University Paul Sabatier

M2-TSI UE21 Labwork Report

Refractive Index of air with a Michelson Interferometer

Author:
Issmail Batou
Solange Eyeang-Mombo
Vanshika Kansal

Students of TSI:
2017-2018

June 8, 2021

1 Introduction

The Michelson interferometer is an optical means to create interferences splitting beams and their amplitude. It takes action for example in medical imagery or detection of gravitational waves. It can be used accord to different configurations and so allows to obtain various interferences patterns.In our study case, as we introduce an angle between the two mirrors, we work in air corner configuration. The lab-work goal is to measure the refractive index of air with a Michelson interferometer and compare the value obtain to the theoretical one.

2 Instrumentation and devices functions

The interferometer is composed of two mirrors named M1 and M2, a beam splitter and a light source. In our experiment, we add a slit, a lens, a vacuum cell with a micro valve related to a pump circuit, a diode laser with a wavelength of about 630nm and a screen.We also use an acquisition card with a lab-view program to run the acquisition and collect data concerning voltage beam, pressure and fringes coming up from interferences.

In this interferometer, the light comes up from the source light and falls on the beam splitter which divides the beam into two arms. One is transmitted toward M1 mirror passing through the vacuum cell.The other arm is reflected toward the mirror M2.After that, M1 and M2 return the light to the beam splitter so as to be recombined and interfere in such way that a single comes out the splitter beam toward the lens. This lens allows to focus this last beam in the slit in order to give an appropriate fringes pattern. We notice that according to the difference of optical path between beams coming from M1 and M2, the fringe pattern oscillate. As one beam passes though a gas cell, we will play on the pressure in this cell to modify the fringes pattern so as to compute the air refractive index.

3 Preliminary questions

If the optical path length of one beam changes by one wavelength, the interference pattern is shifted by one fringe. The optical path length is n*L, where n is the refractive index and L is the cell length. The optical path length can be varied by changing either n or L. If the refractive index changes by Δn, the path length changes by 2*L*Δn. The pattern will shift by one fringe each time the refractive index changes by an amount of :

$$\Delta \mathrm{n} = \lambda \ / \ 2\mathrm{L}$$

A shift of m fringes will occur when the refractive index changes by an amount of

$$\Delta \mathrm{n} = \mathrm{m}\lambda \ / \ 2\mathrm{L}$$

The refractive index for most gases is close to 1. In addition for air, n-1 is proportional to the pressure p of the gas such that:

$$\mathrm{n}\text{-}1 = \alpha \mathrm{p},$$

where α is an unknown constant.

When the pressure changes, the change in the refractive index is

$$\Delta \mathrm{n} = \alpha \ \Delta \mathrm{p}$$

We can therefore relate the number of fringes, m, to the change in pressure as follows:

$$\Delta \mathrm{p} = \Delta \mathrm{n} \ /\alpha = \mathrm{m} \ \lambda / \ 2\mathrm{L} \ \alpha$$

Therefore, the unknown constant is given by:

$$\alpha = \mathrm{m}\ \lambda/\ 2\mathrm{L}\Delta\mathrm{p}$$

Thus if we measure m fringes while the pressure changes by an amount Δp, we can calculate the refractive index of air at room temperature using the following equation:

$$\mathrm{n_{air}}\text{-}1 = \mathrm{m}\ \lambda\ \mathrm{p}/\ 2\mathrm{L}\ \Delta\mathrm{p}$$

Using the previous equation and our experimental setup values (λ=635 nm, L = 11.8cm, n_{air} = 1.00029, p = room pressure measured during experiment was 730.78 Torr, Δp = 1000 Torr), we estimate the mean value of fringes:

$$\mathrm{m}=14$$

4 Experimental methods

First of all, we have to create a lab-view program so as to record our data that is to say the fringes pattern and pressure values. To do this, we start NIMAX on the computer desktop.After we click on :

1. ACQUISITION CARD
2. AUTOTEST
3. TESTS PANNELS

This allows us to check if the acquisition card properly works. The second step consists of display the acquisition window. We come to this following these different tasks :

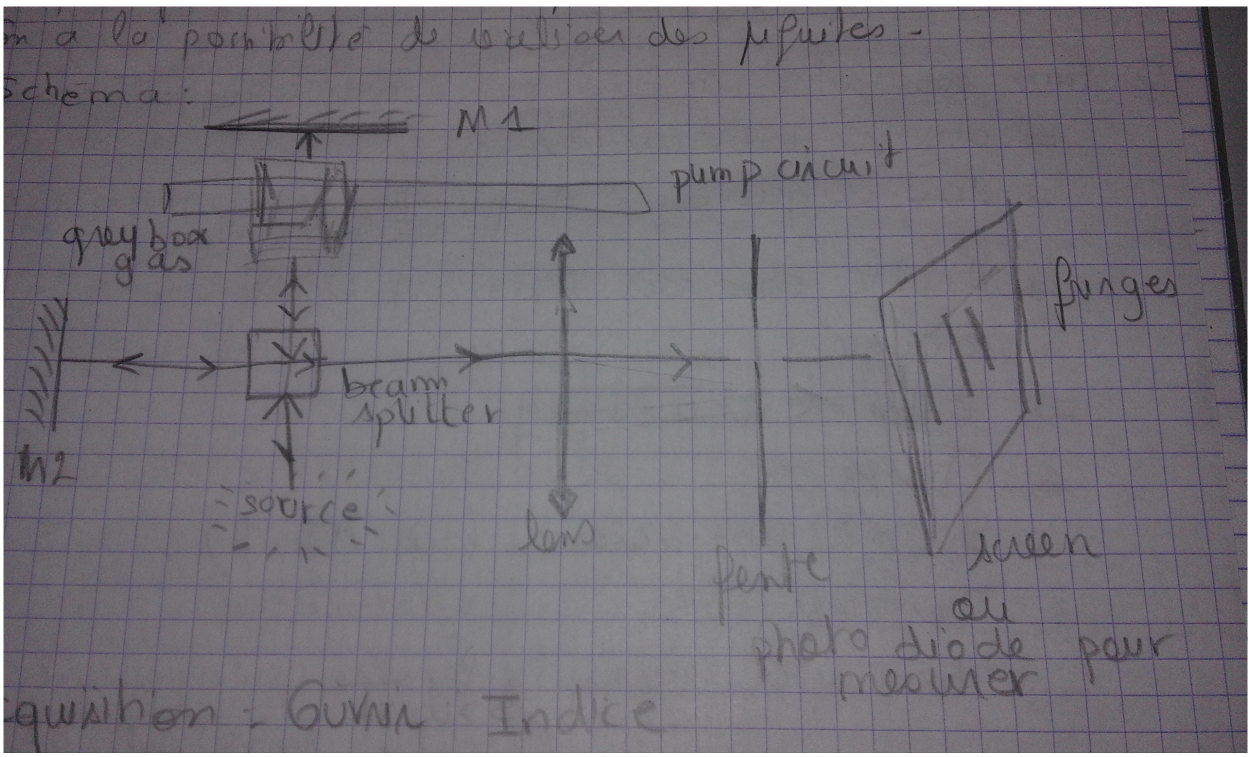
1. we open Lab-view(2)
2. we select DATA ACQUISITION WITH NI DAQ MIX
3. we double click on ASSISTANT DAQ
4. we choose ACQUIRE SIGNALS
5. then ANALOGIC INPUT
6. TENSION
7. we choose one channel, in our case it is AI1
8. we click on DONE then EXCECUTE in the DAQ ASSITANT WINDOW which appears
9. we end on OK

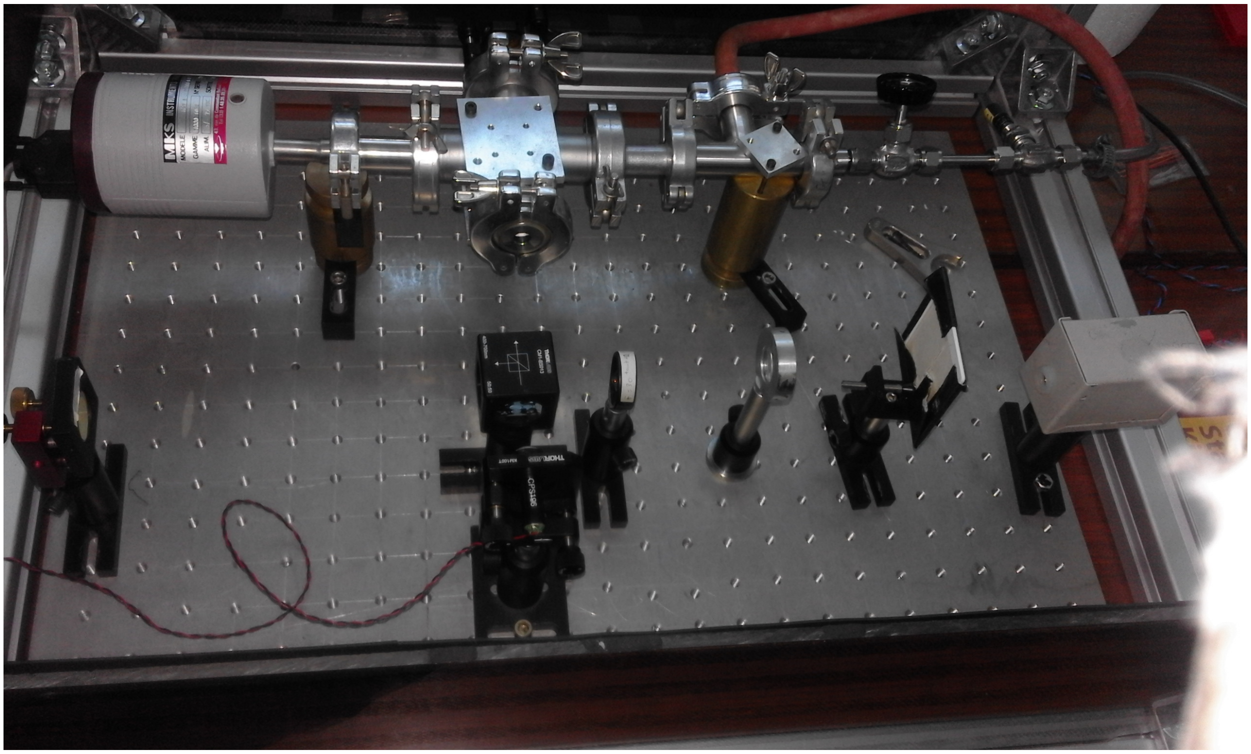
We observe that the VI is built automatically.Afterwards, we open terminal of DATA and follow instructions from the DATA ACQUISITION DIAGRAM with NI-DAQ-MIX. Thereafter, we create a file in which will be written all data about fringes and pressure:

1. right click
2. click on the blue disk

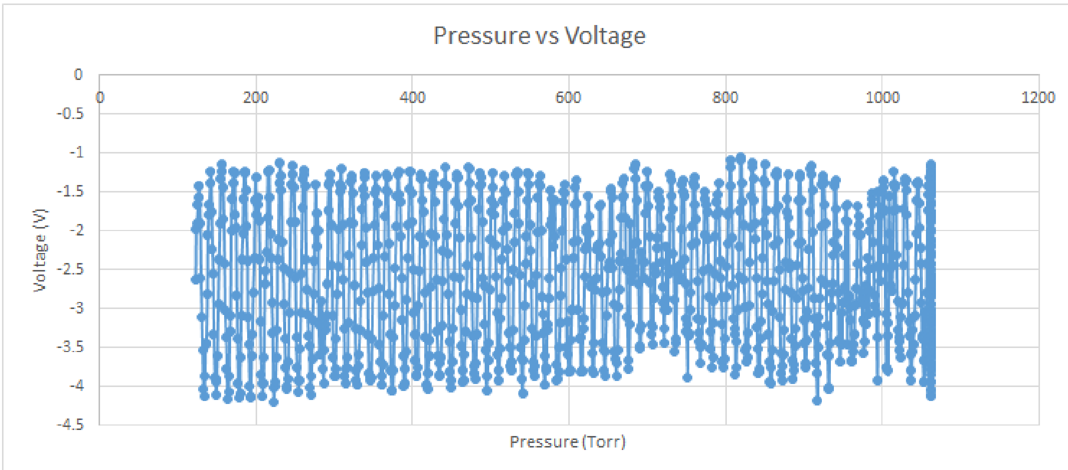
3. write in a file
4. create a folder and save the file

After completing all these tasks, we can now set up the interferometer so as to display fringes on the wall. These following pictures show the installation of each elements of the interferometer.

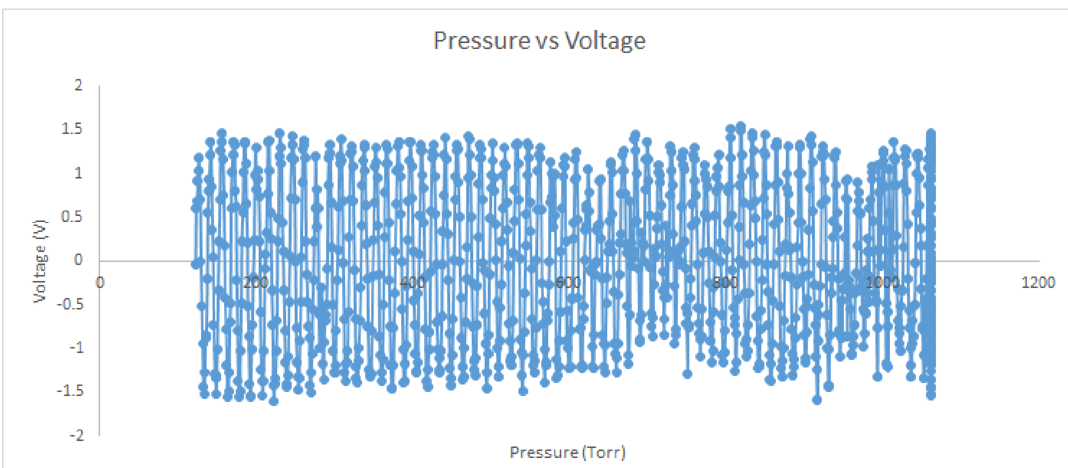




This set up describes the path of the laser beam from the source to the screen or the photo-diode which measure the intensity of beam. Indeed, the source emits a beam which goes through a beam splitter. The beam is then split into two beams: one goes straight to the M1 mirror through a gas box which pressure is regulated by the pump circuit. It then comes back to the beam splitter.The second one goes toward the M2 mirror and comes back also to the beam splitter. Afterwards,both beams in the splitter beam are sent toward a lens so as to be focused through a rift. These two beams finish their race on a screen to show fringes off or on a photo-diode. At a later stage, we can run an acquisition on Lab-view: we open the file INDICE and we select INDICE LABVIEW INSTRUMENT.Next step is to switch the pump under the table on and then to switch it off.We proceed this way so as to observe light appears and disappears on the screen paper. This gives birth to fringes. Thanks to our set up and data recorded on our file with Lab View, we use Excel to plot pressure against voltage shown below. As the result we obtain the graph of fringes.



We proceed afterward to the stabilization of the axis to the value zero. We are now able to count the number of fringes. However, we realize that it is not easy to count the number of fringes. As a matter of fact,frequency and amplitude of these fringes change all the time. Therefore we suggest to write an algorithm which takes into account the sign of each value and establish a threshold(like a baseline) to be able to count the number of fringes. To do so, we need to compute the average of voltage values. Then we add this average to each value of voltage we have.In our case, we choose a zero baseline. Finally we obtain this kind of graphic which represents voltage against pressure:



If we want to increase the number of points in our sampled curve we must play on the sampled speed. Because this speed indicates when we acquire a value of pressure.

Thereafter, we know that:

n_{air} = 1 - (λ*p*m)/(2*L*Δp)

- λ: laser wavelength, λ = (635 +/- 2)nm
- L:cell length, L = (11,8 +/- 2)mm
- m: number of fringes
- p: atmospheric pressure in mmHg
- Δp : difference between atmospheric pressure and pressure in the gas cell.

We calculate the refractive index of air using Edlén Equation.

$$n_{air} -1 = [(8342.13 + \frac{2406030}{130-k^2} + \frac{15997}{38.9-k^2}) \text{ X } \frac{0.00138823p}{1+0.003671T}] \text{ X } 10^{-8}$$

Where, p is the air pressure in Torr, T is the temperature in °C, k is the vacuum wave number $\frac{1}{\lambda_\circ}$ in µm^{-1} ($\lambda_\circ$ wavelength in vacuum).

k = 1.57480315 µm^{-1} using λ = 635 nm; T = 20 °C; p =730.78 Torr

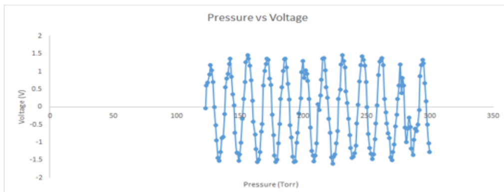
The obtained value is:

$$n_{air} = 1.00026$$

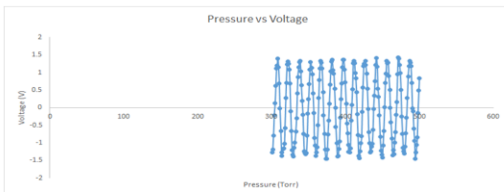
The uncertainty of calculated refractive air index from Edlén equation is equal to 3E-05.

In order to get most optimized value of refractive index we used small parts of data to count the fringes and do our calculations.

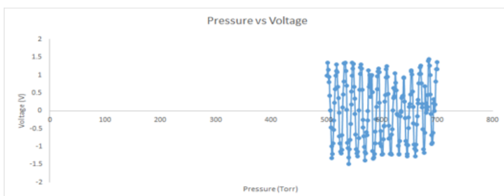
We used Δp = 200, so our dataset is subdivided into 5 sub-dataset and we plot and calculate the number of fringes for all sub-dataset as shown below.



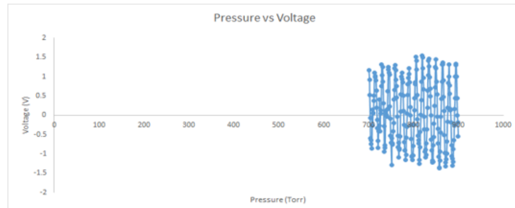
(a) m = 13 with Δp = 200 (range 100-300); coefficient $\frac{m}{\Delta p}$ = 0.065



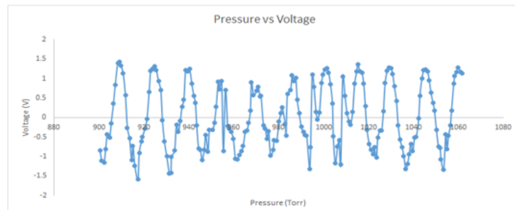
(b) m = 13 with Δp = 200 (range 300-500); coefficient $\frac{m}{\Delta p}$ = 0.065



(c) m = 15 with Δp = 200 (range 500-700); coefficient $\frac{m}{\Delta p}$ = 0.075



(d) m = 17 with Δp = 200 (range 700-900); coefficient $\frac{m}{\Delta p}$ = 0.085



(e) m = 14 with Δp = 200 (range 900-1100); coefficient $\frac{m}{\Delta p}$ = 0.07

Now, we take mean value of the fringes which comes out to be m = 14 as we estimated above. We obtain the value of n_{air} using n_{air}-1 $=\frac{m\lambda p}{2L\Delta p}$ and it is equal to 1.00014.

The uncertainty of the calculated refractive air index is equal to 1.5E-04.

5 Conclusion

The experiment performed in this lab was conducted to familiarize ourselves with the various uses of a Michelson Interferometer. Particularly with respect to the computation of refractive air index. We noticed that the adjustment of all components of Michelson interferometer plays an important part in obtaining a good fringes pattern but also the number of these fringes. By adjustment, we mean laser beam alignment from the source to the two mirrors and the beam splitter so as to reach the electric diode.This lab based on Michelson interferometer is a good way to find out about what occurs throughout communications in different environment especially Earth-Space communications. This could allow us to understand what causes offsets during communications. Beside, in this case, we notice that this experiment leads us to a refractive air index value very close to the theoretical one.This shows the relevance of this lab.