Senior Thesis

Computer Controlled Laser Interferometer

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Course of study, Applied Physics

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Table of contents

Introduction

Since the advent of the laser in the 1960's, optical metrology has provided a means of remote and non-contact measurement in the most difficult of environments. There are many cases of engineering interest where this approach is either impractical or impossible due to such things as very hot, lightweight, or rotating surfaces. One such example was brought up by Seimens; they wanted to use a laser for the purpose of drilling very small, very precise holes with a diameter of less than one millimeter. If there is any vibration at all the hole will not be drilled in the desired place. The idea is, if it is possible to measure the vibration we can then modulate the laser as the vibration modulates the material.

Some past research has solved the problem of vibration measurement using an extensive program to correlate the optical output with a vibrating mirror, but because the mirror was controlled by the investigator, the exact position was an approximation.

The purpose of this project is to eliminate all approximation from this measurement. The optical device for the vibration measurement will be a computer controlled Michelson Interferometer. This test bench will be controlled using software provided by Oriel Optics.

Michelson Interferometer

Interferometry was used by Albert Michelson; he used it to measure the velocity at which light itself propagates through space. Interferometers are measurement devices that send coherent light or other kinds of waves over two or more paths. The idea behind this interferometer is when you combine two coherent light waves of an interference pattern is formed. That interference pattern can be used to make very precise measurements of distances and ~~angels~~ angles. / 2/

Optical Setup

For this project the optical setup is a Michelson Interferometer with one mirror driven by a computer controlled motor actuator. The light from a HeNe laser, it then is sent into a spatial filter and beam expander. This optical device is used to effectively filter optical noise from the beam. The beam is directed by a turning mirror to a beam-splitter 8 inches away. This device divides the light in two different segments. One segment travels through to a fixed mirror 8 inches away. The other segment travels to the computer controlled motor actuator driven mirror 8 inches away. The two segments are then reflected back to the beam-splitter and recombined. The signal then passes through one of two convergent lenses, in order to better measure the changes. The first has a focal length of 15mm, and the second has a focal length of 100mm. You then get an interference pattern on the photodetector. As seen in figure 1:

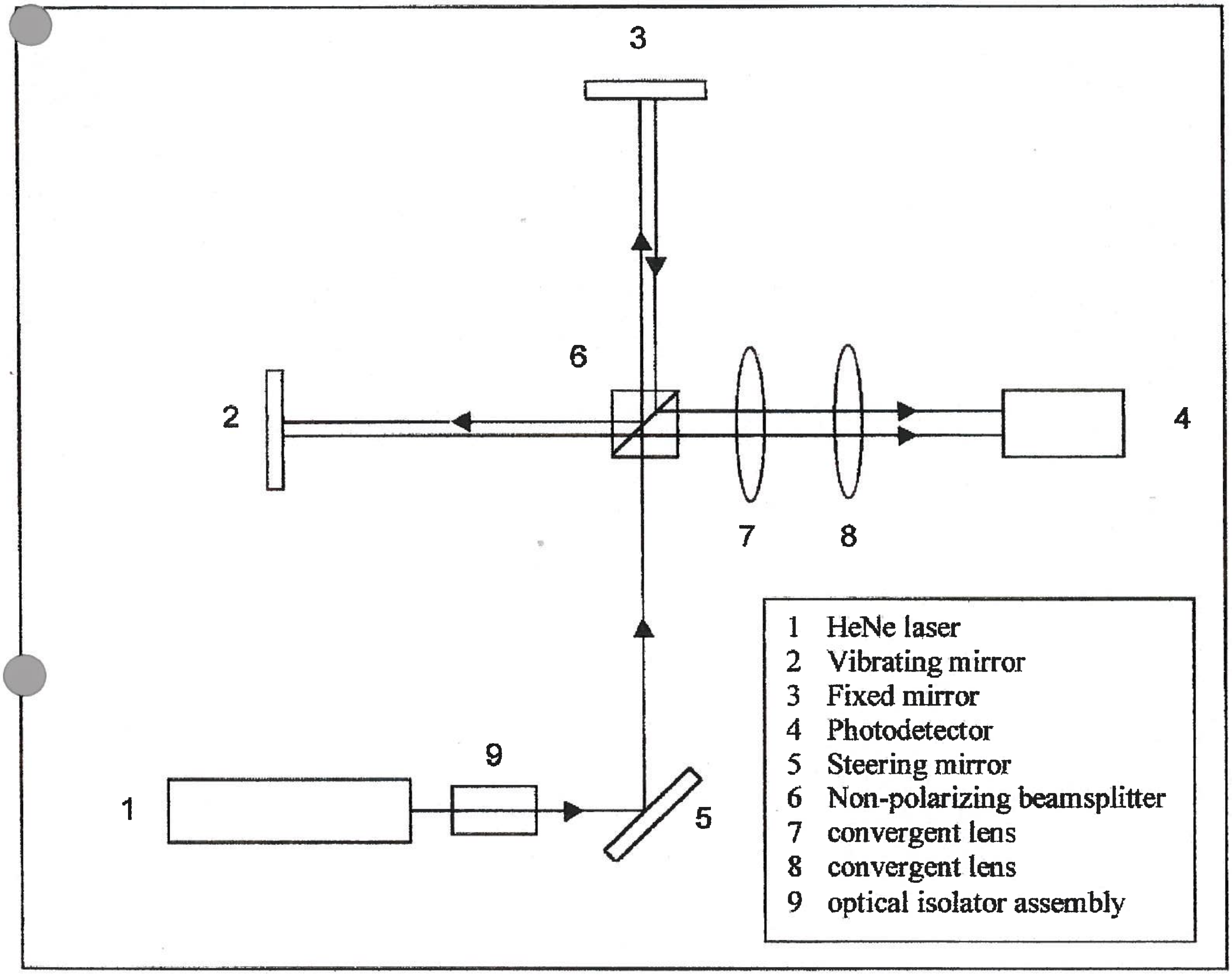

Figure 1: The Optical Setup

The Devices

The Helium Neon Laser

Laser is the abbreviation for " Light Amplification by Stimulated Emission of Radiation". The laser is filled with a mixture of helium (He) and neon (Ne). These two gases are under low pressure, and the specific mixture in the laser used is 10:1 He to Ne. Two mirrors form a resonant cavity. One mirror is totally reflective, and the other one is reflecting without the wavelength of the laser's output. This is called a Fabry-Perot cavity.

The He does not participate in the laser process. It is used to pump the Ne atoms into a higher energy state by coupling energy from the discharge to the Ne through collisions with the Ne atoms. The result of this process is that more Ne atoms are in the higher energy state than the ground state. The higher excited state means that light with a wavelength of 632.8nm can be radiated.

A 5-milliwatt frequency stabilized HeNe laser was used in the test bench. It is a laser of the class IIIb. The laser was manufactured by AROTECH, and its serial number is 017521.

Spatial Filter

A spatial filter is made up of a well-corrected positive lens, this is a microscope. A pinhole is placed at the focal length of this lens. This arrangement means that all collimated light is focused precisely at the pinhole. Other light, which originated at points of contamination is focused before or after the pinhole and consequently will not pass through it.

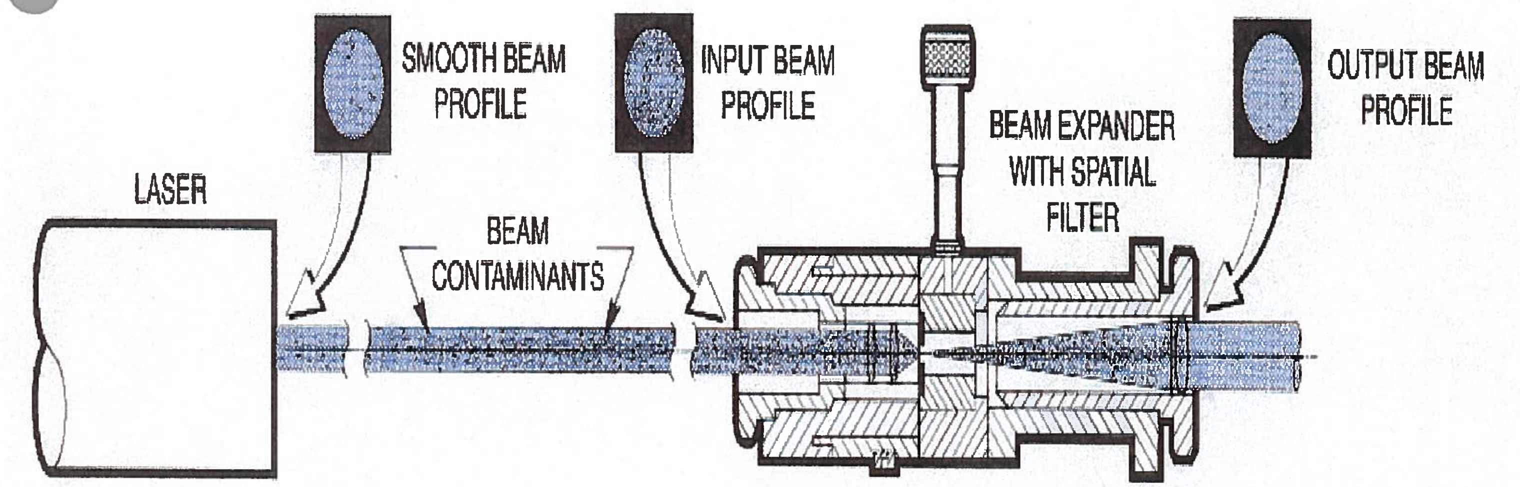

Figure 2 Spatial Filter

That energy is filtered out of the system by the pinhole. The spatial filter used in this setup has a focal length of 25.5mm, and the pinhole has a diameter of 20μm. The device was constructed by Oriel Instruments and the model number is 13570. /1/Beam-Splitter

For this test bench a cube beam splitter was used. It has a coated interface that turns part of the beam through 90°. The input and output interfaces are anti-reflection coated in order to eliminate subsidiary beams. Cube beam-splitters produce no beam displacement and have orthogonal beam-splitting geometry. /1/

Encoder Mike

The Encoder mike is a motorized actuator. They push or drive mechanisms such as our translation stage.

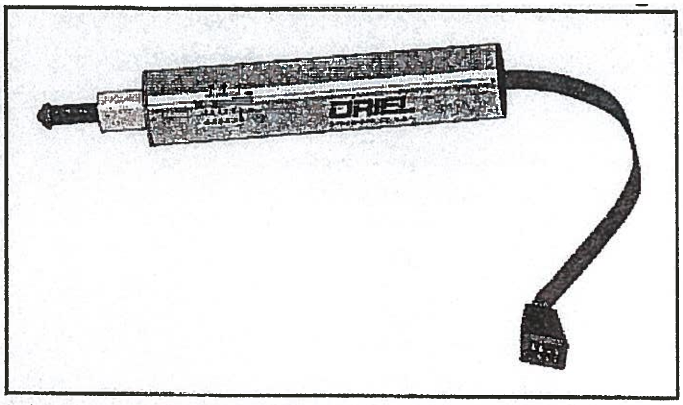

Fig. - Encoder Mike with extended spindle, i.e. in an up position.

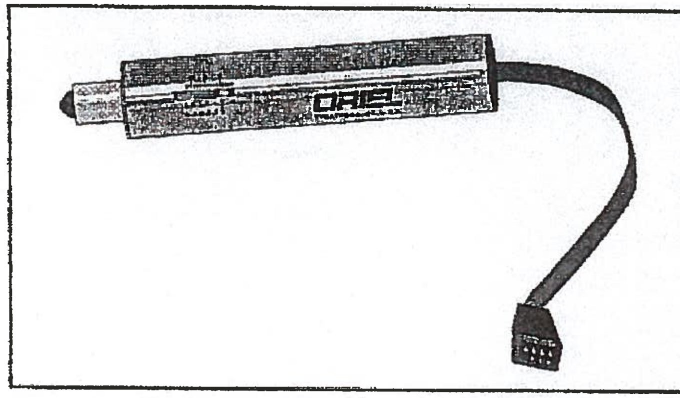

Fig. - Encoder Mike in fully down position, i.e. spindle retracted.

When the spindle or screw of the actuator is moving back into the body of the device, the actuator is moving in the down direction. Oriel provided the device and a LabVIEW interface to both drive the device and monitor its exact position. /4/

Photodetector

The Photodetector used in this experiment was developed in the lab during the course of testing. It was discovered that a more sensitive detector was needed. A detector was built using a photodiode, a Hammamatsu S1133, and an instrumentation amplifier, an AD622 from Analog Devices.

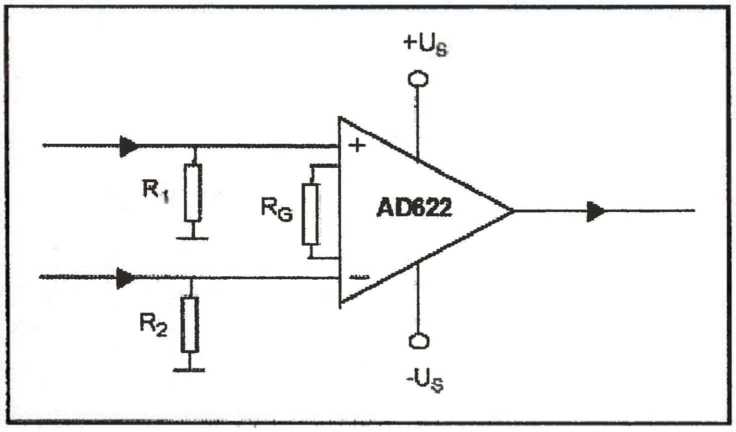

Figure 5 Amplifier with resistors

This photodiode has an effective active area of $6.6mm^2$ and a photosensitivity, for the wavelength used of 0.19 A/W. The signal from the photodiode was amplified with the AD622. The AD622 requires one external resistor to set any gain between 2 and 1,000.

Figure 5 Amplifier AD622 with resistors

The input voltage of the amplifier is 30V which gives U_s =15V. The gain- setting resistor has the value of 120Ω and the other two resistors of 1 kΩ. You can calculate the gain with the equation: $G= ((R_1+R_2)/R_G)+1$.

The G for this is 17.7. /5/

The Advantages of the Encoder Mike

The key feature that this device brings to this research is the data acquisition of the mirror position. In all of the previous test benches the investigator was forced to approximate the mirror position using several external programs, and setups. Most of these programs and setups are quite extensive and time consuming. This arrangement, however is very exact and extremely compact.

Another possible use for this test bench is the study of Fourier Transform Spectrometer (FTS) algorithms, in particular when applied to the Michelson setup, this test bench could be used to monitor the green house affect. If the test bench were to view light filtered through the atmosphere of the Earth I.E. sun light. As the drive mirror moved the detector would track all of the different frequencies in white light. If you then preformed a Fourier Transform on those frequencies you would see the suns color spectrum curve.

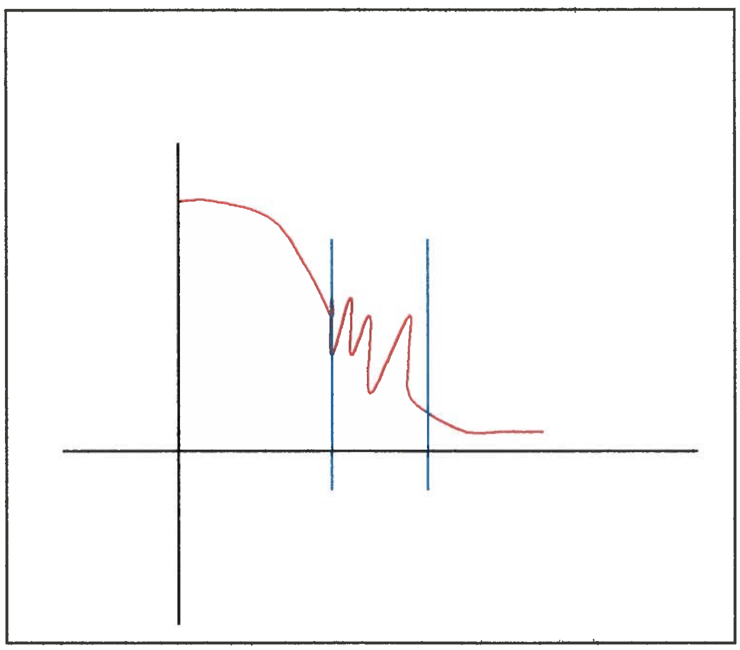

Figure 6 Sun's spectrum curve.

Notice the part of the spectrum between the blue line. This represents, although not to scale, the light that was absorbed by various gases, CO and CO_2. These results could then be compared laboratory results to find the amount of those gases in the atmosphere.

Summery and Outlook

This computer aided test bench, when used for vibration measurements, are very precise and do not require the amount of time that previous setups did. There does, however, remain much testing to be done on this test bench. And further pursuit of the Fourier Transform Spectrometer in the Michelson mode should prove very interesting and rewarding.

References

/1/ Oriel Instruments, The Book of Photon Tools

/2/ http//sim.jpl.nasa.gov/interferometry/index.html

/3/ Oriel Instruments, Instruction Manual for the Encoder mike 1811

/4/ Low Cost Instrumentation Amplifier AD622, Analog Devices Inc.. 1999