.1mm. Figure 5 shows the results of the test.

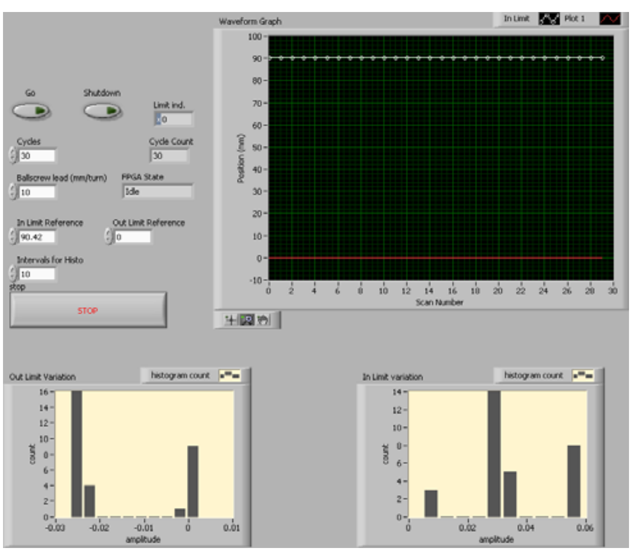

Figure 5: Limit switches repeatability test.

In December 2010 the built prototype 1 was tested with beam to see the quality of signal that could be acquired with this device. Signal was tested both with and without a bias voltage applied to the wires. The results with the bias "off" are shown in Figure 6. The results with the bias "on" are shown in Figure 7.

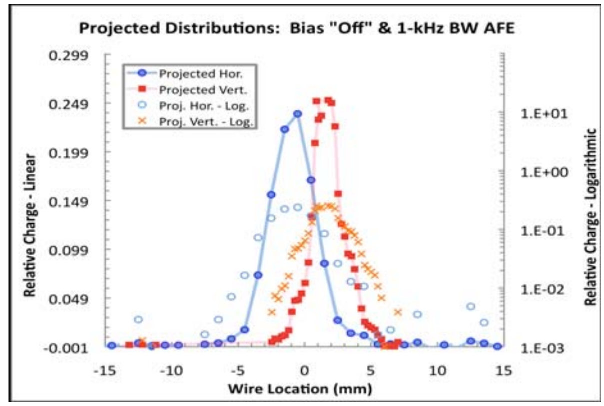

Figure 6: Projected Distributions with bias "off".

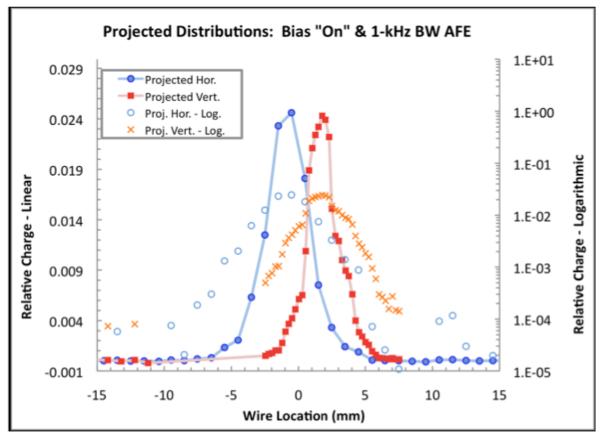

Figure 7: Projected Distributions with bias "on".

PROTOTYPE 2 & 3

The second and third prototypes are of a similar design to the first prototype. The main difference between these two and the first prototype are the amount of stroke each requires. The first prototype is designed for about 3.5 inches of stroke while prototypes 2 & 3 are designed for strokes of about 12 inches. The large difference of stroke is due to the large difference in diameter of the beam aperture each actuator has to clear. Figures 8 and 9 show models of prototypes 2 & 3.

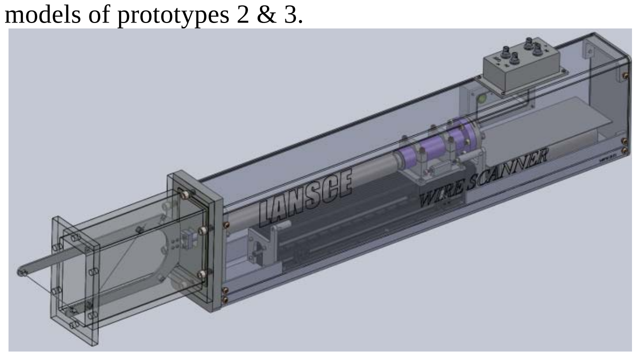

Figure 8: Prototype 2 model.

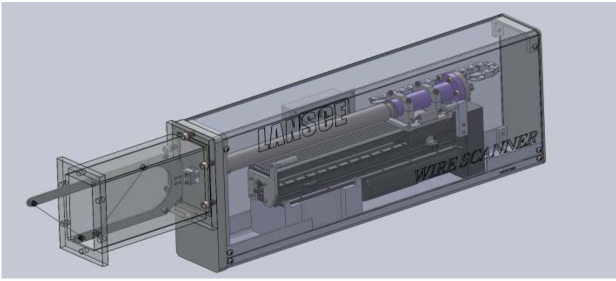

Figure 9: Prototype 3 model.

Although these two actuators are for the same length stroke, they have a significant difference in length. Prototype 2 is a simpler design but its length restricts it from being used in some areas where space is restricted. Prototype 3 was designed to reduce the length of the actuator by mounting the motor parallel to the slide table rather than in-line. These two prototypes were designed in parallel with Prototype 1 and therefore do not have the features that were added and removed from the built prototype. These changes apply to these two prototypes and will be implemented as well.

PROTOTYPE 4

This fourth prototype is being designed mainly to have an alternate design to prototype 1 due to raised concerns regarding the size and weight of prototype 1. This design is shown if Figure 10 and weighs about 10 pounds less than Prototype 1 and although the total length is about the same, this model occupies less volume.

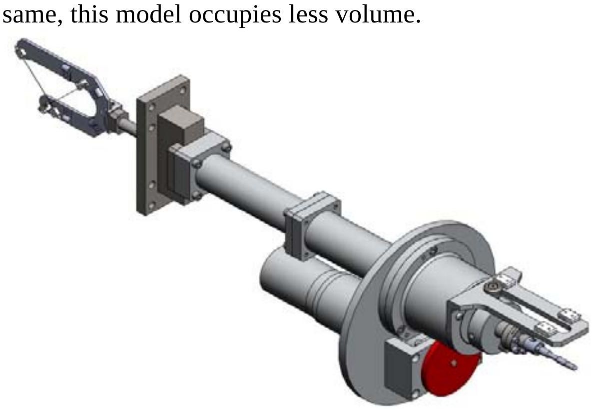

Figure 10: Prototype 4 model.

Prototype 4 is based on the design of our existing MP-11 wire scanners. Like the MP-11, this wire scanner consists of a custom hollow screw driven by a spinning nut which is driven by a motor linked with gears. Figure 11 shows a picture of an existing MP-11 wire scanner.

Figure 11: MP-11 wire scanner.

The main differences between prototype 4 and the MP-11 Wire scanner are that prototype 4 uses a ball screw rather than a lead screw and prototype 4 will have all components fully enclosed. Additional changes include the use of non-crossing signal wires, a flanged vacuum feedthrough, and the implementation of a resolver as opposed to the potentiometer used on the MP-11 model.

PROTOTYPE 1 VS PROTOTYPE 4

Since both prototype 1 & 4 are designed for the same application, in order to down-select to which model will eventually be replacing the existing wire scanner, a comparison must be made. Table 1 compares both designs vs. desirable attributes.

Table 1: Prototype Comparison

	Prototype 1	Prototype 4
Total Weight		X
Total Size		X
Off-the-shelf components	X	
Stability	X	

The stability of each prototype has been based on Finite Element Analysis done to each of the models since prototype 4 has not been built and cannot be physically measure yet. The results of the stability study indicate that both prototypes are within the allowable specifications but prototype 1 is slightly better. There are other attributes that should still be compared such as repeatability of desired positions and these can only be compared once prototype 4 is built. Additionally, we are currently in the process of discussing how much load can be safely applied to the beam structures, i.e. how much weight is acceptable for each actuator.

CONCLUSION

It may seem that there are too many designs presented in this paper but in reality there are only 2 ½. The two main ones are the prototype 1 design and the MP-11-like design. The ½ design refers to prototype 3 since it is almost the same as prototype 2 which is based on prototype 1. These three prototypes utilize a linear slide table driven by a ball screw and motor. Prototype 4 is one that really needs to be developed and thoroughly compared with prototype 1. This comparison combined with a well defined allowable load or stress limit on the beam structures will help in the final decision between these two models. Consequently this down select will influence the design selected for areas where larger strokes are required. At this point this has been our main concentration; to finalize the design of the fourth prototype, and to move forward with the testing and down select.