HW #6 — due 3/8/18 5PM, no later than 3/12/18 5PM

1. Consider a fiber communication system which operates at $1.3\mu m$ and uses a 20km-long fiber with effective area of $50\mu m^2$, attenuation of 0.5 dB/km and Raman gain coefficient of $10^{-13} m/W$. The overall losses without the fiber loss is 16dB and the receiver requires 0.02mW of power.
a) What is the minimum power of the source (transmitter)?
b) What is the power threshold for significant Raman effect?
c) How many optical channels can we put into the system?

2. Consider wave mixing (i.e. four wave mixing and sum frequency generation) with third order nonlinearity ($\chi^{(3)}$) of three channels with frequencies f_a, f_b and f_c. This process can generate 22 unique frequencies out of the possible 6x6x6 possible combinations. List all 22 unique frequencies. Notice negative frequencies do not count, e.g. $f_a + f_b - f_c$ is considered to be the same as $f_c - f_b - f_a$.

3. In class we see that positive nonlinearity can compensate for anomalous dispersion and result in generation of solitons. There is another combination of nonlinearity and dispersion that leads to generation of solitons. Name the combination and explanation their cancellation with frequency shifts at leading and trailing edges with the freq shift versus time curves, similar to those on the web.

4. You are considering the possibility of soliton propagation in a communication link with $\lambda = 1.58\mu m$, $D_{intra} = 30 ps/km - nm$, fiber core radius $5\mu m$ and $n_2 = 3.19 \times 10^{-16} cm^2/W$. a) Find the nonlinear parameter γ by assuming A_e equal to the fiber core area, b) find the pulse width T_o when the peak power $P_o = 10mW$ (notice that the envelope A_o has unit of $\sqrt{W}$), and c) what we need to do if we want solitons with shorter T_o?

Extra-Credit for undergraduate (regular for graduate)
5. Consider a fiber at wavelength of $1.6\mu m$ with effective area of $45\mu m^2$, $\alpha_{dB} = 0.3 dB/km$ and $n_2 = 3.2 \times 10^{-20} m^2/W$. a) Calculate the power launched into a 40-km-long single mode fiber for which the SPM-induced nonlinear phase shift becomes 180^o.
b) If there are two adjacent channels (one has 80mW and the other has 40mW), find the length of the fiber for which the XPM-induced nonlinear phase shift becomes 180^o.

Extra-Credit
6. An nonlinear equation that describes SPM and XPM is $dE/dz = -jk_o n_2 |E|^2 E$ which has an approximate solution of $E = E_o \exp(-jk_o n_2 |E|^2 z)$ by assuming $|E|^2$ to be constant with respect to z. Notice that $|E|^2 = EE^*$. Now consider E is a sum of two fields in different frequencies ω_1 and ω_2, i.e. $E_1 = E_{10} e^{j\omega_1 t}$ and $E_2 = E_{20} e^{j\omega_2 t}$. By keeping all terms in $|E|^2 E$ that contain only $e^{j\omega_1 t}$ and $e^{j\omega_2 t}$ and group terms with the same ω together, write down the formulas for dE_{10}/dz and dE_{20}/dz.