

WAVELENGTH OF THE He-Ne LASER BY USING TWO TYPES OF DIAPHRAGM DIFFRACTION METHODS

Sri Purwaningsih^{1,*}, Hebat Shidow Falah¹, Neneng Lestari¹, Hardiantinus Sitinjak¹, Almahdi Mousa²

¹ Department of Physics Education, Universitas Jambi, Jambi, Indonesia

² Department of Medical Radiation, Faculty of Medical Technology, Bani Walid University, Bani Walid, Libya

Corresponding author email: sripurw4@yahoo.co.id

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Abstract

Light diffraction, characterized by the spreading or bending of waves when encountering narrow obstacles, forms the focal point of this research endeavor. Utilizing the circular diffraction method, this study pioneers the identification of the He-Ne laser wavelength through experimentation with both three and five-slit diaphragms. The investigation with a three-slit diaphragm involves three variations in slit distances: $d = 0.125$ mm, 0.25 mm, and 0.5 mm at a screen distance of 150 nm, revealing diffraction patterns across three orders of magnitude. For the five-slit diaphragm, the analysis extends to a slit distance of $d = 0.25$ nm and a layer distance of 320 nm. Interestingly, the results reveal that the wavelength spectrum of the He-Ne laser depends on the variation of the gap distance. Remarkably, a gap distance as minimal as 0.25 nm yields wavelengths within the range of 641 nm to 660.67 nm, highlighting the diffraction process's sensitivity to minute variations in experimental parameters. This groundbreaking research not only elucidates the intricate interplay between light diffraction and experimental configurations but also underscores the circular diffraction method's versatility in determining the fundamental properties of laser light. This study paves the way for advancements in optical instrumentation and characterization techniques by offering novel insights into wavelength determination methodologies. These findings have far-reaching implications across diverse scientific disciplines, including physics, materials science, and optical engineering, enhancing the precision and capability of optical measurement technologies.

Keywords: Diffraction Method, He-Ne Laser, Two Types Diaphragm, Wavelength



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INTRODUCTION

Education is a process that is set so that the nation's generation has good renewal. Education is an indispensable element of the future development for his future students, given the fact that he will become an educator (Blândul & Bradea, 2022; Andriani et al., 2024). Good education will be fulfilled

well if the functions and objectives of education are really achieved (Ryökkynen et al., 2022; Ugras & Asiltürk, 2018). Understanding each educational function is to direct, train, and mature abilities and understanding in the learning process (Arslantas, 2015). The purpose of education is to prepare the learner for citizenship and stewardship in their local and global community (Abraha, 2020; Kyrychenko, 2018). The purpose of national education can also be reflected based on the 1945 Constitution of the Republic of Indonesia, namely to educate the nation's life.

Light is an electromagnetic wave and is transverse. A propagating wave is a disturbance which can maintain itself from a medium carrying energy and momentum from one place to another. All waves of this kind are ultimately related to the movement of the distribution of the particles that make them up. Light diffraction is the event of spreading or bending of waves by narrow gaps as obstacles. focusing devices based on Fresnel diffraction effects (Cavaliere et al., 2007), describe a theoretical study of the radiation from a point charge moving at constant velocity and passing through the centre of a circular hole (Dôme et al., 1991), Diffraction characteristics of optical vortex (Kumar et al., 2010). The diffracted waves interfere with each other, generating areas of strengthening and weakening. In some classical cases, interference and diffraction phenomena are difficult to distinguish. Interference is a combination of two or more coherent light sources with the right frequency, amplitude, and phase difference which overlap, giving off a brighter state (constructive interference) and a darker state (destructive interference) (Lutfia, & Putra, 2020; Vainrub et al., 2006; Bhattacharyya et al., 2021). When two coherent waves of the same amplitude are combined, a total destructive interference event occurs (elimination, or dark state) when the waves are 180° out of phase. Waves are coherent if they have the same shape, the same frequency, and a constant phase difference, that is, the amount by which the peaks of one wave are in front of or behind the peaks of another wave is not affected by time) (Berg, & Sorensen, 2018; Likharev, 2018).

Diffraction is the event of monochromatic light passing through a narrow barrier to form a light-dark pattern. This diffraction pattern can be formed with a single slit, two slits and multiple slits (Viridi, 2016). Light diffraction is the event of spreading or bending of waves by narrow gaps as obstacles. The diffracted waves then interfere with each other, producing areas of strengthening and weakening. In some classical cases, interference and diffraction phenomena are difficult to distinguish.

Research on wavelengths has been carried out by several previous researchers, including wavelength measurements carried out by Sugito, dkk., 2005 where the measurement process looks at the interference pattern formed from the halogen lamp source. Sariyanto et al., (2014) has conducted research on measuring the wavelength of monochromatic light sources from webcam-based light diffraction patterns and Borland Delphi. Laser-induced refractive index modification by using micro-structuring of diffractive optical devices in ophthalmic polymers is of great interest in the fields of Optics and Ophthalmology (Sola et al., 2020).

In this research, wavelength measurements were carried out by observing the diffraction patterns formed from the He-Ne laser beam source and then determining the distance between the slits, the distance between the diffraction patterns and the wavelength. The novelty in this research is the use of the circular iris method which places a three-slit type diaphragm for various distance measurements between the resulting diffraction patterns, then a five-slit type diaphragm is used and then the distance between the diffraction patterns is measured, from these data the wavelength is then calculated. The aim of this research is to determine the He-Ne laser wavelength from the diffraction pattern using a circular iris method. The form of laser light diffraction is suggested in Figure 1.

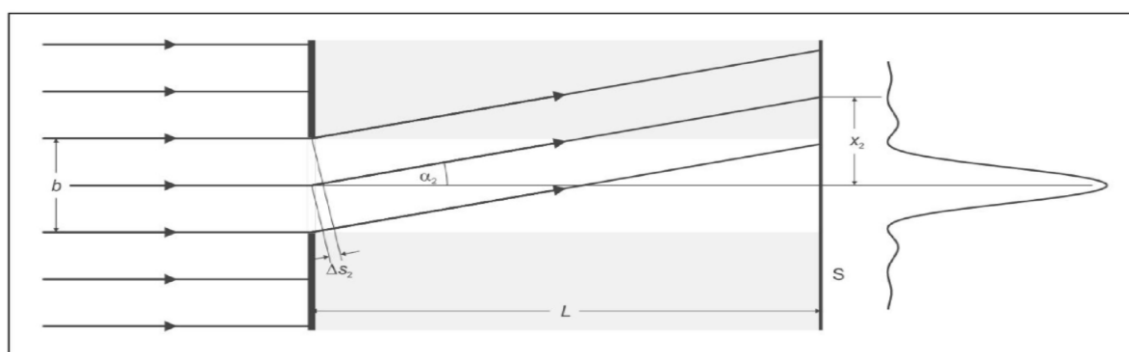


Figure 1. He-Ne laser light diffraction

From Figure 1, the diffraction equation in three slits (Dôme et al., 1991; Mukherjee, 1977) is:

$$d \sin \theta = n\lambda, \text{ in which } \sin \theta = \frac{y}{L}, \text{ leading to } d \frac{y}{L} = n \cdot \lambda \text{ or } \lambda = \frac{y \cdot d}{n \cdot L} \quad (1)$$

where:

y = distance between diffraction orders

d = distance between slits

L = grid distance to screen

λ = light wavelength

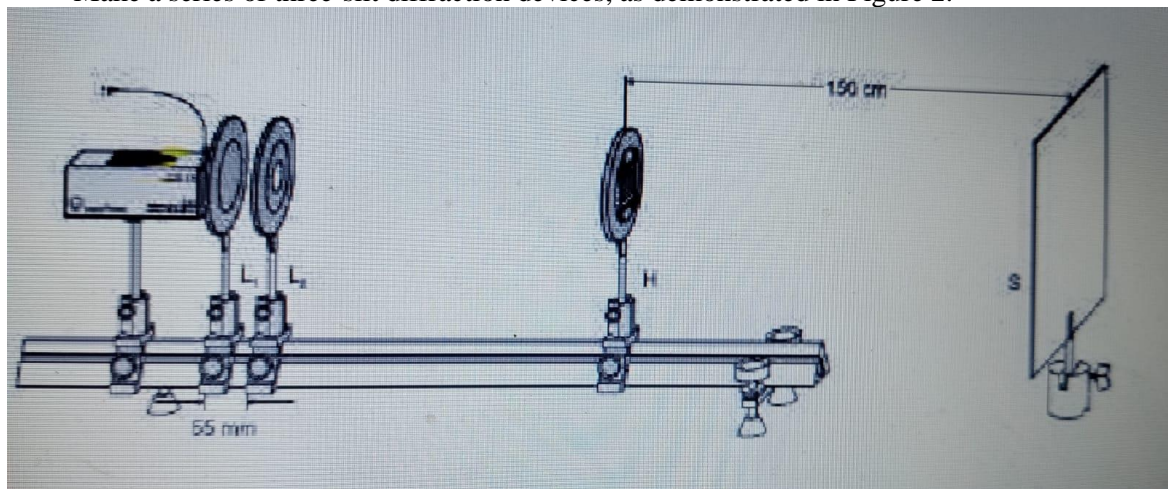
n = order

RESEARCH METHOD

Tools and materials in this experiment included a He-Ne laser, convex lens, single slit, double slit, caliper, ruler, screen, camera, and stand. Data were analyzed using regression analysis and MS. Excel. The light source was a He-Ne laser. A convex lens helped focus the light source beam. A single slit was used to produce a coherent light source. Many gaps produced diffraction patterns. A screen was used to capture the resulting diffraction pattern, and a camera was used to record diffraction patterns. This research uses an experimental approach, measuring the distance between gaps by varying the distance of the radiation source.

The location of this research is in the physics laboratory of the Mathematics and natural science education Department, Faculty of Teacher Training and Education, Universitas Jambi. The implementation is from August 10 2023 to October 30 2023. This research design uses experimental research, with tool settings as in Figure 2. The target of this research is to calculate the He-Ne laser wavelength by using two types of diaphragm diffraction methods.

Make a series of three-slit diffraction devices, as demonstrated in Figure 2.



(a)



(b)

Figure 2. (a) and (b) are research tool settings

Adjust the laser height to make the laser beam hit the center of the diaphragm. 3. Set the distance of the He-Ne laser beam to the spherical lens L1 with a focal length $f = +5$ mm at a distance of 1 cm from the laser (the laser should illuminate the diaphragm evenly). 4. Place a converging lens L2 with a focal length $f = +50$ mm at a distance of 55 mm behind the spherical lens L1 and slide along the optical bench towards the spherical lens L1 until the image of the laser beam on the screen is sharp. 5. The converging lens L2 on the optical mount is slightly further towards the spherical lens L1 until the diameter of the laser beam on the layer widens to 6 mm. 6. To check whether the diameter of the beam is constant between the lens and the screen, hold a piece of paper in the path of the beam and observe the cross-section of the beam along the optical axis. 7. Place the H diffraction object holder with the diaphragm on the optical bench at 50 cm from the laser. 8. Insert the diaphragm (N 469 91) right on the path traversed by the laser beam, and observe a three-slit diffraction pattern with a distance between the slits $A = 0.125$ mm; $B = 0.25$ mm and $C = 0.5$ mm one after another. Place the layer board S from the diffraction object H by 150 cm. Repeat Step 8 for a distance of $d = 0.25$ mm and observe the diffraction pattern with a layer distance of 320 mm. Take measurements at each distance d to determine the effect of the distance between the slits on the diffraction pattern. Photograph the diffraction pattern image on the screen by marking the pattern formed. Note the distance from the center of the light to the next light (orders 1, 2, and so on).



Figure 3. Diaphragm

In this study, variations in diaphragm type, distance between slits d and grid distance to screen L were carried out, then the diffraction pattern was observed by measuring distance between diffraction orders y . The data obtained in Table 1 is then calculated by using equation (1) $\lambda = \frac{y}{n} \cdot \frac{d}{L}$ so that the this calculation results are entered into Table 2, then the wavelength and order data are plotted in a graph, as in Figures 5, 6 and 7.

The data in Table 1 was analyzed using equation (1), namely $\lambda = \frac{y}{n} \cdot \frac{d}{L}$, finally the value of λ was obtained by substituting each value of d , L and y . Finally, the value of λ is obtained for each value of y_1 , y_2 and y_3 . Next, the average wavelength is calculated using the equation (Cavalieri et al., 2007; Mielenz, 1998; Thuan et al., 2015).

$$\bar{\lambda} = \frac{\sum_{n=1}^3 \lambda}{n} = \frac{\lambda_1 + \lambda_2 + \lambda_3}{3} \quad (2)$$

for different y values

RESULTS AND DISCUSSION

In this research, measured the distance between slits and the distance between diffraction patterns on a He-Ne laser using two types of diaphragms, namely three slit diaphragm in Table 1.

Table 1. Results of observing the distance between diffraction patterns for various d

Diaphragm types	d (mm)	L (mm)	y_1 (mm)	y_2 (mm)	y_3 (mm)
3 slit Diaphragm code 46987	0.125	1500	7.59	13.5	19.5
	0.250		4	7.5	11.5
	0.500		1.61	3.3	5.9
5 slit Diaphragm code 46986	0.250	320	0.8	1.7	2.6

Table 1 indicates that the greater the distance between the slits in a three-slit diaphragm, the smaller the separation distance between the bright center and the next bright center, for each order. Meanwhile, in the multi-slit diaphragm, the distance between the slits was 0.25 mm, and the separation distance between the bright center and the next bright center was greater. He-Ne laser diffraction results acquired by varying the distance between the slits presented in Figure 4.

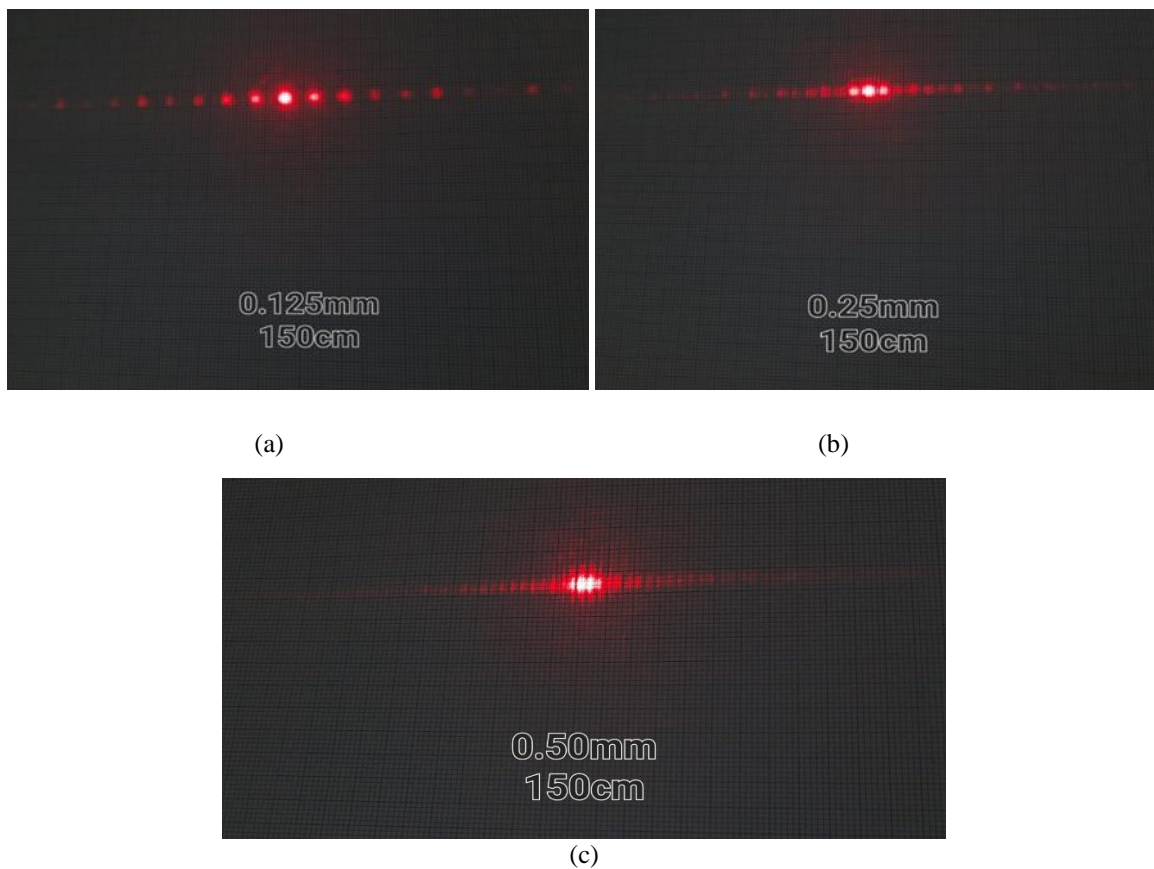


Figure 4. He-Ne laser diffraction for gap distances (a) $d = 0.125$ mm, (b) $d = 0.250$ mm, and (c) $d = 0.500$ mm

Figure 4 shows the diffraction results of He-Ne laser light for various variations in distance between slits using a single-slit diaphragm. The smaller the distance between gaps d , the greater the distance between orders y . Data in Table 1 were calculated using equation (1), and the results are displayed in Table 2.

Table 2. Calculation results of He-Ne laser wavelength, based on the order formed and the distance between the apses d

L (nm)	d (mm)	λ of order 1 (nm)	λ of order 2 (nm)	λ of order 3 (nm)	$\bar{\lambda}$ (nm)
150	0.125	632	562	541	578.67
	0.250	660	625	638	641
	0.500	536	550	650	578.33
320	0.250	625	680	677	660.67

Table 2 shows a variety of He-Ne laser wavelengths obtained, for each diffraction order (only observed up to the third order) and, for each diffraction order. For a three-slit diaphragm, the laser beam wavelength was calculated by varying the distance between the slits $d = 0.125$ mm, 0.250 mm, and 0.500 mm (Figure 5).

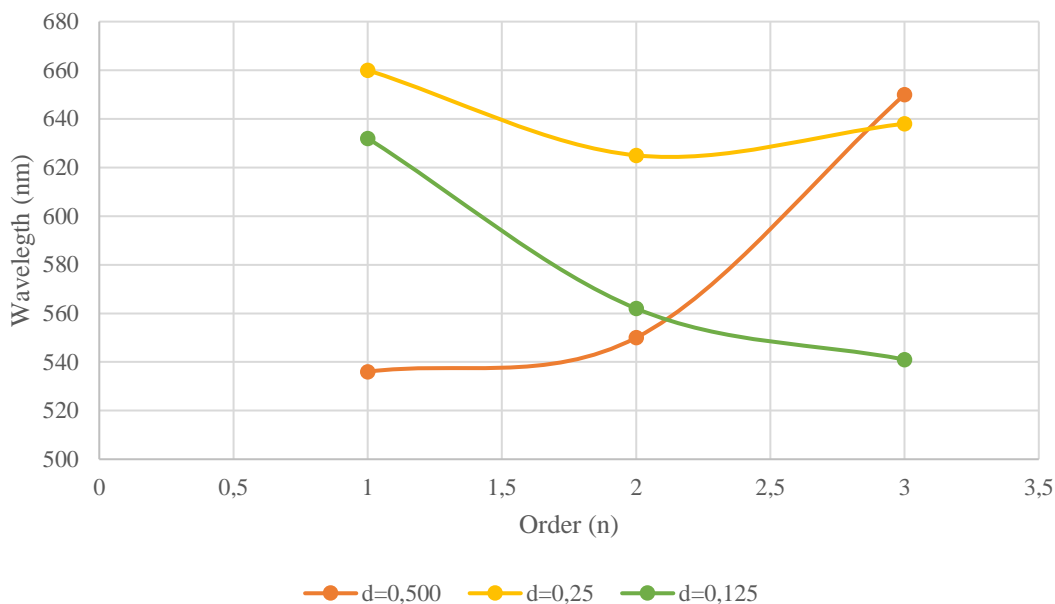


Figure 5. Diffraction order vs He-Ne laser beam wavelength at $d = 0.125$ mm, 0.250 mm, and 0.500 mm.

Figure 5 suggests, a graph of the relationship between wavelength and diffraction order for each measurement of the distance between the gaps d . Furthermore, by averaging the wavelengths obtained for each order and a certain distance between gaps, we obtained $\lambda = 578.67$ nm, which was the average wavelength of three orders at a distance between gaps of 0.125 mm; $\lambda = 641$ nm, the average wavelength of three orders at an inter-slit distance of 0.25 mm and $\lambda = 578$, the average wavelength of three orders at an inter-slit distance of 0.5 mm (figure 6).

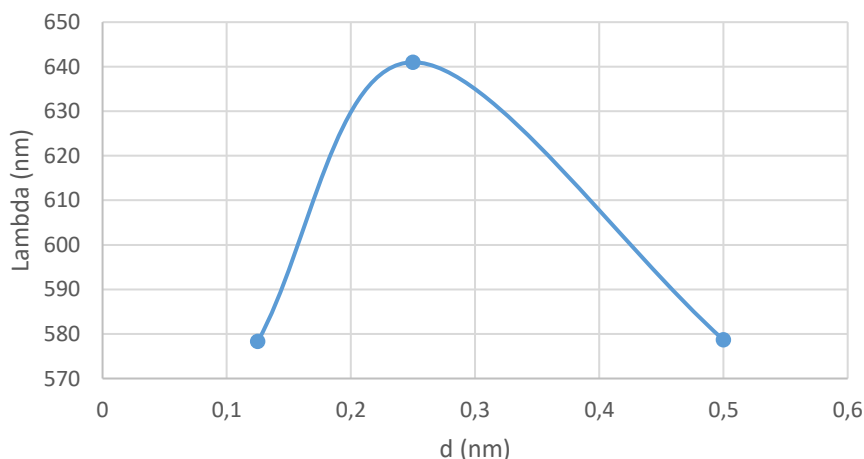


Figure 6. Graph of inter-slit distance d vs average wavelength of each order

Using a five-slit diaphragm, after calculating the wavelength of the He-Ne laser with a slit width of 0.25 mm, we acquired the wavelengths of the first, second, and third diffraction orders, which were $\lambda = 625$ nm, $\lambda = 680$ nm, and $\lambda = 677$ nm, respectively (Figure 7).

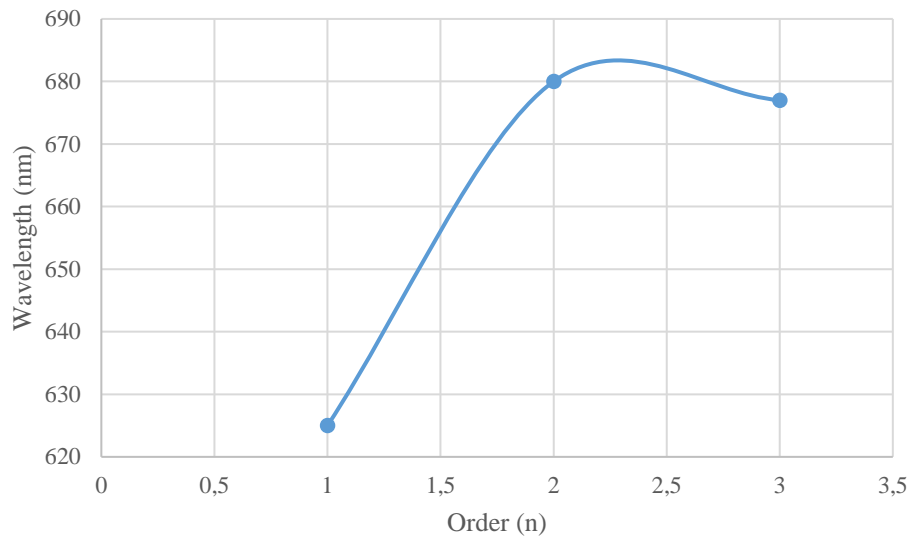


Figure 7. Graph of diffraction order vs wavelength using a five slit diaphragm

Figure 7 displays the wavelength of He-Ne laser light for each order at, constant distance between the gaps $d = 0.25$ mm. Following equation (1), the greater the distance between gaps, the smaller the distance between fringes. In diffraction experiments with a five slit He-Ne lasers, the distance between slits affected the fringe distance significantly. Furthermore, if the wavelength obtained for each order was averaged, the wavelength of the He-Ne laser light was 660.67 nm. According to (Cavalieri et al., 2007; Moen & Vander Meulen, 1970). The wavelength of the He-Ne laser was 632.8 nm, and accordingly. Thus, the wavelengths obtained in this research were within the range of wavelength measured by previous researchers.

The novelty in this research is being able to calculate the He-Ne laser wavelength by introducing a new method, namely the circular iris method which places a three-slit type diaphragm to measure various distances between the resulting diffraction patterns, then a five-slit type diaphragm is used and then the distance between the diffraction patterns is measured.

CONCLUSION

Grounded on the results, the greater the distance between gaps, the smaller the resulting wavelength as the distance between orders was greater. Additionally, results showed the wavelengths of the He-Ne laser based on variations in the distance between slits: $\lambda = 578.67$ nm, 641 nm, 578.33 nm using a three-slit diaphragm and $\lambda = 660.67$ nm using a five-slit diaphragm. From the calculation results, the He-Ne laser wavelength is in accordance with the literature from previous research. It has been proven that using the circular method the wavelength length of the He-Ne laser can be determined.

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AUTHOR CONTRIBUTIONS

In carrying out this research, tasks were divided among all research members team. The first author (Sri Purwaningsih) as the main researcher was responsible for all stages of the research, in particular in the process of planning and interpreting research results, the main author of this article. The second writer (Hebat Shidow Falah) as Research members are tasked with preparing research tools. third author (Neneng Lestari) and fourth the author (Hardiantinus Sitinjak) as a research member was responsible for preparing the diaphragm. Meanwhile, the Fiveth author (Almahdi Mousa) carried out the data analysis process.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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