Autonomous Control of Laser Components

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Abstract

This project seeks to create a device by which error in optical component alignment can be corrected when using an optical table. These adjustments would be made without human intervention as the room that contains the laser is radioactive while in use. Discussed herein are the development and testing relevant to the design of a mechanical device and the supporting code. The purpose of this project is to design a prototype that could be implemented for Argonne National Lab's Wakefield Accelerator, with autonomous controls.

Background

Various lenses, apertures, shutters, and mirrors are used to focus and control the laser beam. All of these opto-mechanical devices are currently adjusted manually. Manual adjustment can be troublesome due to the fact that the laser must be powered down in order to make these adjustments. Vertical and horizontal adjustments need to be made with the utmost accuracy and precision. This device seeks to increase accuracy and reduce down time by performing these operations autonomously.

Results

Using a high resolution camera to track the position of the laser, two stepper motors are employed to keep the laser on target. The camera used has a resolution of one pixel which translates to 0.26mm. Any deflection in the laser captured by the camera is assessed by the code contained on a Raspberry Pi and compensated for by one of the two motors. The step size for the motors used is 29 nanometers, or 2.9e-5mm. When combined with the lever arms of the device, the system is capable of steps on the order of 3.5e-7 degrees.

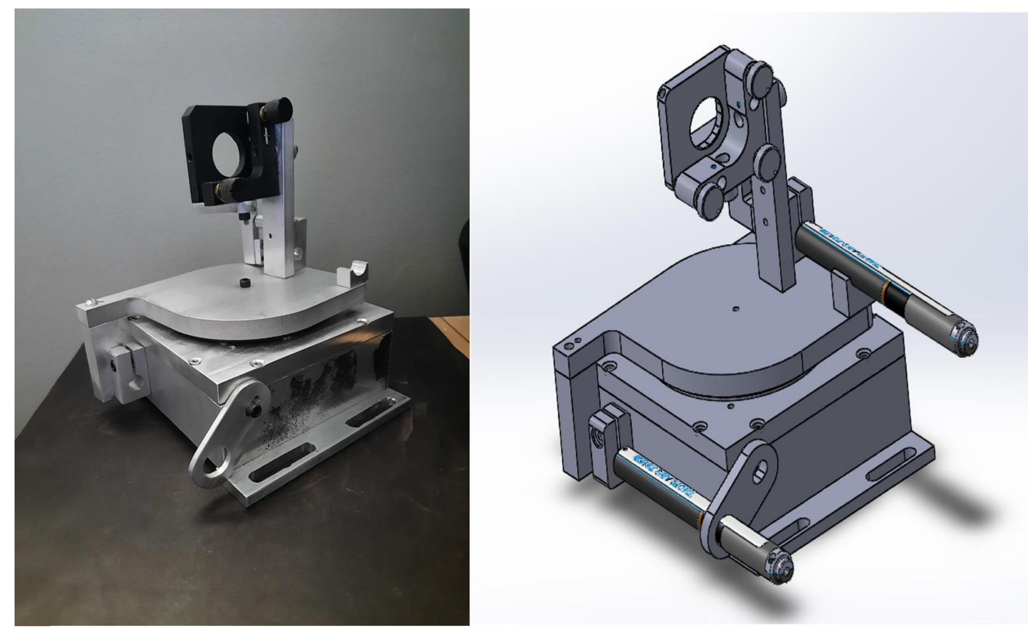

Figure 1: The mechanical device shown next to the CAD model

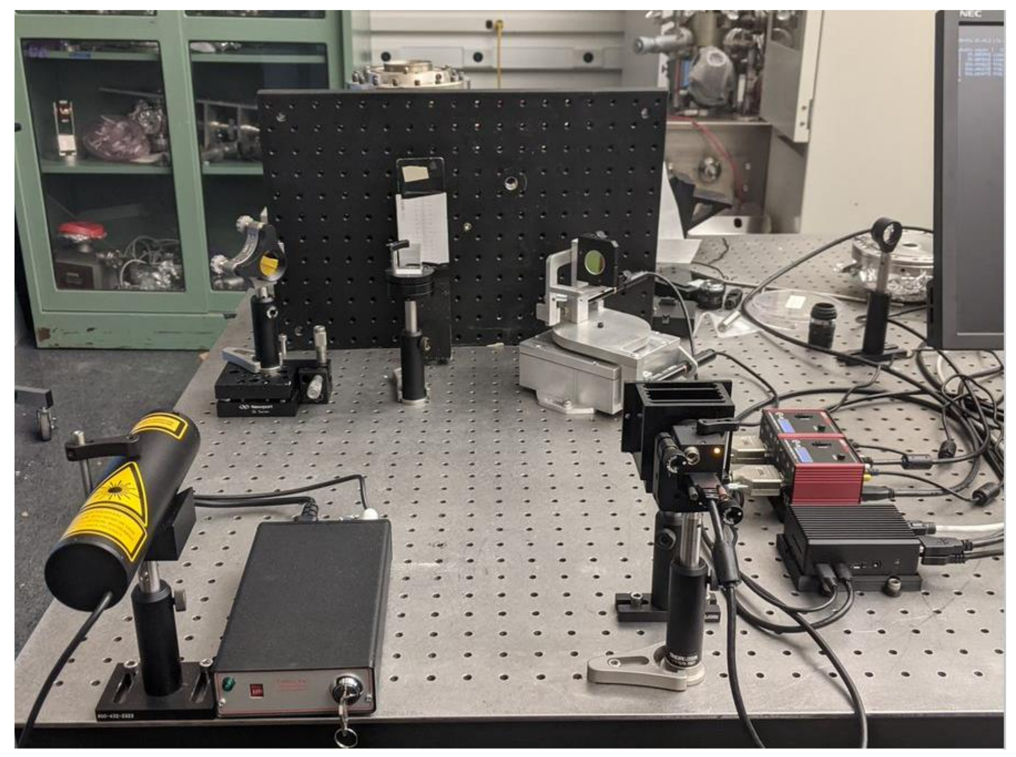

Figure 2: Display of Optical Setup with implemented Autonomous Control System.

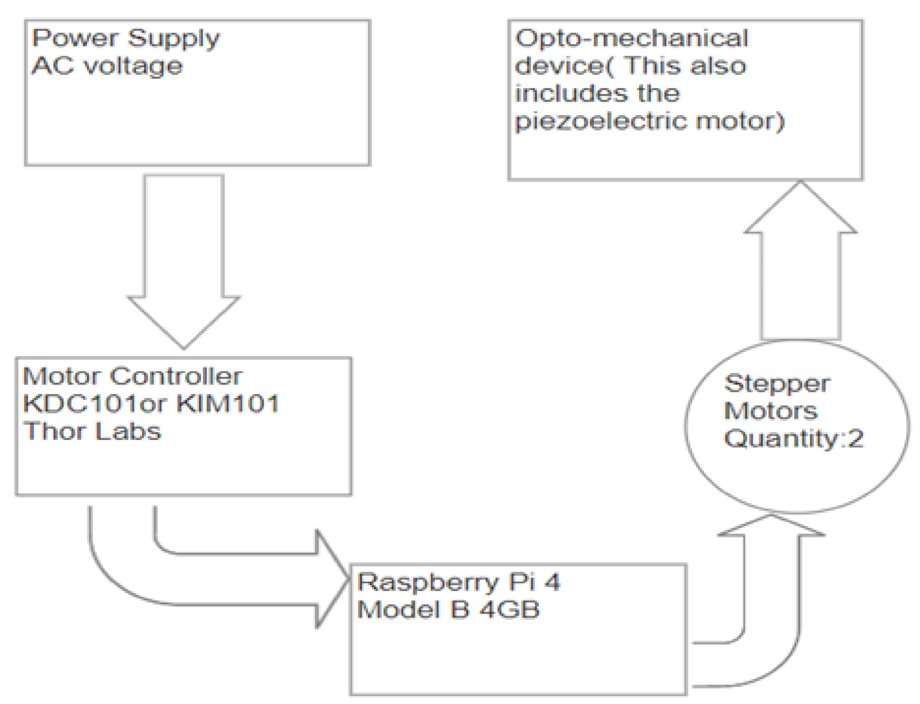

Figure 4:Block diagram of control system.

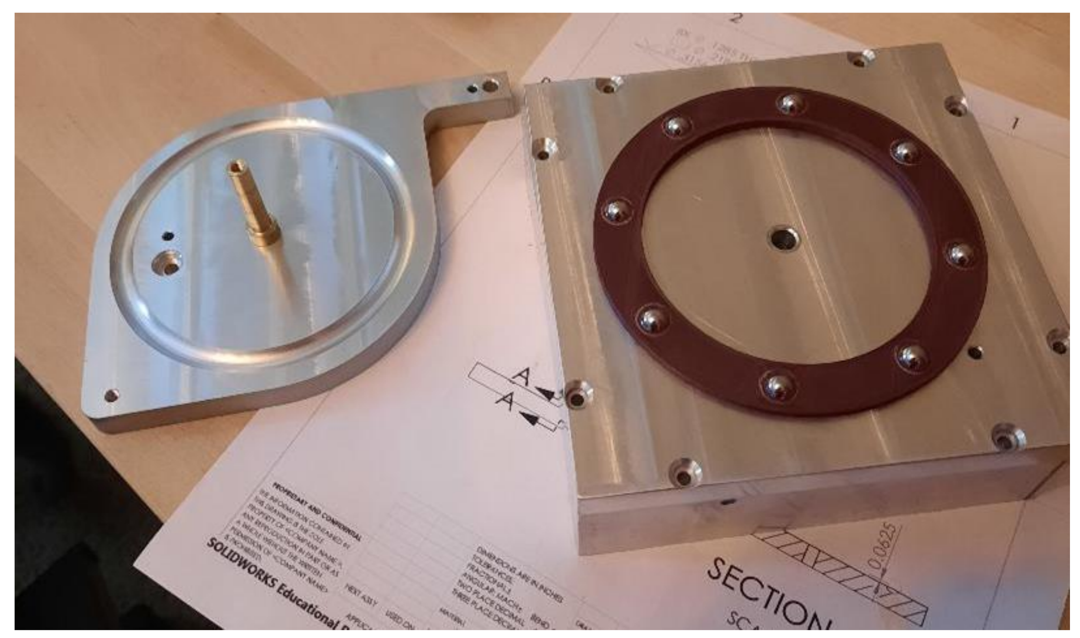

Figure 4: The rotational plate, which is responsible for horizontal adjustment, rides on 5/16 bearings separated by a 3D printed retainer and a brass pin in the center.

```python
# Jog KDC101
# direction - 1/2 = forward/backward
def jog(ctrl, params , direction=1):
    [p,ch,d,s] = params

    jog_dir = 0x02
    if direction == 2:
        jog_dir = 0x01

    ctrl.write(pack('<HBBBB',0x046A,ch,jog_dir,d,s))
    wait_for_move(ctrl,params)


# Absolute Move to pos
# pos - position in mm
def move_to(ctrl, params, pos, timeout = 5):
    [p,ch,d,s] = params

    ctrl.write(pack('<HBBBBHL',0x0450,0x06,0x00,d|0x80,s,ch,int(pos*34303.90665)))

    ctrl.write(pack('<HBBBB',0x0453,ch,0x00,d,s))

    wait_for_move(ctrl,params,timeout)
```

Figure 5: Jog command in Python. Incrementally moves laser back to target.

Objective

The device detailed within is a control system device to operate multiple stepper motors that will able to accurately and safely adjust optical devices for the Argonne Laboratories Wakefield Accelerator.

Methods

Device is fabricated with 6061 aluminum and is capable of adjusting the optical device in the x and y axis. Code is then written to prepare protocols for different scenarios encountered in experimentation and to react to them. Code is implemented using Python in a Jupyter server so that the control system can be controlled and edited from a remote terminal.

Conclusions

As the temperature in the test chamber varies, the components on the optical table distort minutely, with this project these corrections can be made automatically and precisely. With this device the experiment does not need to be shut down and adjusted manually saving lab users time that could be spent on other more important aspects of research.

Acknowledgements

This project would not have been achievable without the help of our excellent professor Dr. Stanislav Baturin, who has guided the team throughout all of our struggles. It would also not be possible without the help of AJ Dick, who created and developed the initial motor controls for the ThorLabs motors and helped the team with coding complications.