PSE605A (Photonics Lab Techniques)

Lab Report: Experiment 9

AO Modulator

Submitted by

Md Sk Sahidulla

Roll Number: **231160005**

M.Tech,2023

Submitted to

Dr. Pratik Sen

Mr. Shwet Prasoon

Center for Lasers and Photonics

IIT KANPUR

Academic Year 2023-2024

Date: 26/02/2024

Contents

List of Tables

Acousto-Optic Modulator

1 Objectives

a) **To observe the diffraction pattern using acousto-optic modulator for two wavelengths**

b) **To measure the diffraction efficiencies corresponding to different RF powers.**

c) **To calculate diffraction angle with respect to the acoustic frequencies.**

2 Apparatus

He-Ne Laser (632.8nm), Laser diode (960nm), Have wave plate & lense setup, Polarizer, Reflecting mirrors, Acousto-optic modulator, Graph paper, IR Card, Photo detector, Multi-meter, RF power source.

3 Theory

The acousto-optic effect occurs when a light beam passes through a transparent material, such as glass, in which traveling acoustic waves are also present, as depicted in Fig. 1. Acoustic waves are generated in the glass by a piezoelectric transducer that is driven by a RF signal source. The spatially periodic density variations in the glass corresponding to compressions and rarefactions of the traveling acoustic wave are accompanied by corresponding changes in the index of refraction for propagation of light in the medium.
For acoustic waves of sufficiently high power, most of the light incident on the Acousto-optic modulator can be diffracted and therefore deflected from its incident direction.

4 Diffraction patterns and efficiencies

4.1 For He-Ne laser

4.1.1 Tables

Table 1: Table for the diffraction of the He-Ne laser

RF power (dBM)	RF frequency (MHz)	Diffraction order	output voltage (V)	Diffraction efficiency (η) $\left(\frac{1st/2nd\ order\ voltage\ output}{0th\ order\ voltage\ output}\right)$
19.000000	100.000000	0	1.462000	
		1	0.027000	0.018468
		2	0.006000	0.004104
	110.000000	0	1.451000	
		1	0.027000	0.018608
		2	0.004000	0.002757
	120.000000	0	1.436000	
		1	0.020000	0.013928
		2	0.001000	0.000696
21.000000	100.000000	0	1.410000	
		1	0.035000	0.024823
		2	0.005000	0.003546
	110.000000	0	1.386000	
		1	0.034000	0.024531
		2	0.001000	0.000722
	120.000000	0	1.400000	
		1	0.028000	0.020000
		2	0.001000	0.000714
23.000000	100.000000	0	1.363000	
		1	0.052000	0.038151
		2	0.009000	0.006603
	110.000000	0	1.396000	
		1	0.055000	0.039398
		2	0.003000	0.002149
	120.000000	0	1.378000	
		1	0.048000	0.034833
		2	0.003000	0.002177

Table 2: Diffraction Efficiency of the He-Ne laser

RF power (dBM)	RF frequency (MHz)	1st order Diffraction efficiency (η_1) ($\frac{1st\ order\ voltage\ output}{0th\ order\ voltage\ output}$)	2nd order Diffraction efficiency (η_2) ($\frac{2nd\ order\ voltage\ output}{0th\ order\ voltage\ output}$)
19.000000	100	0.018468	0.004104
	110	0.018608	0.002757
	120	0.013928	0.000696
21.000000	100	0.024823	0.003546
	110	0.024531	0.000722
	120	0.020000	0.000714
23.000000	100	0.038151	0.006603
	110	0.039398	0.002149
	120	0.034833	0.002177

4.1.2 Plots

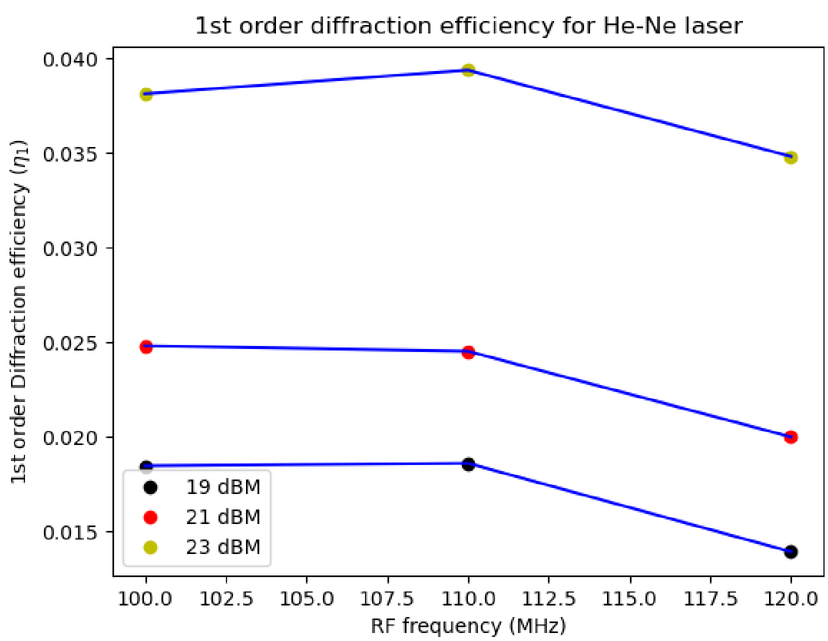


Figure 1: 1st order diffraction efficiency varying RF frequencies for He-Ne laser

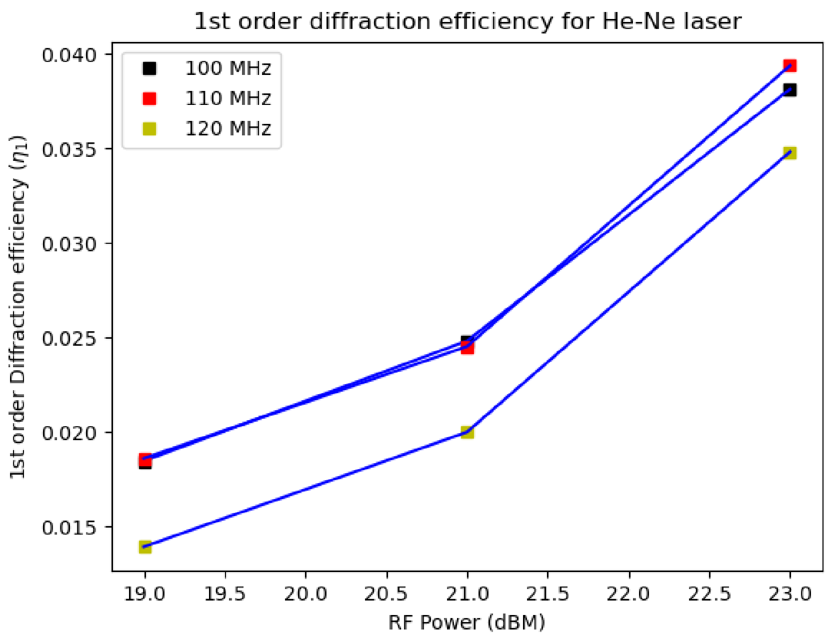


Figure 2: 1st order diffraction efficiency varying RF power for He-Ne laser

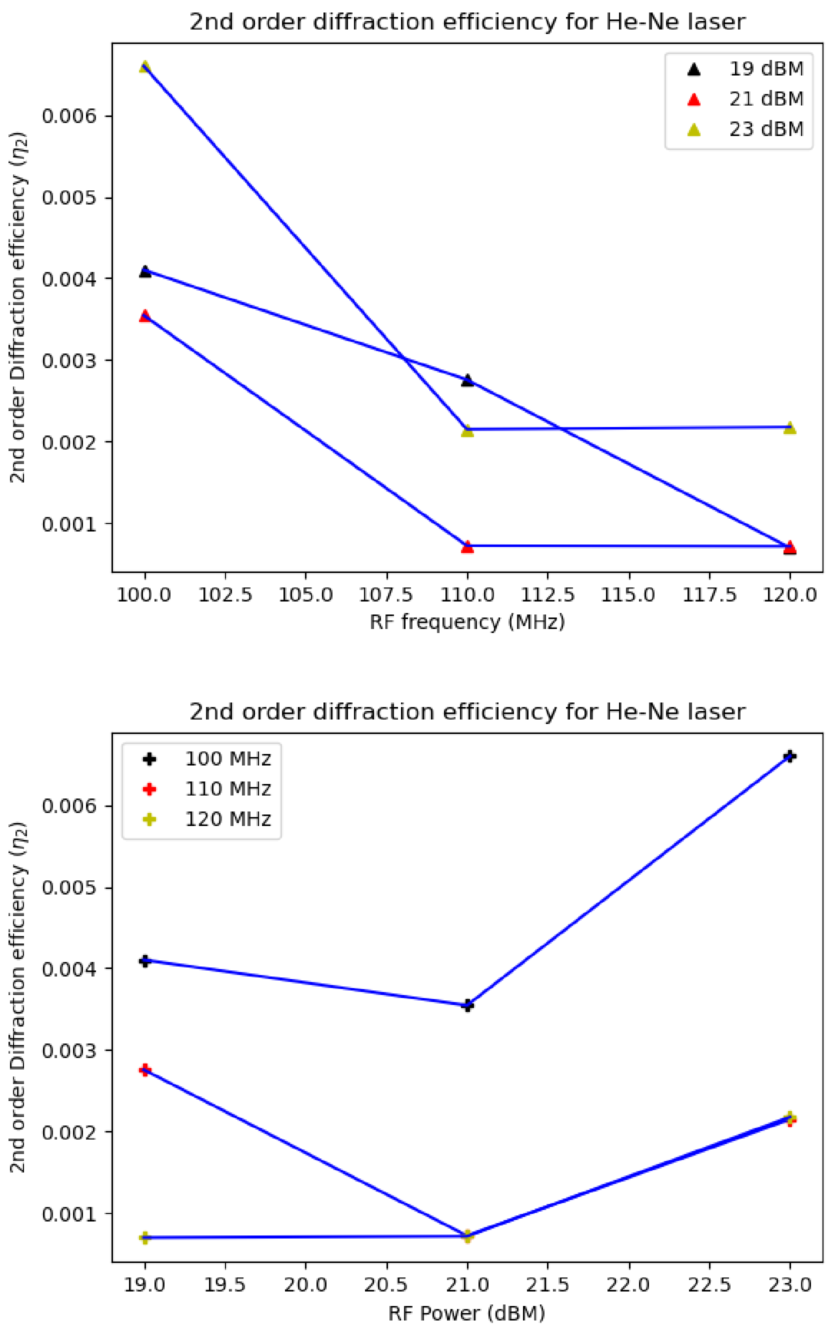


Figure 3: 2nd order diffraction efficiency for He-Ne laser

4.2 For Diode laser

4.2.1 Tables

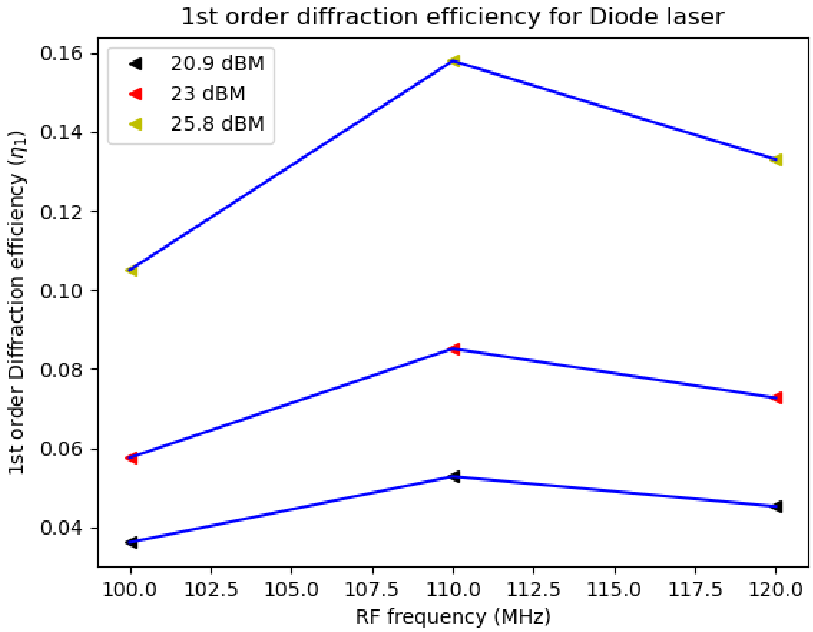
Table 3: Table for the diffraction of the Diode laser

RF power (dBM)	RF frequency (MHz)	Diffraction order	output voltage (V)	Diffraction efficiency (η) $(\frac{1st/2nd\ order\ voltage\ output}{0th\ order\ voltage\ output})$
20.900000	100.000000	0.000000	2.490000	
		1.000000	0.090000	0.036145
	110.000000	0.000000	2.460000	
		1.000000	0.130000	0.052846
	120.000000	0.000000	2.540000	
		1.000000	0.115000	0.045276
23.000000	100.000000	0.000000	2.500000	
		1.000000	0.144000	0.057600
	110.000000	0.000000	2.430000	
		1.000000	0.207000	0.085185
	120.000000	0.000000	2.420000	
		1.000000	0.176000	0.072727
25.800000	100.000000	0.000000	2.370000	
		1.000000	0.249000	0.105063
	110.000000	0.000000	2.260000	
		1.000000	0.357000	0.157965
	120.000000	0.000000	2.300000	
		1.000000	0.306000	0.133043

Table 4: Diffraction Efficiency of the Diode laser

RF power (dBM)	RF frequency (MHz)	1st order Diffraction efficiency (η_1) $(\frac{1st\ order\ voltage\ output}{0th\ order\ voltage\ output})$
20.900000	100	0.036145
	110	0.052846
	120	0.045276
23.000000	100	0.057600
	110	0.085185
	120	0.072727
25.800000	100	0.105063
	110	0.157965
	120	0.133043

4.2.2 Plots



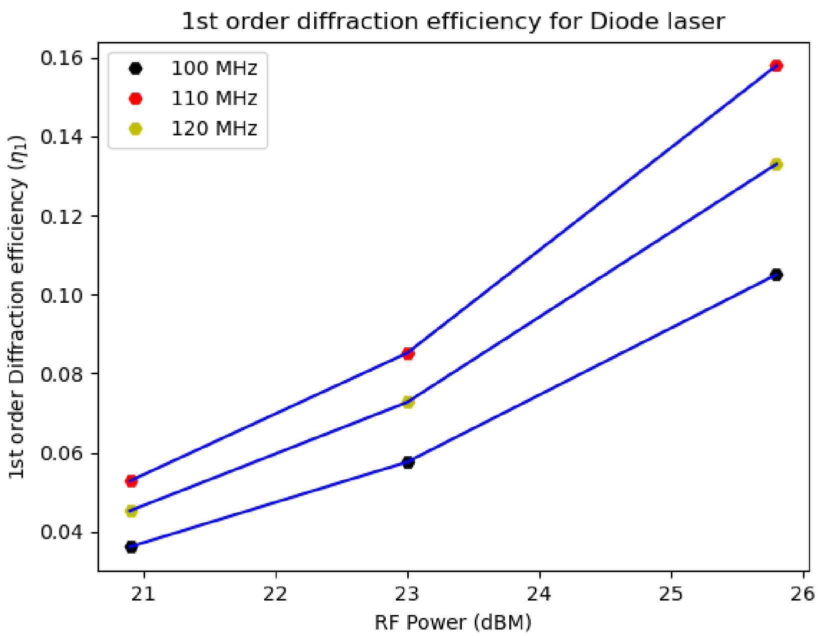


Figure 4: 1st order diffraction efficiency for diode laser

5 Diffraction angle

Given,
The refractive index of the material, $n = 2.2749$.
acoustic velocity, $V = 4260\ m/s$.
Distance between Modulator and screen, $D = 30\ cm$.
The wavelength of the He-Ne laser is 632.8 nm.
The wavelength of the Diode laser is 960 nm.

5.1 He-Ne laser

Table 5: Diffraction angle for the He-Ne laser

RF power (dBM)	RF frequency (MHz) (f)	Diffraction order (m)	Theoretical diffraction angle (deg) ($\theta_t = 2 * sin^{-1}\left(\frac{m\lambda f}{2nV}\right)$)	Distance from 0th order (d)	Experimental diffraction angle (deg) ($\theta_e = tan^{-1}\left(\frac{d}{D}\right)$)	Percentile error $\left\lvert\frac{\theta_t-\theta_e}{\theta_t}\right\rvert * 100\%$
19.0	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.376342	0.400000	0.652366	73.343609
		2	0.766907	0.900000	1.043884	36.116151
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.414499	0.500000	0.762348	83.920299
		2	0.848282	1.000000	1.088448	28.312133
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.452809	0.500000	0.762348	68.359625
		2	0.931181	1.100000	1.126533	20.978996
21.0	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.376342	0.400000	0.652366	73.343609
		2	0.766907	1.000000	1.088448	41.927040
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.414499	0.400000	0.652366	57.386570
		2	0.848282	0.900000	1.043884	23.058676
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.452809	0.500000	0.762348	68.359625
		2	0.931181	1.100000	1.126533	20.978996
23.0	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.376342	0.400000	0.652366	73.343609
		2	0.766907	1.000000	1.088448	41.927040
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.414499	0.400000	0.652366	57.386570
		2	0.848282	0.900000	1.043884	23.058676
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.452809	0.500000	0.762348	68.359625
		2	0.931181	1.100000	1.126533	20.978996

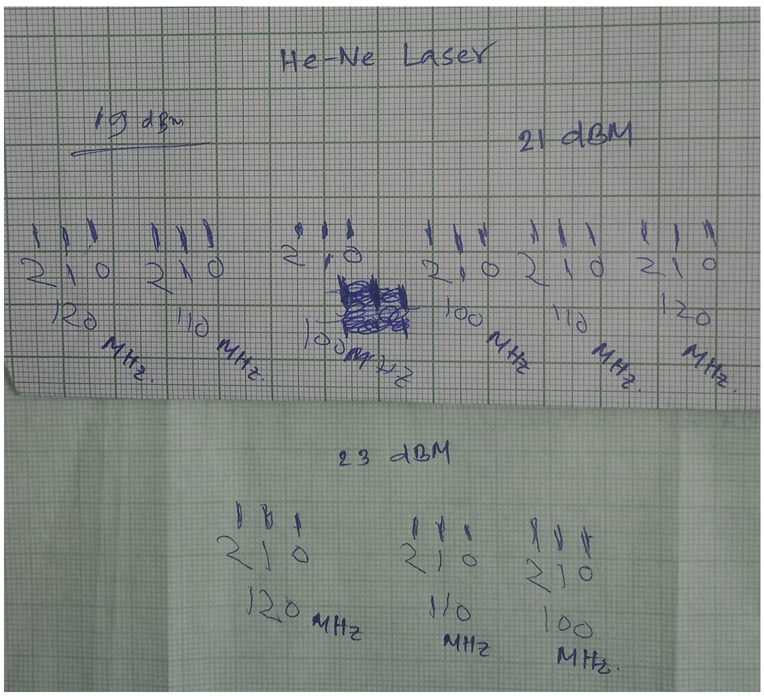


Figure 5: Bright points on the screen for He-Ne laser

5.2 diode laser

Table 6: Diffraction angle for the Diode laser

RF power (dBM)	RF frequency (MHz) (f)	Diffraction order (m)	Theoretical diffraction angle (deg) ($\theta_t = 2 * sin^{-1}\left(\frac{m\lambda f}{2nV}\right)$)	Distance from 0th order (d)	Experimental diffraction angle (deg) ($\theta_e = tan^{-1}\left(\frac{d}{D}\right)$)	Percentile error $\left\|\frac{\theta_t-\theta_e}{\theta_t}\right\| * 100\%$
20.9	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.575482	0.600000	0.853291	48.274158
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.634943	0.800000	0.991265	56.118828
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.694991	0.900000	1.043884	50.201170
23.0	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.575482	0.800000	0.991265	72.249673
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.634943	0.800000	0.991265	56.118828
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.694991	0.900000	1.043884	50.201170
25.8	100.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.575482	0.700000	0.928578	61.356595
	110.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.634943	0.900000	1.043884	64.406042
	120.000000	0	0.000000	0.000000	0.000000	0.000000
		1	0.694991	0.800000	0.991265	42.629981

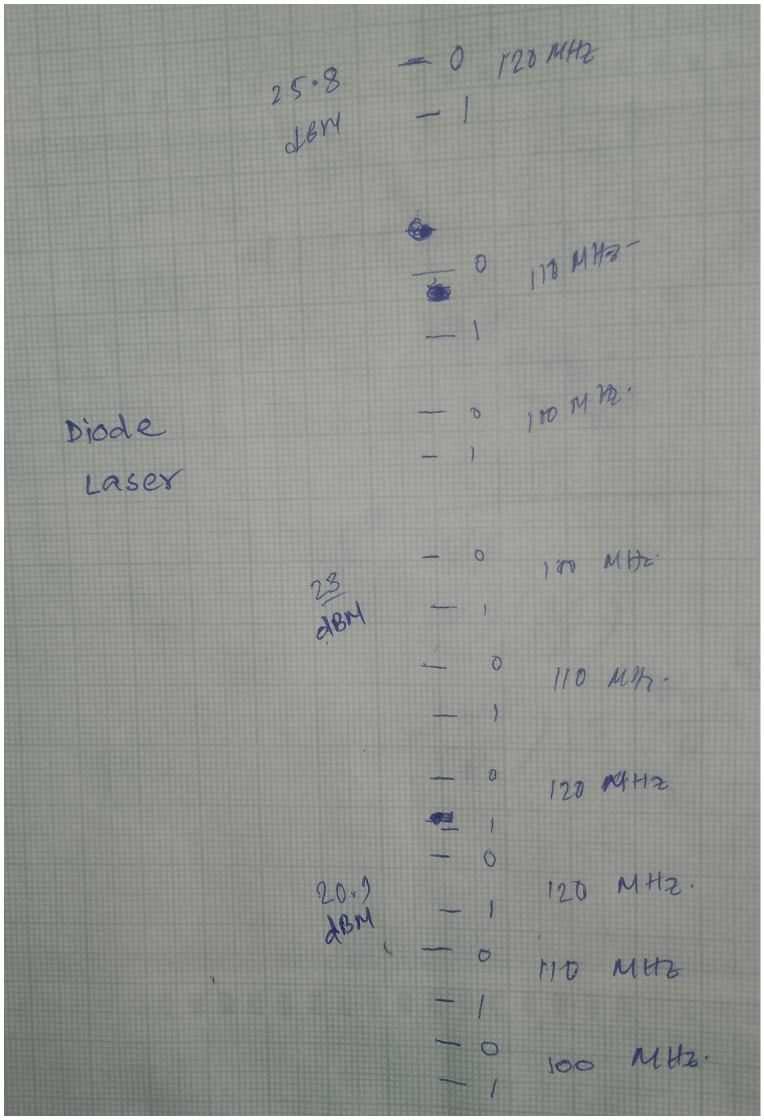


Figure 6: Bright points on the screen for Diode laser

6 Error calculation

From Table 5,
for He-Ne laser, RF power 19 dBM, f=100 MHz and m=2,
Theoretical diffraction angle,

$$\theta_t = 2 * sin^{-1}\left(\frac{m\lambda f}{2nV}\right)$$

$$\theta_t = 2 * sin^{-1}\left(\frac{2 * 632.8 * 10^{-9} * 100 * 10^6}{2 * 2.2749 * 4260}\right) = 0.766907^0$$

for the same order, d=0.9 cm
Experimental diffraction angle,

$$\theta_e = tan^{-1}\left(\frac{d}{D}\right)$$

$$\theta_e = tan^{-1}\left(\frac{0.9}{30}\right) = 1.043884^0$$

So, the percentile error,

$$\frac{\delta\theta}{\theta}100\% = \left|\frac{\theta_t - \theta_e}{\theta_t}\right| * 100\%$$

$$\frac{\delta\theta}{\theta}100\% = \left|\frac{0.766907 - 1.043884}{0.766907}\right| * 100\% = 36.11\%$$

So, we can calculate all the error calculations in the above process.

7 Discussions & Conclusions

- **Diffraction efficiency Comparison w.r.t RF frequency:**
  For the He-Ne laser, both the 1st and 2nd-order diffraction efficiency decreases with the RF frequency for a fixed RF power. Also, for the same RF power and RF frequency, values of 2nd-order diffraction efficiency is less than the 1st-order.
  For the diode laser, Only 1st order is detectable at our RF power and frequency. For the 1st order, the diffraction efficiency at 110 MHz is greater than at 100 and 120 MHz.
  1st order diffraction efficiency for diode laser is greater than the He-Ne laser for a fixed RF power.

- **Diffraction efficiency Comparison w.r.t RF power:**
  For the He-Ne laser, the 1st diffraction efficiency increases with the RF power for a fixed RF frequency. But for 2nd order, the Diffraction efficiency at 21 dBM is higher than at 19 and 23 dBM. Also, for the same RF power and RF frequency, values of 2nd-order diffraction efficiency are

less than the 1st-order.
For the diode laser, the 1st diffraction efficiency increases with the RF power for a fixed RF frequency.
1st-order diffraction efficiency for the diode laser is greater than the He-Ne laser for a fixed RF frequency.

- **Diffraction angle comparison:**
  For, Both He-Ne and Diode laser, the diffraction angle increases w.r.t RF frequency.
  However, the diffraction angle for the Diode laser is higher than the He-Ne laser for a fixed RF power. It means the diffraction angle increases with wavelength.

- **Analyzing Errors of diffraction angle:**
  Here the percentile errors for diffraction angle are relatively very high.
  For the He-Ne laser, errors for 2nd order are relatively less than the 1st order. But errors for the He-Ne laser the percentile errors are higher than the diode laser.

8 References

"Optical electronics" by Ajoy Ghatak and K. Thyagarajan, Cambridge University Press, 1st Edition (2009)