Development of light detector for Michelson Interferometer Experiment Instrument

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Abstract

We developed a supplementary instrument for Michelson Interferometer experiment instrument. In this experiment, we have to count numbers of fringes to determine wavelength of He-Ne laser. Without this extra instrument, the counting is hard and easy to make error because the fringes are very small. This instrument serves as light counting device. It composes of light sensor, comparable circuit, microcontroller and LCD panel. This device is designed to count only high intensity light and specific wavelength (600-1,000 nm). When there is a constructive fringe pass the light sensor, this device will count the fringes. We found that using this device can improve experiment results compared to using only by eyes. We calculated the wavelength of He-Ne laser to be 632.6 nm which was only 0.032 % error. This device is a part of interactive multimedia for advance physics lab. This research was supported by Rajamangala University of Technology Thanyaburi Research Fund.

***Keywords*:** Michelson, Interferometer, light detector

Introduction

In 1887, Albert Michelson and Edward Morley reported their most famous research from the experiment which they designed for finding ether, the hypothesis medium of light. This experiment used an optical interferometer to detect the relative motion of Earth against the static ether and they did not observed relativistic effect.

Nowadays, this interferometer is used for many applications for example, measuring precious wavelength of light, measuring distance, determining the reflective index of liquid, etc. Therefore, the Michelson interferometer is one subject in Intermediate physics laboratory course. The interferometer instrument consist of He-Ne lasers diode as light source, beam splitter and two mirrors and all instruments set up shown in Figure 1. The two of equal intensity beams divide from one laser beam and after that combined again and then interferometer pattern appear on the screen. The interference fringes are changed to light or dark when micrometer screw is turned and the displacement of mirror is changed to *d*. To determine the wavelength of laser, we count the number of the light fringes *n* appear at the center of circle interference pattern and wavelength is calculated from

Figure 1 Instrument set up for measuring wavelength with Michelson interferometer

The problem was found when students did the experiment. Errors are easily occur while counting light fringes. Since the light fringes are very small (less than 1 mm) and moving so fast because micrometer screw is very sensitive. This research is designed a supplementary instrument for Michelson Interferometer experiment by using photodiode for detecting light fringes at the center of circle of interference pattern and using microcontroller to count the number of fringes.

$$\lambda = \frac{2d}{n} \qquad (1)$$

Materials and Methods

Design circuit

To design the instrument for counting light fringes, we used microcontroller for counting them and display results on LCD panel. For detecting the light fringes, we used photodiode with the comparator circuit. Photodiode is an electronic device which allow current pass through when light is incident. The photodiode used for sensor in this research as shown in Figure 2 their wavelength interval are 600-1000 nm which is suitable for detect the light of laser.

Figure 2 Photodiode was used to be light sensor.

Figure 3 shows the circuit of detecting light sensor including with photodiode circuit (a), amplifier circuit (b) and comparator circuit (c). For normal light, the output voltage from photodiode is zero but when the light fringes pass the photodiode, the output voltage will increase from 0V and the increasing depend on the intensity of incident light. However the intensity of light fringe is usually low, hence it gives low signal voltage from photodiode so we have to use an amplifier circuit to amplify the signal. The amplifier circuit contain with one op-amp (LM324) and two resistors that designed for gaining 50 times of photodiode voltage that made the output voltage greater than approximately 3V. Since microcontroller receive only logical electronic signal, the gained signal was send to comparator circuit that use another op-amp in LM324 for comparing signal with the reference voltage which is about 2.5V. If the light fringe is incident on photodiode, then the voltage signal is greater than reference voltage and the output of comparator circuit is zero or logic '0'. Otherwise, if the normal light or dark fringe is incident on photodiode, then the voltage signal is lower than reference voltage and the output of comparator circuit is approximately 5V or logic '1'. After that the signal from comparator circuit is send to microcontroller via input/output port 2.
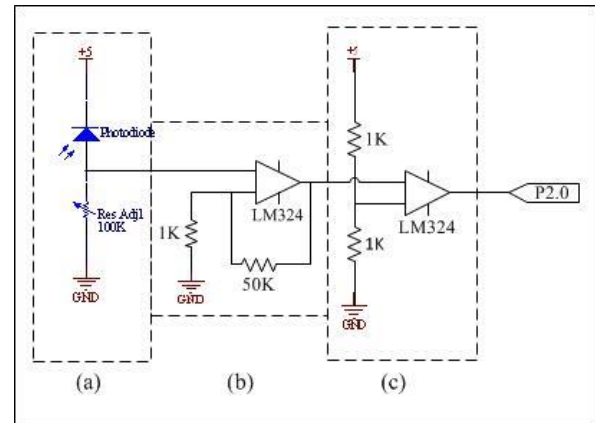

Figure 3 Sensor circuit design

In addition, the LED circuit was designed for showing statement of counting light fringes connecting with the output of comparator circuit. In normal light, LED is on but when the light fringe pass sensor then the LED is off. The complete instrument is shown in Figure 4. After the power switch on, the count number 'n' shown on LCD is equal to zero and the number of count is increasing when the light fringes pass the sensor. The reset button is used for reset the number of count.
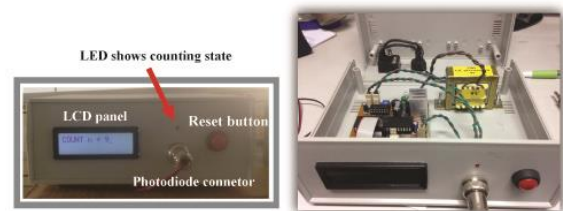

Figure 4 the instrument of counting light fringes for Michelson interferometer

Microcontroller programing

We developed a program for counting output signal from sensor using C language. After that we program to microcontroller MCS51. Figure 5 shows the flow chart of program. The microcontroller receive signal from sensor circuit via input port 2 pin 0 (P2.0). The while statement is used for checking if there is any signal coming to P2.0 all time. The variable count was initially zero and this variable was defined for counting the logic '0' sending from P2.0 and will increase when every time that there is a light fringe passing photodiode sensor. The count value was sent to display on LCD panel and then return to the top of loop.
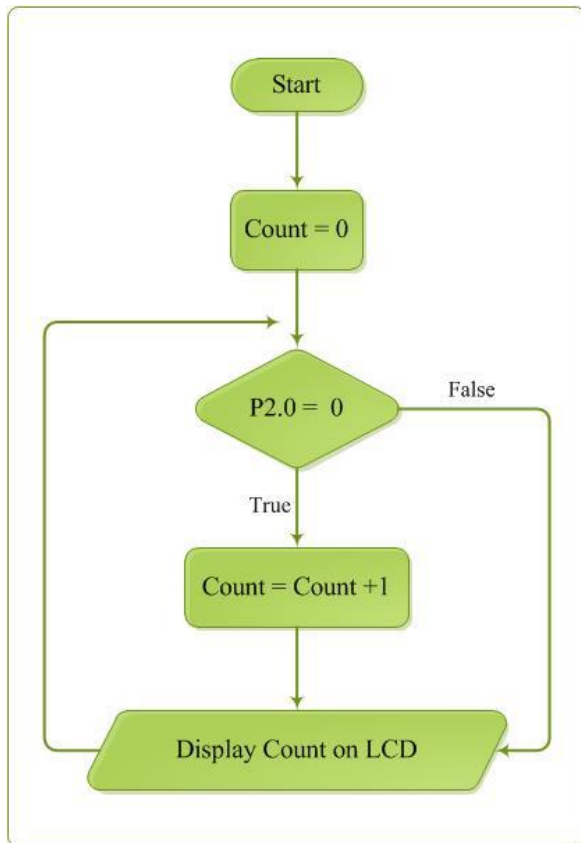
Figure 5 Flow chart of counting light fringes program

Results and Discussion

The Michelson interferometer experiment determining the laser wavelength was used for testing the performance of instrument. Initially, we set up the Michelson interferometer instrument and put the photodiode sensor on screen at center of circle of interferometer pattern. Before doing the experiment the laser was turned off and the resistance of adjustment resistor in the photodiode circuit was suitable adjusted for light in laboratory room which will allow sensor to count only light fringes from laser. In the set up process, the LCD panel may display count number more than zero therefore after this process we press the reset button for clearing count value and the display will show "n = 0".

Table 1 The number of light fringes and the wavelength of laser

No.	without counting instrument		with count instrument	
	n	λ (nm)	n	λ (nm)
average ($\bar{x}$)	448	669.2	473	632.6
standard deviation (sd)	13.2	20.0	1.58	1.78
uncertainty	4.2	6.3	0.5	0.6
%error	-	5.7	-	0.032

The result of counting the number of light fringes is shown in Table 1. This is the result from

counting light fringes and changing displacement of mirror 2 by turning micrometer screw in d = 0.15 mm. We repeated the experiment ten times with respect to the precision of average number of light fringes n. The average number of light fringes counted by instrument was n = 473 and the standard deviation was 1.58. To compare the result we also counted the fringes without the supplementary instrument. We found that the number of count from the instrument was less uncertainty than counting light fringes by eyes. In addition, the average wavelength calculated from Equation (1) using the counting number of fringes with instrument was compared with the wavelength of laser 632.8 nm. We found that the experiment with supplementary instrument has less percent error than by eyes.

Conclusions

Counting the number of light fringes by using the supplementary instrument has better precision number of count than counting by eyes. We calculated the wavelength of He-Ne laser to be 632.6 nm which was only 0.032 % error. The accuracy of wavelength measurement depends on the number of light fringes. The wavelength has a high accuracy when counting more number of light fringes. Counting the number of light fringes by eyes is not easy to get precision result as the instrument was developed. However, during the measurement do not revere turning the micrometer and must slowly turning micrometer because the sensor cannot detect the light fringes if they moving pass so fast.

Acknowledgments

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