Lab Report
Experiment 7 Measurement of Fundamental Constants: The Speed of Light

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Abstract

By inducing a phase shift in a beam of light using two sine generators to scale down the input to an oscilloscope by a factor of 601.506 ± 0.025 at regular distances allowed for a calculation to find c_{air} the speed of light in air which was calculated to be $c_{air} = (2.955 \pm 0.042) \times 10^8 \text{ms}^{-1}$

1 Introduction

This experiment aims to confirm the established value for the speed of light $c = 299792458\text{ms}^{-1}$[1] through a scaled but direct measurement of the time taken for light to travel a known distance between a laser emitter and receiver and comparing the phase difference between the emitted and received signals.

2 Theory

This experiment arose from the difficulty found in directly measuring the speed of light from the first known attempt when Galileo attempted the measurement in 1667 when he and his assistant stood on top of a hill a known distance apart, each with a lantern, he was unable to determine if at a distance of less than a mile if light travelled instantaneously or not [2]. To when Hippolyte Fizeau's method was used, while still attempting to make a direct measurement, using the Fizeau-Foucault apparatus of reflecting light from a revolving mirror to a mirror a known distance away and measuring the angular difference between the departing and returning light was improved upon by physicists until Leon Foucault obtained a value of 2.98×10^8 ms^{-1} which is very close to the modern accepted value[3].
The difficulty of such gave rise to this experiment which uses the technique of time-dilation to allow the response signals from transmitter and receiver to be read by setting up the experiment such that the laser emits light at a frequency of 60.0 Hz from the first sine generator, which is then mixed (multiplied) by the 59.9 Hz from the second sine generator both before it is transmitted and then after the receiver to give 2 waves on the oscilloscope that are out of sync with each other such that, $\Delta t' = \frac{\Delta t}{\Delta t'}$ where $\omega_1 = 2\pi f_1$and $\omega_2 = 2\pi f_2$, where $f_{1,2}$ are the frequencies of each wave, are used to calculate the time dilation factor

$$\Delta t' = \frac{\omega_1}{\omega_1 - \omega_2}\Delta t \tag{1}$$

where $\frac{\omega_1}{\omega_1 - \omega_2}$ is the time dilation factor, $\omega_{1,2}$ is the angular frequency of each wave and Δt and $\Delta t'$ are the measured phase difference and time taken for the light to travel from the transmitter to the receiver respectively.

3 Experimental set-up and procedures

In this experiment the equipment is set-up as described above and represented in Figure 1. After such it is a simple task to measure the phase shift between the waves at increasing distances on the oscilloscope by setting up the y axis such that the waves appear vertical on the display, direct measurement can then be made of the phase shift until data is obtained such that a table is made with repeat measurements as in appendix 1.

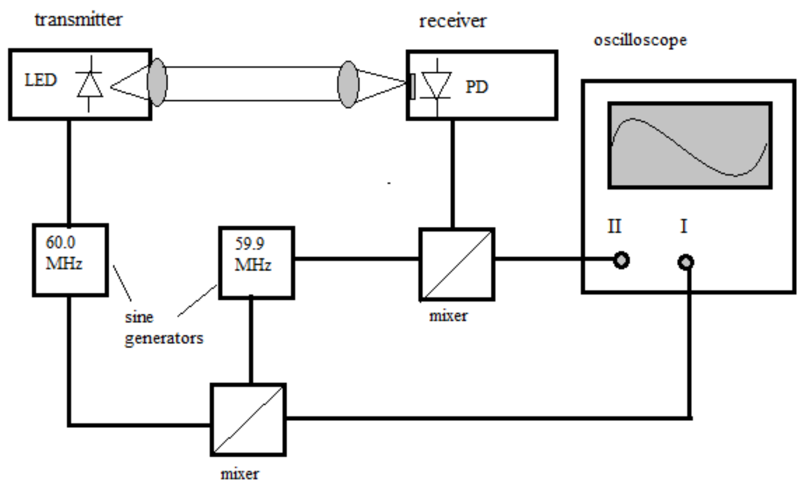


Figure 1 [4]

4 Results and analysis

After acquiring the data in appendix 2 the digital counter was attached to the to give us the value of f_1 and to the receiver for f_2 and then using this and (1) to calculate the angular frequencies of those waves which can then be used in the calculation of the time dilation factor;

$$\Delta t' = \frac{60.0002 \pm 0.00005 \text{ MHz}}{99.75 \pm 0.025 \text{ KHz}} \Delta t = 601.506 \pm 0.025 \Delta t \tag{2}$$

and then use this to multiply each of the average values in the table in appendix 1 to give actual values for the time the light takes to travel between the transmitter and receiver as shown in the table in appendix 2

Which was then used to produce a graph, Figure 2, of the scaled phase differences against displacement between transmitter and receiver, the gradient of which is our reciprocal of the speed of light

$$(3.3838 \pm 0.0482) \times 10^{-9} \tag{3}$$

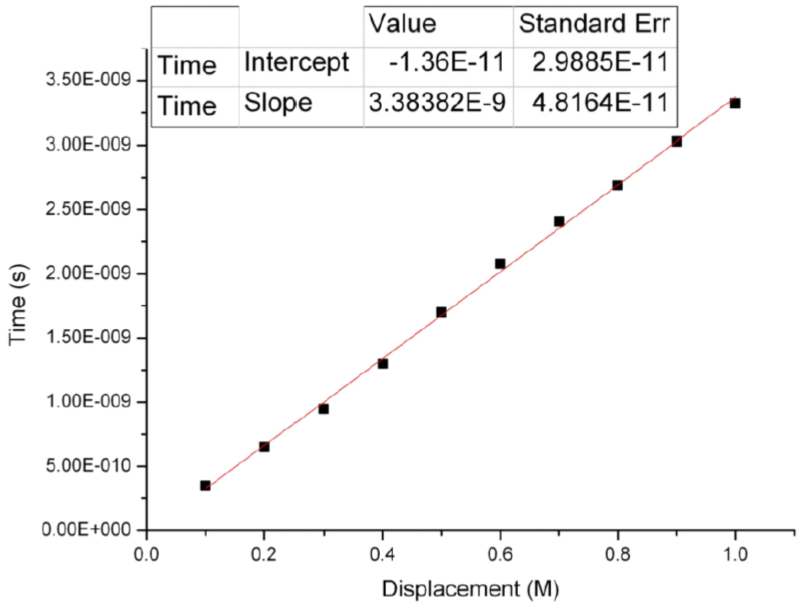
, as shown by;

$$c = \frac{1}{\frac{\Delta t'}{\Delta s}} \tag{4}$$

Where $\frac{\Delta t'}{\Delta s}$ is the gradient of the line and such our value for the speed of light is

$$c_{air} = (2.955 \pm 0.042) \times 10^{8} \text{ms}^{-1} \tag{5}$$

which is consistent with the established value $c = 299792458\text{ms}^{-1}$[1].



5 Conclusions

The aim of this experiment is to determine the speed of light, however this in itself is a flawed concept as any more accurate calculation for the speed of light will result in a change in the length of a metre which is defined as the distance light travels in $\frac{1}{299792458\text{ms}^{-1}}$ seconds[5]. By this, if the determined value were to be taken as absolutely accurate then the length of a metre would be redefined as

$$0.9856 \pm 0.0147 \times \text{the length of the current metre} \tag{6}$$

6 Appendix

Appendix 1

Time Difference$\Delta t \times 10^{-4}$				
Δs	1	2	3	average
10	2.2	2.0	2.2	2.1
20	4.0	4.0	3.8	3.9
30	6.0	2.0	2.2	5.7
40	7.8	7.8	7.9	7.8
50	10.0	10.0	10.5	10.2
60	12.5	12.5	12.5	12.5
70	14.5	15.0	14.5	14.5
80	16.5	16.0	16.2	16.2
90	17.5	18.5	18.5	18.2
100	20	20	20	20

Appendix 2

Δs	Time$\Delta t' \times 10^{-4}$
10	0.0035
20	0.0065
30	0.0095
40	0.0130
50	0.0170
60	0.0208
70	0.0241
80	0.0269
90	0.0303
100	0.0332

References

[1] Newell, P. J. M. . B. N. T. . D. B. (2007) CODATA Recommended Values of the Fundamental Physical Constants, NIST, .

[2] Drake, G. G. . S. (1974) Two New Sciences, Univ. Wisconsin P, .

[3] Philip Gibbs, University of California, R. (2010) *How is the speed of light measured?*

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