Investigation of Laser Diode Coherence and Fringes Visibility

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Abstract

This paper investigates the experiment work of laser diode coherence properties which are the most fundamental property. In this experiment a scientific instrument designed which called Michelson interferometer to measure a beam of light that splitting it into two equal halves by using a beam-splitter which one of the beams called reference beam and the second beam travels an extra distance, so it gets slightly out of the phase. the output power is measured by photo-detector as a function of the input current in order to determine threshold current, because of the laser diode is sensitive to temperature, which it set to25°C, the measured results was above the threshold current because laser diode

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may be unstable around threshold current. Also the wavelength was modulated in order to generate fringes, the visibility of fringes was observed clearly at current above threshold current. Although the wave rising and falling pattern of peaks and troughs shine and get a characteristic pattern of light and dark areas. The degree of coherence of a laser beam reflects the extent to which the phase of a light wave is preserved in time that is temporal coherence laser coherence that is the phase of laser determined accurately where the path difference is less than the coherence length of the laser diode.

Keywords—*fringes visibility; threshold; optical path, Diode.*

1. Introduction

This paper presents principles of one scheme of unique instrument which is known as Michelson interferometer in terms of Its composition, multiplicity of purposes and main applications over wide range of operational conditions, The main parts of this device consist of two well-polished plane mirrors(M_1,M_2), and beam splitter (BS) is lightly brushed so that the beam (1) coming from the source (S) which is divided into two beams of equal beam (2) and beam (3) and the two beams that are window (3) an reflected (2) from the beam splitter BS are transmitted towards the two mirrors(M_1,M_2), the beam that is reflected vertically from a mirror M_2 through the plate BS for the third time and reaches the eye, as well as the beam that is reflected (2) from the mirror M1 for the second time to reach the eye in the form of a beam (4). The mirror M_1 is installed on a movable piece equipped with a micrometric ruler that can be moved forward and backward and to get the fringes, the two mirrors are adjusted so that they are completely perpendicular using the adjustment screws behind the mirror M_1 as shown in figure 1 which has two orthogonal optical axes. This visual system can be represented by an optical system with one visual axis, by replacing the real mirror M_1 with her estimated image M_1^- which formed by the reflection from the BS, where M_1^- is parallel to the mirror M_2. Because of the multiple reflections in the real interferometer, we can assume that the source S is behind the observed figure 2, and the observer sees it through the two mirrors M_2, M_1^- and the two virtual images act as sources S_1, S_2 interconnected in phase. If the distance d between M_2, M_1^- then the distance between the two imaginary sources is 2d. [1, 2].

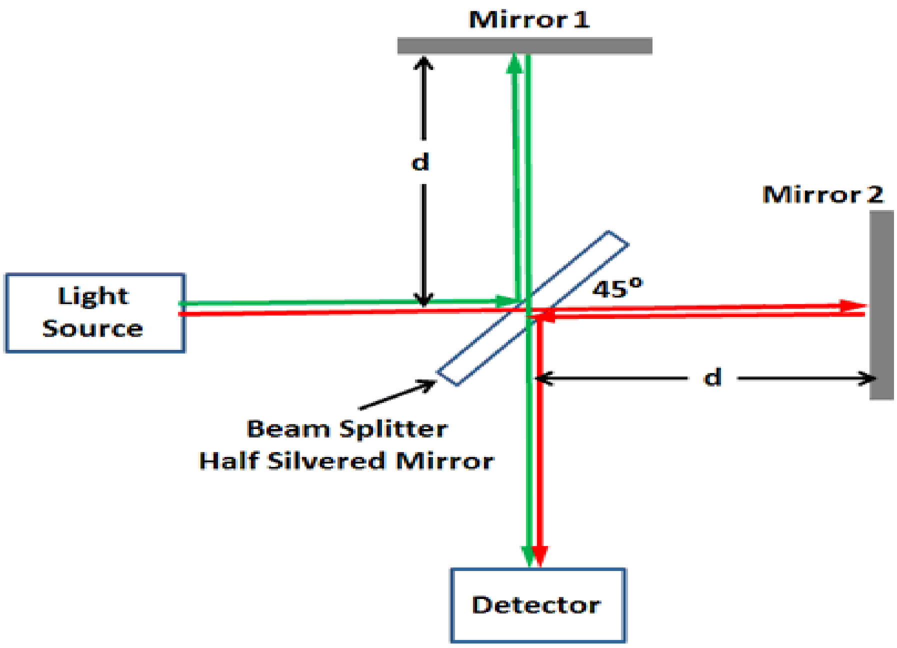

Figure 1 a simple schematic of the Michelson interferometer

It can notice that the path difference between the two beams connecting to the eye at the two points P1, P2 is 2dcosθ, and θ is the angle of inclination of the beam from the axis of the vertical and of the vertical fall i.e when it is θ= 0 and the path difference is Δ_p=2d, and this result is expected for us because when one of the two mirrors is away from the BS splitter plate by a distance d, the path difference is 2d and since the angle θ is fixed when mλ is fixed, then the end of the serpent will be the form of circular cilia around the line between the viewer's eye and the two mirrors. The degree of coherence of a laser beam reflects the extent to which the phase of light wave is preserved in time that is temporal coherence, and spatial coherence which in space, the coherence length is related to the coherence time, the coherence of laser diode is the most fundamental properties of laser light, and distinguished it from the light from other source. Thus, a laser maybe defined as a source of coherent light. The importance of coherence cannot be understood until other concept have been introduced, but evidence of the coherence of laser light can be observed easily by using Michelson interferometer which splits a light beam into two by the beam splitter which are returned to the beam splitter where the fringes are observed.

2. Fringes formed by the Michelson Interferometer:

When using the Michelson interferometer different types of fringes can be observed in the field of view of the device, such as circular fringes (of equal inclination) and straight fringes (of equal thickness) and colored fringes depending on the type of position of the two mirrors M_1,M_2 and the nature of the light used with the scale. Each of these types is used in a specific application field, for example, circular fringes can be obtained when the two mirrors are completely perpendicular, and the light source used is monochromatic (such as the source used in this experiment). These circular fringes are used in most types of interferometer measurements. The diagram in the figure 2 shows the vertically reflected ray from the two mirrors being in the same phase while the light rays reflected at different angles are in different phases. [1, 2].

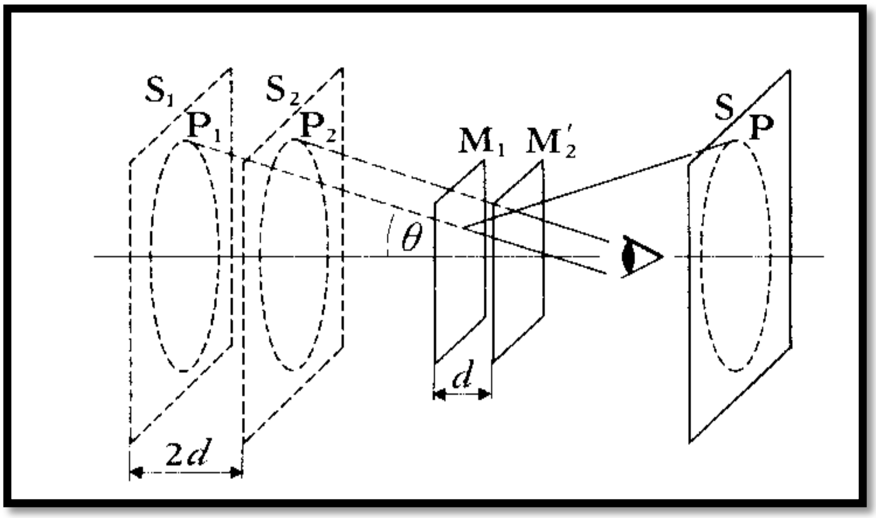

Figure 2 Radiograph of the michelson interferometer in one optical axis

3. Theory of laser diode coherence:

Precise measurements of lengths and dimensions can be made in terms of the wavelength of light. For example, when moving the mirror in the figure 1 slowly from one location to another, the fringes either enter or appear in the centre of the field of vision of the device, and the number of fringes that enter the centre of the field of vision is a measure of the length or the distance moved by the mirror in terms of the wavelength used λ. In the case of the vertical fall of light, the position of the mirror M_2 is X_1 the corresponding to the dark fringe in the rank m_1 and is given by the following relationship: -

$$2X_1=m_1\lambda \qquad (1)$$

Likewise, the second position of the mirror X_2 which corresponding to the dark fringe m_2 is given by the following relationship: -

$$2x_2=m_2\lambda \qquad (2)$$

by subtracting the equation 1 from the equation 2, we find that

$$\Delta X = x_1 - x_2 = \Delta m\frac{\lambda}{2} \qquad (3)$$

therefore, the distance through which the mirror M_2 moved is equal to the number of fringes that have been counted, and it is not necessary that this distance be equal to an integer in half-wavelengths, and it can reach parts. In "wavelength" if the measurement is carried out accurately. Thus, the wavelength can be measured with an accuracy of 1% of the wavelength. the interference fringes quality can be described quantitatively in terms of fringes visibility (v) which is defined as:

$$v = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \qquad (4)$$

where , I_{max} and I_{min} are the maximum and minimum values of the irradiance in the interference pattern.

The visibility is correspond to the module of γ which in the case of typical Michelson interferometer that having equal irradiances in the superposed beams can be expressed as :

$$v = 2\gamma\frac{\sqrt{I_{max} I_{min}}}{I_{max} + I_{min}} \qquad (5)$$

In the case of complete coherence where (γ=1), the fringes visibility is equal to the modules of γ.

So, the interference fringes have the maximum contrast (v=1), whereas, for complete incoherence where (γ=0) , the visibility fringes is (v=0) which mean there are no interference fringes. [3-6].

4. Apparatus and experimental procedure:

The Apparatus and experimental procedure are summarized in the following points: -

- The experimental set up is as shown in figure 1 , It Modulated the temperature to 25°C because laser diode is sensitive to temperature so may be un stable at above this degree and it has Measured the power output by photo-detector as function of input current in order to determined threshold current of laser then have been Setup Michelson interferometer by modulation the laser current by modulating laser wave length and Measure the max and min intensity in order to obtain the visibility of fringes and also, Figure out the distance and the visibility .[7, 8].
- in order to obtain the largest possible number of interference fringes, the two mirrors of the interferometer must be all adjusted and first of all the lens should be removed and the laser beam strikes the half-silvered mirror at an angle 45°° splitting the beam so, the resulting two beams are reflected by the mirror and impinge on the screen and by adjusting the two screws fitted to one of the mirrors. if the lens is mounted in the light beam the points of light are enlarged and the interference patterns are observed on the screen (bands, circles) and by adjustment carefully an interference image of concentric circles will be obtained.
- To measure the wavelength, the micrometer screw must be turned to any initial position at which the centre of the circles is dark then by carful the micrometer screws is now further turned in the same direction and the light-dark periods thus produced are counted. The distance travelled by the mirror must be read off on the micrometer screw and divided by ten lever reduction 1:10. The central point of the circles should be moved outside the light spot area a readjustment has to be performed. [9,10].

- Figure out the Fringe visibility as a function of optical path difference in (mm) and find out coherence as a function of pump laser.

4. Results and discussion:

4.1 Measurement of the lengths and dimensions:

Precise Distance Measurements by Michelson Interferometer A red laser light of wavelength 632 nm is used in a Michelson interferometer. While keeping the mirror M1 fixed while the mirror M2 is moved. The fringes are found to move past a fixed cross-hair in the viewer. the distance of the mirror d is moved for a single fringe to move past the reference line.

4.2 Measurement the output power as function of current:

The results shown below correspond by using laser diode where λ=632nm, When the laser diode starts lasing that means get threshold current where the ideal laser diode shows a linear curve. the shift of threshold current is due to the temperature dependency of the carrier concentration of the active layer. we measured the output power as a function of current shown in figure 3 . The result obtained is show in the figure 3 which a nonlinear relationship between output power (v) of the laser and current (mA).

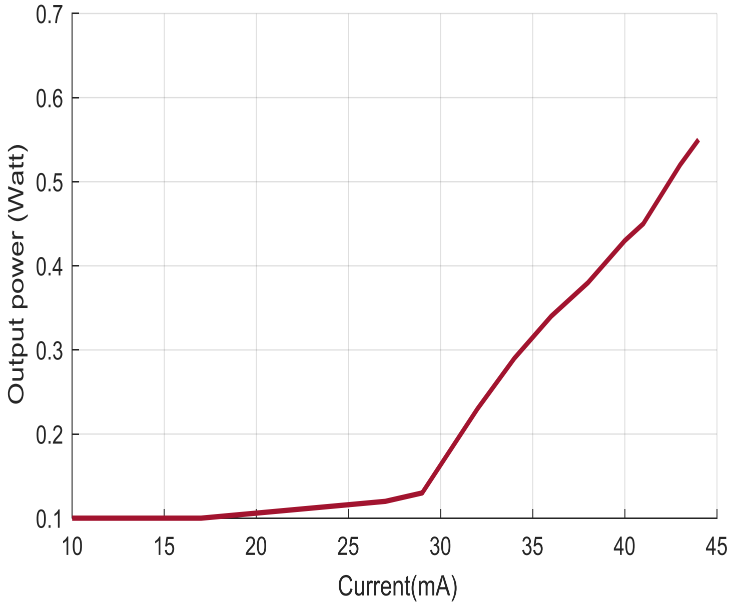

Figure 3 shows output power as a function of current

4.3 Measurement_fringe visibility as function of optical path difference:

When the laser is operating at single frequency the fringe contrast is unaffected by path length difference but when the laser was oscillating at several frequencies we saw that there were positions where the fringe contrast went to zero. The contrast was seen pretty good as shown in figure 4 . The constructive area are places where the two light beams have added together so become brighter but when the beams have subtract from one another then darek areas are places. the exact pattern of interfering depends on the different way of the distance that one of the beam has traveled.

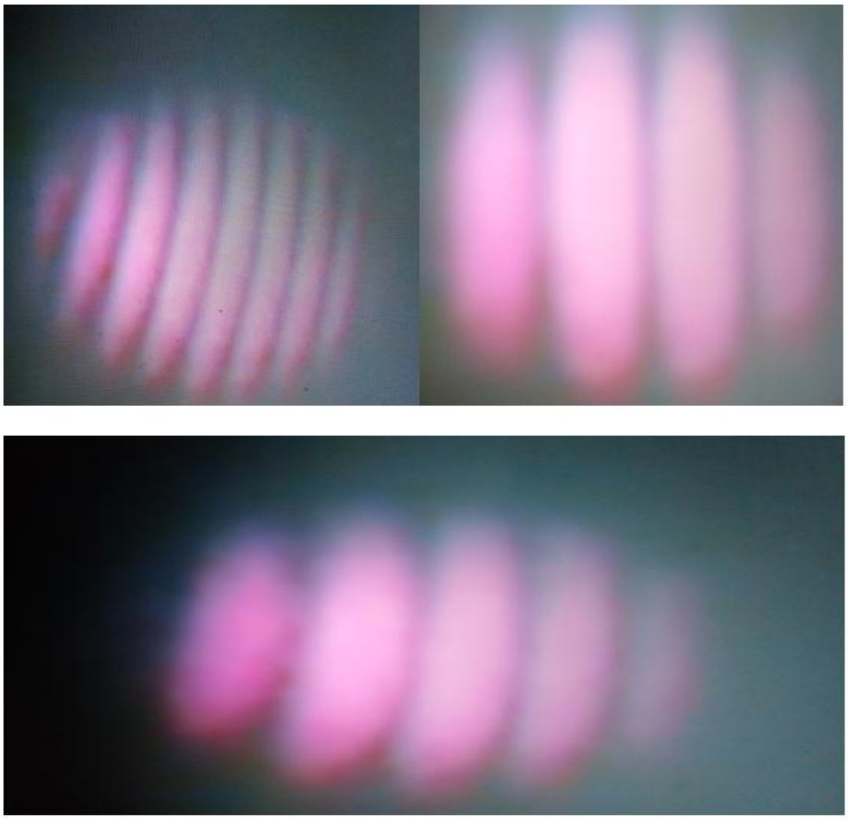

Figure 4 fringes visibility of the laser diode coherence.

It can be seen that there is a connection between the laser cavity and the length of the laser and the position of good fringe contrast in the interferometer contrast deteriorate when the laser is oscillating at several frequencies. It finds the relationship between optical path difference (ΔL) and fringe visibility as shown in figure 5 and the averaged visibility measurement at 8ps.

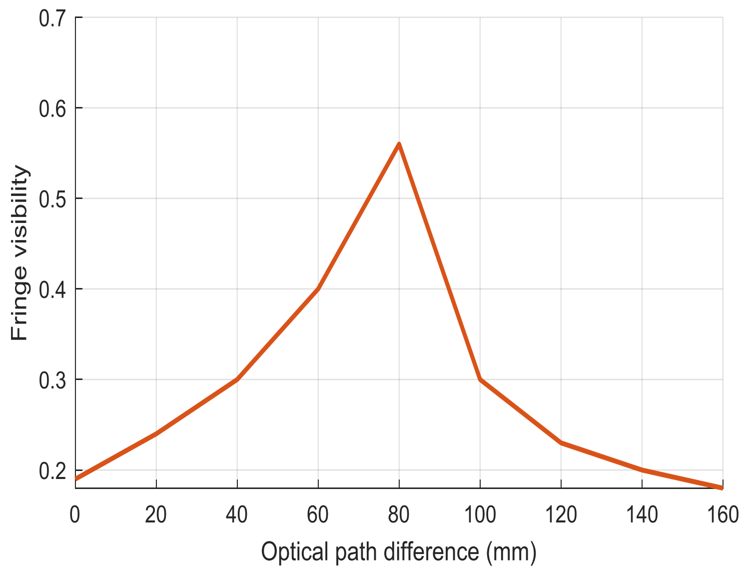

Figure 5 fringe visibility as a function of optical path difference.

4.4 Measurement coherence as function of pumping laser:

The most common way to measure the coherence length or as known a line width of a laser is with an interferometer method the coherence functions are also calculated from these frequencies as a function of laser pumping power as illustrated in figure 6. It can produce the simplest interferometer in zero length difference in fringes visibility between its two optical paths which by this Michelson interferometer determination which depend on the spectral characteristics.

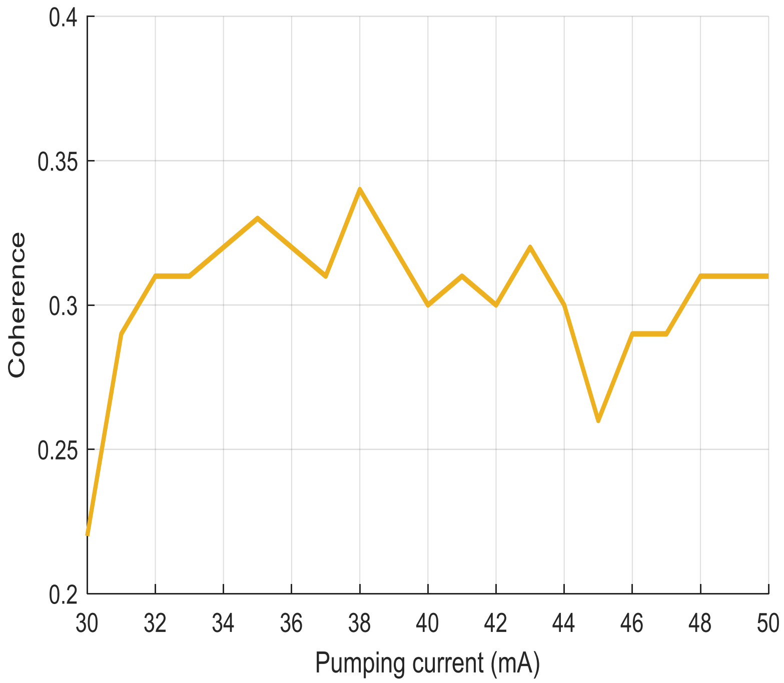

Figure 6 coherence as a function of laser pumping power.

5. Conclusion:

This paper presents the coherence properties 0f the optical path difference of laser diode, we determined the threshold current of the input current as function of the output current which to get the best result of fringes visibility and interference pattern that has formed by the Michelson interferometer and we noticed that when a drive current increased the coherence length increases accordingly. Also we modulated the wavelength to generate fringes and to observe the visibility clearly. a linear relationship between output power (v) of the laser and current (mA) has been got it and it measured fringe visibility as function of optical path difference (mm) and also Measured coherence as function of pump laser.

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