# TEM $_{00}$ Mode Selection of He-Ne Ring Laser

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**ABSTRACT**

In this work, experimental verification of separation of main transitions of $He^3$-$Ne^{20,22}$ Laser viz. 3.39, 1.15 μm and 632.8nm as well as achieving of single longitudinal, single transverse and single polarized beam is presented. The separation of transitions have been experimentally verified using Ando Spectrum Analyser. $TEM_{00}$ mode has been verified using Fabry Perot Interferometer (FPI) and single polarization has been confirmed using Glen Thomson polarizer test setup.

## 1.0 INTRODUCTION

**1.1** One of the more interesting devices that the laser has made possible is the Ring Laser Gyro (RLG). RLG basically consists of a ring cavity of zero thermal expansion glass ceramic material, around which two laser beams travel in opposite directions. These two beams are made to combine to form interference pattern. An examination of the interference pattern will provide information about the rotation rate of the ring cavity relative to an inertial frame.

**1.2** He-Ne gas laser used in RLG essentially has the qualities of laser beam such as monochromatic output, single longitudinal mode, single transverse mode and single P-polarised beam.

**1.3** The lasing medium of He-Ne has 130-plus stimulated emission lines of pure neon due to splitting of energy states of neon to several sub levels. However, three output transitions viz. 3.39, 1.15 and 0.6328 μm are prominent and are greatly amplified by resonance. The of RLG work with utilizing lowest wavelength i.e. 0.6328 μm for high resolution and stability. Therefore it is essential to eliminate other two IR lines (3.39 and 1.15 μm ) from the laser output.

**Key words:** Wavelength, Fabry Perot Interferometer, $TEM_{00}$ Mode, Glen Thomson Polariser, Threshold Voltage: minimum voltage required to sustain the lasing.

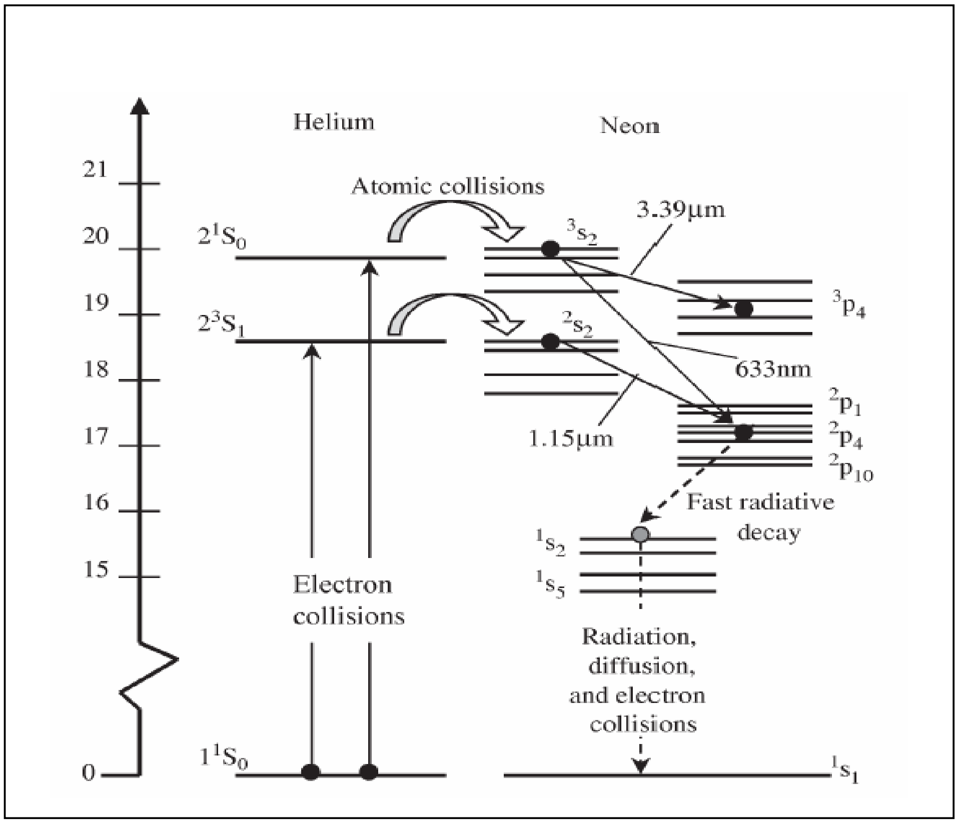


**Fig 1: He-Ne Energy Level Diagram**

**1.4** Both the 0.6328 and 3.39 µm transition start with the same upper energy state (3S2) as shown in Fig.1. The 3.39µm (infrared) transition has a much higher gain than the 632.8 nm (visible red) transition and can deplete the 3S2 level, reducing or eliminating completely the visible output of laser.

## 2.0 Options for achieving the requirement

**2.1** Several techniques are reported for the elimination of 3.39 µm transition and to amplify the 632.8 nm transition. Out of available methods most commonly employed technique is the reflection method wherein the laser mirrors are designed to be highly reflective at 632.8 nm but highly transmissive at 3.39 µm. The round trip gain at the visible wave transition can then be satisfactorily high, while at the same time the gain for the infrared transition never reaches threshold.

Another technique is based on Zeeman Effect by employing small magnets along the length of the laser tube, thereby creating an inhomogeneous magnetic field. The magnetic field produces a splitting of certain spectral lines in to several components. It is known that the gain per unit length at the lasing transition is inversely proportional to the line width. The Zeeman splitting broadens the infrared 3.39µm laser line more than the visible line, decreasing its gain, so the visible transition is favored.

## 3.0 Constraints of the System

**3.1** In the present case the Laser cavity is enclosed with Quartz prisms. The prism does not have coating and quartz material is very sensitive to magnetic field too. Therefore, both the above methods can not be deployed for removing the 3.39 µm transition form the combination of three prominent wavelengths 3.39 , 1.15 and 0.6328 µm .

## 4.0 Method adopted for elimination of 3.39 µm output

**4.1** A ring cavity is being created using four total internal reflection prisms at four corners of laser block. The two prisms creating the active channel is known as first prisms

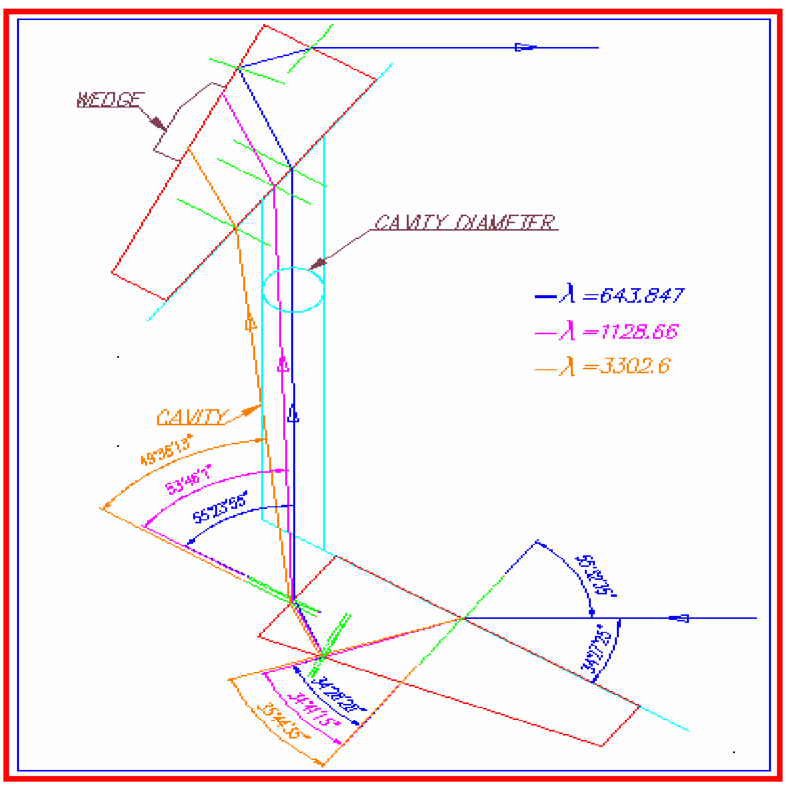


**Fig 2 : Removal of 3.39 µm**

and have a radial surface. The other two prisms on remaining other two corners are called as second prisms. As soon as the He-Ne gas mixture discharge gets activated, the three wavelengths laser beams will deviate differently inside the prism after first refraction at prism surface as shown in fig.2. After total internal reflection at the second surface, when these three beams will face one more refraction to come out from the prism, they will be divergent in three different directions due to refractive index variation with wavelength, the cavity has been designed in such a way that 3.39 μm will not be able to enter the cavity as shown in fig.2 and get absorbed by the cavity material and in turn the gain of 0.6328 μm transition is enhanced.

## 5.0 Method adopted for elimination of 1.15μm output

**5.1** The cavity assembled with the four prisms has 1.15 and 0.6328 μm beams. Modes of 1.15 and 0.6328μm are captured and the same is shown in fig 3a. In order to remove the 1.15 μm beam from the cavity, it is essential to stop the amplification of the 1.15μm beam through round trip of beam inside the cavity. As soon as the 1.15 μm beam enters the second prisms, at total reflection surface it gets deflected out of the cavity using special diaphragms optically contacted on second prism. The IR beam gets diminished from the cavity, a reduction in threshold voltage required for sustenance of 0.6328 μm has been observed. The modes of 0.6328 μm is captured using a CCD camera and the same is shown in fig 3b.

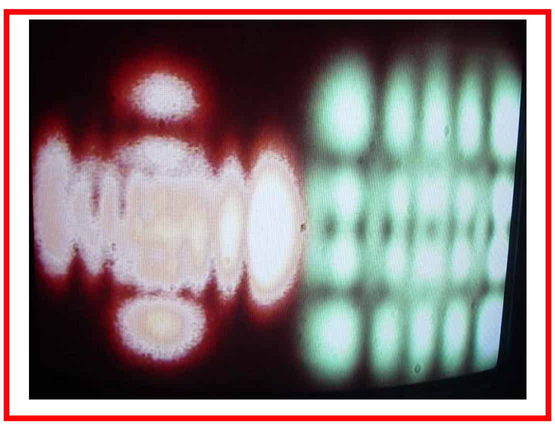

**Fig. 3a: 1.15 and 0.6328 μm Multi Modes**

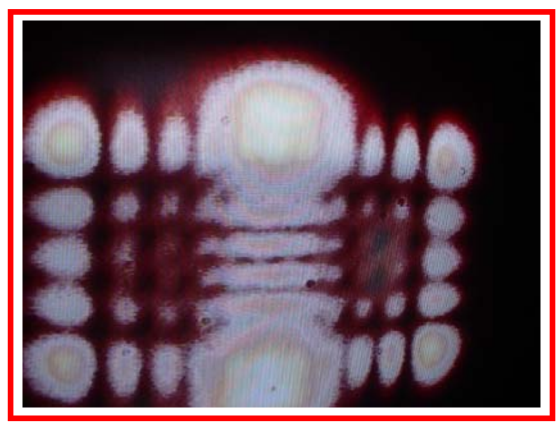

**Fig. 3b: Multi Modes of 0.6328 μm**

## 6.0 Achieving of Single Longitudinal and selection of $TEM_{00}$ mode

**6.1** For a linear laser the allowable lasing frequencies are expressed by the equation

$$\nu = Nc/2L$$

Where c is velocity of light and L is length of the resonator.

The spacing between the modes ($\Delta\nu$) is equal to c/2L and is typically defined in units of MHz.

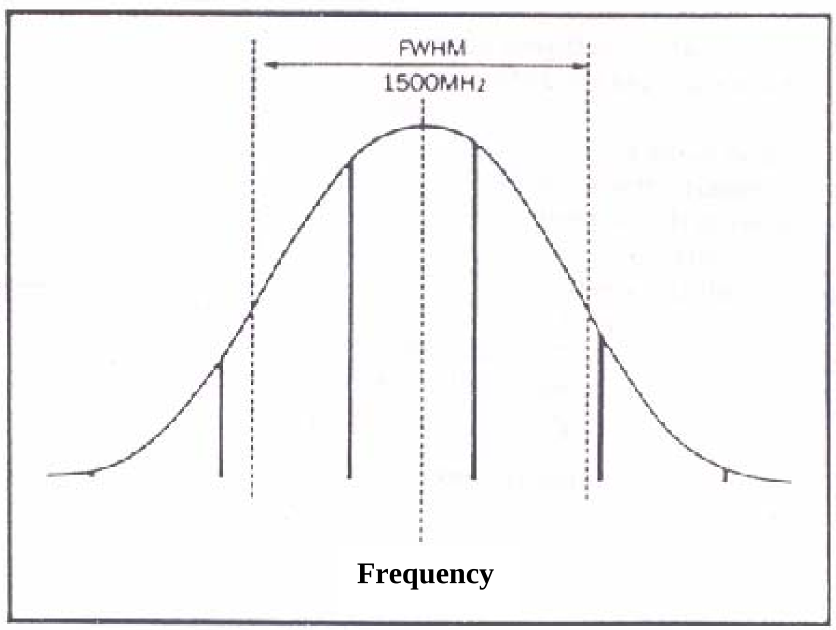


**Fig. 4: Longitudinal Modes Oscillating within the Doppler Broadened He-Ne Laser Gain Curve**

**6.2** Several of the axial modes will fall with in the frequency range defined by the Doppler broadened gain bandwidth and will oscillate simultaneously. The number of simultaneously oscillating modes (n) can be determined by the expression given below.

$$N = \frac{line \quad width}{\mathrm{mod}\, e \quad spacing} = \frac{1500 MHz}{\Delta \nu}$$

**6.3** In case of Ring Laser the mode spacing $\Delta\nu$ is c/L. In the present case L being 283 mm, the $\Delta\nu$ works out to be 1060 MHz. This results that there exist only one longitudinal mode. (ref 4).

**6.4** To eliminate the higher order Transverse Modes (as shown in Fig 3c,d,e) stop (with radius edge to take care of diffraction loses) is being used, which touches the laser beam in real sense to cutoff the higher modes. One more optical component is being used to select finally $TEM_{00}$ mode as well to combine the two counter propagating beams resulting in to interference pattern.

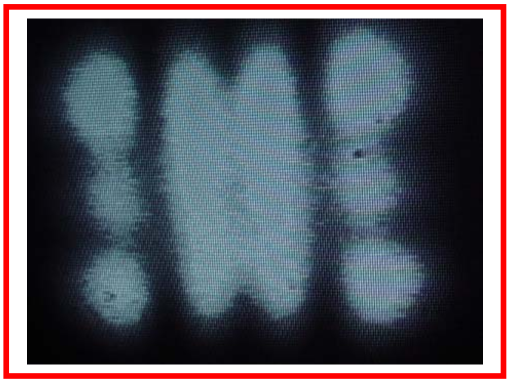

**Fig 3c: $TEM_{32}$ modes of 0.6328 μm**

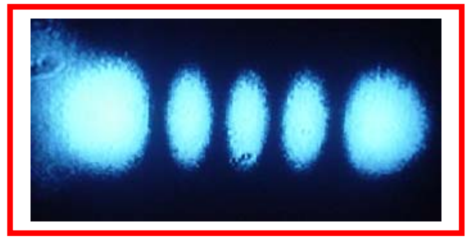

**Fig 3d: $TEM_{40}$ modes of 0.6328 μm**

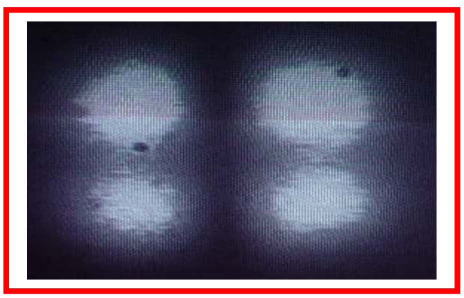

**Fig 3e: $TEM_{11}$ modes of 0.6328 μm**

**Fig 3f: $TEM_{00}$ mode of 0.6328 μm**

## 7.0 Experimental Verification

**7.1** Spectrum analyzer and polarization test set up is utilised to confirm the output laser beam has all desired qualities necessary for a RLG to function. He-Ne discharge has been fed to Ando Spectrum Analyser (Fig 5) and Fig 6a clearly indicates that discharge contains both 1.15 and 0.6328 μm wavelength. Presence of 3.39 μm could not be recorded due to the measuring limitation 400-1700 nm of the spectrometer. These results are obtained when stop/aperture has not been used.

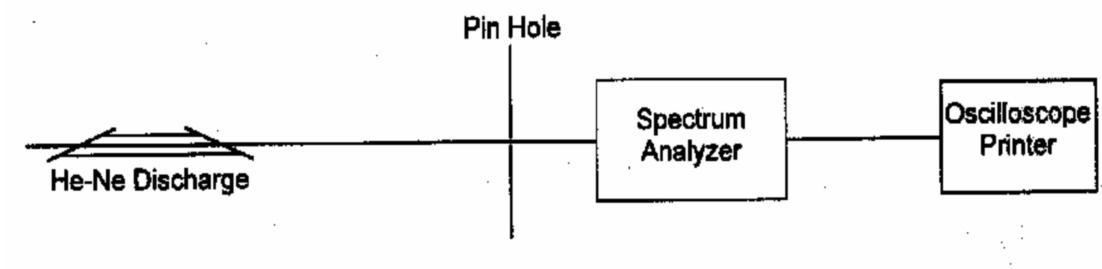


**Fig. 5 : Setup for He-Ne discharge spectral Analysis**

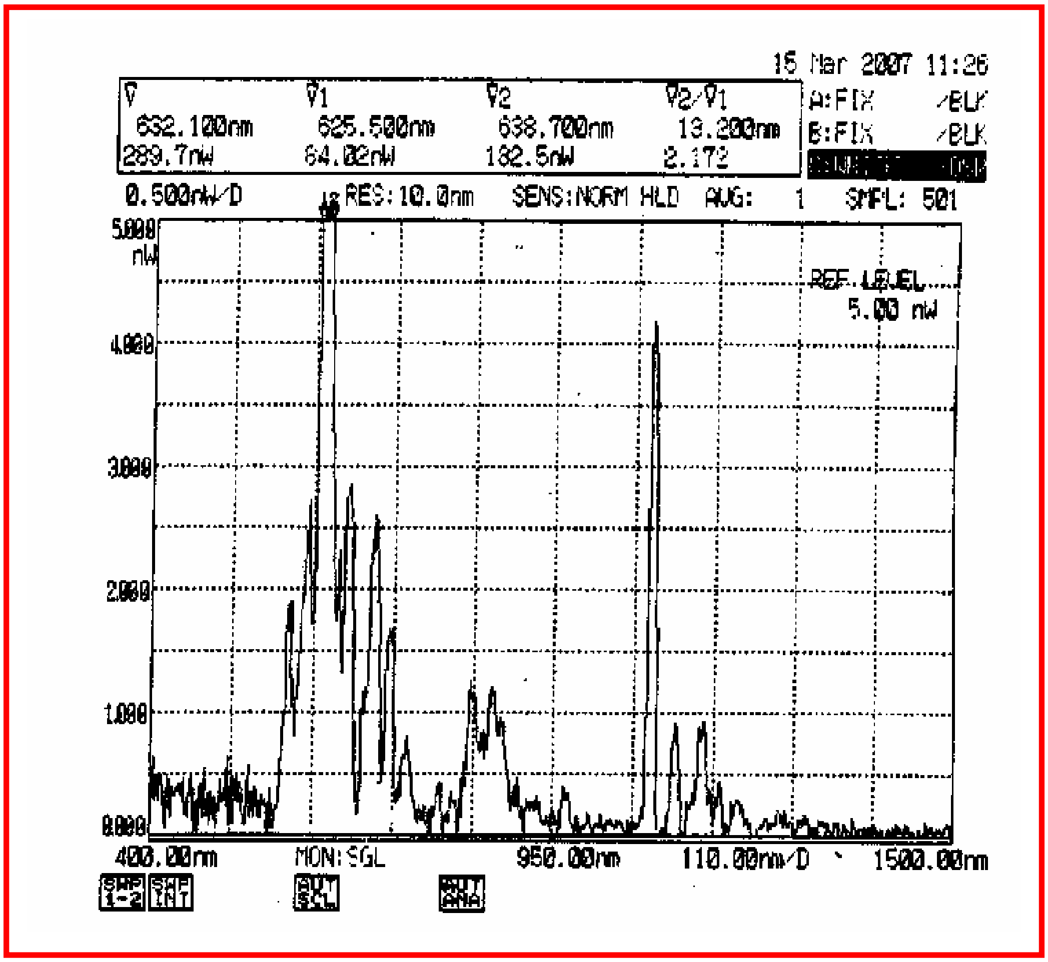


**Fig 6a: Spectrum of He-Ne discharge without any diaphragm**

Same experimentation was carried out with the diaphragm assembled as shown in figure 2, and output has been verified using Burleigh Spectrum Analyzer and results are shown in Fig. 6b.

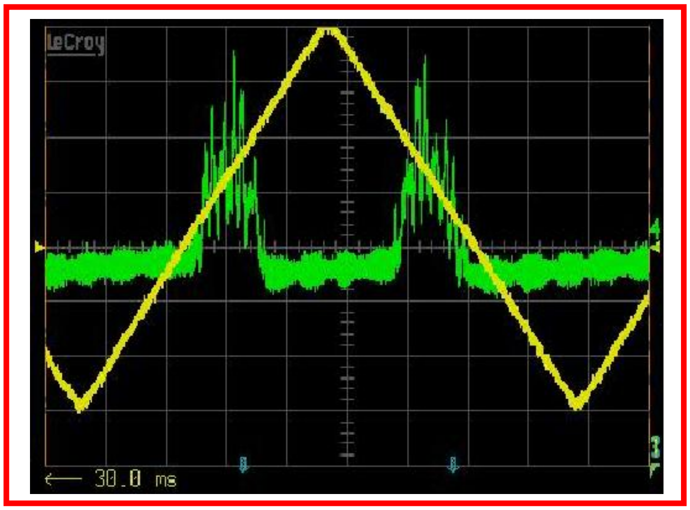


**Fig 6b: Multi-mode structure of 632.8 nm**

After assembly of round edge stop and beam combining prism, $TEM_{00}$ mode output was achieved. The results are verified by using Fabry Perot Interferometer based Burleigh Spectrum Analyzer model no SA200 and the results are shown in Fig 6c.

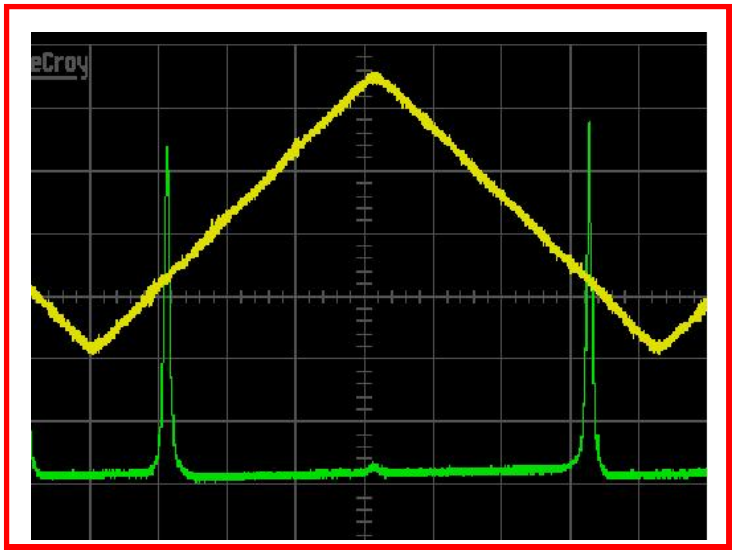

**Fig. 6c: Single mode structure of 632.8nm**

**7.2** Single p - polarization has been verified using Glen Thomson Polariser/analyzer test set up. Laser output intensity has been measured for full 360° rotation of the polarizer and corresponding intensity has been measured and plotted. Intensity max and minima has been calculated as 79.6 and 0.05 respectively. It has been observed that degree of polarization is 99.87%.

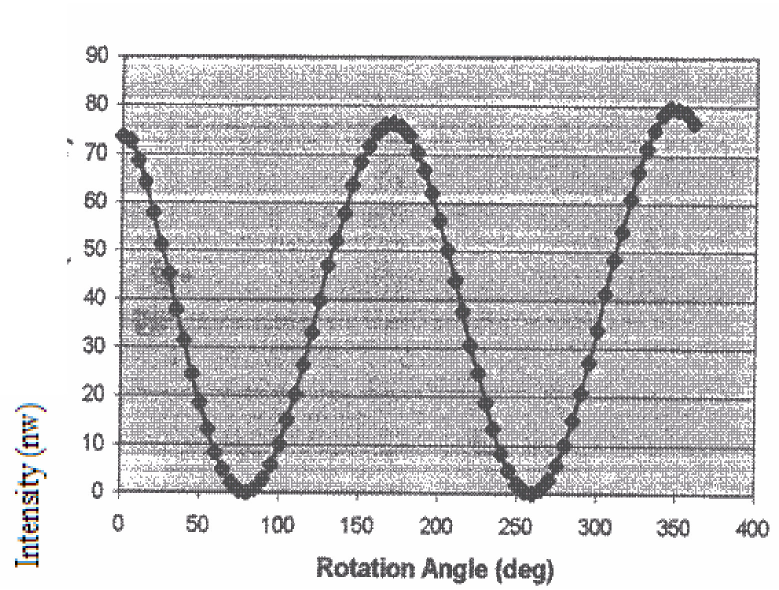


**Fig. 7: Single Polarisation of 632.8 nm**

## 8.0 Conclusion

**8.1** The systemic experimental evaluation carried out reveals that the output laser beam of RLG is monochromatic, single longitudinal and transverse mode and p-polarized.

## 9.0 References


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