

Automation of ALPHA's laser power

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1 Introduction

The main goal of ALPHA (Antihydrogen Laser PHysics Apparatus) is to try to understand the open questions in fundamental physics. To mention some of them, they are related to why does the universe is made of just matter, and where has all the antimatter gone.

ALPHA studies antimatter directly, using antiprotons delivered by CERN and trapping them in a Penning trap. Then, these antiprotons are combined with positrons to form antihydrogen, they can be stable for 60 hours thanks to magnetic fields. After that, the annihilation with the walls occurs, which provides an excellent detection efficiency for spectroscopy studies.

ALPHA is capable of determining the 1S-2S transition of the antihydrogen [1]. To achieve this, a 243 nm laser is overlapped with the antihydrogen atoms. All of this while being in an intra-vacuum cryogenic cavity that increases the laser power and enables two photon transition in a Doppler way. The 243 nm are needed because two photons bridge the energy gap between the 1S and 2S state, so it's important to measure the power automatically after each measurement. The same laser induces an additional ionization that excites the anti-atoms. This laser illuminates the cloud for several minutes because the number of anti-atoms is limited [2].

It is important to monitor the laser power and its spatial mode inside the cavity to determine the transition with the best accuracy. The automation can be done using LabVIEW by programming a device capable of rotating the laser's power measure device. In more detail, I had to design and 3D print a mechanical construction that allows to move a power measurement device in and out of the laser beam.

2 Main Goal

This project aims to measure the power of ALPHA's laser by creating a mechanical construction to insert and remove a power measurement device, which constitutes a Servo, an Arduino Nano and pieces made in a 3D printer. A servo is an electrical device that rotate parts of a machine with high efficiency and with great precision. The servo's shaft movement will be controlled by a LabVIEW code.

3 Method

We need a servo motor that works in a strong magnetic field, such as the solenoid magnet used for trapping antihydrogen. We used an analog servo motor that works in that magnetic field.

The circuit used is very simple, the Arduino Nano is connected to the PC through an USB cable, and the servo cables are connected to the Arduino according to their colors: brown to ground, orange to 5 V and yellow to D9. The LabVIEW code moves the shaft of the servo to the position needed.

The design in 3D to hold the servo was made with Inventor 2020. This software allows you to create 3D forms and converting them to 3D printable pieces. I measured the servo's dimensions to considerate them in the design of the piece, using a vernier.

In figures 1 and 2 I show my sketches and the 3D view of the design I made for the piece that holds the servo in the experiment. The dimensions were specifically made for the analog servo.

Besides Inventor, I used PrusaSlicer to slice the 3D object I have created to make it printable. I had to print three different pieces, modifying and improving the design. The

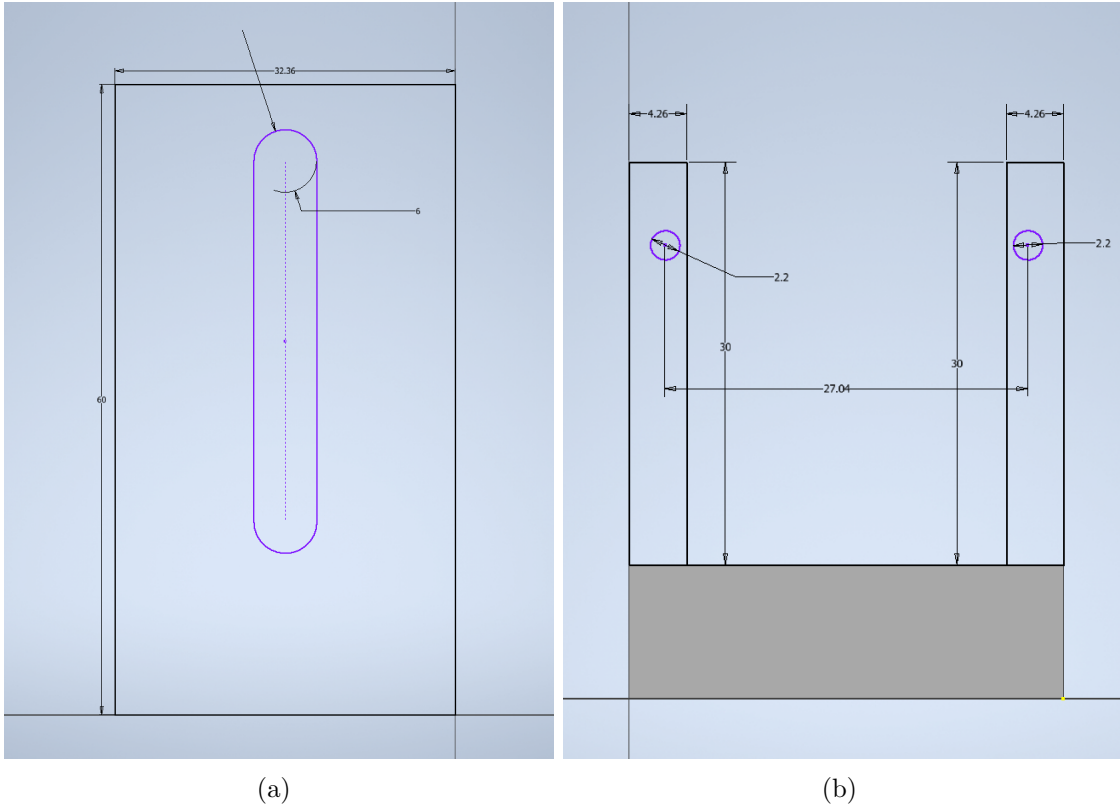


Figure 1: Dimensions and sketches of the piece in Inventor. (a) top view, (b) front view.

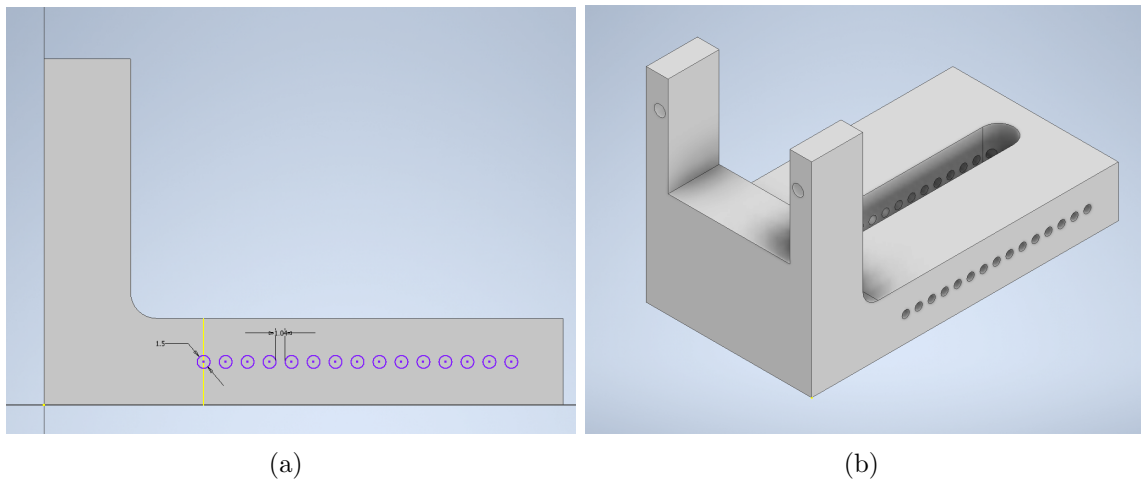
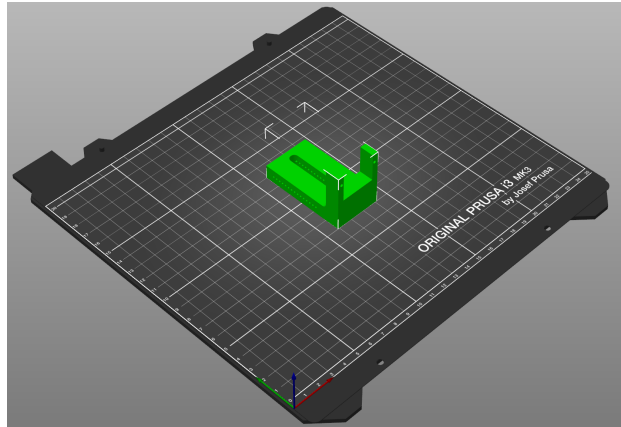
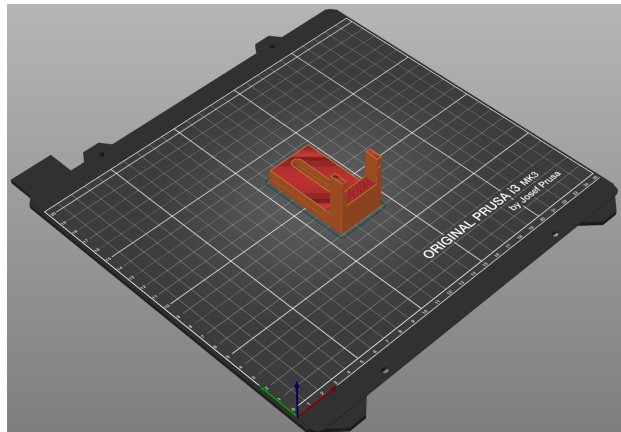


Figure 2: Dimensions and sketches of the piece in Inventor. (a) lateral view, (b) 3D view.

figure 3 shows the piece in PrusaSlicer, the orientation I chose to print, and the sliced piece ready for printing. This sliced piece generates a G code which contain commands to move parts within the printer. The G code basically tells the 3D printer how to move in order to obtain the final piece.



(a)



(b)

Figure 3: (a) Orientation of the piece in PrusaSlicer before slicing, (b) piece sliced before printing.

4 Results

It took me three times printing to have the correct piece, finally the last one is showed in figure 4. This piece holds the servo and the Arduino Nano. The servo's shaft will be connected to the laser power meter to move it in and out of the laser. I also 3D printed a piece that connects the servo's shaft and the power meter.

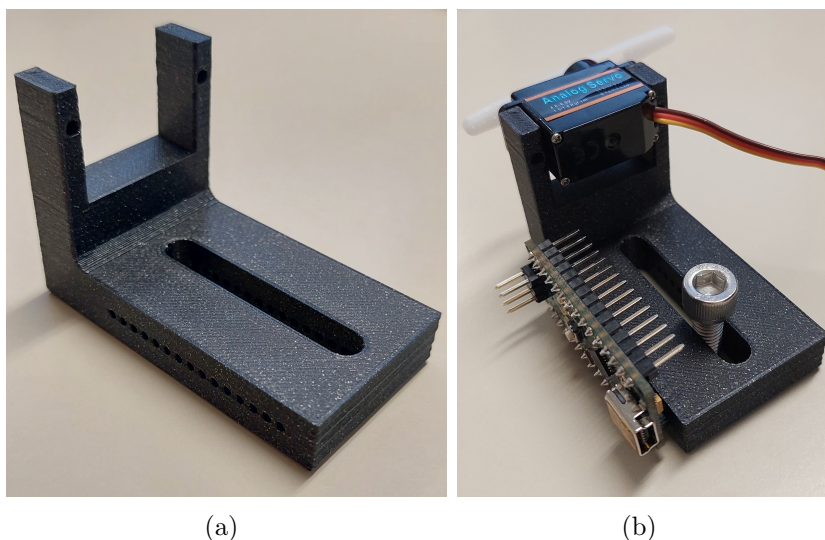


Figure 4: (a) The final piece, (b) the piece with the Arduino Nano and the servo attached.

Table 1: Measurements of the laser's power.

n	P_{ideal} [mW]	P_1 [mW]	P_2 [mW]	P_3 [mW]	P_4 [mW]
1	1.469	1.372	1.359	1.432	1.46
2	1.471	1.36	1.367	1.419	1.451
3	1.467	1.373	1.36	1.422	1.453
4	1.466	1.374	1.361	1.417	1.455
5	1.465	1.371	1.347	1.429	1.462
6	1.47	1.367	1.345	1.425	1.459
7	1.468	1.354	1.357	1.432	1.463

I made the measurements shown in table 1 using a laser of wavelength 532 nm, the piece

holding the servo and another piece that connects the servo's shaft to the power meter. The final setup is shown in fig. 5.

I realized the laser goes in and out of the laser with angles 20° and 0° respectively. But first, I measured the ideal laser power, where I put the power meter totally aligned to the laser, shown as P_{ideal} . The measurements using the 20° degrees of the LabVIEW code are shown as P_1 , P_2 , P_3 , P_4 , and n is the number of measurements made.

In P_1 and P_2 I just moved the servo using LabVIEW and took the measurements. But in P_3 I started adjusting the power meter angle a bit and got better results. In P_4 I adjusted the entire piece and find a better angle for the power meter, and that is why it is the closest one to P_{ideal} .

I plotted all the data in table 1 to compare the results obtained. It shows that P_4 is the measurement that aligns better with P_{ideal} .

5 Conclusions

I designed and create the piece that holds the servo and the Arduino in place. I also used a LabVIEW code to move the servo's shaft and also move the laser's power meter in and out of the laser.

It is recommended to fix the power meter better in the piece I designed, or to design a different piece that makes the power meter's screw correctly fit in.

There are some problems with the connectors and the breadbord used, making the circuit unstable. It is also recommended to improve this circuit and the precision of the servo's movement.

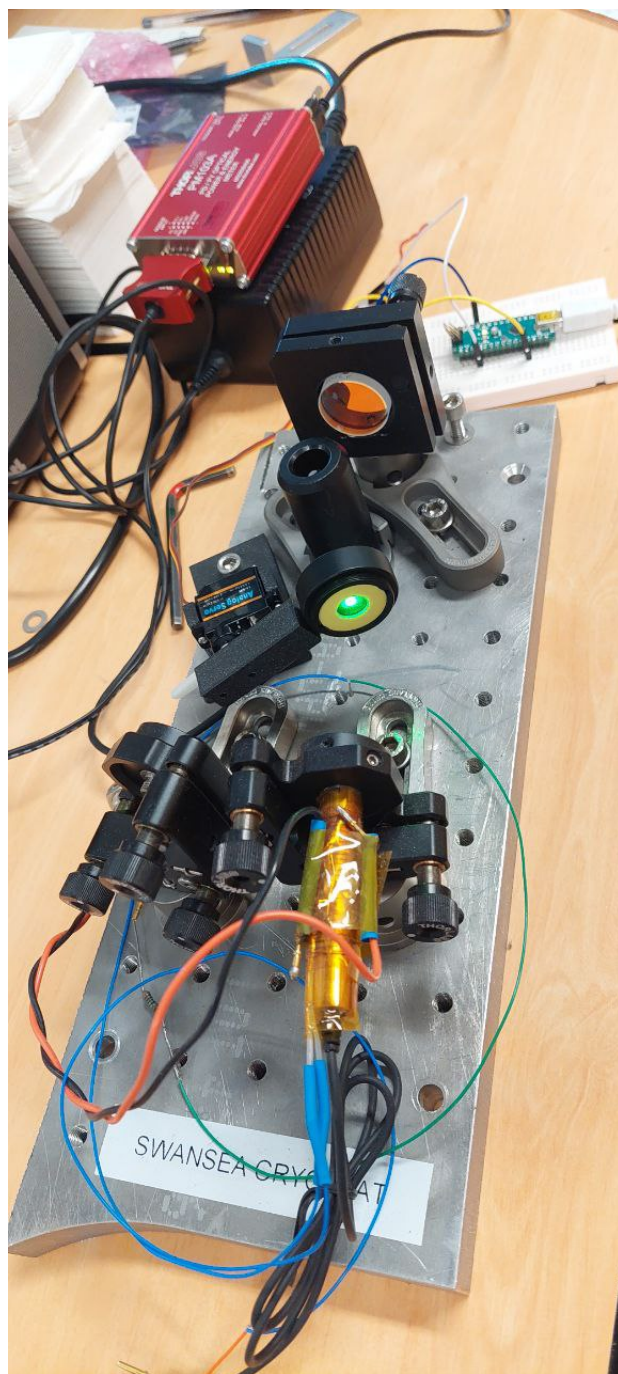


Figure 5: Final setup of the experiment.

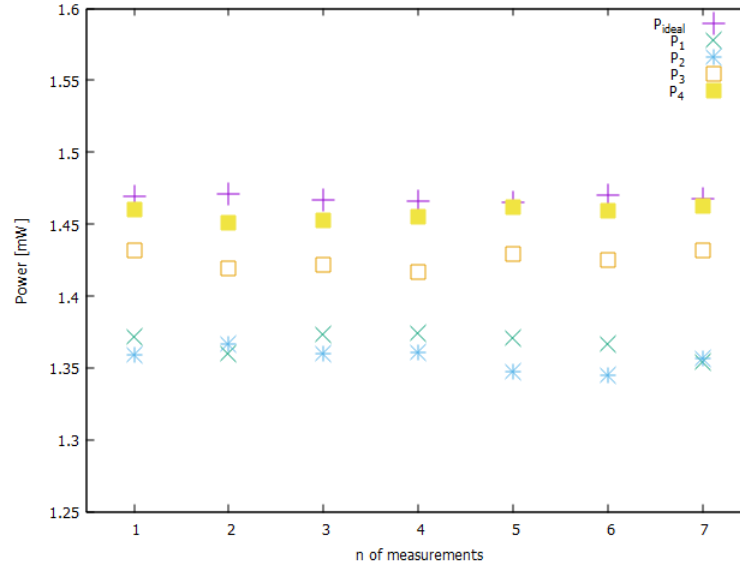


Figure 6: Number of Measurements vs. Laser Power

References

- [1] M Ahmadi et al. “Characterization of the 1S–2S transition in antihydrogen”. In: *Nature* 557.7703 (2018), pp. 71–75.
- [2] CJ Baker et al. “Laser cooling of antihydrogen atoms”. In: *Nature* 592.7852 (2021), pp. 35–42.