ULTRASONIC VIBRATION-ASSISTED LASER CUTTING HEAD

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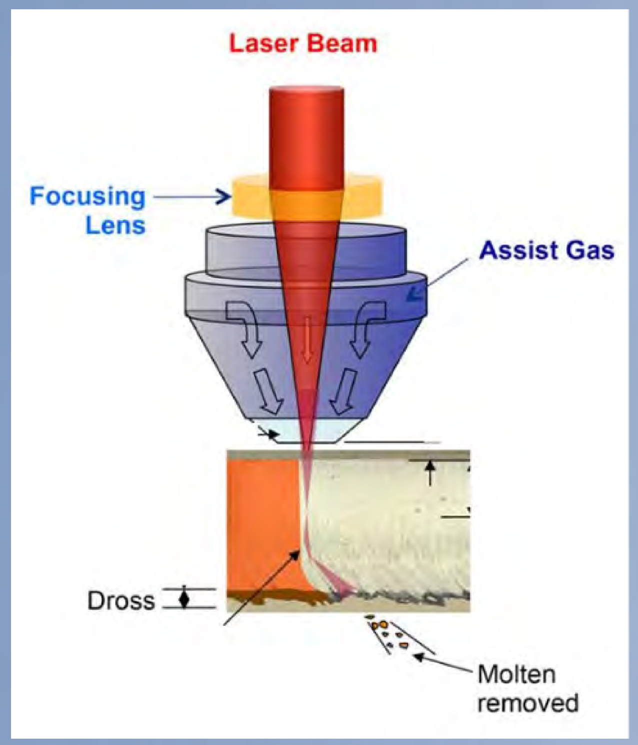
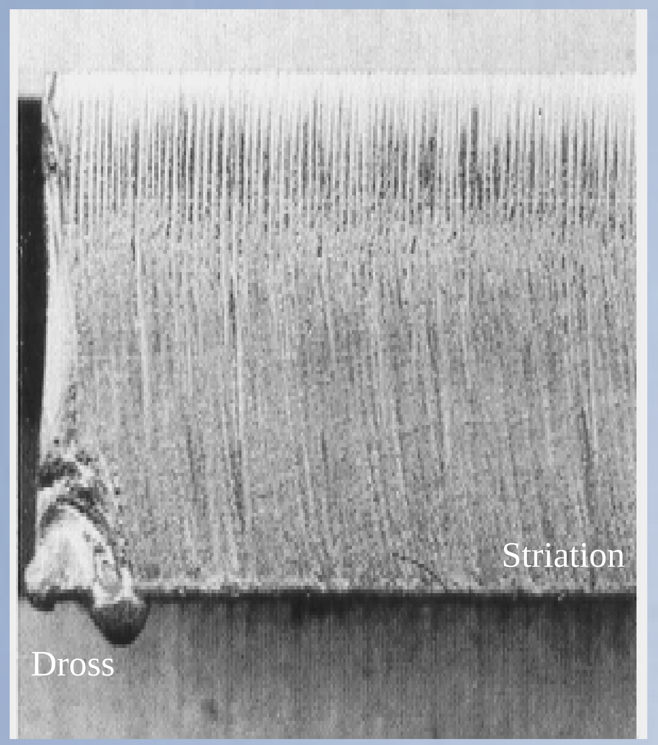
Introduction

In laser cutting, metal is melted by a laser and then removed by an assist gas. Laser cutting suffers from two major quality defects: dross, striation. Dross and striation occur when the molten metal solidifies before being removed by an assist gas. In this project, we designed an ultrasonic vibration system to oscillate the focal point of the laser to help reduce the dross and striation. This will allow the metal to stay molten until it is removed by the assist gas.



General Laser Cutting Process



Workpiece Cut Surface

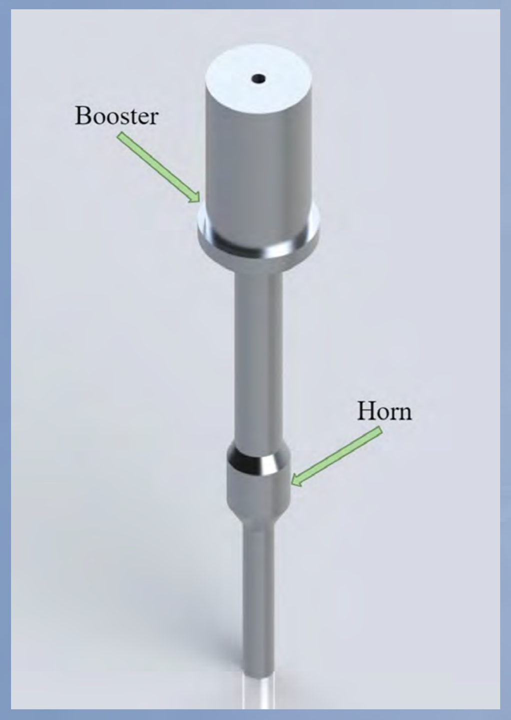
Problem Statement

Design a laser head capable of ultrasonically displacing the laser focusing lens by 50 micrometers.

Design Decisions

Component Needed	Reason
Booster + Horn	Amplify vibration
Horizontal Arms	Position the laser lens in phase of vibration modes
Displacement Testing	Verify magnitude of vibration
Nozzle + Assist Gas	Remove molten material

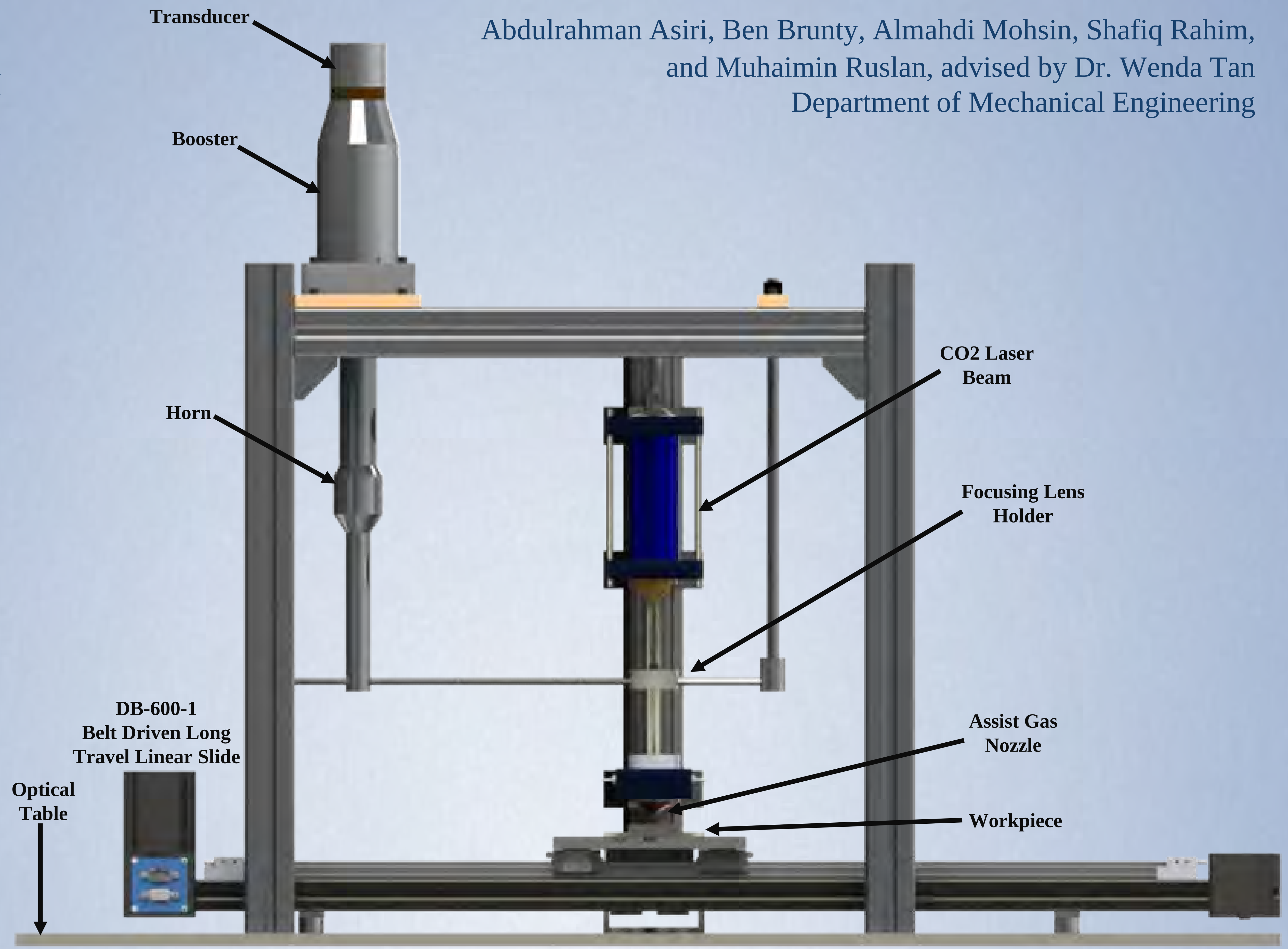
Horn and Booster



Gain Factors of Booster and Horn

Device	Gain Factor
Booster	3.063
Horn	3.00
Booster + Horn	9.189

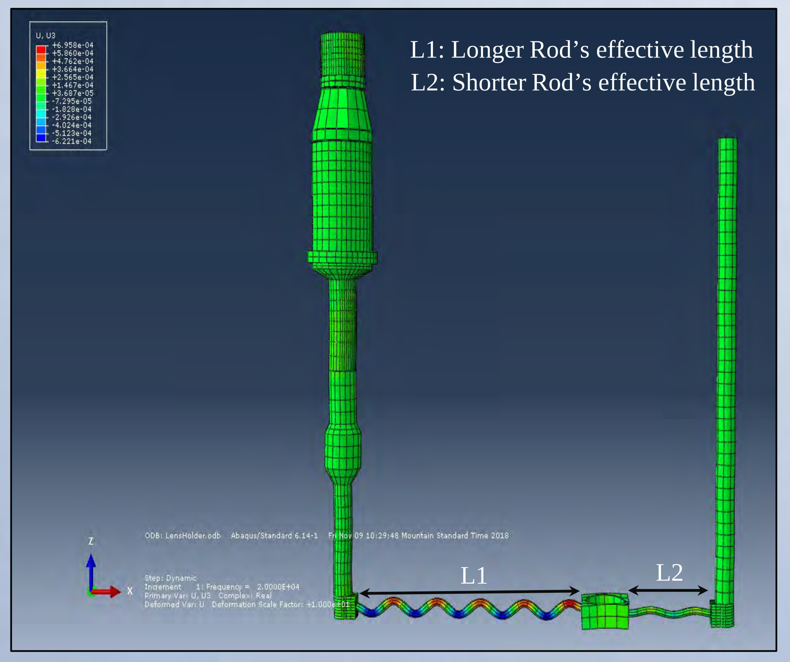
The booster and horn are used to amplify the displacement generated by the transducer. The displacement amplitude is increased based on the gain factor, which is computed by dividing the upper half mass by the lower half mass of each device.



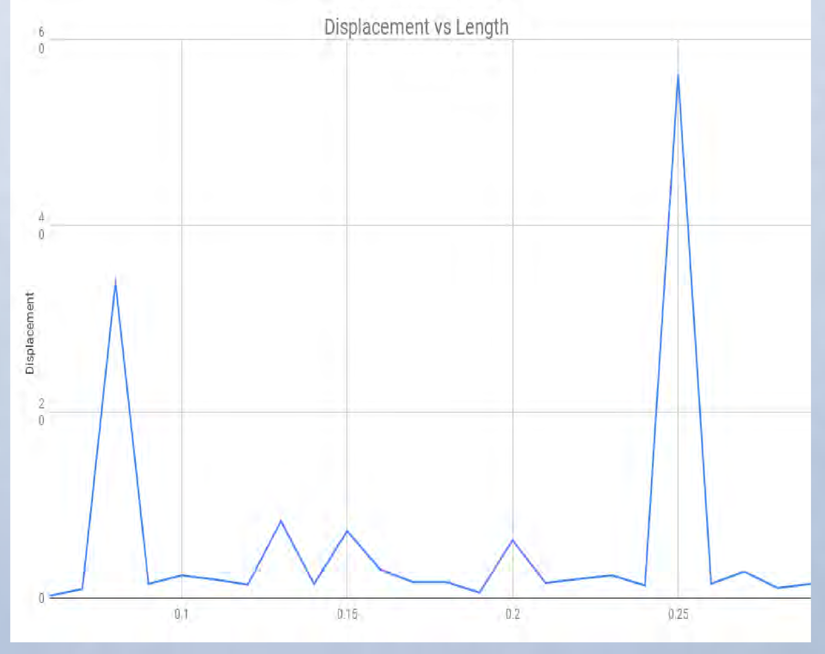
Overview of Laser Cutting Head CAD model

Horizontal Arms

We used Abaqus to aid us in determining the optimal dimensions of the horizontal arms connected to the lens holder. The graph below shows how the magnitude of vibration is a function of the length of these arms.

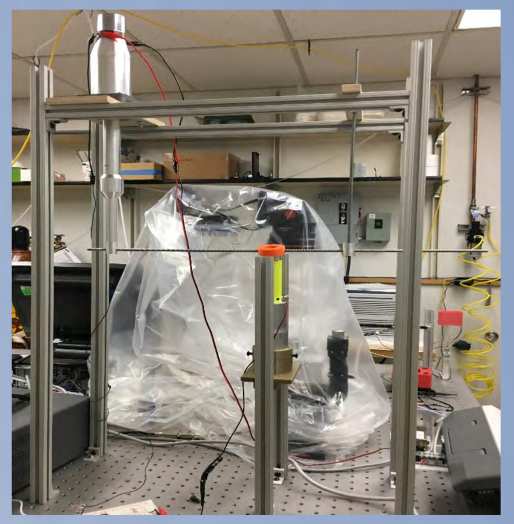


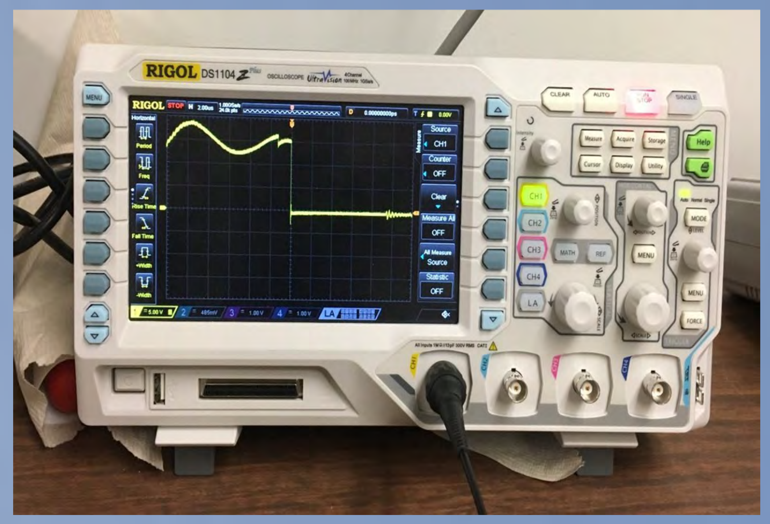
Abaqus Model



Lens Displacement Vs. Longer Arm Length

Physical Testing





Two tests were conducted in order to prove that the vibrating system is operating properly; resonance testing to check if the booster and horn are tuned to the desired frequency, and displacement testing to measure the displacement of the vibration system using a micrometer head.

Result

From the resonance test, we obtained 8783 m/sec for the speed of sound in the aluminum alloy. Moreover, taking the average of two displacement readings gave us 49 µm with an error of %18.1 compared to the Abaqus model (56.2 µm) and %2.00 when compared to the desired theoretical value (50 µm). Nevertheless, the team was able to reduce the percentage error by changing the effective length of the horizontal rods (L1 and L2).

Displacement Test Results Comparison

Component	Abaqus [µm]	Test 1 [µm]	Test 2 [µm]	Avg. [µm]	Error [%]
Horn	72	65	83	74	2.78
Lens	56.2	48	50	49	18.1

Critical Design Specifications

Specification	Dimension	Value [mm]
Horn	Length	198
	Input Diameter	30
	Output Diameter	20
Booster	Length	198
	Input Diameter	66.2
	Output Diameter	30
Lens Holder Longer Horizontal Rod, L1	Length	250
Lens Holder Shorter Horizontal Rod, L2	Length	90
Lens Holder Case	Length	38
Nozzle	Diameter	1

Conclusion

The design project was a success because the vibration system behaved as expected in terms of vibration frequency and displacement amplitude (a range of vibrational frequency and amplitude of 20 kHz and 50 µm, respectively). Some aspects of the project that need to be refined include Abaqus model, physical testing and vibration system. Additionally, it was made possible to easily change the effective lengths of both horizontal rods to change the displacement of the lens.