Examination *S-108.3110* 21.12.2007

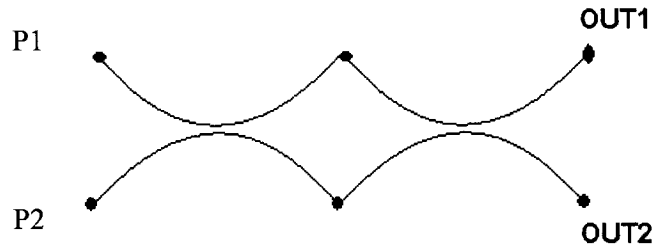
All the questions should be answered. Please, provide clear and readable answers!

1. Tell if the following statements are true (T) or false (F).
   1. T Standard optical fibers exhibit normal dispersion above 1.32 μm.
   2. T The number of modes propagating in an optical fiber is proportional to the numerical aperture of the fiber.
   3. T The fundamental mode of single-mode optical fibers is well-approximated by a Gaussian function.
   4. F Self-phase modulation induces pulse spreading in time.
   5. F Brillouin scattering transfer energy from the signal to a wave propagating in the same direction.
   6. F Raman scattering is caused by the interaction of light with the vibration modes of silica molecules.
   7. T Brillouin scattering amplifies signal shifted by 11 GHz from a strong pump.
   8. F The number of mixing terms resulting from four-wave mixing in a N channels systems is proportional to N^3.
   9. T The finesse of Fabry-Pérot filters is defined as the ratio of the width of the transmission peak to the free-spectral range.
   10. T Mach-Zehnder filters have a very sharp pass-band.
   11. F The signal transmitted across a 2×2 coupler experience a pi phase-shift.
   11. T Erbium-doped fiber amplifiers are not sensitive to the data-rate.
   13. F The gain of Erbium-doped fiber amplifiers is independent of the signal input power.
   14. — The noise figure of Erbium-doped fiber amplifiers represents the degradation of the signal-to-noise ratio during amplification.
   15. F Raman amplifiers require low pump power.
   16. T Micro electro-mechanical systems can be used for performing optical switching.
   17. F Over-illumination means that the photodiode is saturated?
   18. F Light-emitting-diodes usually have higher output power than laser diodes at their peak wavelengths.
   19. T Avalanche photodiodes can detect signals with lower power compared to PIN photodiodes.
   20. F Cutback method can be used to study the attenuation spectrum of the fiber?

2. We consider an optical fiber with a core diameter of 16 μm and a fractional refractive index difference of 0.005. Assuming that the refractive index of the core is equal to 1.45, calculate the number of modes supported by the fiber at a wavelength of 1000 nm. Above which wavelength is the fiber is single-mode? Calculate the distance over which the injected optical power P_{In} is reduced by a factor of 2 if the fiber has an attenuation coefficient of 0.5 dB/km.

3. We consider two different optical fiber links.
   a) The link number 1 consists of a multimode-fiber that transmits data at a wavelength of 0.8 μm with a rate of 20 Mb/s. At this wavelength, the multimode-fiber attenuation is 1 dB/km. The fractional refractive index difference of the fiber is 0.01 and the core refractive index is 1.5. Calculate the inter-modal dispersion of the fiber. Deduce the maximum possible length for the link. Assuming a transmitter with an output power P_{Out} =0.5 dBm, calculate the minimum sensitivity of the detector.
   b) The link number 2 consists of a single-mode fiber that transmits data at a wavelength of 1.55 μm with a rate of 1 Gb/s. At this wavelength, the fiber attenuation is 0.5 dB/km and the fiber intra-modal dispersion is 17 ps/nm×km. The spectral width of the transmitter is $\Delta\lambda$=1 nm and the transmitter output power is P_{Out}=1 mW. Assuming that the detector sensitivity is equal to -30 dBm what is the maximum possible length for this link?

4. Two 50/50 couplers are used in cascade as shown in the figure below. Calculate the power exiting ports OUT1 and OUT2 as a function of input powers P1 and P2.



5. The responsivity of a photodiode is defined as the ratio of output photocurrent (in A units) to the incident optical power (in W units). Calculate the responsivity of the photodiode at a wavelength of 1500 nm. The refractive index is 3.5. What is the responsivity when the active material thickness is 250 μm and the absorption coefficient is 4 mm^{-1}?

6. Discuss the different types of scattering in optical fibers.