Prob 1) P.S. 3

a) Just the area of the CD / spot area $= \pi \times 10^2 / \pi \times (10^{-4})^2 \simeq 10^{10}$ bit

b) $\Omega = 7500$ rpm $= 2\pi \times \frac{(7500)}{60} = \pi \times \frac{(750)}{3} = \pi(250)$ rad/sec

$\therefore v = 10 \times \pi(250)$ cm/sec

$\therefore$ 1 bit in $\frac{2 \times 10^{-4}}{\pi \times 2500} = 2.55 \times 10^{-8}$ sec.

$\therefore$ bit rate $= 3.93 \times 10^{7}$ bits/sec.

c) $C = 2\Delta f \ln_2 (1 + S/N)^{1/2} \simeq \frac{2}{2} \Delta f \frac{\ln_{10} S/N}{\ln_{10} 2}$

$= \frac{2}{2} \Delta f \frac{10 \ln_{10} S/N}{10 \ln_{10} 2}$

$= .332 \, (S/N)_{dB} \, \Delta f$

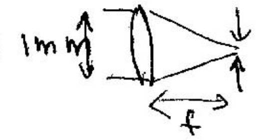
$= .332 \times (35) \, \Delta f$

$\therefore \Delta f = \frac{3.93 \times 10^{7}}{.332 \times 35}$ = <u>sampling band-width</u>

(Note as S/N increases $\Delta f$ decreases because each sample can have a greater number of levels for quantization).

d) If binary encoding is used then the band-width must be at least $\ln_2(M)\Delta f$ since that many bits must be sent in $T_s$. This makes the required channel bandwidth at least $(3.93 \times 10^{7})$. This can be decreased by using a) multilevel encoding schemes b) compression

e) ~~For~~ No of bits/sample $= \frac{\ln_2(M)\Delta f}{2\Delta f}$

f) 


$\therefore 1\mu m \simeq (F N)\lambda = \left(\frac{f}{D}\right)\lambda \quad \therefore f \simeq \frac{1\mu m \times .1cm}{\lambda}$

$\simeq .1$ cm (very short)

g) The advantage of a blue laser is in the ability to focus to a spot which has a radius which is $\frac{\lambda_{blue}}{\lambda_{red}}$ smaller. The area is thus $\left(\frac{\lambda_{blue}}{\lambda_{red}}\right)^2$ smaller. The spot density and size can thus be decreased significantly. (These are just coming on the market.

Problem 2) Take $f(t,z) = \frac{e^{i\omega t - ikz + i\Delta\varphi}}{2i} + c.c.$

The Gaussian is $\frac{1}{\sqrt{2\pi\sigma^2 t}} e^{-(\Delta\varphi)^2/2\sigma^2 t} = p(\Delta\varphi)$

Consider $\int_{-\infty}^{+\infty} e^{i\Delta\varphi} p(\Delta\varphi)\, d\Delta\varphi$

$$= \underbrace{\int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi\sigma^2 t}} e^{-\frac{1}{2\sigma^2 t}\left[\Delta\varphi - i2\frac{\sigma^2 t}{2}\right]^2} d\Delta\varphi}_{1} \left(e^{-\frac{\sigma^2 t}{2}}\right)$$

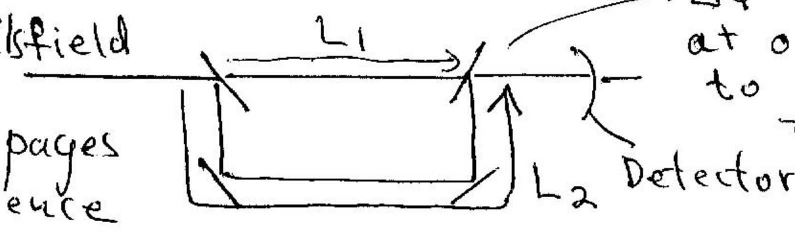
$$= e^{-\sigma^2 t/2}$$

The complex conjugate $e^{-i\Delta\varphi}$ gives the same result.

Thus $\overline{f(t,z)}\Big|_{Averaged} = \sin(\omega t - kz)\, e^{-\sigma^2 t/2}$

The relevance is coherence $\Delta\varphi$ becomes the relative phase between a signal and its time delayed value when phase fluctuations are present. Thus the discussion concerning

For details field See the web pages on coherence



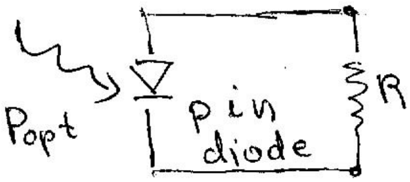

$\Delta\varphi$ is the fluctuating phase at one time $t$ relative to its value at $t - \frac{L_2 - L_1}{c}$

The detector does the averaging

Prob 3) $S/N = 20$ dB

$\Re = .7$ amps/watt

Noise $= 7 \times 10^{-6}$ Volts.




← thermal noise is

$\overline{v_N^2} = 4kTR\Delta f = 7\times10^{-6}$ Volts

signal $= \Re$ Popt $\times R = v_{signal}$

$$\frac{\text{Signal}}{\text{noise}} = \frac{\Re\, P_{opt}\, R}{\sqrt{4kTR\Delta f}} \Rightarrow (20\text{ dB}) = 100$$

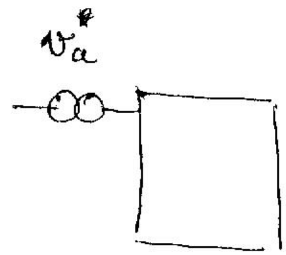
$$\therefore\ P_{opt} = \frac{(100)}{\Re}\sqrt{\frac{4kT\Delta f}{R}}$$

$$= \frac{100}{.7}\left(\frac{7\times10^{-6}}{R}\right)^{1/2}$$

If R = 5 kΩ (must know R or Δf)

= ~~61.342mW~~, 7.56 μW →

Problem 4)




$G_m = 50$

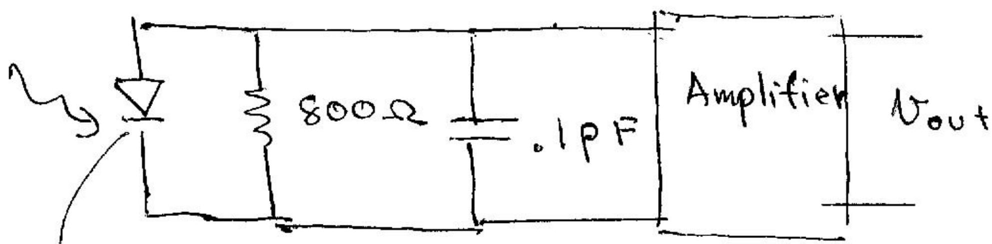
$F_A = 5$

$\mathcal{R} = .7$ amps/W

$R = 800\Omega$

$C = .1\,pF$

Equivalent Circuit.




APD Equalent circuit

$G_m P_{opt} \mathcal{R} = I_{signal}$

$= 50 \times .7\, P_{opt}$ amps.

$P_{opt} = .1\,\mu w$

$RC = 800 \times .1 \times 10^{-12}$

$= .08 \times 10^{-9}$ sec

RC rolloff at $\frac{1}{2\pi RC} \cong 2GHz$

Thus need not worry about C for assumed band width of 1 GHz

We can assume this is shot-noise limited (The purposed for which the APD is used). Thus $v_a^*$ of the amplifier should be negligible. Assume a band width of 1 GHz (limited by the amplifier). The noise is "white" and is the signal shot noise

$$G_m^2 F_A (2e \mathcal{R} P_{opt}) \Delta f$$

$$= (50)^2\, 5\, (2 \times 1.6 \times 10^{-19})(.7)\, .1 \times 10^{-6}\, 10^9$$

$$= 7.9 \times 10^{-16} \text{ amps}^2$$

The noise voltage is thus

$$(7.9 \times 10^{-16})^{1/2}\, 800 = 22.51\ \mu V$$ referred to the input.

b) The signal voltage is $50 \times .7 \times .1 \times 10^{-6} \times 800 = 2.8 \times 10^{-3}$ Volts

$\uparrow$ $G_m$ (50), $\uparrow$ $R$ (.7), $\uparrow$ $P_{opt}$ ($.1 \times 10^{-6}$), $\uparrow$ $R_i$ (800)

b) Signal / Noise $= 2.8 \times 10^{-3} / 22.51 \times 10^{-6} = 124.$