Dispersion Limited Fiber Length

Objective:

Calculate the dispersion-limited fiber length for a fiber optic transport system that employs standard single-mode fiber and a directly-modulated single-mode laser diode transmitter.

Simulate the resulting system and verify that it meets performance objective.

Theory:

The maximum allowable dispersion (or pulse spread) Δt_{max} is given in terms of the transmission rate R by the following engineering guideline

$$\Delta t_{max} = \frac{1}{4R}$$

This guideline provides reasonable assurance that there will be no significant inter-symbol interference (ISI) due to pulse spread.

For standard single-mode fiber driven by a directly-modulated laser diode transmitter, the pulse spread due to chromatic dispersion is given by

$$\Delta t = LD(\lambda)\Delta\lambda$$

where
- Δt = pulse spread (ps)
- L = fiber length (km)
- $D(\lambda)$ = chromatic dispersion factor (ps/nm-km)
- λ = operating wavelength (nm)
- $\Delta\lambda$ = spectral width of the transmitter output (nm)

The chromatic dispersion factor can be calculated from the formula

$$D(\lambda) = \frac{S_0}{4}\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

where
- S_0 = zero dispersion slope (ps/nm^2-km)
- λ_0 = zero dispersion wavelength (nm)

The dispersion-limited fiber length is the value of L such that $\Delta t = \Delta t_{max}$.

Note that there can be additional pulse spread due to the transmitter and receiver rise times. The somewhat conservative engineering guideline allows for this, but the results of the simulation should be checked to verify acceptable system performance.

Pre-lab Calculation:

The specifications for the system are summarized in the table below

Transmitter	Transmission rate	2.5	Gb/s
	Output power	0	dBm
	Operating wavelength	1550	nm
	Spectral width	0.6	nm
Fiber	Zero-dispersion slope	0.09	ps/nm^2-km
	Zero-dispersion wavelength	1312	nm
	Input/output coupling efficiency	0	dB

The fiber attenuation factor and coupling efficiencies are set to 0 in order to isolate the effects of dispersion from those of attenuation.

Using the data in the table (and in the fiber data sheet) and the theory summarized above, determine the dispersion-limited fiber length.

Layout:

Open up the OptiPerformer file called "Dispersion Limited Fiber.osp". This layout uses the Laser Rate Equations laser diode component with default parameters. It models a directly modulated laser diode based using a standard rate equation model. One of the effects of this model is that it generates a signal with a spectral width of about 0.6 nm for the default parameters with 2.5 Gb/s, return to zero modulation.

Within the layout, there are several "Visualizers." The "Optical Time Domain Visualizers" allow the user to the view the simulated signal as a function of time. There is one at the output of the laser and one at the end of the fiber. This allows the user to directly observe the changes in the pulses due fiber dispersion. The "Optical Spectrum Analyzer" allows the user to view the spectral content of the signal. It this lab it is used to verify that the spectral width is about 6 nm. The "BER analyzer" provides calculations of the Q factor, the bit error rate (BER) and provides a plot of the eye diagram.

Simulation:

Set the laser power such to achieve a transmitter output power of 0 dBm. The transmitter power can be viewed by double clicking the "Output Power Meter Visualizer." The power will read -100 dBm until the first run is made.
Using the chromatic dispersion factor equation, determine the dispersion of the fiber at 1550 nm and set the fiber dispersion parameter accordingly.

Using the equations above, determine the dispersion-limited fiber length.

Run the simulation 5 times with the following values for fiber length:

Iteration	Fiber Length
1	Calculated dispersion-limited fiber length
2	25 km
3	50 km
4	75 km
5	100 km

After the first run, use the optical spectrum analyzer to verify that the spectral width at the transmitter output is about 0.6 nm. To do this, right click on the spectrum plot and choose "Marker". Place one marker on either side of the main signal. The spectrum is noisy so a precise measurement can not be obtained in this way, but it should be clear that the spectral width is about 0.6 ± 0.1 nm

For each iteration:

- Use the BER analyzer to measure and record the Q factor, the bit error rate and the eye diagram.
- Use optical time domain analyzers to compare the pulse width at the input and output of the fiber.

Analysis:

Compare the result of the simulations and your pre-lab calculations and record your observations. Provide an explanation for any differences between the pre-lab calculations and the simulation results.