ECE425S Optical Communication Systems

FINAL EXAM April 13, 1999

ATTEMPT ALL 6 PROBLEMS
[All problems have equal weight]

Useful constants:

Velocity of light in vacuum: $c = 2.998 \times 10^{8}$ m/s
Planck's constant: $h = 6.626 \times 10^{-34}$ J-s
Electron charge: $q = 1.602 \times 10^{-19}$ C

A p-i-n detector is used with a load resistor $\mathbf{R_L}$ to detect digital optical signals with an average optical power $\mathbf{P}$. Assume an equal number of "1"s and "0"s; a detector with quantum efficiency of $\eta = 0.7$ and no dark current or surface leakage current, and a receiver bandwidth Δf, and write the condition for the detection to be shot noise limited. How can this condition be achieved in practice?

One might think that a step-index single-mode optical fibre with a large core diameter (say 50 µm) might be simpler to couple into and to splice than the conventional step-index single-mode fibre with a small core (typically 8 µm). How would you design a step-index single-mode fibre with a 50 µm core? What are the considerations that lead systems designers to prefer the current small-core step-index single-mode fibre design?

A semiconductor laser operating at $\lambda = 1.5$ µm has a net rate of stimulated emission (per photon) of $\mathbf{G} = \mathbf{G_N}(\mathbf{N} - \mathbf{N_o})$ where $\mathbf{G_N} = 3 \times 10^{2}\ \mathrm{s}^{-1}$, $\mathbf{N}$ is the number of electrons contributing to laser action, and $\mathbf{N_o} = 1 \times 10^{8}$. If the photon lifetime in the laser resonator is $\tau_p = 100$ ps, and the carrier lifetime is $\tau_c = 1$ ns, estimate the laser threshold current. Estimate the laser output power when it is driven at twice the threshold current. [You may assume 100% internal quantum efficiency, and that internal losses are negligible i.e. the photon lifetime is determined by the laser mirror transmission.]

Discuss the use of optical amplifiers to overcome loss in a long-distance fibre communications link. What are the key limitations of this approach, and how can they be addressed?

A simple point-to-point optical communications system is designed to operate with a laser producing a signal of bandwidth $\Delta\lambda = 10$ nm, and power of +6 dBm coupled into the fibre, and with a system margin of 3 dB. If the (single-mode) fibre has a loss at the operating wavelength $\lambda = 1.5$ µm of 1 dB / km, and a group velocity dispersion coefficient $\mathbf{D} = 10$ ps / nm-km, what is the longest link that can be designed for a) a signal bit rate $\mathbf{B} = 1$Mbit/s? ; and b) for $\mathbf{B} = 10$ Gbit/s? Assume that in both cases a BER of 10^{-9} is required and that you can use an ideal receiver that is shot noise limited.

Discuss the reasons for the current interest in wavelength-division-multiplexed (WDM) optical communication systems. Why is WDM used rather than optical time-division-multiplexing (TDM)?