University of California
College of Engineering
Department of Electrical Engineering
and Computer Sciences

EECS 118
3 units
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T. K. Gustafson

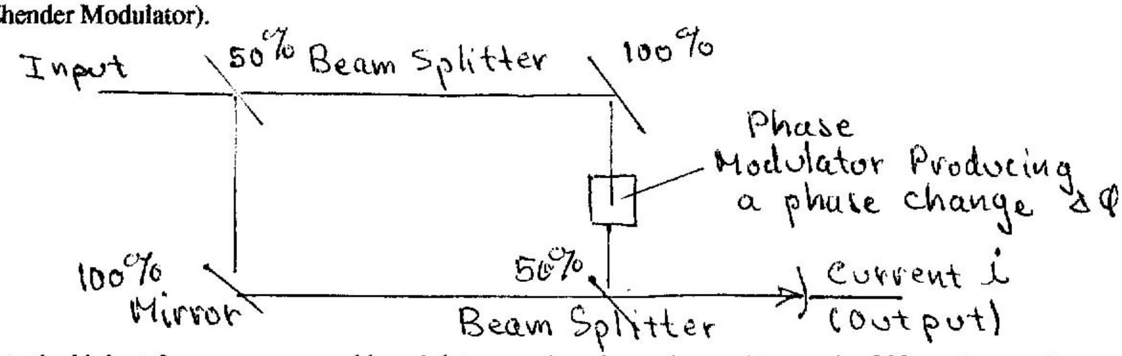
Optical Communications Systems

T.K. Gustafson 459 Cory, 2-3139, Office hrs Tue,Th 9:30-11:00

Problem Set Five:

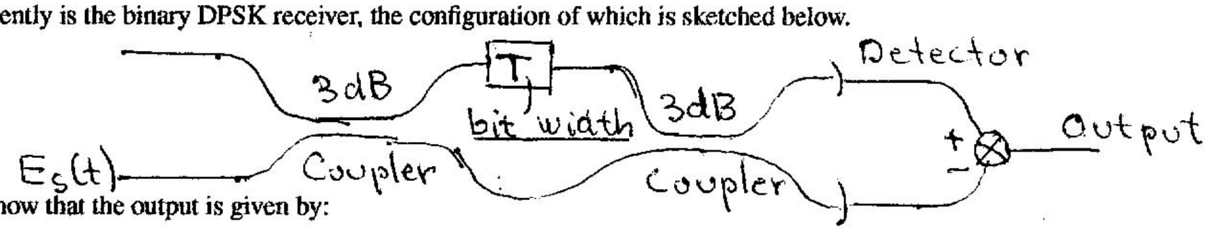
1) **Optical Filter Design**
a) A F.P. filter is used to select 100 channels spaced apart by 0.1 nm. What should be the length and mirror reflectivities of the filter? Assume a refractive index of 1.5 and an operating wavelength of 1.55 μm.
b) Design an AWG that can multiplex/de-multiplex the 100 WDM of a). Specify the spacing beteen the input-output wave-guides, the path-length difference between successive array wave-guides, the radius of the grating circle, and the F.S.R of the AWG.

2) **Modulation**
a) For a single integrated wave-guide in $iLiNbO_3$ if the electro-optic coefficient r_{33} is $3 \cdot 10^{-12}$ m/V, estimate the voltage needed to obtain a phase shift of π with respect to propagation through the guide when no voltage is applied. Take a length of .5 cm and a guide width of 3 μ m . Use a wavelength of 1 μ m and a refractive index of 2.
b) Obtain the output as a function of phase change $\Delta\phi$ for the two-branch configuration shown below (Mach-Zhender Modulator).



c) Estimate the highest frequency one could modulate a semiconductor laser with a cavity 300μ m long and a 5μ by 5μ cross-section if it is driven by a current of 100mA.

3) **Differential Phase Shift Keyed Receiver** a) The most sensitive receiver which utilizes band-width efficiently is the binary DPSK receiver, the configuration of which is sketched below.



Show that the output is given by:

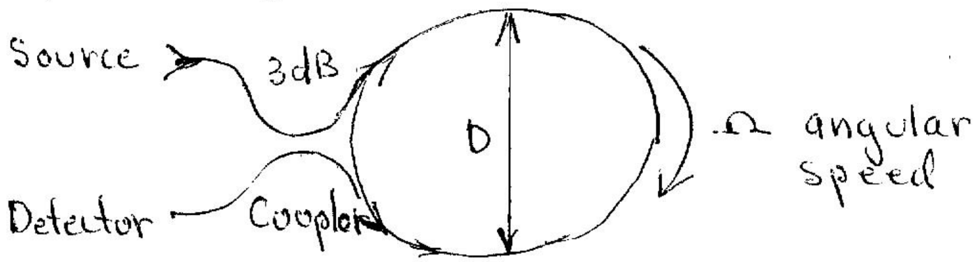
$$i(t) = R_s\, |E_s(t) + E_s(t-T)|^2 - |E_s(t) - E_s(t-T)|^2$$

and that it gives a positive signal if there is no change in successive bits and a negative signal if there is.

d) Estimate the BER in terms of the signal to noise ratio for such a receiver in terms of the current i and the noise σ.

4) Optical signal processing depends upon the fact that the Fourier transform of an image in the focal plane of a lens is imaged in the focal plane on the other side of the lens. Assuming a convex lens show that this is true. If one wanted to remove a periodic line in an image how could this be accomplished.

5) Various modern optical applications depend upon effects induced by relative motion. One such is the optical gyroscope which depends upon the Sagnac effect.
a) For the configuration shown below, obtain the relative phase shift produced by the clockwise and counter clockwise modes as a function of the rotational speed of the fiber optic coil. Assume a fiber coil .5 m in diameter and 1000 turns. The effective index is 1.5 and the wavelength is 1 μ m? How would you convert such a phase shift to a voltage?



b) A second application is Doppler radar. As an example, calculate the frequency resolution necessary to discern 2 mi/hr.
For both of these use a wavelength of 1 μ m .

6) **Gratings**
a) Show that the reflectivity of a grating mirror is equal to;

$$R = \frac{-\kappa^* \, sinh(SL)}{\Delta\beta \sinh(SL) + iS\cosh(SL)}$$

where $S = (|\kappa|^2 - (\Delta\beta)^2)^{1/2}$. κ is the coupling constant between the forward and backward waves and $\Delta\beta$ is the Bragg detuning $k - \frac{\pi}{\Lambda}$
b) Plot the reflectivity versus frequency for a grating spacing of 1.55000 μm, a coupling constant of 50 cm^{-1} and a length of 1 cm.