Remote Control of Laser Components

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***Abstract*—This project seeks to create a device by which drift due to temperature fluctuations can be corrected when using an optical table. Discussed herein are the development and testing relevant to the design of a mechanical device and the supporting code. For the purpose of this paper, the design is viewed in the context of a prototype developed at Northern Illinois University for an eventual implementation at Argonne National Laboratory.**

Keywords-Optic table, Laser calibration, Automated Controller

I. Introduction

Thermal expansion is a phenomenon by which materials expand as their temperature is increased. These deformations are generally incredibly small. As an example, the coefficient for linear expansion in aluminum is $25X10^{-6}$ (1/C^0). While these dimensional variances might not have an appreciable effect in most cases, when working at high levels of precision, these variations must be considered.

Argonne National Laboratory is an industry leader in particle acceleration research. To these ends, they employ an optical table to create electron packets for use in their accelerator experimentation. When working at the atomic level, as is required in accelerator research, thermal distortions can provide an appreciable source of inaccuracy.

The device discussed was developed to provide a real-time correction for any thermal distortion encountered due to temperature fluctuations in an experimental setup. It employs two high-precision stepper motors to adjust the trajectory of the laser on both the horizontal and vertical axes. The magnitude and direction of these adjustments are determined by a Raspberry Pi running a code developed as part of this project that uses the input from a high-definition camera to assess what corrections are necessary.

II. Design Methods

The solution proposed here utilizes a mechanical device that is driven autonomously by decisions made by a program developed during the execution of this project. This project contains both a mechanical component and a software element, which are discussed in this section.

A. Electrical Components

This project is designed around the use of a Raspberry Pi 4b, a microcomputer with a Linux based operating system meant to be flexible for multiple uses. *Jupyter notebook* is an open-source software used to execute python scripts [1]. The Jupyter notebook interacts directly with the raspberry pi implementing the logic of the controller via a web service that allows users to write, edit and execute python scripts with the hardware. This service is essential, as it allows users to interact with the controller remotely, as the controller needs to be in proximity to be hardwired into the motors. For Argonne this is crucial as the enclosure housing the optical tables and controller can be hazardous at times.

Additional electrical components include the use of the Thor Labs KDC101 Stepper Motor and Controller. Two of these are necessary to fulfill the mechanical design of this project as two are needed to control the adjustments in the y and x axes. Thor Labs KDC 101 stepper motor can be adjusted for use in python by translating the hex-based codes sent to the motor into python, allowing for “Forced” commands [2].

B. Software

The program receives the position of the laser as an input from a high-definition digital camera. Upon start-up, the position of the laser is noted by the program in terms of an X and Y component. These initial values are viewed, and the controller is designed to use this to make decisions to reach a desired target position. The software will continue to make all efforts to adjust the optical mount to correct the laser to the targeted position. The program continually assesses the value of both the X and Y values to make these corrections.

C. Mechanical

The mechanical portion of the project incorporates two THOR labs stepper motors (P/N Z825B) to manipulate the horizontal and vertical trajectory of the beam. All components were machined from 6061 aluminum unless otherwise noted. This provides consistent thermal properties throughout the mechanism. The lens holder, seen in black, was provided by the Northern Illinois University physics department.

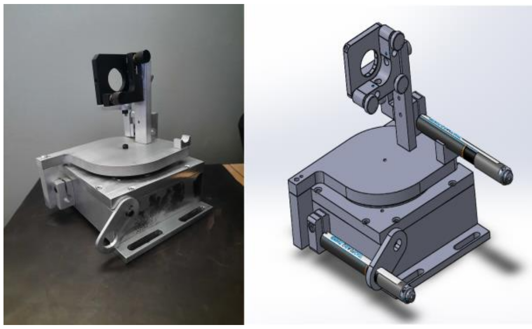

Figure 1: Shown here is the actual device compared to the CAD model. Very few changes were made from the original design to the piece that was produced.

As the horizontal motor extends, the rotational plate spins clockwise, moving the beam to the right. As the motor is retracted, the spring return located in the base keeps the push block tight against the end of the motor, moving the beam left. The rotational plate is located by a 360-alloy brass center pin. It rests on 8 5/16 steel ball bearings that are spaced by a 3D-printed retainer.

Vertical motion is accomplished by control of the stepper motor mounted to the mast. As the stepper motor is spun out, it acts against the vertical push block tilting the lens upward. As the motor is retracted, the spring keeps the push block tight against the motor thus lowering the beam.

III. Results and discussion

This design implemented currently works for any indoors environments and can be assumed to be functional in other indoor settings. The logic behind the corrections made in the software to adjust the Thorlabs motors is geared towards making micro adjustments relative to the change in temperature in an environment that might warp or otherwise change the optical setup in a way that is not intended by lab users. This software can run indefinitely and has the correct housing to ensure that it can run indefinitely save for loss of power. The housing acts as a heat sink and protects the pi from any external environmental factors.

The device employs two THOR Labs stepper motors (P/N Z825B). These units have a resolution of 29 nanometers[1] (3.94e-8 inches) per step. When combined with the lever arm used in the horizontal direction, each step of the motor results in a change of $3.5X10^{-7}$ degrees. For the vertical direction, the resolution is $4.1X10^{-7}$ degrees per step. At a distance of one meter, this translates to a deflection of 6.1 micrometers on the horizontal axis and 7.2 micrometers in the vertical direction.

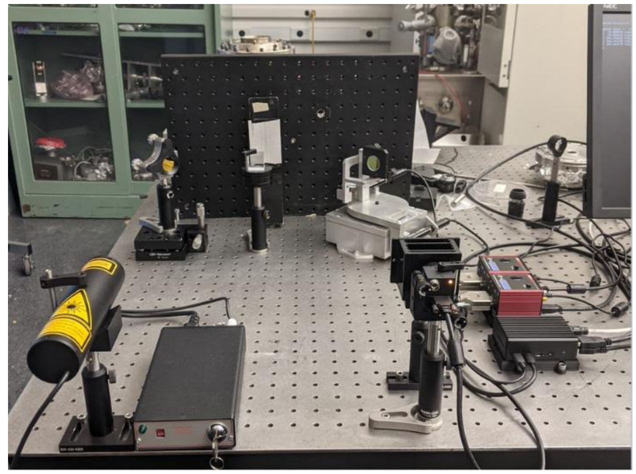

Figure 2. Laser system set up.

IV. Conclusion

Through the course of this project, a program was developed allowing remote access to manipulate the trajectory of a laser system on an optical table. The supporting hardware was also created to allow for this process to occur. A Python script was loaded onto a Raspberry Pi that can manipulate two stepper motors to maintain a laser's trajectory based on input from a camera. The interface with the system happens through Jupyter allowing the device to be controlled from a remote location. Further development on this project could include a more refined mechanism that can accomplish the same high level of resolution with a smaller footprint on the optical table. The implementation of the laser positioning system will allow experiments to be run more efficiently and precisely. Various problems concerning the environmental effects on the position of the laser beam can now be mitigated. In the future the code can be refined to be able to handle more complex parameters.

V. Acknowledgements

The authors would like to thank the NIU Machine shop for their assistance in production of portions of the device. Additional thanks to A.J. Dick for assistance with portions of the code. The authors would also like to thank Dr Stanislav Baturin for his guidance. Thank you to Dr. Piot and Argonne Labs.

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