Exercise 1

A 1.55 um lightwave systems operating at 5 Gb/s is using 100 ps (FWHM) Gaussian pulses chirped such that $C = -6$. Neglect laser linewidth and assume that $\beta_2 = 20\ \mathrm{ps^2/nm}$.

(a) What is the dispersion limited maximum fiber length using the criteria $4B\sigma_{max} \leq 1$?

(b) How much will it change if the pulses were unchirped?

Exercise 2

Starting from the definition for the group velocity $v_g = \frac{d\omega}{d\beta} = \frac{c}{n_g}$ prove that the group index can be expressed as a function of wavelength as $n_g(\lambda) = n(\lambda) - \lambda \frac{dn}{d\lambda}$.

Exercise 3

Let us consider a fiber made of the glass material fused silica SiO2. The refractive index can be modeled using Sellmeier relation and the following coefficients:

$$n^2 = 1 + \sum_{j=1}^{3} \frac{A_j \lambda^2}{\lambda^2 - \lambda_j^2}$$

$$A_1 = 0.6961663$$

$$\lambda_1 = 0.0684043\ \mu\mathrm{m}$$

$$A_2 = 0.4079426$$

$$\lambda_2 = 0.1162414\ \mu\mathrm{m}$$

$$A_4 = 0.8974794$$

$$\lambda_4 = 9.896161\ \mu\mathrm{m}$$

Using matlab:

(a) Plot $n(\lambda)$ from 200 nm to 3000 nm

(b) Plot the group index n_g and the group velocity dispersion β_2. It is preferable to base the derivation on an equally spaced **frequency** grid. Remember: that the group index is most conveniently written in terms of frequency and is given by $n_g = \frac{d\beta}{d\omega} c$, with c the speed of light. And that the GVD is given by $\beta_2 = \frac{d^2\beta}{d\omega^2}$

Exercise 4

A 1.06 μm pulsed Q-switched Nd:YAG laser emits an un-chirped Gaussian pulse with 1 nJ energy and 100 ps FWHM. The pulses are transmitted through a 1 km long fiber with 3 dB/km loss, $n_2 = 3 \cdot 10^{-20}\ \mathrm{m^2/W}$ and an effective area of 20 $\mu\mathrm{m}^2$. Assume 94% of the energy of a Gaussian is within its FMHW.

(a) Calculate the maximum values of the nonlinear phase shift at the fiber output.

(b) Express the frequency chirp at the fiber output. Plot it using matlab. What is the maximum value of the frequency chirp (in THz) and at which time (relative to the pulse center) does it occur ?

Exercise 5

We have a 50 km long fiber link. The radius of the fiber is 2.5 μm and the peak Raman coefficient is $g_R = 2 \cdot 10^{-13}$ m/W. The loss at 1.3 μm and 1.5 μm is 0.5 dB/km and 0.2 dB/km, respectively.

(a) Calculate the threshold power for stimulated Raman scattering if the operating wavelength is 1.3 μm.

(b) How much does the threshold power change if the link operating wavelength is changed to 1.5 μm.

Graded Exercise

The pulse broadening equation, where σ_0 is the initial RMS pulse width and σ the RMS pulse width after a propagating distance of L, is given the following equation. For a RMS spectral width of σ_ω, V_ω is defined as $V_\omega = 2\sigma_\omega\sigma_0$.

$$\frac{\sigma^2(z)}{\sigma_0^2} = \left(1 + \frac{C\beta_2 z}{2\sigma_0^2}\right)^2 + (1 + V_\omega^2)\left(\frac{\beta_2 z}{2\sigma_0^2}\right)^2 + (1 + C^2 + V_\omega^2)^2\left(\frac{\beta_3 z}{4\sqrt{2}\sigma_0^3}\right)^2$$

We have the following operating conditions: small spectral width, no chirp, zero-dispersion wavelength operation (λ close to 1320 nm)

(a) Simplify equation 1 according to the operating conditions.

(b) Find the input pulse width condition $\sigma_{0,min}$ for which σ is minimized (think derivative …). What is σ in this case (it should be a function of β_3 and L)?

(c) Given that the constraint on RMS pulse width after propagation relative to the bit width is given by $\sigma \leq 1/(4B)$, and using the results derived in b), express the BL limit for this system

(d) Using the derived equation, what is the limiting bit rate for $L = 100$ km and slope $S = 0.117$ ps/(nm^{2}km).