ENEE 785 Project

Polarization evolution due to nonlinearity and chromatic dispersion

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1 Purpose of project

The main purpose of this project is to understand how the Kerr nonlinearity affects the evolution of the polarization states of the channels in a WDM system in the case that the chromatic dispersion is locally large and the polarization effects of PMD, PDL, and PDG are neglected. The project is based primarily on a paper of Wang and Menyuk [1]. The main result of [1] is that if the local dispersion is sufficiently large then the only effect of the nonlinearity is to rotate the Stokes vectors of all the channels by the same amount as the signal propagates through the fiber. Consequently, in this case, the nonlinearity will only have a slight effect on the evolution of the degree-of-polarization (DOP) of the signal. However, there are parameter regimes where the DOP does depend on the nonlinearity. One reason the paper is important is that it provides a preliminary, partial validation of Wang and Menyuk's Reduced Stokes Model [2].

A secondary goal of the project is to investigate the degree to which the evolution of the DOP is affected by the combination of chromatic dispersion,nonlinearity and a small amount of PMD.

2 Details

- Reproduce the derivation of the Mean Field Equations. (5.21) and (5.26) of Wang's thesis [3][1] and understand the assumptions made in the derivation. You should include all the small sub-steps that are missing in this derivation. A careful, neat, hand written write up is sufficient.
- Your first simulation task is to compare the solutions of the systems of ordinary differential equations in (5.21) and (5.26) to the analytical formula for their solution given in (5.22) and to simulations performed using the Manakov-PMD partial differential equation. This will require you to do the following
  - Add a method to the class OptSignal in OCS that enables you to adjust the input DOP and unit Stokes vector of an NRZ or CRZ signal to any desired value. Use the method of [4] to set the DOP (see also [3] Section 5.5.3). Carefully test your implementation of the method!
  - Add a class to OCS that can be used to perform simulations using the Mean Field Equations, i.e., Eqs. (5.21), (5.26), and (5.22).

[1] Wang's thesis is at http://www.photonics.umbc.edu/internal/Theses_and_Papers/currentpapers.html

  - You are to compare the models using two variants of the 10 Gb/s noise-free Tyco system in MyApp.cc over 6000 km. The first variant should use the parameters we gave you. The second should use higher values of chromatic dispersion, as in [1].
  - When there is no gain/loss in the system, you should compare the three methods: Mean field ODEs (5.21), Analytical solution (5.22) and Manakov PMD equation. Plot the evolution of the Stokes parameters and DOP as a function of distance. You should make this comparision for several different random choices of input Stokes parameters in each channel, and different DOPs. Use 50 GHz and 100 GHz channel spacings, and 3 and 7 channels. Find limits in which the models give the same and different results.
  - Repeat the previous bullet when there is gain/loss, this time comparing the Mean field equation (5.26) with the Manakov-PMD equation.
  - It would be very cool to make a Matlab movie showing the evolution of the Stokes parameters on the Poincaré sphere.

- Your second main task is to investigate how PMD affects the results you found above. Add a small amount of PMD (say 0.1 ps/km$^{1/2}$) to the Manakov-PMD equation. Investigate how the evolution of the Stokes parameters and the DOP changes as you changes the fiber realization. Run simulations over many fiber realizations and make histograms of the DOP as a function of distance. Plot the mean and standard deviation of this histogram as a function of distance. What conclusions can you make?

References

[1] D. Wang and C. R. Menyuk, "Polarization evolution due to the Kerr nonlinearity and chromatic dispersion," *J. Lightwave Technol.*, vol. 17, pp. 2520–2529, 1999.

[2] D. Wang and C. R. Menyuk, "Calculation of penalties due to polarization effects in a long-haul WDM system using a Stokes parameter model," *J. Lightwave Technol.*, vol. 19, pp. 487–494, 2001.

[3] D. Wang, *Polarization effects in dense WDM system*, Ph.D. thesis, University of Maryland Baltimore County, May 2000.

[4] N. S. Bergano, "Wavelength division multiplexing in long-haul transmission systems," *J. Lightwave Technol.*, vol. 14, pp. 1299–1308, 1996.

[5] R.-M. Mu, V. S. Grigoryan, C. R. Menyuk, G. M. Carter, and J. M. Jacob, "Comparison of theory and experiment for dispersion-managed solitons in a recirculating fiber loop," *IEEE J. Sel. Topics Quant. Electron.*, vol. 6, pp. 248–257, 2000.