Universität Tübingen

Physikalisches Praktikum II

MS

Michelson Interferometer

Von:
Fabian Kraus
Simon Fischer

Betreuung:
M. Coffaro

10. Dezember 2021

Inhalt

1 Motivation

The goal is to study the interference pattern of electromagnetic waves with the Michelson-Morley interferometer and also to obtain results about the refraction index of light in certain media in order to show that it depends on the pressure.

2 Theory

2.1 Interference pattern

Assuming that the laser emits plane waves, the incident waves that arrive on the screen (wall) are also plane waves. They interfere with a difference in change in path Δs and form a pattern. For a maximum the condition reads

$$\Delta s = k\lambda, \tag{1}$$

where $k \in Z$ and λ denotes the wavelength of the light emitted by the laser.
In the case of divergent light, one can use Huygens principle and see that spherical waves at each point form a new plane wave. Thus, the same change in path and the same condition for a maximum arise.

2.2 Wavelength

The relation for computing the wavelength can be derived from the geometry of the experiment in the following way (see figure 1):
The optical path is given by the difference in way of the two beams ΔL times the speed of light, i.e.

$$\Delta s = \Delta L c \tag{2}$$

This can be further computed by using the times $t_1 = \frac{2L_1}{c}$ and $t_2 = \frac{2L_2}{c}$, where L_1 and L_2 denote the lengths of the arms of the interferometer. Using the condition for constructive interference ($\Delta s = k\lambda$, where $k \in C$, we get

$$k\lambda = 2\Delta L. \tag{3}$$

By adjusting the distance with a screw that is turned by d, this becomes

$$\lambda = \frac{2d}{m}. \tag{4}$$

Taylor expansion for small pressures p yields the final result

$$n(p) \approx 1 + \frac{dn}{dp}p. \tag{5}$$

Since it is rather hard to measure the pressure directly, we can use that $\Delta s = dn - n$ for our setup, thus

$$n = 1 + \frac{k\lambda}{2d}, \tag{6}$$

which we will use in section 4.1.

3 Procedure

A Michelson interferometer consists of a beam splitter, two mirrors and a laser. They are set up like in the image below.

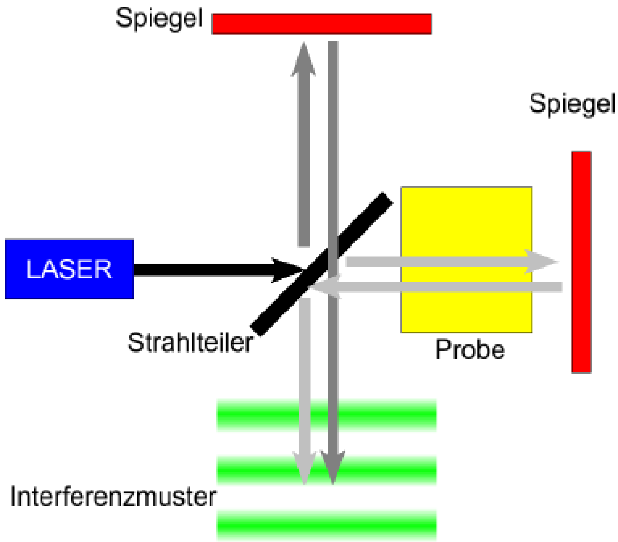

Abbildung 1: Michelson interferometer

The light of the laser is partly reflected by the beam splitter and partly passes it. When both rays converge again, they overlap and interfere. Constructive interference leads ti a maximum on the detector (wall), while desctructive one leads to a minimum respectively.

4 Results & elaboration

4.1 Wavelength of the laser

The wavelength was determined by moving one mirror by a known distance Δs. The translation rate was 225 : 1, i.e. 0.35mm per rotation. By turning the lever by 360, the mirror moved by

$$\Delta s = \frac{0.35\text{mm}}{225} \tag{7}$$

away from the beam splitter. Approximantely 6 new rings appeared with every 360. Therefore, by using $\Delta s = N\frac{\lambda}{2}$, where N is the number of maxima, we obtain

$$\lambda = \frac{2\Delta s}{N} = \frac{2 \cdot 0.35\text{mm}}{6 \cdot 225} \approx 518.2\text{nm}, \tag{8}$$

which is a rather good result as the green laser has a wavelength of roughly 550nm. The deviation may result from manually counting the rings, as well as from the table that was shaked a little which led to a variing number of rings.

4.2 Refraction index of air

The tube of length 10cm was evacuated and air was slowly filled back in. The difference in pressure was determined by CASSY using the following data.

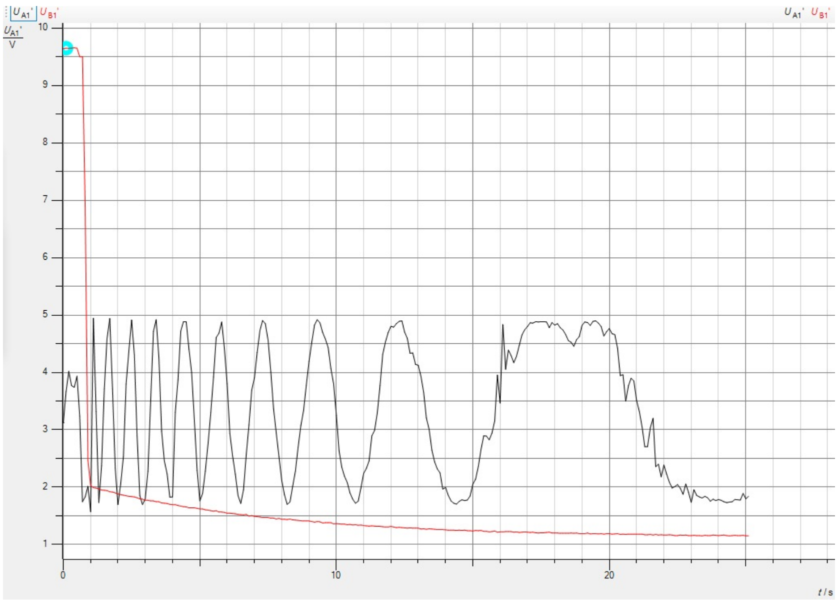

Abbildung 2: Data plots

CASSY determined it to be $\Delta p = 3.19\text{V}$, which equals approximetely $0.71\text{bar} = 7.1 \cdot 10^4\text{Pa}$. The change in number of maxima could not have been observed due to unknown reasons. Maybe the change in voltage was too low or maybe we were not able to see it by the naked eye. Thus, we assume the value $\Delta N = 80$ from other protocolls. With this value we end up with the refraction index

$$n \approx 1 + \frac{\Delta N}{\Delta p}\frac{\lambda}{2s}p, \tag{9}$$

which leaves us with

$$n \approx 1 + \frac{80}{7.1 \cdot 10^4\text{Pa}}\frac{518.2 \cdot 10^{-9}\text{m}}{2 \cdot 0.1\text{m}}p. \tag{10}$$

The figure below illustrates this relation and proves the statement that the refration index of air changes linearly with the pressure.

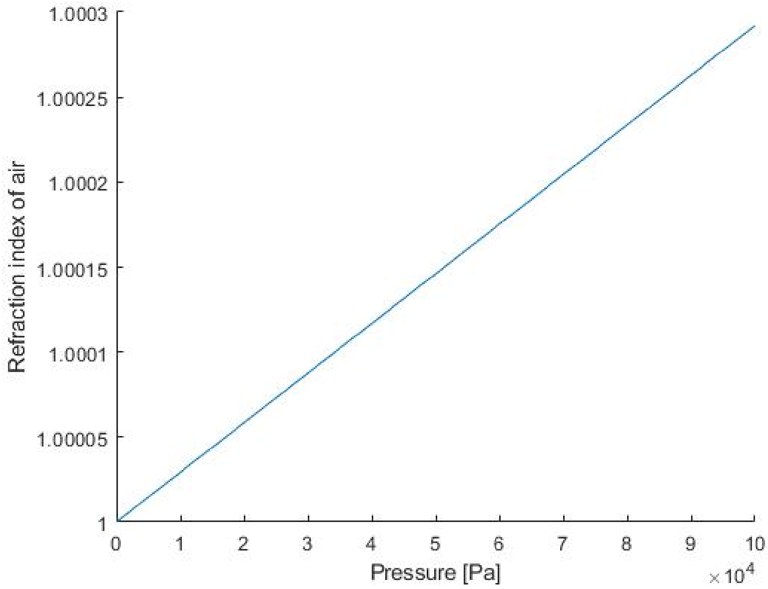

Abbildung 3: Linear relation between the refraction index of air n and the pressure p

In the figure we have inteprolated in steps of 1000Pa, which yields a good result. Under normalized conditions (0.925bar), the refration index is given by $n_{normalized} \approx 1.00027$, which is very close to the literature that predicts $n = 1.00029$.

4.3 Hysteresis of the Piezo element

The data obtained can be seen in the following figure.

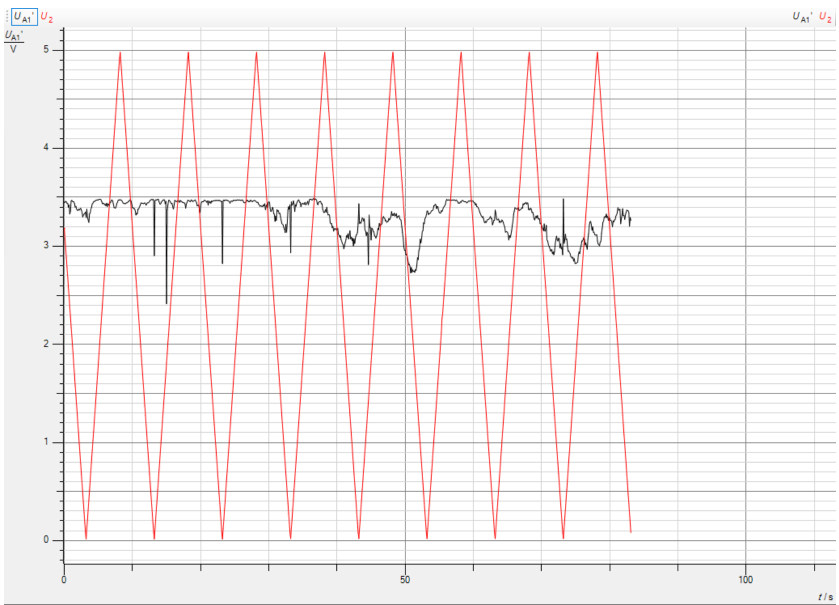

Abbildung 4: Data of the piezo actor

The red curve shows the incoming voltage, while the black one should have shown the hysteresis. Obviously the measurement has some serious flaws as it should be an oscillating signal. A potential mistake could be that the wire was loose. This has happened one time and we fixed it, but maybe it occured again, which led to a random white noise signal.