Available online at
http://www.thesciprobe.com/

Online Open Access

Analysis of Ring Laser Configuration with reference to its Rotation Rate

Priyangshu Rana Borthakur[1], Dr. Banashree Saikia[2]

[1]Faculty of Science and Technology,The ICFAI University Tripura, Kamalghat, Tripura(W), Agartala - 799210.
priyangshu.rana@gmail.com

[2]Department of Physics, Nowgong College, Nagaon, Assam.

banamoni@gmail.com

ABSTRACT

The rotation rates of laser structure in different ring cavities are calculated. The beat signal spectra in the presence of noise for a ring cavity at different rotation rates are calculated. The graph of beat signal spectrum vs laser gyro beat frequency is plotted. It is anticipated from the graph that at high rotation rate, ring laser would be an efficient device for very high resolution work.

KEYWORDS: ring cavity, beat signal spectrum, beat frequency etc.

INTRODUCTION

Ring laser are of interest in science and technology, because unlike usual linear laser, ring cavities can sustain the oscillation of traveling waves rather than standing waves. A ring laser utilizes an optical resonator consisting of at least three reflecting mirrors. Instead of the standing waves in a two mirror resonator, the ring resonator allows traveling waves which may run clockwise or counterclockwise through the resonator. Many works have already been done dealing with important aspects of ring laser operations. These factors include the effects of rotation, different modes of operation and their stability, behavior of the beat, frequency locking phenomena, effects of collisions and noise fluctuations, use of ring laser as a laser gyroscope [1-8] etc. A systematic formulation of the theory of ring laser was given by Menegozzi and Lamb [9, 10]. The limitations of laser gyroscopes arise mainly because of effects of back scattering of radiation and frequency locking phenomena are explained in the theory. It is also indicates that if details measurements are made they should provide sufficient information for determining the rotation rate.

The unidirectional ring laser system is relatively simpler than from that of the two mirror laser system. The two mirror field is composed of two running waves traveling in opposite directions and the standing wave gas laser may exhibit a dip in the intensity versus detuning curve but the unidirectional laser cannot. The simple operation of the ring laser is more general than that of the two mirror standing wave laser for, without non reciprocal losses or suitable mode inhibitory effects. Under the standing wave field, the oppositely directed running waves in the bidirectional ring laser may have unrelated amplitude, phases and frequencies. Generally, a clockwise rotation of the laser about an axis perpendicular to the plane of the mirror Doppler downshifts the frequency of the clockwise running wave and, Doppler up shifts the counter clockwise running wave. The beat note between the waves provides a measure of the rotation rate, leading to the use of the ring laser as gyroscope.

THEORY

Beat signal of the laser gyro:

The equation of motion for the phase difference between the clockwise and the counter clockwise running waves in a laser gyro is given by

$$\dot{\Phi}(t)=a+b\sin\Phi(t)----------------(i)$$

where,

$$a=-\frac{8\pi}{\lambda L}\vec{\mathrm{A}}.\vec{\Omega}------------------(ii)$$

$\left|\vec{\mathrm{A}}\right|$ is the area covered by the optical path of length L along the ring cavity, $\vec{\Omega}$ the rotation rate of the gyro, and λ is the wavelength of the laser; b is backscattering coefficient.
Taking time derivative of equation (i)

$$\ddot{\Phi}(t)=ab\cos\Phi+b^2\sin\Phi\cos\Phi--------------(iii)$$

We may interpret $\Phi(t)$ in the following way. Equation (iii) is analogous to a classical mechanical equation of motion for a particle of unit mass in a potential V (a, Φ). Identifying $\Phi=\Phi(t)$ as the coordinate of this particle, its equation of motion is

$$-\frac{\partial V}{\partial\Phi}=\ddot{\Phi}-------------(iv)$$

Which together with equation (iii) gives

$$V(\Phi,a)=-\frac{1}{2}(a+b\sin\Phi)^2----------(v)$$

Where, $V(\Phi=0,a)=-\frac{1}{2}a^2$

From equation (iv) we obtain the conservation law

$$\eta(t) = \frac{1}{2}\dot{\Phi}^2 + V(\Phi, a) = 0,$$

This is the analog of usual law of conservation of energy. The motion of the particle in $V(\Phi, a)$ is completely determined by the initial coordinate $\Phi_0 = \Phi(t=0)$ and the initial velocity $\dot{\Phi}_0$, given by

$$\dot{\Phi}_0 = a + b\sin\Phi_0 .$$

Since equation (i) is periodic in Φ, it is sufficient to consider only the domain $0 \le \Phi \le 2\pi$.

Spectrum in the presence of noise:

The general spectrum of the beat frequency as calculated by Cresser et.al, is given by

$$f(\omega) = \frac{1}{2}\left[\frac{D}{(\omega - a)^2 + D^2} + \frac{D}{(\omega + a)^2 + D^2}\right]$$

It may be inferred from the above equation that the spectrum $f(\omega)$ vs ω is not strictly Lorentzian.

In this communication rotation rate of the laser structure in different ring cavities were calculated (Table – 1). Different values of beat frequency and rotation rate (Table – 2) has been calculated. A plot of various values of beat frequency versus rotation rate gives the shape of the spectrum (fig. 1).

RESULT AND DISCUSSION

Firstly the rotation rates of laser structure in different ring cavities are calculated, so that the rotation rate of the laser structure is equal to the rotation rate of the earth. All the results are given in the Table – 1. Secondly the spectrum of the beat frequency in presence of noise for various values of ω and *a* are calculated (Table – 2) and plotted in the fig 1.

The conspicuous feature of the spectrum is that for low rotation rates like *a* = 0, *a* =0.05, *a* =0.06, the spectrum is strictly Lorentzian. However when the rotation rate is *a* =0.07 a hole appears in the profile. This hole becomes deeper as the rotation rate increases. For *a* =0.7 as for example the biggest hole appears at the central tuning and we observed two Lorentzians symmetrically placed about the central axis represented by $\omega = 0$. The situation is an analogue of hole burning in the theory of gas laser.

From what has been stated above it is reasonable to infer that for high rotation rate in the limit 0.06< *a* <1; the ring laser will be an efficient device for very high resolution work.

Table 1: Rotation rates of laser structure in different ring cavities.

$\Delta\upsilon$ cycles	λ	l	ϖ
100	10^{-4} cm	150 cm	13.7568^0/hr
100	10^{-4} cm	130 cm	15.8732^0/hr
100	10^{-4} cm	140 cm	14.7394^0/hr
100	10^{-4} cm	135 cm	15.2853^0/hr
100	10^{-4} cm	136 cm	15.17294^0/hr
100	10^{-4} cm	137 cm	15.0621^0/hr
36	10^{-3} cm	500 cm	14.8573^0/hr
37	10^{-3} cm	510 cm	14.9706^0/hr
50	10^{-4} cm	69 cm	14.9530^0/hr
50	10^{-4} cm	70 cm	14.7394^0/hr
50	10^{-4} cm	68 cm	14.7394^0/hr
146	10^{-5} cm	20 cm	15.0636^0/hr
145	10^{-5} cm	20 cm	14.96052^0/hr
151	10^{-5} cm	21 cm	14.83769^0/hr
152	10^{-5} cm	21 cm	14.93595^0/hr
153	10^{-5} cm	21 cm	15.034217^0/hr
200	10^{-5} cm	27 cm	15.285^0/hr

51	10^{-4} cm	70 cm	15.034217^{0}/hr
22	10^{-3} cm	300 cm	15.13248^{0}/hr
10	10^{-3} cm	135 cm	15.285333^{0}/hr
10	10^{-3} cm	138 cm	14.953043^{0}/hr
10	1.06x 10^{-4} cm	15 cm	14.582208^{0}/hr
10	1.06x 10^{-4} cm	14 cm	15.62379^{0}/hr
9	1.06x 10^{-4} cm	13 cm	15.143062^{0}/hr

Table 2: Beat frequency in the presence of noise for various values of ω and *a.*

a	**D**	ω	F(ω)
0	0.1	0	10
		-0.02	9.62
		-0.05	8
		-0.1	5
		-0.2	2
		-0.3	1
		-0.4	0.58
		-0.6	0.27
		-0.7	0.2
		-0.8	0.15
		-0.9	0.12
		-1	0.099
		0.02	9.62
		0.05	8
		0.01	5
		0.2	2
		0.3	1
		0.4	0.58
		0.6	0.27
		0.7	0.2
		0.8	0.15
		0.9	0.12
		1	0.099
		0	8
		-0.01	7.99
		-0.04	7.71
		-0.1	5.55
		-0.2	2.23
0.05	0.1	-0.3	1.07
		-0.4	0.61
		0.01	7.98
		0.04	7.71
		0.1	5.53
		0.2	2.23
		0.3	1.07
0.06	0.1	0	7.35
		-0.01	7.36
		-0.02	7.36
		-0.04	7.30
		-0.05	7.21
		-0.1	5.72
a	**D**	ω	F(ω)
		-0.2	2.33
		0.01	7.36
		0.02	7.36
		0.04	7.30
		0.05	7.21
		0.1	5.72
		0.2	2.33
0.07	0.1	0	6.71
		-0.01	6.73
		-0.02	6.76
		-0.03	6.81
		-0.04	6.85
		-0.05	6.86
		-0.06	6.81
		-0.07	6.69
		-0.08	6.49
		-0.1	5.87
		-0.2	2.46
		0.01	6.73
		0.02	6.76
		0.03	6.81
		0.04	6.85
		0.05	6.86
		0.06	6.81
		0.07	6.69
		0.08	6.49
		0.1	5.87
		0.2	2.46
		0	5
		-0.02	5.09

0.1	0.1	-0.03	5.21
		-0.05	5.54
		-0.07	5.87
		-0.08	5.99
		-0.09	6.04
		-0.1	6
		-0.2	3
		-0.3	1.29
		-0.4	0.69
		-0.5	0.43
		-0.6	0.29
		-0.7	0.21
		0.02	5.09
		0.03	5.21

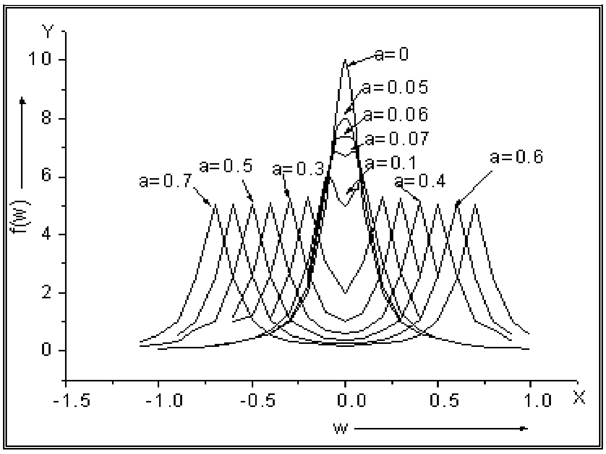
a	**D**	ω	F(ω)
		0.05	5.54
		0.07	5.57
		0.08	5.99
		0.09	6.04
		0.1	6
		0.2	3
		0.3	1.29
		0.4	0.69
		0.5	0.43
		0.6	0.29
		0.7	0.21
0.2	0.1	0	2
		-0.1	3
		-0.2	5.29
		-0.3	2.7
		-0.4	1.13
		-0.5	0.57
		0.1	3
		0.2	5.29
		0.3	2.7
		0.4	1.13
		0.5	0.57
0.3	0.1	0	1
		-0.1	1.29
		-0.2	2.67
		-0.3	5.27
		-0.4	2.6
		-0.5	1.2
		-0.6	1

		0.1	1.29
		0.2	2.69
		0.3	5.27
		0.4	2.6
		0.5	1.2
0.4	0.1	0	0.59
		-0.1	0.69
		-0.2	1.14
		-0.3	2.6
		-0.4	5.08
		-0.5	2.6
		-0.6	1.14
		0.1	0.69
		0.2	1.14
		0.3	2.6

a	**D**	ω	F(ω)
		0.4	5.08
		0.5	2.6
		0.6	1.14
0.5	0.1	0	0.38
		-0.1	0.43
		-0.2	0.72
		-0.3	1.08
		-0.4	2.56
		-0.5	5.05
		-0.6	2.54
		-0.7	1.03
		-0.8	0.74
		-0.9	0.32
		-1	0.21
		-1.1	0.16
		0.1	0.43
		0.2	0.72
		0.3	1.08
		0.4	2.56
		0.5	5.05
		0.6	2.54
		0.7	1.03
		0.8	0.74
		0.9	0.32
		1	0.21
		0	0.27
		-0.1	0.29
		-0.2	0.37

0.6	0.1	-0.3	0.56
		-0.4	1.05
		-0.5	2.54
		-0.6	5.03
		-0.7	2.53
		-0.8	1.03
		-0.9	0.54
		0.1	0.29
		0.2	0.37
		0.3	0.57
		0.4	1.05
		0.5	2.54
		0.6	5.03
		0.7	2.53
		0.8	1.03
		0.9	0.54

Fig. 1: The spectrum of the beat frequency in the presence of noise for various values of ω and *a*.



REFERENCES

Aronowitz F. (1970). *J. Appl. Phy*. 41, 2453.

Aronowitz F. and Collins R.J. (1965). *Appl. Phys. Letters* 9, 235.

Aronowitz F.(1965). *Phy. Rev.* 139, 635.

Chow W., Hambenne J., Hutchings T., Sanders V., Sargent M. and Scully M.O. (1980). *J. Quantum Electron* 16, 918.

Cresser J.D., Louisell W.H. and Scully M.O. (1982). *Phy. Rev.* 25, 2214.

Einstein A. (1917). *Phy. Z.* 18, 121.

Gordon J.P., Zeiger H.J. and Townes C.H. (1954). *Phy. Rev.* 95, 282.

Lamb Jr W.E. (1967). *Phy. Rev.* A134, 208.

Lamb Jr W.E. and Scully M.O. (1967). *Phy. Rev*.159, 208.

Maiman T.H. (1960). *Nature* 187, 493.

Menegozzi L. and Lamb Jr W.E. (1973). *Phy. Rev*. A 8, 2103.

Rybakov B.V. and Demidenkov Yu V. (1979). *Sov. Phys. JEPT* 30, 646.

Schawlow A.L. and Townes C.H. (1958). *Phy. Rev*. 112, 1940.

------------------xxxxxx-------------------