ECE425S Optical Communication Systems

FINAL EXAM
April 24, 2001; 2:00 pm - 4:30 pm

ATTEMPT ALL SIX PROBLEMS

all problems have equal weight

Useful constants:

Velocity of light in vacuum: $\mathbf{c} = 2.998 \times 10^{8}$ m/s
Planck's constant: $\mathbf{h} = 6.626 \times 10^{-34}$ J-s
Boltzmann's constant: $\mathbf{k_B} = 1.381 \times 10^{-23}$ J/K
Electron charge: $\mathbf{q} = 1.602 \times 10^{-19}$ C

1. A step index optical fibre is made with two types of fused quartz with refractive indicies of 1.449 and 1.452 respectively. What fibre core radius would be necessary to assure single-mode transmission at a (vacuum) wavelength $\lambda = 1.55$ μm? What would be the acceptance angle for this fibre in air?

2. Describe the fundamental similarities and differences between a semiconductor light-emitting diode (LED) and a semiconductor laser diode. What are the key characteristics that affect their application in optical communications systems?

3. A 1.5 μm digital receiver is designed to operate at 5 Gbits/s. It uses a p-i-n detector with 80% quantum efficiency and a dark current of 30 nA. Estimate the value of the load resistor that should be used if the receiver is to be shot noise limited with an optical power at the receiver of 5 μW. Assume an amplifier noise figure of 6 dB.

4. A 1.3 μm lightwave system uses an LED capable of coupling 0.1 mW of average power into a single-mode fibre. Assume 1 dB/km fibre attenuation, 0.2 dB splice loss at 2-km intervals, and 6-dB system margin. If the receiver sensitivity is 2000 photons/bit, develop an expression for the dependence of the maximum (loss-limited) transmission distance on the bit rate **B** of the system.

5. Wavelength division multiplexing (WDM) and time division multiplexing (TDM) are useful techniques for increasing the capacity of optical communications systems. Briefly describe the advantages and current limitations of each technique and suggest how these limitations might be overcome.

6. How many photons / bit are required by an ideal shot-noise-limited p-i-n digital receiver in order to achieve a bit error rate (BER) of 10^{-9}? If a lightwave system only delivers an average of 5 photons / bit at this receiver, can 10^{-9} BER performance be achieved using an optical preamplifier in front of the receiver? Estimate the minimum gain required and indicate what must be done in order to minimize the required gain.