HW #9 due 4/19/13 5PM
no later than 4/23/13 5PM

1. Repeat question 4 of HW 8 if the photodetector is an APD having a gain of 75 and an unamplified dark current of 2nA.

2. The optical power reaching the receiver is 1μW (DC value without modulation). The detector's responsivity is 0.45A/W and its dark current is 3nA. The temperature is 0^oC, the receiver's bandwidth is 400MHz and the load resistance is 150Ω.
a) Compute the signal to noise ratio.
b) Compute the thermal-noise-limited SNR.
c) Compute the shot-noise-limited SNR.
d) Compute the NEP for this receiver.

3. A thermal-noise-limited PCM system must operate with an BER better than 5×10^{-11}. The load resistance is 75Ω and the temperature is 300K. The data rate is 500 Mbps (NRZ), the wavelength is 1.3 μm and the photodetector's quantum efficiency is 0.9.
a) What is the required minimum SNR?
b) How much optical power must reach the receiver?
c) Compute the number of incident photons per bit (that is, the number of photons when a binary 1 is received) at this power level.

Extra-Credit for undergraduate (regular for graduate)
4. In class, I have only given information on Δf_{FSR} for WGR. Here I give more specifications for design equations for path difference ΔL and channel spacing $\Delta\lambda_{CS}$. The couplers in Fig. 3.24 are specifically called star coupler.
Path difference between adjacent channel $\Delta L = m\lambda_c/n_c$ where m is the diffraction order (an integer), λ_c is the central design wavelength (e.g. for an array of 101 fibers, λ_c is the wavelength of the 51st fiber) and n_c is the refractive index of the arrayed waveguide.
The channel spacing $\Delta\lambda_{CS} = x\lambda_c dn_s/(L_f \Delta L n_g)$ where n_s is the refractive index of the star couple, L_f is the spatial separation between input fiber array and arrayed waveguide, n_g is the group refractive index for the arrayed waveguide, x is the spacing between fibers in the input array and d is the spacing between channels in the arrayed waveguide.
Consider a WGR having $L_f = 10mm$, $x = d = 5\mu m$, $n_c = n_s = 1.45$, $n_g = 1.47$, and a central design wavelength of 1550nm. For diffraction order of 1, find a) path difference ΔL, b) channel separation $\Delta\lambda_{CS}$, c) free spectral range Δf_{FSR}, d) possible number of channels (note: use λ_c as λ in your calculations).

Extra-credit
5. A plane reflection grating can be used as a wavelength-division multiplexer. The angular properties of this grating are given by the grating equation $a(\sin\theta_i + \sin\theta_d) = m\lambda$. (note: This is the same equation obtained in extra-credit of HW3 with θ_i being the angle of the input beam, θ_d being the angle of the diffracted beam and a being the period of the grating.)
a) Using the grating equation, show that the angular dispersion is given by $d\theta_d/d\lambda = m/(a\cos\theta_d)$.
b) Assuming $\theta_i \approx \theta_d$, show that the angular dispersion can be further expressed as $d\theta_d/d\lambda = 2\tan\theta_d/\lambda$.
c) If the fractional beam spread S is given by $S = 2(1+p)\Delta\lambda(\tan^2\theta_d)/\lambda$ where p is the number of wavelength channels, find the upper limit on θ_d for beam spreading of less than 1 percent given that $\Delta\lambda = 26nm$, $\lambda = 1360nm$ and $p = 3$.