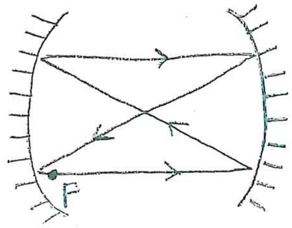
EC591 Lab 3 Report Notes

3.1 A)



mirror reflection : $M_r = \begin{bmatrix} 1 & 0 \\ 2/R & 1 \end{bmatrix}$

free-space propagation between the two mirrors $M_p = \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix}$

symmetrical confocal configuration : $R = -d$

↳ because the mirrors are concave

Starting from point P in the figure above, the ray-transfer matrix for one pass in the cavity is $M_1 = \begin{bmatrix} 1 & 0 \\ -2/d & 1 \end{bmatrix}\begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & d \\ -2/d & -1 \end{bmatrix}$

For two passes : $M_2 = M_1^2 = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$

For four passes : $M_4 = M_2^2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

the distance traveled over which a ray reproduces itself is $L_{tot} = 4d$

In general the free spectral range V_{FSR} is equal to c/L_{tot}

$\Rightarrow V_{FSR} = \dfrac{c}{4d}$ in a symmetric confocal cavity

3.1B)

$$a = \frac{\Delta d}{100 \cdot V_{pp}}$$

piezoelectric responsivity ← a

Δd → maximum displacement of the movable mirror

V_{pp} → peak-to-peak voltage of the scan monitor signal on the oscilloscope

100 → attenuation factor of the scan monitor output (as discussed in the lab handout)

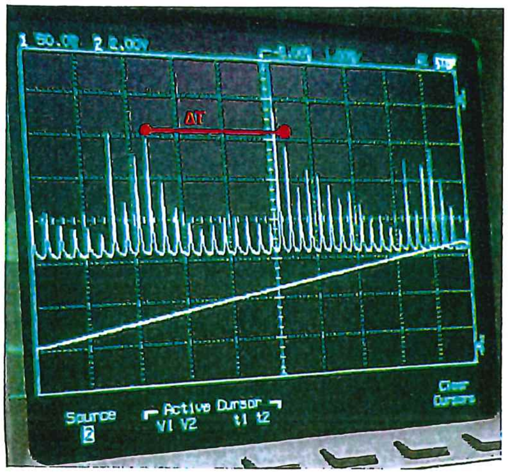
Ex) for $\Delta d = 480$ nm and $V_{pp} = 5.8$ V : $a = 0.83 \frac{nm}{V}$

3.1C) mirror spacing $d = \frac{c}{4 \cdot V_{FSR}}$ $\Big\{ = 7.5$ mm for $V_{FSR} = 10$ GHz

FWHM of transmission peaks $\delta V_{FWHM} = \frac{V_{FSR}}{F}$ $\Big\{ = 50$ MHz for $V_{FSR} = 10$ GHz and $F = 200$

As the movable mirror is displaced, the cavity length changes by a negligible amount (480 nm) compared to its initial value (7.5 mm) and therefore the FSR does not change by any appreciable amount

3.2) The figure below shows a representative oscilloscope trace of the spectrum of a HeNe laser measured with a cavity with $V_{FSR} = 10$ GHz



Two consecutive replicas of the laser spectrum (generated by two consecutiv transmission peaks of the cavity, which differ in frequency by $\nu_{FSR} = 10$ GHz are separated by a time interval $\Delta T \approx 3.4$ ms

$\Rightarrow$ any time increment Δt in the oscilloscope trace corresponds to a frequency increment $\Delta\nu = \frac{\nu_{FSR}}{\Delta T}\Delta t \approx 2.94 \frac{GHz}{ms} \times \Delta t$

3.2A) FSR of the laser cavity $\Big\}$ $\nu_{FSR}^{laser} = \left(\frac{\nu_{FSR}}{\Delta T}\right)\Delta t_{\substack{adjacent\\lines}}$

$\hookrightarrow$ time separation between two adjacent lines in the oscilloscop trace

In the figure above, $\Delta t_{\substack{adjacent\\lines}} \approx 0.2$ ms $\Rightarrow$ $\nu_{FSR}^{laser} = 590$ MHz

If the laser cavity has flat mirrors, its length is $l = \frac{c}{2\nu_{FSR}^{laser}} \Big\{ \approx 25$ cm

3.2B

$$\left.\begin{array}{l}\text{finesse of the}\\ \text{laser cavity}\end{array}\right\} F_{laser} = \frac{\nu_{FSR}^{laser}}{\delta\nu_{FWHM}^{laser}} \left\{\begin{array}{l} = 590 \text{ if } \nu_{FSR}^{laser} = 590\,MHz \\ \text{and } \delta\nu_{FWHM}^{laser} = 1\,MHz\end{array}\right.$$

3.2C For the spectrum shown in the figure above, the FWHM of each line was measured to be

$$\delta t_{FWHM}^{laser} \approx 20\,\mu s \Rightarrow \delta\nu_{FWHM}^{laser}\Big|_{measured} = \frac{\nu_{FSR}}{\Delta T}\,\delta t_{FWHM}^{laser} \approx 59\,MHz$$

This value makes sense because the measured peaks are a convolution of the laser lines with the transmission peaks of the cavity.

$$\downarrow \qquad\qquad\qquad\qquad \downarrow$$

$$\text{FWHM } \delta\nu_{FWHM}^{laser} = 1\,MHz \qquad\qquad \text{FWHM } \delta\nu_{FWHM} = 50\,MHz$$

Because $\delta\nu_{FWHM} \gg \delta\nu_{FWHM}^{laser}$, $\delta\nu_{FWHM}^{laser}\Big|_{measured} \approx \delta\nu_{FWHM}$

3.2D As you rotate the polarizer, you should see two distinct sets of equally spaced lines appear and disappear

$\Rightarrow$ { individual lines are polarized
but
the overall output is unpolarized

3.2E Grasping the laser causes a small change in the temperature inside the cavity, and therefore in the refractive index of the laser gain medium. As a result, the optical length and therefore the FSR of the laser cavity also change, and you should see all the laser lines drift in the oscilloscope

3.2F Reflecting the laser light back into the cavity can result in caothic behavior (leading to large fluctuations in the laser spectrum) through interference effects