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A Comparative Study on Beam Divergence Angle and Wave Length between Semiconductor Laser and Helium-Neon Laser

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ABSTRACT

In this experimental study, I have seen that a comparative study on semiconductor laser and Helium-Neon laser is presented using the experimental techniques and tried to compare the experimental value with that of the theoretical one. On this work the wave length and beam divergence angle of the two types of lasers up to ten number of trials in the three orders, starting from 20cm to 200cm, with an interval of 20cm for each order was measured and I found that in the first and second order in the two types of laser , the wave length and the divergence angle is greater for Helium-Neon laser than semiconductor laser, thus, from this it is possible to understand that semiconductor laser is highly directional, means that it has high intensity, whereas, in the third order the Helium-Neon laser is not visible but semiconductor laser is visible, which is one of the indicator of Helium-Neon laser is not highly directional. And again, I examine that the beam divergence angle and wave length can have inverse relationship for the two types of lasers, as we see from figure 2.1 and 2.2. Thus, we concluded that the experimental result is almost agreed with that of the theoretical one.

Keywords: *directionality, divergence angle, wavelength*

INTRODUCTION

The term laser is an acronym for light amplification by stimulated emission of radiation. The laser was the first device capable of amplifying light waves themselves. The emitted laser light is a spatially coherent, narrow low-divergence beam, when the waves (photons) of beam of light have the same frequency, phase and direction, it is said to be coherent [1]. Laser light is the study of emitting coherent electromagnetic radiation and they have assumed tremendous importance in the fields of science and technology because of their impact in both basic researches as well as in various technological applications [2]. They can be found consumer, goods and services such as music players, laser printers, scanners for product identification, industrial like that of metal cutting, welding, hole drilling, marking, medical surgery and applications of scientific research [3]. Laser light is available in all colors from red to violet and also far outside the conventional limits of the optical spectrum over wide portion of the available range laser light in different fields [4].

Laser light exactly the same color or monochromatic which means a single wave is occurred in laser light in one of the main characteristics of laser light is coherent, which described laser light different from light produced by any other sources of light wave produced by laser leave the larger traveling in very nearly the same direction [5]. One result of this directionality is that larger beam is focused to a very small spot, greatly increasing its intensity. The laser light is generally different characteristics such as coherence, directionality, monochromaticity, and high intensity [6]. When laser light is power full (high intensity) in a smallest wave length or in the largest frequency [7]. In fact that different wave length experience different propagation and therefore travels with different velocity casing a longer temporal pulse at the end of the fiber [8].

Laser can have various types among them in my study mainly; I am trying to focus on semiconductor laser and helium- neon laser. Semiconductor laser, which is electrically pumped laser. It is unique when compared to other types of laser [9]. They are very small; they operate in a different way in that they require the merging of two different materials and the laser action occurs in the interference between those two materials. One of the materials has an excess of electron (n-type) and the other material (p-type) has a deficit of electron [10, 11]. A semiconductor laser is used in the field of long distance communication and in compact disk players. Other uses of semiconductor laser includes high speed printing free space communication, pump sources for other solid state lasers (including fiber amplifiers), laser pointers, and various medical applications [11, 12]. The semiconductor laser is highly directional than Helium-Neon laser, because it is highly convergent laser [12, and 13].

Helium-Neon laser was one of the first lasers ever developed and is still one of the most widely used lasers. The lasers are trouble free and have extremely long operating lifetimes. They operate in low-pressure mixture of helium and neon gases, and the laser transitions occur within the neutral atomic species. The most common wave length is 632.8nm transition in the red position of the spectrum [13, 14]. Thus, we know that laser can have wide verities of applications and types, in this study mainly, I am trying to focus on the two types of lasers and say something about their beam divergence angle versus wave length and identifies, which laser types is highly directional, because according to the theoretical explanation the semiconductor laser is highly directional than Helium-Neon laser, now I was tried to verify this by experiment.

2.Objectives

2.1 General objective:

The general objective of this research work is to study about the beam divergence angle and wave length between semiconductor laser and Helium-Neon laser.

2.2. Specific objective:

The specific objectives of this research work are:

- To determine the beam divergence angle of semiconductor laser and Helium-Neon laser

- ❖ To determine the wave length of semiconductor laser and Helium-Neon laser
- ❖ To explain the relationship between wave length and divergence angle for the two types of laser
- ❖ To identify which laser type is highly directional

MATERIALS AND METHODS

3.1 Study area:

The University is found at Debre Markos town which is located in north western part of Ethiopia. The town is 300 Km's North West of the capital, Addis Ababa and 265 Km's south east of Bahir Dar, the capital of Amhara National Regional State. It is geographically located at 10020'N37043'E/10.3330N37.7170E with an average altitude of 2446m above sea level. It has conducive weather condition with1380 mm average annual rainfall and 180c average annual temperature.

According to the municipality's report, the town has over 123,000 residents of which 97 percent are Amhara and the remaining three percent are from Agaw, Oromo, Tigre and others nations. Although there are various religions (orthodox Christians, Muslims and Evangelical Christians), most of the dwellers are Orthodox Christian.

The University is found in the area endowed with potential resources, such as the Choke Mountains water-shade which covers six different agro-ecology zones within 50km radius with various bio-diversity and the source of many tributaries to the Nile, and Upper Blue Nile Gorge.

Around the vicinity of the University, there are historic, renowned and ancient church schools: Dima Giorgis, Mertule-Mariam, Debre Work Mariam and Debre Elias, etc. These schools played significant role in the development of modern education in Ethiopia. Prominent scholars who have contributed for the development of education and Ethiopian literature were the products of these traditional schools.

On the other hand, the university is found in the area with high environmental degradation such as soil erosion and degradation, deforestation, depletion of wet lands and reduction of water bodies. All these potentials and challenges are great opportunities for the university to effectively manage the teaching-learning, undertake research, and provide community service activities with wider applicability of the results. Thus, this research is mainly conducted in this university department of physics laboratory.

3.2.Materials

To conduct the experiment and collect the data the following instruments was used: grating (300lines/mm), helium-neon laser (red), semiconductor laser (green), screen, holder, ruler, and table.

3.3.Data collection:

To collect the data by using the above listed instruments, I have tried to setup the instruments as such given below:

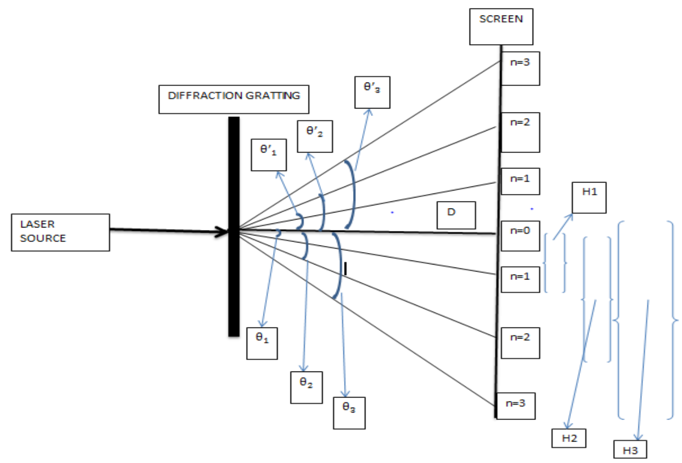

Figure.1. Experimental setup for theoretical calculations

And again by using the correct experimental procedures one by one to their order the following data's were recorded. By using the following experimental setups shown in the figure below:

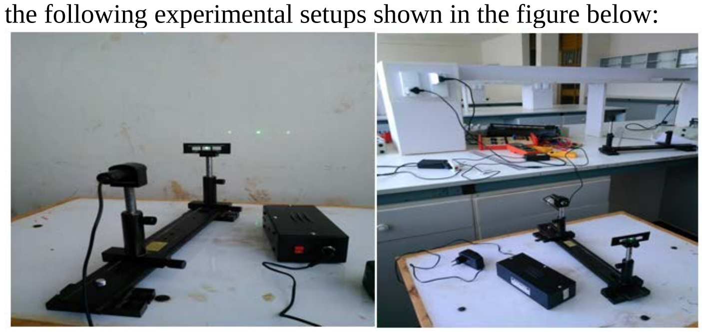

Figure .2. Experimental setup for experimental measurements

Table .1. The laser source is semiconductor laser

Trial no.	Order (m)	D (cm)	H_n (cm)			$\theta = \tan^{-1}\left(\frac{H_n}{D}\right)$	sinθ	λ (m)
			LHS	RHS	Mean			
1	1	20	3.5	3.2	3.35			
2	2	20	7	6.8	6.9			
3	3	20	11.7	11.1	11.4			
4	1	40	6.5	6.7	6.6			
5	2	40	13.9	13.8	13.85			

6	3	40	22.6	22.5	22.55			
7	1	60	10	10	10			
8	2	60	21.2	20.4	20.8			
9	3	60	35	33	34			
10	1	80	13.4	13.2	13.3			
11	2	80	28	27.5	27.75			
12	3	80	45	44.2	44.6			
13	1	100	16.6	16.5	16.55			
14	2	100	34.6	34.4	34.5			
15	3	100	55.9	55.8	55.85			
16	1	120	19.9	19.9	19.9			
17	2	120	41.4	41	41.2			
18	3	120	67	66.8	66.9			
19	1	140	23	23	23			
20	2	140	47.5	47.5	47.5			
21	3	140	76.1	79	77.55			
22	1	160	26.2	26.6	26.4			
23	2	160	54	56.2	55.1			
24	3	160	86.4	92.5	89.45			
25	1	180	29.2	29.8	29.5			
26	2	180	60.9	62.5	61.7			
27	3	180	97.7	102.8	100.25			
28	1	200	33.3	33	33.15			
29	2	200	69.5	68.5	69			
30	3	200	113	111	112			

Table .2. The laser source is Helium-Neon laser

Trial no.	Order (m)	D (cm)	H_n (cm)			$\theta = \tan^{-1}\left(\frac{H_n}{D}\right)$	$\sin\theta$	λ (m)
			LHS	RHS	Mean			
1	1	20	4.3	4.2	4.25			
2	2	20	9.3	8.5	8.9			
3	3	20	------	------	-------			
4	1	40	8.4	8	8.2			
5	2	40	18.3	16.4	17.35			
6	3	40	------	-------	---------			
7	1	60	12.5	11.7	12.1			
8	2	60	28	23.7	25.85			
9	3	60	------	------	-------			
10	1	80	16.4	15.5	15.95			
11	2	80	35.8	32	33.9			
12	3	80	-----	------	--------			
13	1	100	20.7	19.6	20.15			
14	2	100	46	39.6	42.8			
15	3	100	-----	-----	------			
16	1	120	24.5	23.3	23.9			
17	2	120	54	47.7	50.85			
18	3	120	-----	-----	-------			
19	1	140	29	27.4	28.2			
20	2	140	64.8	55.3	60.05			
21	3	140	-----	------	---------			
22	1	160	32.2	32	32.1			
23	2	160	69	66.6	67.8			
24	3	160	-----	------	--------			
25	1	180	36.4	35	35.7			
26	2	180	78.5	72.5	75.5			

27	3	180	------	------	-------			
28	1	200	42.5	38.8	40.65			
29	2	200	96	78.3	87.15			
30	3	200	-----	------	-------			

And the rest parameters i.e. the beam divergence angle and the wave length for each order and each laser types can be calculated from the following formulas: [14]

To calculate the wave length:

$$m\lambda = a\sin\theta \qquad (1)$$

And also to find the beam divergence angle:

$$\theta = \tan -1 \left(H_n / D\right) \qquad (2)$$

a , is the number of lines per meter in the grating in lines/mm, which is called as the grating element and defined as the distance between two consecutive slits (lines) of grating.

H_n, is the distance of the spot from the central maximum in m

D, , is the perpendicular distance between grating and the scale in m

m, is the order of the spectrum

Again, after calculating the possible values, the result can be summarized as in the following table, for the two types of lasers:

Table .1. The laser source is semiconductor laser

Trial no.	Order (m)	D (cm)	H_n (cm)			$\theta = \tan^{-1}\left(\frac{H_n}{D}\right)$ In degree	$\sin\theta$	λ (m)
			LHS	RHS	Mean			
1	1	20	3.5	3.2	3.35	9.50877	0.1652	5.51×10^{-7}
2	2	20	7	6.8	6.9	19.034434	0.3262	5.43×10^{-7}
3	3	20	11.7	11.1	11.4	29.68314	0.4952	5.50×10^{-7}
4	1	40	6.5	6.7	6.6	9.369385	0.1628	5.43×10^{-7}
5	2	40	13.9	13.8	13.85	19.098412	0.3272	5.45×10^{-7}
6	3	40	22.6	22.5	22.55	29.41212997	0.4911	5.456×10^{-7}
7	1	60	10	10	10	9.46232	0.1644	5.458×10^{-7}
8	2	60	21.2	20.4	20.8	19.1197	0.3275	5.459×10^{-7}
9	3	60	35	33	34	29.53878	0.4930	5.478×10^{-7}
10	1	80	13.4	13.2	13.3	9.4391	0.1640	5.466×10^{-7}
11	2	80	28	27.5	27.75	19.1304	0.3277	5.462×10^{-7}
12	3	80	45	44.2	44.6	29.13966	0.48694	5.4104×10^{-7}
13	1	100	16.6	16.5	16.55	9.3973	0.1633	5.443×10^{-7}
14	2	100	34.6	34.4	34.5	19.03443	0.3261	5.4356×10^{-7}
15	3	100	55.9	55.8	55.85	29.1834	0.4876	5.4178×10^{-7}
16	1	120	19.9	19.9	19.9	9.415859	0.1636	5.453×10^{-7}

17	2	120	41.4	41	41.2	18.949	0.3247	5.4121×10^{-7}
18	3	120	67	66.8	66.9	29.1396	0.4869	5.4104×10^{-7}
19	1	140	23	23	23	9.3295	0.1621	5.4038×10^{-7}
20	2	140	47.5	47.5	47.5	18.7413	0.3213	5.3549×10^{-7}
21	3	140	76.1	79	77.55	28.9833	0.4845	5.3839×10^{-7}
22	1	160	26.2	26.6	26.4	9.3693	0.16279	5.4266×10^{-7}
23	2	160	54	56.2	55.1	19.0024	0.3256	5.4268×10^{-7}
24	3	160	86.4	92.5	89.45	29.2079	0.48798	5.422×10^{-7}
25	1	180	29.2	29.8	29.5	9.30739	0.161731	5.391×10^{-7}
26	2	180	60.9	62.5	61.7	18.92057	0.292847	4.8808×10^{-7}
27	3	180	97.7	102.8	100.25	32.35042	0.486569	5.4063×10^{-7}
28	1	200	33.3	33	33.15	10.4569	0.163519	5.4506×10^{-7}
29	2	200	69.5	68.5	69	21.14937	0.3261	5.4356×10^{-7}
30	3	200	113	111	112	32.498695	0.4886	5.4289×10^{-7}

Table .2. The laser source is Helium-Neon laser

Trial no.	Order (m)	D (cm)	H_n (cm)			$\theta = \tan^{-1}\left(\frac{H_n}{D}\right)$ In degree	sinθ	λ (m)
			LHS	RHS	Mean			
1	1	20	4.3	4.2	4.25	13.32988	0.207858	6.9286×10^{-7}
2	2	20	9.3	8.5	8.9	26.6545	0.406562	6.776×10^{-7}
3	3	20	------	------	-------	-----	------	-------
4	1	40	8.4	8	8.2	12.87236	0.2008	6.6941×10^{-7}
5	2	40	18.3	16.4	17.35	26.0542	0.39793	6.6322×10^{-7}
6	3	40	------	-------	---------	------	------	------
7	1	60	12.5	11.7	12.1	12.668581	0.19768	6.5896×10^{-7}
8	2	60	28	23.7	25.85	25.897764	0.39567	6.5946×10^{-7}
9	3	60	------	------	-------	-----	------	--------
10	1	80	16.4	15.5	15.95	11.275495	0.1955	6.5176×10^{-7}
11	2	80	35.8	32	33.9	22.9648	0.39016	6.5028×10^{-7}

12	3	80	-----	------	--------	------	-----	-------
13	1	100	20.7	19.6	20.15	11.392546	0.197529	6.5843×10^{-7}
14	2	100	46	39.6	42.8	23.171	0.39348	6.5579×10^{-7}
15	3	100	-----	-----	------	-----	-------	---------
16	1	120	24.5	23.3	23.9	11.2640	0.19533	6.511×10^{-7}
17	2	120	54	47.7	50.85	22.965	0.39017	6.5028×10^{-7}
18	3	120	-----	-----	-------	-----	-------	-------
19	1	140	29	27.4	28.2	11.3886	0.19746	6.5821×10^{-7}
20	2	140	64.8	55.3	60.05	23.255875	0.3942	6.5699×10^{-7}
21	3	140	-----	------	---------	-----	-----	-----
22	1	160	32.2	32	32.1	11.34436	0.19671	6.5568×10^{-7}
23	2	160	69	66.6	67.8	22.9648	0.3902	6.5028×10^{-7}
24	3	160	-----	------	--------	------	--------	-------
25	1	180	36.4	35	35.7	11.2181	0.194544	6.4848×10^{-7}
26	2	180	78.5	72.5	75.5	22.75534	0.386796	6.4466×10^{-7}
27	3	180	------	------	-------	------	-------	--------
28	1	200	42.5	38.8	40.65	11.4888	0.199176	6.6392×10^{-7}
29	2	200	96	78.3	87.15	23.5452	0.3995	6.6579×10^{-7}
30	3	200	-----	------	-------	-------	-------	-------

Based on the above given table 1 and table 2 we have the following wave length vs. beam divergence angle for semiconductor laser and He-Ne laser, for figure 3 and figure 4 given below, respectively:

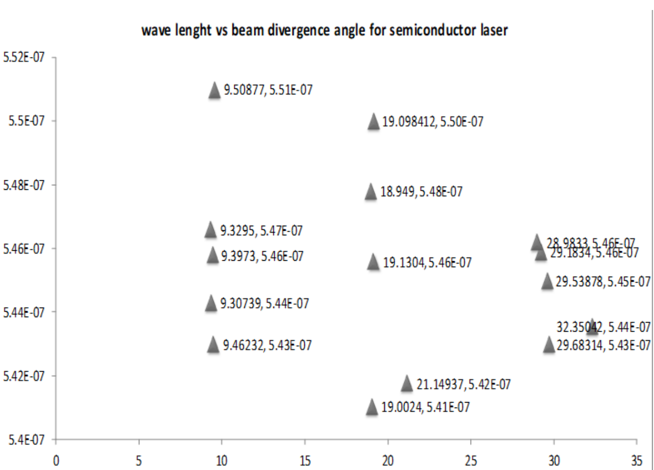

Figure .3. Wave length vs. beam divergence angle for semiconductor laser

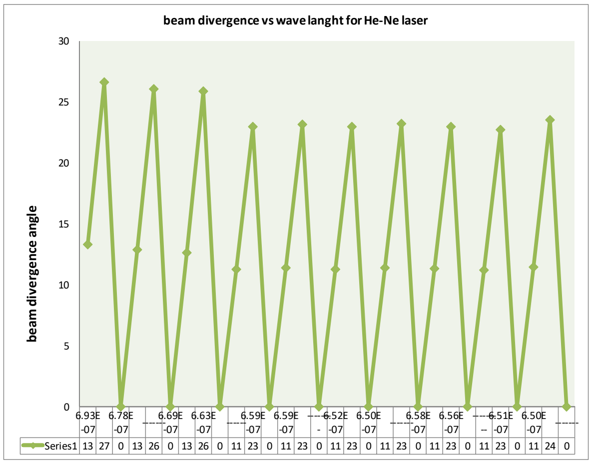

Figure .4. Wave length vs. beam divergence angle for He-Ne laser

Result and Discussion

As we see from the above tables 1 and 2 and figures 3 and 4 we examine that the relationship between beam divergence angle and wave length for each order and each number of trials, in the first order and second order measurement starting from trial one up to the last trial, the Helium-Neon laser can have high beam divergence angle and also wave length, but semiconductor laser can have low beam divergence angle and wave length but in the third order trial Helium-Neon laser is not visible, whereas, semiconductor laser is visible, thus, from this result we examine that the semiconductor laser has highly directional than Helium-Neon laser. And also, for the two types of laser the beam divergence angle and wave length can have inverse relations.

Conclusion

In this work, I have presented an experimental analysis of the two types of laser of their wave length and beam divergence angle for ten numbers of trials. Thus, from this study the result indicates that for the two types of laser the phenomenon of beam divergence angel and wave length can be calculated but for Helium-Neon laser in the third order calculation is not possible, which is not visible. And also, I have seen in both types of laser up to second order, the wave length and beam divergence angle can have inverse relations and we can say that, since, semiconductor laser is electrically pumped it is highly directional and intense than Helium-Neon laser. Thus, I concluded that the experimental result is almost agreed with the theoretical one.

1. Recommendation

After doing the research, the researcher can forward the following points as recommendation for the future researcher. If anyone, who is interested to do further study on this topic and related topics, a number of trials and orders should be greater than what I used in this study.

2. Acknowledgment

First and for the most, I would like to thank the almighty God for giving me strength to do this research paper. Secondly, my deepest and whole gratitude goes to my family specially my beloved child Yonatan Senamaw with his Mother Kelebie Tamiru for their moral and financial support, encouragement and advice throughout my education and my study at large.

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