DETERMINATION AND OPTIMIZATION OF 
THE GAIN PARAMETERS FOR THE HE-NE 
PLASMA TUBE OF ISRO RING LASER 
GYRO

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Abstract—The He-Ne based ILG are advanced inertial navigational sensors based on sagnac effect which are highly sensitive and accurate. He-ne discharge is fundamental parameter for the performance of the gyro for the gain need to be optimized. Gain of the amplifying medium was optimized with RF excitation pump mechanisms. The major obstacle in inertila navigathional system(INS) was the system stability. In this to improve the performance of RLG, gain parameters such as electron temperature(T_e), Electron energy distribution function(EEDF) etc by both direct and indirect methods is adopted and established for the ISRO Laser Gyroscope

Index Terms—ILG, plasma, pD (pressure-cavity Diameter product),ILG Gain

I. INTRODUCTION

The gain provided by the He-Ne discharge is one of the fundamental parameter for the performance of the laser gyroscope. Basically, for initializing a laser action, gain medium provides the amplification for the light waves that are generated due to spontaneous emission from the gain medium in the direction of the cavity and thus due to feedback action of cavity elements and after sufficient amplification, a sustained laser output comes out from the cavity. The amplification depends on the population inversion, shape of the gain curve, radiative life times frequency of transition etc. In specifically gas lasers, the single pass gain itself decides the total output power and this depends on certain parameters such as the total gas pressure, gas mix ratio, plasma discharge, pump power, cavity geometry etc... Siegman[3] empirically showed that gain per unit length is a function of PD factor and it has inverse relationship with the tube diameter. In spite of the total axial gain, the radial gain profile is also plays an important role so it is necessary to select the lowest order transverse electro-magnetic mode(TEM_00) and also the gain variation with optical axis perturbation should be within the cavity

Thus the two important points for better performance of gyro is that

(i) It should follow TEM_00 mode
(ii) Variation should be negligible with the small optical axis perturbation due to assembly and other environmental error factors

Various people [2-5] have studied the radial gain distribution for RF He-Ne discharge and DC discharge with different pump powers. In this paper, a direct and indirect measurement method of gain is adopted to measure the single pass gain and its radial distribution of RF excited gain medium of RLG at optimized values of PD factor and He-Ne ratios. The PD factor is 10.5torr mm and the ratio of HE-Ne is varied for a wide range of about 5:1 to 20:1 has been theoretically and experimentally optimized by using direct ratio method and by spectroscopic methods.

II. THE RLG(RING LASER GYRO)

A. The Rlg (Ring Laser Gyro) Principle Of Operation

The RLG are the rotational sensors working under Sagnac effect. The Sagnac effect occurs in a closed system. It is defined as that angular rotation is proportional to the phase shift between the two propagating beams. Thus the angular rotation is given by the formula

$$\Delta \phi = \frac{4\pi L}{c}$$

And the optical path difference between two beams is given by

$$\Delta L = \frac{4\pi L}{c}$$

Where A-area enclosed by the beam and it is given as A=\(\frac{4\pi r^2}{c}\) and \(\phi\) is the angular rotation, thus larger the ring, easier is the detection of the Sagnac Frequency. Large size also mitigates certain effects such as lock-in, a major problem with he active ring laser, which occurs at low angular velocity, Lock-in is the tendency of the counter propagating laser
beams to lock one or the other frequency of either Clockwise(CW) or counter clock wise(CCW) beam, practically binding the ring laser \textit{to act as a rotation sensor}

\textbf{B. Types Of Gyro’s}

There are different types of gyro available in this paper we consider for the two types mainly

(i) Active Gyro’s-the two beams are generated within the optical path

\textbf{Eg:-RLG} (Ring Laser Gyro)

(ii) Passive Gyro’s-the laser source is made external that is the major difference \textbf{Eg:-FOG} (fiber optic gyro)

\textbf{III. THE INPUT SOURCE (HE-NE LASER SYSTEM)}

\textbf{A. The Helium-Neon laser system}

He-Ne is the Helium Neon laser system which is used as a input source for this setup. The He-Ne laser was relatively a lower power device with output in both visible and IR regions. For this setup, the most common wavelength produced in the visible region of 632.8nm is selected while the other wavelengths of 1.15 and 3.39 \text{nm} are eliminated passing into the detector by the laser line filters. The laser lines are produced by the atomic transitions with the neon atoms. The helium does not produce laser light directly so it acts as buffer gas but are found to be more excited than neon atoms by electron impact ionization. The purpose of buffer gas is to assist the atoms of neon gas to provide lasing action. When energy from the pumping source was applied to He-Ne gas mixture, then some of the energy was absorbed by helium atoms. In other words, helium atom has achieved the excited state. Now, when the helium atoms move within the laser tube, they get collided with the neon atoms. At each collision, some of the energy within the helium atom was transferred to the Ne atom and so raising it to an excited metastable state. When a sufficient number of Ne atoms reach to this state then population inversion occurs and thus lasing takes place. When energy from the pumping source was applied to He-Ne gas mixture, then some of the energy was absorbed by helium atoms. In other words, helium atom has achieved the excited state. Now, when the helium atoms move within the laser tube, they get collided with the neon atoms. At each collision, some of the energy within the helium atom was transferred to the Ne atom and so raising it to an excited metastable state. When a sufficient number of Ne atoms reach to this state then population inversion occurs and thus lasing takes place.

Typical He-Ne lasers use a ratio of 5:1 to 10:1 it may be up to 20:1. For further theoretical understanding of gain and its radial distribution, the energy level of He-Ne should be known. Figure-1 shows the basic atomic transitions which gives rise to 632.8nm emission. The RF pumping mechanism brings the He atoms to a long lived metastable energy level of about 20.6ev. The lifetime of this state was about 2.04ms which is for our purpose and its essentially for ever. There was a close coincidence in energy level between the 2s(He) and those of Ne(2s and 3s) levels of He and Ne. The collision between a ground state neon and He will result in energy transfer leaving the neon atom either in one of the 3s or 2s doublet states. In our case we are interested primarily in the 3s state because it was the 3s to 2p transition which provides laser action at the familiar visible region(632.8nm). The 3s states are long lived sufficiently up to (~55ns) to allow a population inversion. After the occurrence of stimulated emission we can note that the Ne remains in an excited 2p state. Transitions from the 2p level directly to the ground state (life time ~19ns) are effectively forbidden. In practice collision with the walls are mostly responsible for the final transition to the ground state.

\textbf{B. Capacitively Coupled Plasma}

A capacitively coupled radio frequency discharge is achieved by two typically plane parallel electrodes of either the same or different surface areas. One of the electrodes is powered by while the other is grounded. The electrodes are located in the vacuum chamber in direct contact with the plasma or isolated from the plasma by a dielectric barrier. Figure-2 shows the setup of a capacitively coupled RF discharge.

\textbf{IV. OPTIMIZATION OF GAIN}

For initializing a laser action, gain medium should provide amplification to photons generated by spontaneous emission. After sufficient amplification, a sustained laser comes out of the cavity[7,8]. This amplification factor is called gain and it depends on many factors as in figure-3. Gain per unit length was a function of pD product of the gain varies inversely to the diameter of the tube.
followed and these errors should be minimized or eliminated for the better performance of system gain

a) Laser Ripple
b) Plasma Oscillations
c) Background light fluctuations
d) Dark Current fluctuations
e) RF Interference
f) Accounting for erroneous signals

V. EXPERIMENTAL SETUP

The experimental setup is classified into two based on the method used

(i) Direct gain measurement-Direct Ratio Method
(ii) Indirect gain measurement-Optical Emission Spectroscopy(OES)

Direct Ratio Measurement
For the direct ratio method the experimental setup is splitted into two namely Optical and other is Electrical setup.

The optical setup consists of the components such as

(i) Probe Laser
(ii) Optical Isolator
(iii) Neutral Density Filter
(iv) Laser Line Filter
(v) Beam expander
(vi) Beam Splitter
(vii) Variable Aperture
(viii) Photo detector etc.,

In the same the electrical setup consists of the components such as

(i) Power Meter
(ii) Amplifier card
(iii) DAQ setup
(iv) Polari Meter
(v) Beam Profiler and Data Logger with its required software setup

The experimental setup of direct ratio method is shown in figure-4

Indirect Method Measurement
The indirect method measurement is carried out by the spectroscopic method. The most suitable method selected is Optical Emission Spectroscopy(OES) because of its easy operation and time saving technique for measurement. From this method the laser line transition, electron number density(N_e), electron temperature(T_e), Electron Energy Distribution Function(EEDF) etc., can be determined and the relationship between them is plotted in the form of graph and the values are obtained for various pressure levels. In this paper the result is discussed only with regarding to electron temperature only.

VI. RESULTS AND DISCUSSION

Direct method gain calculated

![Figure-5 Gain For 14mm](image)

![Figure-6 Gain For 7mm](image)

![Figure-7 10:1 ratio comparison between different voltage range](image)
VII. CONCLUSION

The experimental setup for direct gain measurement of RF excited RLG block is established and verified. Thus the spectroscopic technique for determining electron temperature was used as a tool for the optimization of gain parameters for the He-Ne laser medium. This method is very simple and useful to minimize the processing trails for measuring gain distribution of medium by sophisticated optical methods and hence it is verified.

REFERENCES