ECE425S Optical Communication Systems

FINAL EXAM April 19, 2000

ATTEMPT ALL 8 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
Boltzmann's constant $k_B = 1.381 \times 10^{-23}$ J/K

1. What is the dispersion-limited transmission distance for a 1.55 μm lightwave system making use of direct modulation at 10 Gb/s? Assume that frequency chirping broadens the Gaussian-shape pulse spectrum by a factor of 5 from its transform-limited (minimum) width. Use $D_\lambda = 20$ ps / (nm-km) for the fibre dispersion.

2. A single mode fibre has a core with a refractive index of 1.45 and an index step of 0.007. Calculate the core radius if the fibre has a cutoff wavelength for the second order mode of $\lambda = 1.1$ μm. Estimate the fraction of modal power in the core for a mode of wavelength $\lambda = 1.5$ μm.

3. Describe the main sources of dispersion in optical systems and the ways that dispersive effects limit system performance.

4. A 1.5 μm receiver has a bandwidth of 30 MHz which is determined by the **RC** time constant of the detector load resistance and the 1 pF junction capacitance of the photodiode. The photodiode has a quantum efficiency of 0.7 and a dark current of 1 nA. The receiver amplifier has a noise figure of 3 dB. Determine the rms noise currents due to shot noise and thermal noise when the receiver is illuminated with 5 μW of optical power and calculate the signal-to-noise ratio (SNR). How much incident power would be required in order for the detector to be shot noise limited?

5. Photons at a rate of 10^{11}/s are incident on an avalanche photodiode (APD) with responsivity of 8 A/W. Calculate the quantum efficiency and the photocurrent at the operating wavelength of 1.5 μm if the APD has a gain of 10.

6. In what ways are a semiconductor p-i-n detector and light-emitting diode (LED) similar? In what ways are they different? How are their basic operating mechanisms related?

7. A 1.3 μm lightwave system uses a laser transmitter capable of coupling 100 μW of average power into the optical fibre. Assume 2 dB / km attenuation, a 2 dB connector loss at each end of the fibre link, and a system margin of 6 dB. What is the longest link (without amplification) that can be designed for a signal bit rate **B** = 40 Gbit/s? Assume that a BER of 10^{-9} is required and that you can use an ideal receiver that is shot noise limited. You may also assume no dispersive effects in the transmission path.

8. Describe the factors that will limit the number of channels that may be used in a WDM (wavelength-division-multiplexed) communications system. How would you design a WDM system to maximize the number of channels?