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ENABLING PHOTONIC TECHNOLOGIES

OPTIMIZATION OF MODE LOCKER AND MIRROR SPACING

DOCUMENT NUMBER: 55A04131D

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Optimization Analysis of Mode Locker and Mirror Spacing

Optimization analysis of mode locker and mirror spacing relationship was also analyzed with low frequency devices (38, 41. and 50 MHz). A portion of this analysis was suggested by Dick Johnson [1]. Some observations made are as follows.

1. In the Raman Nath (shown in figure 1), the first order diffraction for incident and reflected waves add constructively or destructively.

2. In Bragg (shown in figure 2), the first order diffraction do not add coherently since the incident and reflected wave angles are different.

3. Raman Nath standing wave interaction (see figure 1) is more efficient than Bragg.

The following is the mathematical representation of the Raman Nath interactions with normal incidence (see figure 1).

Path length difference ΔL:

$$\Delta L = \frac{2L}{\mathrm{COS}\,2L} - 2L \qquad (1)$$

where L is the distance between the mode locker and mirror.

Consider the reflected diffraction and in incident diffraction. Interference, the distance for destructive interference occurs when M = 1, 3, 5 … and constructive interference occur when M = 0, 2, 4 … in the following equation:

$$\Delta L = m\frac{\lambda_0}{2n} \qquad (2)$$

And substitute equation (2) into equation (1):

$$L = m\frac{n\Lambda^2}{2\lambda_0} \qquad (3)$$

Where λ_0 is the wavelength and n is the refractive index.

Ideally, one wants to have total construction as m = 0, so that the zero order energy is minimum. But in reality the mirror will be some distance away from the device and m = 0 is impossible. So the next choice is m = ½ and the maximum distance allowed under this condition is:

$$L_{max} = \frac{n\Lambda^2}{4\lambda_0} \qquad (4)$$

Normally L should be as short as possible but if this distance can not be physically realized, then one can use the next maximum, i.e. m = 2.

$$L = \frac{n\Lambda^2}{\lambda_0} \qquad (5)$$

We now calculate the intensity due to a double pass. We have established the total length difference as

$$\Delta L = L\left(\frac{\lambda}{\Lambda}\right)^2 \quad (6)$$

The phase difference is then (Assuming the intensity of two diffracted beams are equal).

$$E_\Psi = E_s\left(1 + \exp\left(j\,\frac{2\pi}{\lambda}\,L\left(\frac{\lambda}{\Lambda}\right)^2\right)\right) \quad (7)$$

$$\Theta = \frac{2\pi}{n}\,\frac{\lambda_0 L}{\Lambda^2} \quad (8)$$

Where E_s is from the single pattern interaction and n equals 1 in free space. Therefore,

$$|E_\Psi|^2 = 2\,|E_s|^2\,(1 + \cos\Theta) \quad (9)$$

Let's consider the beam translation inside the mode locker. The reflected beam from the incident diffraction goes through a beam translation equal to

$$L\,\frac{\lambda}{\Lambda} \quad (10)$$

The over lap is computed assuming a rectangular shaped beam and is as follows:

Diameter of beam = dia. in mm
Beam shift = L λ / Λ in mm
Fraction of overlap = (dia. – L λ / Λ) / dia
Fraction of shift = (L λ / Λ) (1 / dia.)

Total Diffraction = coherent, overlap, diffraction + non coherent, non overlap, diffraction

$$\text{Total diffraction} = 2\,(1 + \cos(\Theta))\,\frac{\text{dia} - \left(\frac{L\lambda}{\Lambda}\right)}{\text{dia}} + 2\,\frac{L\lambda}{\Lambda}\,\frac{1}{\text{dia}} \quad (11)$$

The maximum intensity for 100% over lap is 4; where as, the maximum intensity for just complete separation (non coherent addition) is 2. Two sample calculations are shown: one to plot the function 2 (1 + cos Θ), and one taking the beam shift into account.

The parameters are:

Dia. = 1.25 mm
f = 38 MHz, 41 MHz, 50 MHz
Vel = 5.96 mm/μs (SiO_2)
λ = 1.06 microns (Nd:Yag)

We vary L (mirror and mode locker distance) from 0 to 40 mm, the results are plotted in figure 3, 4, 5. The second maximum point at 41 MHz is a null at 50 MHz as seen in figure 4 and 5. For best performance, pick the 2nd maximum point, and avoid the first null.

Raman Nath is advantageous in 2 ways. First it is more efficient in loss modulation, and second is the coherent addition of the two passes. As we can see that it is very important to pick proper mirror spacing in the laser cavity.

Reference:

1. D. Johnson, VP, Uniphase Corporation, private communication.

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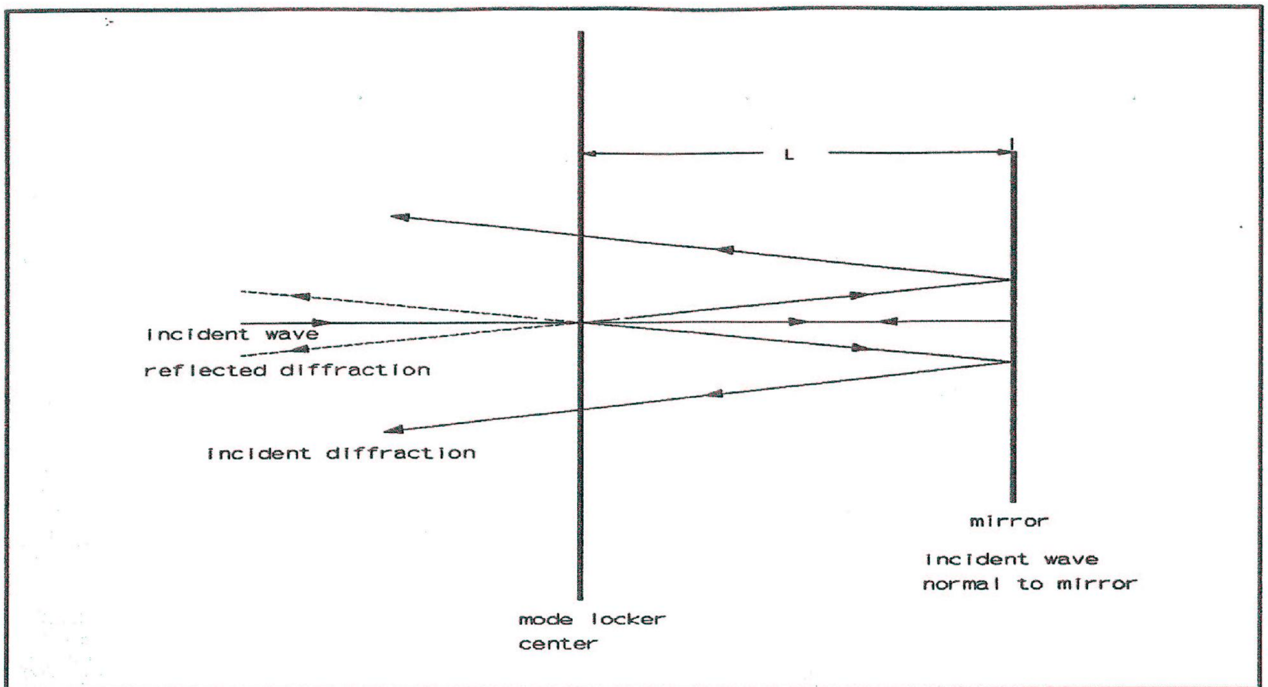

Figure 1 Mode locker and mirror spacing for Raman Nath regime

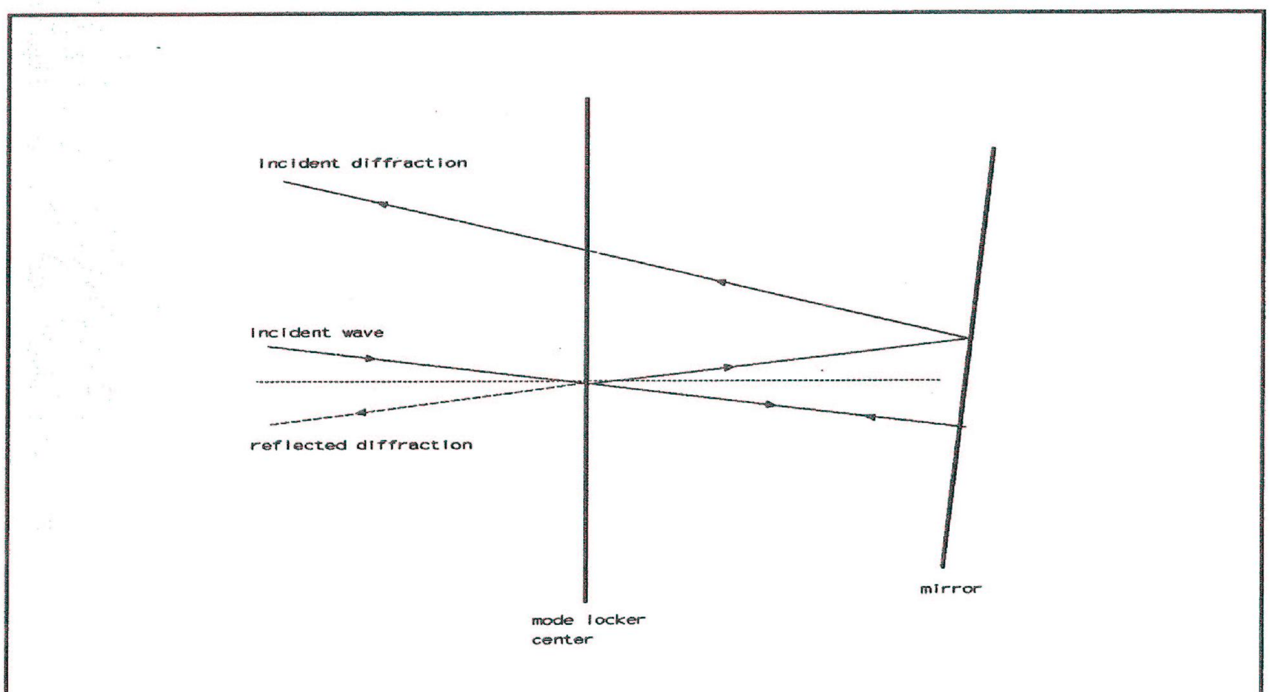

Figure 2 Mode locker and mirror spacing for Bragg regime

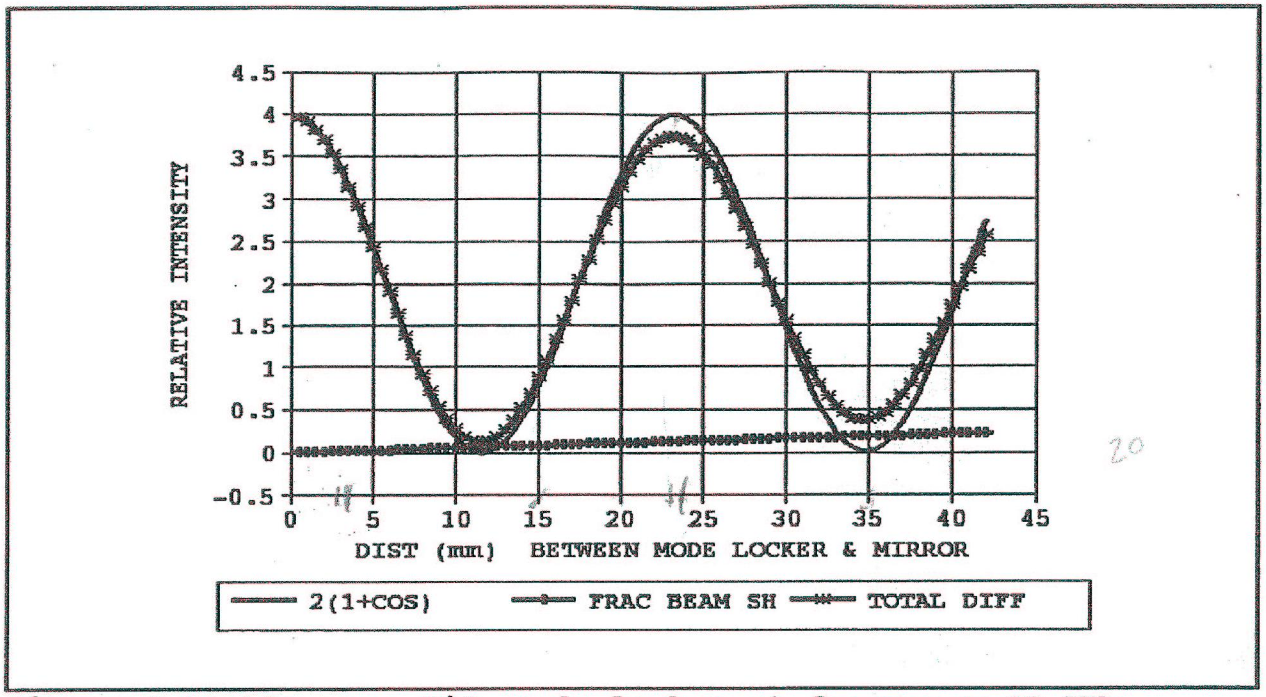

Figure 3 Double pass SiO_2 mode locker at frequency 38 MHz, λ 1.06 μm, and velocity of 5.96 mm/μsec

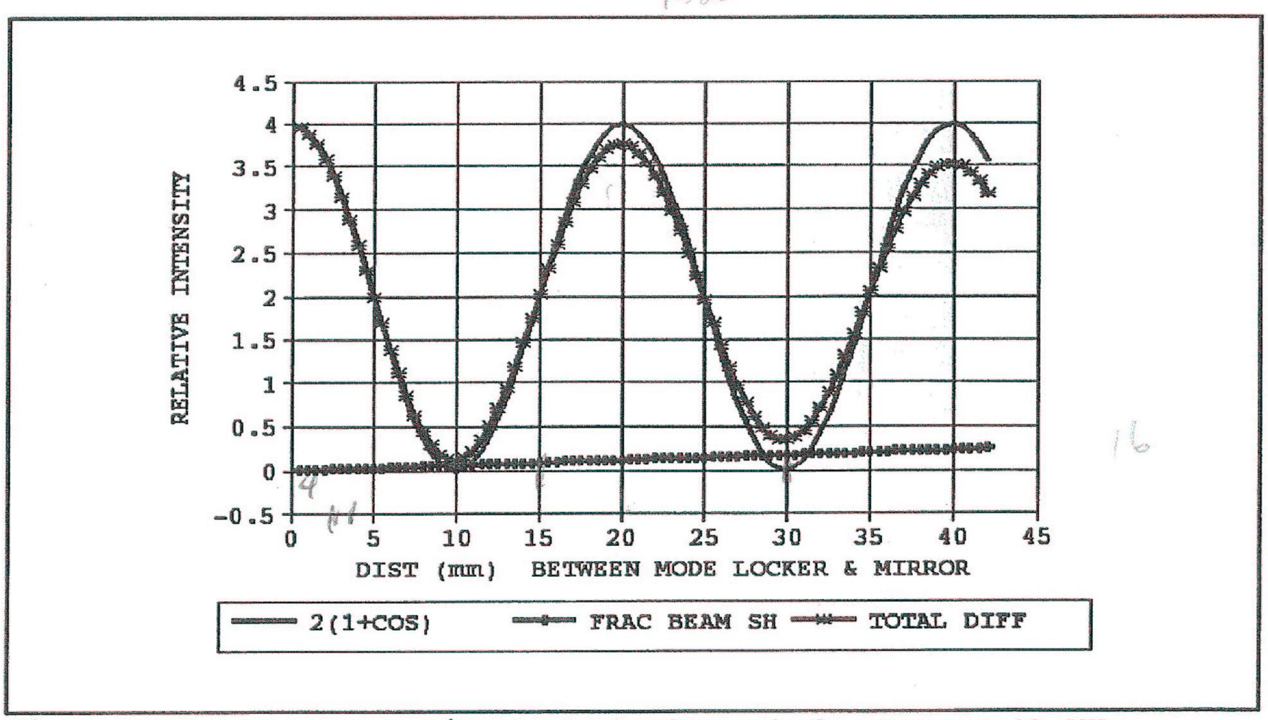

Figure 4 Double pass SiO_2 mode locker at frequency 41 MHz,

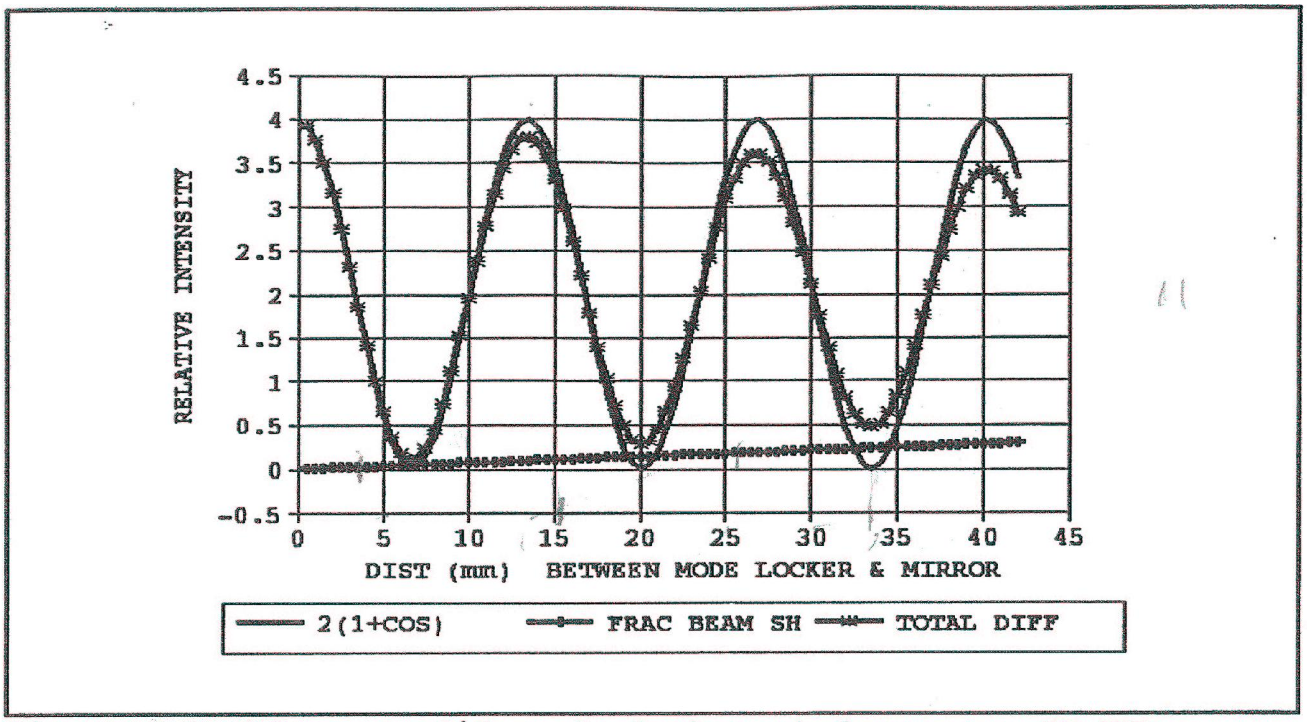

Figure 5 Double pass SiO_2 mode locker at frequency 50 MHz, λ 1.06 μm, and velocity of 5.96 mm/μsec