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Qualitative Analysis of SPM & Performance Analysis of FWM in Commercial Optical Fiber by using Optisystem

Subhrajit Pradhan*
Research Scholar
Department of Electronic Sciences
Berhampur University, Berhampur, India

Bijayananda Patnaik
Assistant Professor
IIIT Bhubaneshwar
Bhubaneshwar, Odisha, India

Rashmita Kumari Panigrahy
Lecturer
Department of Electronic Sciences
Berhampur University, Berhampur, India

Shalini Gupta
UG Student
Gandhi Institute of Engineering & Technology
Gunupur, Rayagada, Odisha, India

Pooja Kumari
UG Student
Gandhi Institute of Engineering & Technology
Gunupur, Rayagada, Odisha, India

Mansha Acharya
UG Student
Gandhi Institute of Engineering & Technology
Gunupur, Rayagada, Odisha, India

Abstract

Focus on development of broadband optical communication systems is incredible since it offers combination of wide bandwidth and low losses unmatched by any other transmission medium. There are some limiting factors related to data rate and capacity in optical fiber communication system. These limiting factors can be linear or non-linear. We can compensate the linear effect such as dispersion and attenuation by using dispersion compensation methods. But the non-linear effects still accumulate with the increase in optical power levels. When all the input signal frequencies interact due to fiber nonlinearities, the output bit stream may behave in a complicated way giving adverse effects on system performance. In wavelength-division multiplexing (WDM) systems, inter-channel interference due to fiber nonlinearities may limit the system performance significantly. Therefore, it is crucial to understand fiber nonlinearities and their effects on fiber-optic communication systems. The main motivation of this work was to study theoretical and simulation studies of broad band optical communication systems due to fiber nonlinearities. Here, we investigate Modulation (SPM) and Four Wave Mixing (FWM), by using the parametric run feature in Optisystem. The eye diagram highlights the conversion due to the SPM and FWM. Specifically the eye opening decreases with increasing transmitted power.

***Keywords**: SPM, FWM, Optisystem.*

****Author for correspondence*** subhrajit.pradhan@gmail.com

1. Introduction

Nonlinear optics (NLO) is the branch of optics that describes the behaviour of light in nonlinear media, that is, media in which the dielectric polarization P responds nonlinearly to the electric field E of the light. This nonlinearity is typically observed only at very high light intensities (values of the electric field comparable to inter atomic electric fields, typically 108 V/m) such as those provided by pulsed lasers. When an optical signal is transmitted through long haul communication systems (the transmission of a light signal over fiber for distances typically longer than 100 km) of optical fiber, a significant distortion will be seen in the received signal. Distortion could be result of chromatic and polarization mode dispersion in Time Division Multiplexing (TDM) and fiber nonlinearity's in Wavelength Division Multiplexing (WDM) impact transmission performance. Nonlinear effects play a major role in optical fiber with respect to transmission capacity and performance of the system. To achieve maximum transmission rate, combination of TDM and WDM is used and optimized configuration of combination depends on few factors such as dispersion and optical signal power. There are upsides and downsides of using nonlinear effects in optical fiber.

2. Non Linear Effects

Fiber nonlinearities become a problem when several channels coexist in the same fiber. Nonlinearity effects arose, when optical fiber data-rates, transmission lengths, number of wavelengths, and optical power levels are increased.

A. Self Phase Modulation

Nonlinear phase modulation of beam caused by its own intensity by the kerr effect. Due to kerr effect high optical intensity in medium causes a non linear phase delay which has same temporal shape as optical intensity. This can be described as a non linear change in refractive index. Phase modulation of an optical signal by itself is known as SPM. SPM generally occurs in single wavelength system. It occurs through interaction of rapidly varying and time dependent laser pulse with nonlinear intensity dependent change in refractive index of an optical material. At high bit rate SPM tends to cancel dispersion, but it increases with signal power level. Phase shift by field over fiber length is given by

$$\varphi = \frac{2\pi nL}{\lambda}$$

Where, n = refractive index of the medium; L= length of the fiber; = Wavelength of the optical pulse.

The design of SPM is stimulated using Optisystem tool. Coding of nonlinear Schrodinger equation is done in MATLAB and analysis of Eye diagram, bit error rate (BER), and Q factor is done. Chirp produced by SPM is used to reduce the effects of dispersion caused by pulse broadening. These effects depend mostly on Input power of the signal transmitted, which can be used as a threshold condition for the frequency chirp to occur. SPM is major limitations in single channel systems.

B. Four Wave Mixing

In this nonlinear effect, three optical fields when propagated through fiber will give rise to a new optical field, which depends on the three optical fields.

$$\omega 4 = \omega 1 \pm \omega 2 \pm \omega 3$$

FWM is not dependent on bit rate as the other two nonlinear effects; instead they depend on channel spacing and dispersion of fiber. Dispersion depends on wavelength, so newly generated optical wave and reference signal wave have different group velocities. With different group velocities, phase matching is not possible, which decrease power transfer to new optical wave. At the same time, if the newly generated wave and original wave has same wavelength, results in interference. The interference of the signals decreases signal to noise ratio. Whenever we observe different group velocities then FWM effect decreases and channel spacing increases and sodoes dispersion.

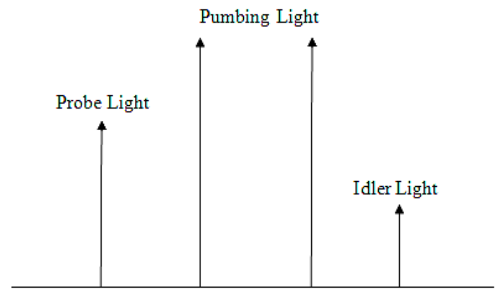

Fig.1: Four Wave Mixing Phenomena

3. Design and Simulation

Self Phase Modulation using Optisystem Tool

a) Simulation Model of SPM

In the simulation layout of SPM, consists of a pseudorandom generator, NRZ modulator, continuous wave laser, Mach-Zehnder amplitude modulator and EDFA amplifier. Each component block has its own parameters apart from the parameters of the design called as global parameters, which are helpful if we want to use the same parameter for two or more components in the model. In the simulation layout of SPM, consists of a pseudo random generator, NRZ modulator, continuous wave laser, Mach-Zehnder amplitude modulator and EDFA amplifier. Each component block has its own parameters apart from the parameters of the design called as global parameters, which are helpful if we want to use the same parameter for two or more components in the model.

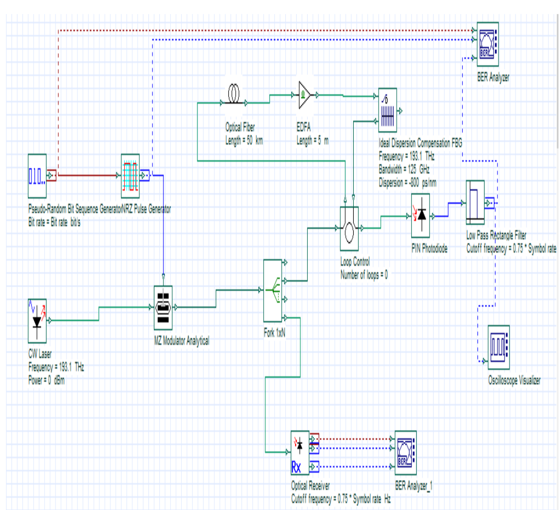

Fig. 2: Simulation Layout of SPM

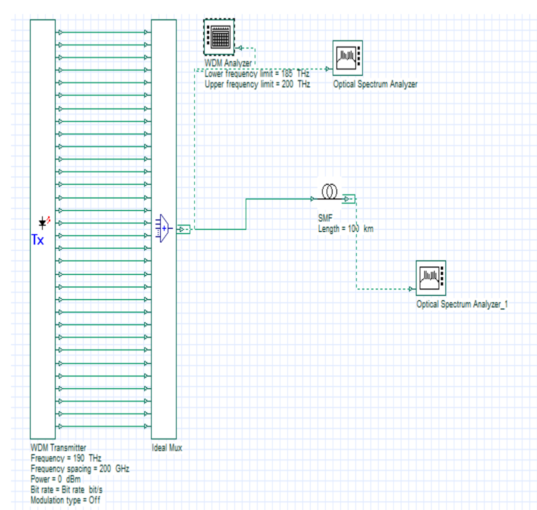

Fig. 3: Simulation Layout of FWM

Wavelength, frequency, power of the signal is initialized and phase parameter of signal is set to random in CW laser block. We placed electrical and optical oscilloscope to observe waveforms. The transmission rate used is 10Gbps, power of light wave is 3.98mW, fiber length is 50km, wavelength is 1550nm and frequency is 193.1 THz . It is shown as iterative loop component. The iterative loop component consists of an optical fiber, fiber compensating techniques and a pre-amplifier. Output of fiber is sent to fiber bragg grating which is used to compensate the distortion of signal by inducing dispersion after each stage. The receiver consists of EDFA, photodiode, low pass Bessel filter whose cut off frequency is 0.7 * bit rate, BER analyzer and an electrical oscilloscope.

b) Simulation Model of FWM

Four wave mixing effect is also performed with two or more WDM channels. In this design model, there are two WDM channels. Signals generated from these channels are used to generate new signal with the new frequency.

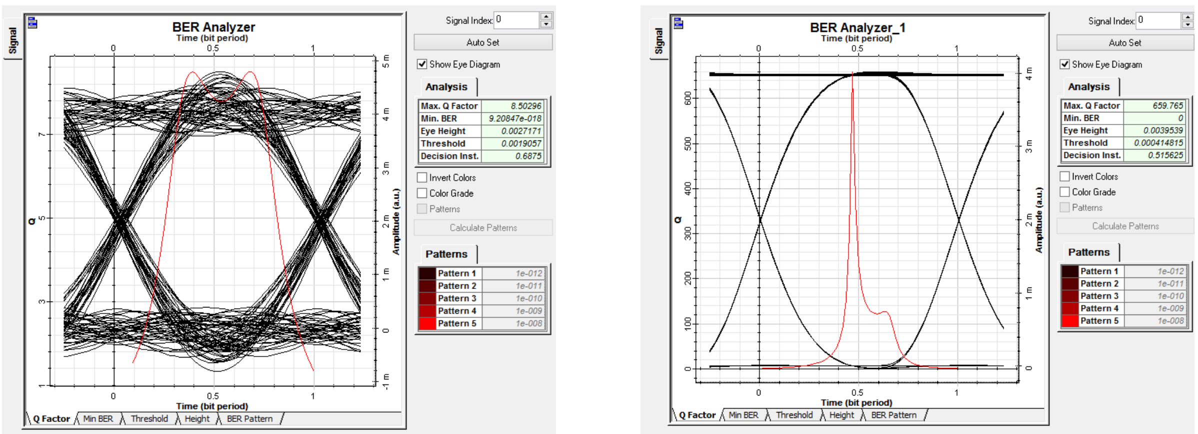

Fig. 4: Eye diagrams for Self Phase Modulation for 3.98mw

4. Results and Discussion

In the simulation, different types of non linearity's are analyzed. The result of the block schematic in the previous chapter is provided with the obtained results. Different types of visual parameters are used to obtain the Non Linear analysis. The main analysis tools taken into account are Q factor, BER, Spectrum, Oscilloscope Visualizes etc. Eye diagram is the methodology used to evaluate the performance of the system. The important parameters of eye diagram are Quality factor and Bit error rate.

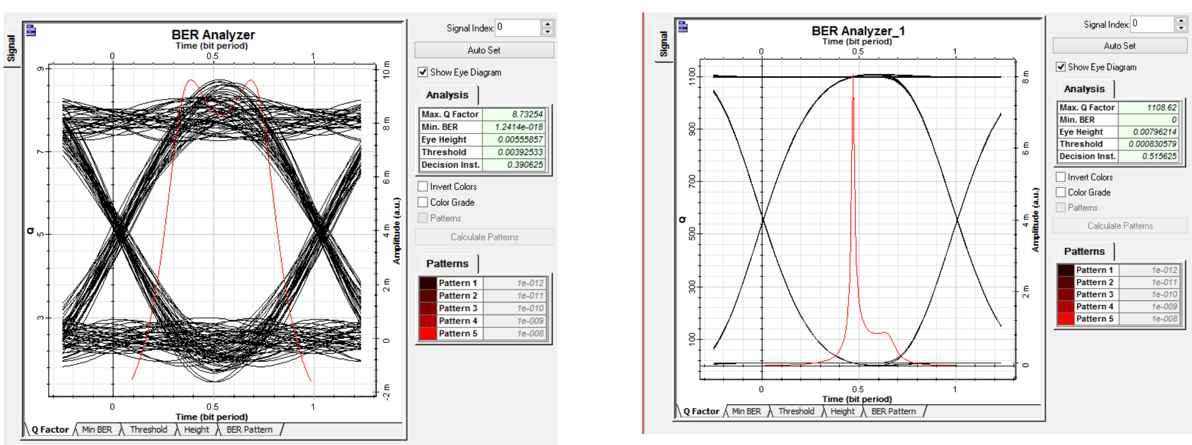

Fig. 5: Eye diagrams for Self Phase Modulation for 8 mw

A. Eye Diagram Analysis of Self Phase Modulation

In the analysis of SPM, the input power is taken as 3.98mW and 8mW and thus obtained corresponding eye diagrams.

B. Eye Diagram Analysis of FWM

An 8 channel WDM is created to analyze FWM and thus obtained the corresponding Spectrum. Four waves mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more different wavelengths is launched into a fiber. Four-wave mixing can be compared to the inter-modulation distortion in standard electrical systems.

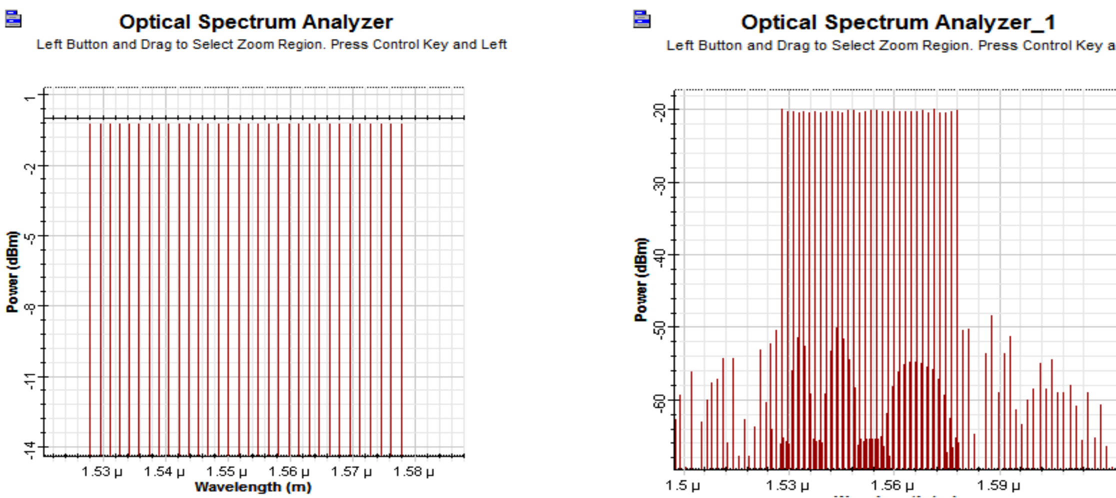

Fig. 6: Input & output optic signal of FWM circuit

5. Conclusion

Nonlinear effects arose as optical fiber data rates, transmission lengths, number of wavelengths, and optical power levels increases. This nonlinearity is typically only observed at very high light intensities such as those provided by pulsed lasers. The behaviour of SPM versus the optical power for two spans amplified system has been investigated. By increasing the power, SPM grows and depletes the signal, and the measured power actually decreases with the increase of the transmitted power. Specifically the eye opening decreases with increasing transmitted power. Four-wave mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more different wavelengths is launched into a fiber. Generally speaking FWM occurs when light of three different wavelengths is launched into a fiber, giving rise to a new wave (known as an idler), the wavelength of which does not coincide with any of the others.

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