DRIFT COMPENSATION FOR THE SNS LASERWIRE *

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Abstract

The Spallation Neutron Source (SNS) uses a laserwire to measure the transverse profiles in the Super Conduction Linac (SCL). The laser is located in a service building downstream from the SCL. Mirrors direct the laser light to a specific location to interact with the ion beam. Because of the long travel length of the light, up to 200 meters, minor mirror movements become large enough at the downstream station that the drift over time must be corrected. In this paper we describe how we correct for the drift and present our results.

INTRODUCTION

A laserwire is used to obtain transverse profiles in the superconducting linac (SCL). The main advantages of the laserwire over a regular wirescanner are that it has no moving parts inside the beam pipe, it doesn't use a physical wire that could contaminate the superconducting surface, and it can operate at full operational H^- beam power.

The Q-switched laser, located in an electronics building, emits a beam, which is directed by mirrors through the transport line pipes. The light can be sent to the end of the transport line into an optical dump or it can be intercepted by inserting a mirror to direct the light to one of nine laserwire stations placed along the SCL where it will strip electrons from the H^- beam. The freed electrons bend through a magnetic field and are captured in a Faraday cup to provide a signal representative of a slice of H^- beam. Because of the long length of the laser light path, small perturbations in the upstream mirrors can cause significant movement downstream. These laser light movements are documented in [1]. The horizontal drift repeated every day but the vertical drift also included a longer-term drift over many days.

The optics of the laserwire stations are such that even if the laser light drifts in the transport line, it is still focused onto the same interaction point with the H- beam. However, if the drift is large, then some of the light will miss the mirrors and the reduction in the light at the interaction point will affect the measurement. We therefore have to only correct the larger and slower drifts and can ignore the faster but smaller vibrations. Our goal is to correct low frequency, < 0.1 Hz, drifts to within 5 mm enough to prevent the light from missing a mirror. We also want to maintain the mirror position while powered down to maintain control over the light path during a possible failure of the power or restart of the control system. This requirement excludes position control systems that need power to maintain their position.

The initial version of the drift compensation system was implemented in FPGA with a quad detector as position detector, see [1]. This system assumed a continuous laser so that the position could be sampled at speeds around a 1000 Hz. This performed well in the lab, but the quad detectors were too small for the final laser light beam size in the transport line. Also, the final laser is not a continuous laser, but pulses at 30 Hz, limiting the maximum position acquisition to the same rate. While a parallel, low power laser, could have been installed to provide the continuous position data, it was judged the added complexity to the laserwire system did not justify the added bandwidth to the position feedback system. Therefore we decided to implement a feedback system just for the slow drift.

IMPLEMENTATION

Hardware

Because only the slow drift needs to be corrected, the previously installed video cameras are used as position detectors. These video systems use rad-hard CIDTEC cameras and calculate the center position of the laser light. The video systems update their data at about 6 Hz, fast enough to sample the drift.

For the motion control of the mirrors, we chose the picomotors from New Focus. The picomotors actuators use the piezo effect to step forward or backward and keep their position when powered off. The encoder resolution of the picomotors, about 60nm, in combination with a 3-inch mirror, allows sub-millimeter adjustments to the laser beam position at our farthest location of about 200 meters.

The drift compensation system was first tested on an optical table, see [2]. The operation of the picomotor is such that the step size differs for the forward and reverse directions and also varies from step to step. This variability proved troublesome in our initial tests using an open-loop system, in which the true position of the motor can only be estimated by counting steps. Improvements were seen with a closed-loop picomotor system, which uses an encoder and keeps pulsing the picomotor until the desired position is reached. This simplifies the drift compensation feedback loop as it no longer has to account for inconsistent movement versus pulses. The closed-loop picomotor reaches its position very quickly such that we don't expect any interaction with the compensation feedback loop.

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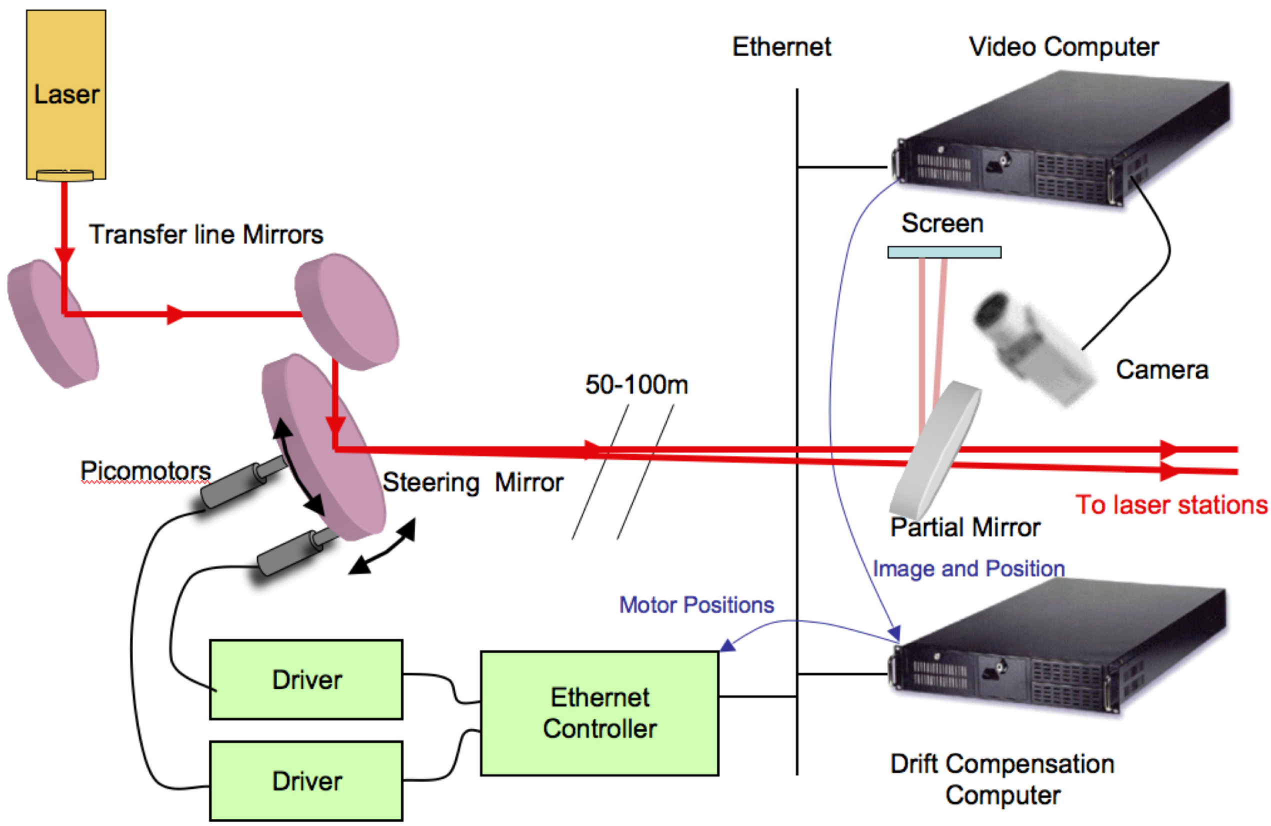

Figure 1. Diagram of the Drift Compensation System.

The installation is shown in Figure 1. Transfer line mirrors guide the laser light from the laser room in the electronics building to the SCL tunnel, where the light is partially reflected onto a screen to be viewed by a camera. One of the transfer line mirrors is equipped with two picomotor actuators—one each for vertical and horizontal adjustments. Not shown are additional mirrors, the laser stations as well as additional locations with cameras. The video computer acquires the image from the CIDTEC cameras and determines the center of the laser beam image. The Drift Compensation computer takes this image, position, and intensity data to calculate the new positions for the picomotor actuators. The commands for position changes are sent to the Ethernet Controller, which controls the closed-loop motor drivers for the picomotors.

Software

The program is based on the standard SNS state-machine template, see [3]. This template includes the Shared Memory IOC to communicate with the EPICS based control system. The Shared Memory IOC links to the scalar position and intensity data from the video camera but doesn't support linking to waveform data. Thus the image data is communicated through LabVIEW's built-in data communication protocol.

The implemented feedback algorithm is as follows:

*Steps = gain * (desired position – measured position)*

To increase the lifetime of the picomotors, the feedback algorithm only actuates the motors when the error exceeds an adjustable threshold value. The feedback is also automatically disabled if there is no laser light in the video image. This is determined by comparing a threshold to the integrated light in the video image.

To recover from a situation where none of the laser light makes it to the video image, the program includes an outward spiral search algorithm and a recover-to-last known-good-setting mode. Lack of laser light in the video image can occur for several reasons. As the laser is turned off between measurements, for example, the mirrors might drift to the extent that when the laser is turned back on the light does not make it through the transport line.

To provide an easy user-interface to control the location of laser light, the main program overlaps the received video image with a red cursor, see figure 2. This red cursor represents the desired position of the laser light. The operator can move this cursor and the mirrors will adjust until the center of the light reaches this position. The current measured position is shown as a green circle, as well are the previous 10 positions. The previous positions fade out as new positions are acquired.

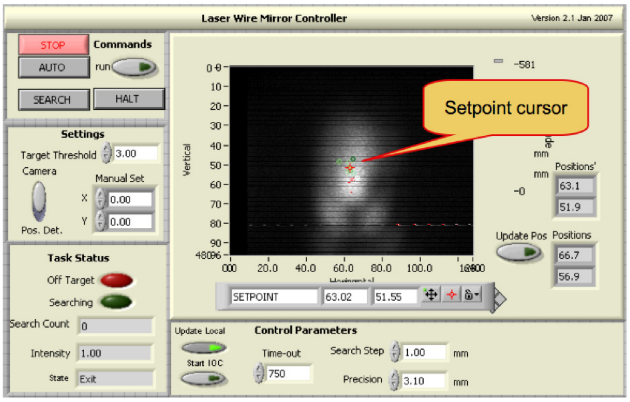

Figure 2. Top of the front panel of the main program.

The program can be linked to different cameras located along the SCL.

OPERATION AND RESULTS

The initial gain value is calculated using the estimated distance from the actuating mirror to the camera, the pixels/mm and the angle per step. We typically lower the calculated gain to increase stability given the vibrations.

An operational example of the feedback loop is shown in Figure 3. The plot shows how the measured position tracks the setpoint for both horizontal and vertical. The amplitude maps to millimeters by multiplying with 2/3. First the feedback is turned off and then the setpoint is changed. Next the feedback loop is turned on and the setpoint is changed multiple times. The plot shows that the feedback loop is capable of reliably controlling the position. In this particular test, the shape of the laser light was not quite round, see figure 2, which contributed to the noise in the vertical position.

We have found that during long laserwire studies, the feedback program does keep the light on the mirrors, when otherwise it would have drifted away. A few times, when the light is near the edge of the image or when the light spot changes shape, the feedback lost the beam spot, but it was recovered using the last known setting.

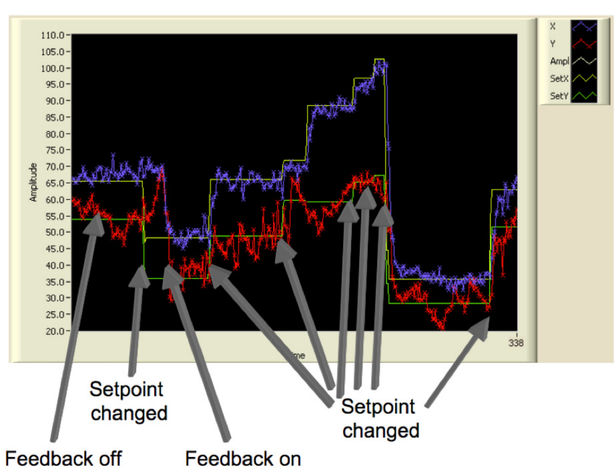

Figure 3. Measured positions and setpoints while adjusting the setpoints.

FUTURE

Various additions will be made to the system to enhance its operation. At the present time, the program must be stopped, the configuration file modified, and the program restarted before another camera can be used. The plan is to be able to switch between cameras on the fly. This will also be useful after maintenance on the laserwire system where the optics were adjusted. After such an adjustment, the laser light typically doesn't make to its most downstream camera. By first applying the program to find the laser light in the most upstream camera and then going to the next downstream, we will speed up the realignment of the laser light to the end of the transport line.

We also plan to more closely study the effect of the drift compensation system on the actual profiles. While we know that we can automatically keep the light on the mirrors, we also want to study whether the actual profiles improve with the feedback turned on versus a scan taken with the feedback turned off but where the light stayed on the mirror.

REFERENCES

[1] W. Blokland et al, "SNS Laser Profile Monitor Progress", EPAC'04, Lucerne, July 2004, p. 2852-.

[2] A. Barker, "Laser Drift Feedback Control for SNS", SULI Student Poster, Summer 2007, ORNL, TN, USA.

[3] W. Blokland et al, "Network Attached Devices at SNS", DIPAC 2003, Mainz, Germany May-5-7, 2003, pp 146-8.