

Investigate the Effects Of Initial Laser Phase, FWHM on Jitter And Soliton Order For Long Haul Communication

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Abstract: Soliton are narrow and high intensity pulses which can retain their shape by compensating the effects of SPM and GVD. Transmission of solitons at data rate of Tb/s effected by different factors. This paper analyzed jitter factor by varying FWHM (full width half maximum) and laser phase. Simulation results for soliton order $N=1$ and $N=2$ are also obtained.

Keywords: laser phase, FWHM , soliton order

1.1 Introduction

Solitons formed through the balance between the pulse broadening by virtue of self-phase modulation and compression as a result of negative group velocity dispersion. These are used for long distance high speed data transmission in communication systems. If the distances over which variation occur are long compared with the soliton period, they act stably contrary to changes of the properties of the medium. Soliton period is defined as the propagation distance in which the constant phase delay is $\pi/4$ [1]. Therefore solitons can adiabatically adapt their actual shape to slowly varying parameters of the medium. Fundamental Soliton ($N=1$) is generated by selecting best of its segments that combine to form soliton transmission system. Higher order Solitons ($N>1$) has higher energy than fundamental soliton. concept of higher order solitons is slightly different from fundamental soliton as the shape of these higher order solitons is not constant, but rather changes periodically during propagation and so regain their shape with periodicity [1]-[2]. John Scott Russell (et.al) (1834) a Scottish naval engineer James Scott Russell first observed Soliton wave when he noticed that a smoothly shaped water heap in narrow water canal was able to propagate in the canal without varying its shape a few kilometers along [3]. Boussinesq(et.al) (1871) and Rayleigh (1876) first explained the mathematical theory of existence of these solitary heaps of water. These are in the form of the equation and its solutions were developed by Korteweg and de Vries (1895) that is most commonly used to explain the waves that have become known as "solitons"[4]. Hasegawa (et.al) (1973) first predicted the generation of solitons in optical fibers systems which would make use of nonlinear wave propagation in the form of pulses called solitons in a lossless single mode fiber [5]. Mollenauer(et.al) (1980) observed narrowing and splitting of short duration pulse from mode-locked laser at a wavelength of $1.55 \mu\text{m}$ using single-mode silica-glass fiber. The reported behavior at certain critical power levels is characteristic of solitons [6]. In 1983 regaining of shape and spectrum of short duration pulses train has been observed in 1.3 km long single-mode fiber at the soliton period. An F_2^+ color-center laser was used as source at $1.55 \mu\text{m}$. Despite of initial spectral broadening because of self-phase modulation and compression from negative group-velocity dispersion acting on the pulse, pulse restoration occurs [7]. In a next experiment in the same year narrowing of 7 psec pulses to 0.26 psec was reported with single-mode, low-loss optical fiber. The $\sim 1.5\text{-}\mu\text{m}$ wavelength falls in the area of negative group-velocity dispersion ($\partial v_g / \partial \lambda < 0$) hence it does

not need any auxiliary dispersive element to complete the narrowing. Corresponding to higher order Soliton, optimum compression was done for input powers of several hundred watts. These results were at least in semi quantitative agreement with the nonlinear Schrödinger equation based prediction [8]. C.R. Menyuk (et.al) (1987) was the first to derive the nonlinear pulse propagation equation under weak birefringence in a single-mode optical fiber (SMF). He described two solitons with orthogonal polarizations as vector solitons which co-propagate together while retaining their shapes and without dispersing their energy [9]. Xiupu Zhang (et.al) (1998) investigated the broadening of solitons in the presence of polarization-mode dispersion. He also suggested that the soliton order and dispersion can be optimized so that a soliton can propagate roughly twice that of a linear PMD-broadened pulse when group-velocity dispersion is not present [10]. Itsuro Morita (et.al) (1999) conducted an experiment where the improvement of transmission performance of forty Gb/s single-channel soliton over 10,200 km by the polarization division multiplexing, by mitigating soliton–Soliton interaction was confirmed [11]. Masataka Nakazawa (et.al) (2000) suggested that an optical pulse of self-waveform-stabilization effect can be very useful for high-speed communication and he prized Soliton to break Tb/s barriers in next millennium. He described 1-Tb/s WDM soliton transmission and 1.28-Tb/s optical TDM (OTDM) linear transmission using soliton effects [12]. Hiroto Sugahara (et.al) (2001) theoretically and numerically examined collision-induced power jitter using variational method in dispersion-managed wavelength-division multiplexed optical soliton transmission systems. The power jitter which results in serious problem dispersion managed line with almost zero average dispersion can be decreased by applying doubly periodic dispersion management [13]. Song Lan (et.al) (2002) explained an optical parametric oscillator (OPO) in a waveguide which is induced by a photorefractive soliton and concluded that the threshold pump power can be reduced. Stability of OPO soliton induced can be enhanced by using singly resonant OPO [14]. Vladimir N. Serkin and Akira Hasegawa (et.al) (2002) showed a method to find the exactly integral nonlinear Schrödinger equation models with varying dispersion and gain based on the generalized inverse scattering transform. They proved that for nonlinear optics this methodology is a useful tool to design soliton lasers [15]. Muhammad Sufi (et. al) (2012) has been investigated and analyzed the variation in soliton pulse with different order number (N) by Nonlinear Schrödinger Equation (NLSE). The Split-Step Method has used for numerical calculation. The change in pulse shape, the slight decrease in power level and dispersion has been observed with increase in the soliton pulse order number. Thus, the soliton pulse parameters can be optimized to acquire the desired output. By using a half-soliton period length of low-loss single-mode fiber, we have been able to demonstrate the pulse compression and pulse splitting associated with several higher-order soliton as well as to observe the fundamental soliton [16].

1.2 Simulation Setup and Results:

Figure 1.24 shows the block diagram for soliton N=1 and N=3. where N is soliton order. the soliton pulse corresponding to N=1 is called fundamental pulse. Pulse N>1 is called higher order soliton pulses. soliton order N depends on balance between dispersion and nonlinearity.

$$N^2 = \lambda P_0 T_0^2 / \beta^2$$

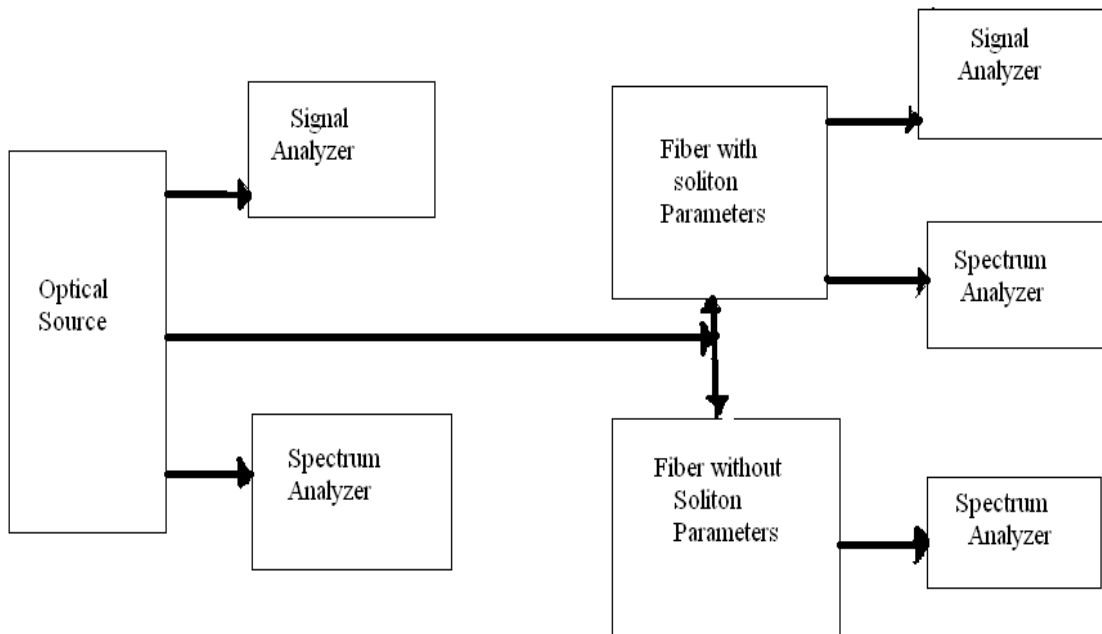


Figure 1.1 Block diagram of Layout for soliton N=1 and N=3

In figure 1.24 initial pulse has sech shape and FWHM pulse width is 35ps corresponding to $\lambda=1550\text{nm}$. pulse power for soliton N=1 is 32.7mW and for N=3 is 293.4mW.

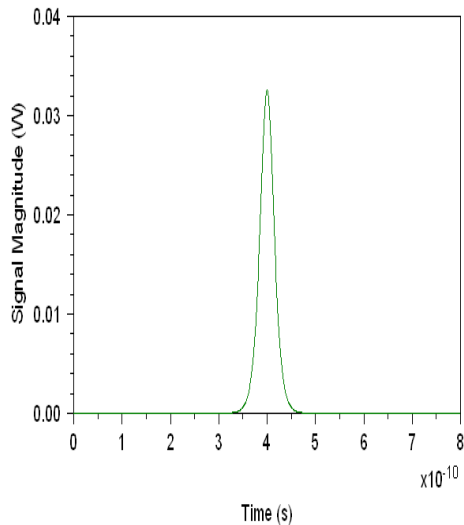


Figure 1.2 Input signal in time domain(N=1)

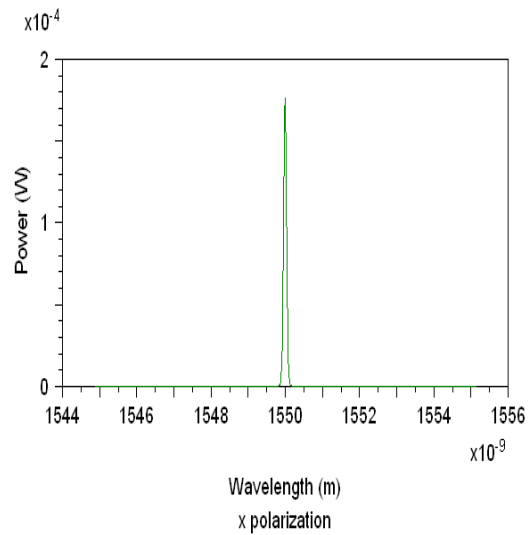


Figure 1.3 Input signal in frequency domain (N=1)

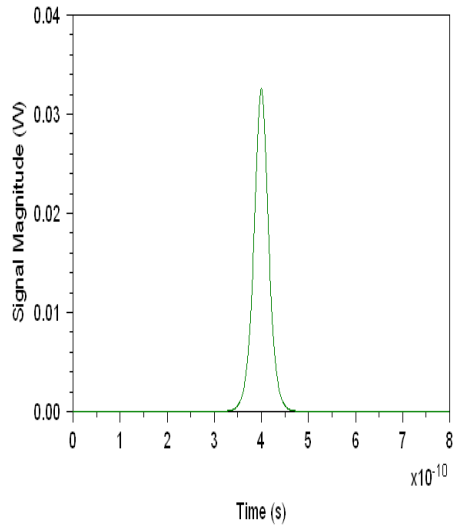


Figure 1.4 output signal in time domain

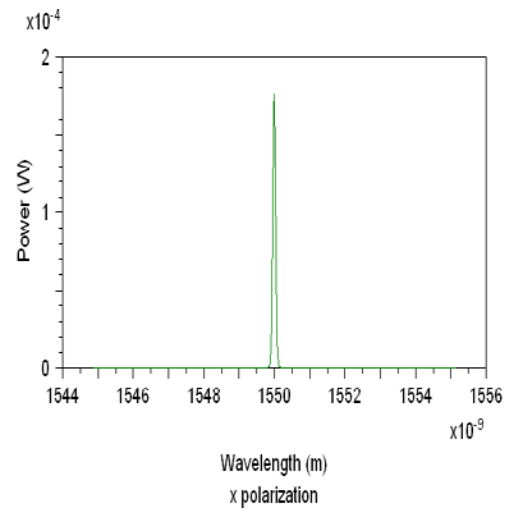


Figure 1.5 Output signal in frequency domain

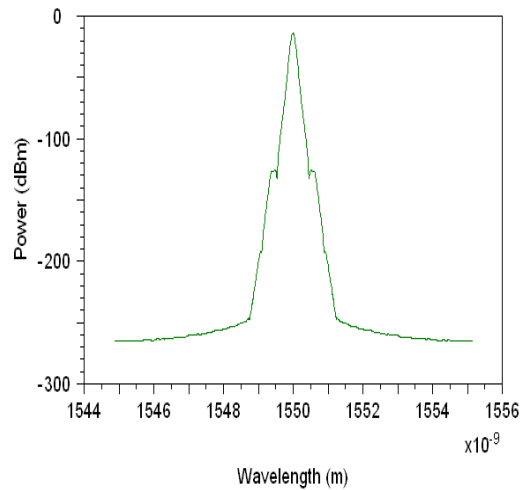


Figure 1.6 output signal in frequency domain (without soliton parameter) N=1

Figure 1.2-1.6 soliton pulse evolution in time domain and in frequency domain in fiber along one soliton period for N=1.

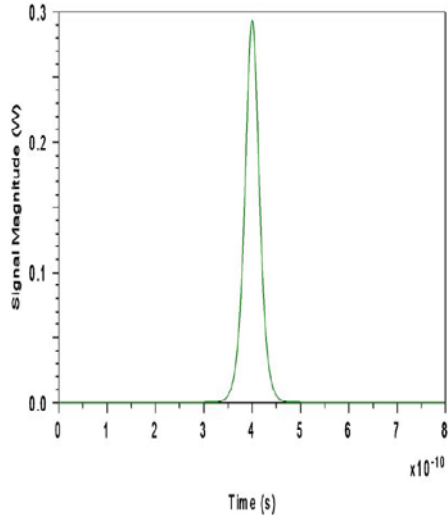


Figure 1.7 input signal in time domain (N=3)

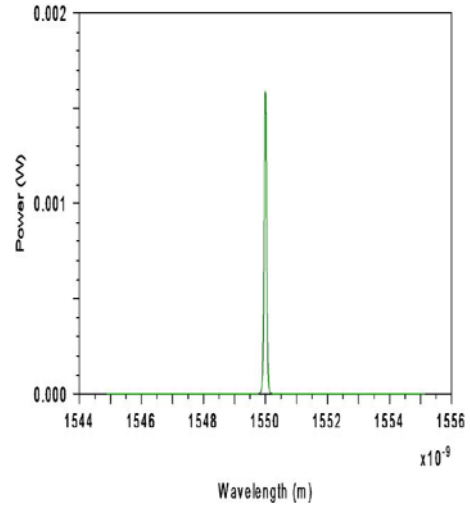


Figure 1.8 Input signal in frequency domain (N=3)

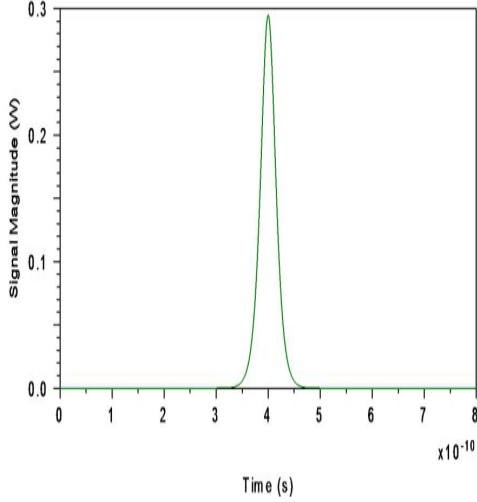


Figure 1.9 output signal in time domain (N=3)

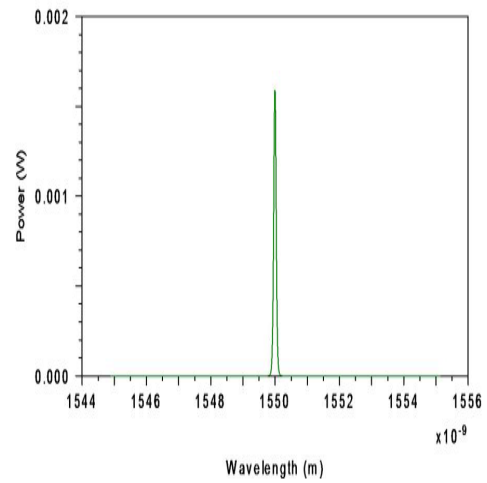


Figure 1.10 Output signal in frequency domain (N=3)

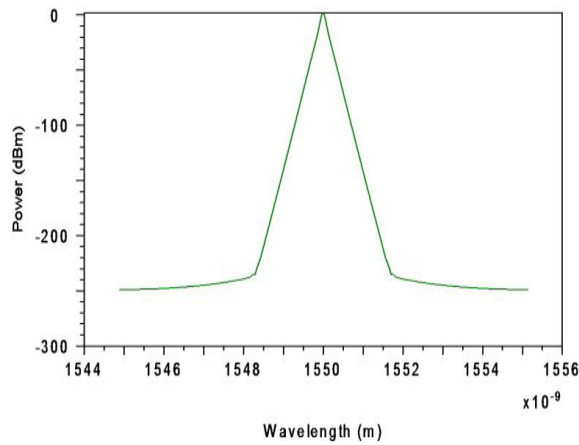


Figure 1.11 Output signal in frequency domain (without soliton parameter) N=3

Figure 1.7-1.11 shows pulse evolution in time domain and in frequency domain in fiber along one soliton period for $N=3$. After comparing input and output figures soliton pulse shapes are same after 30 km distances.

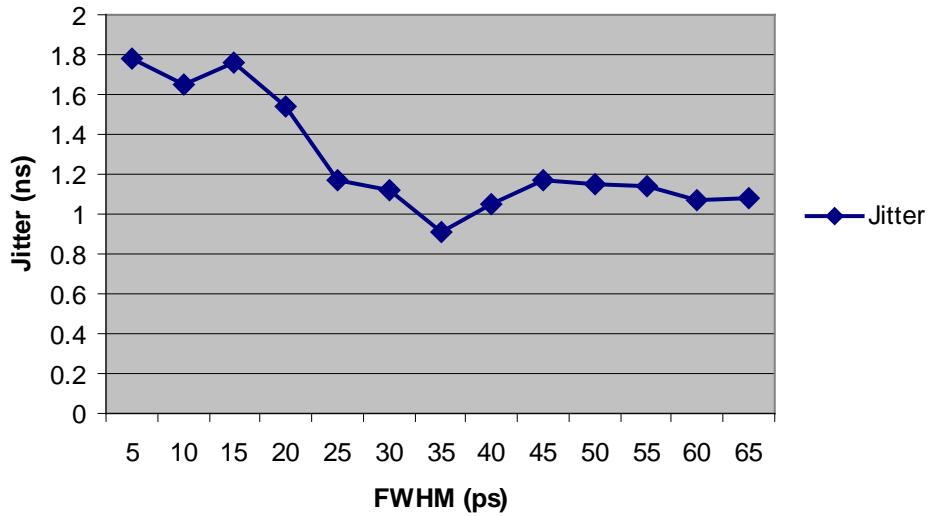


Figure 1.12 Jitter against FWHM

Figure 1.12 has shown that FWHM 35ps gives minimum jitter value that is 0.91 ns.

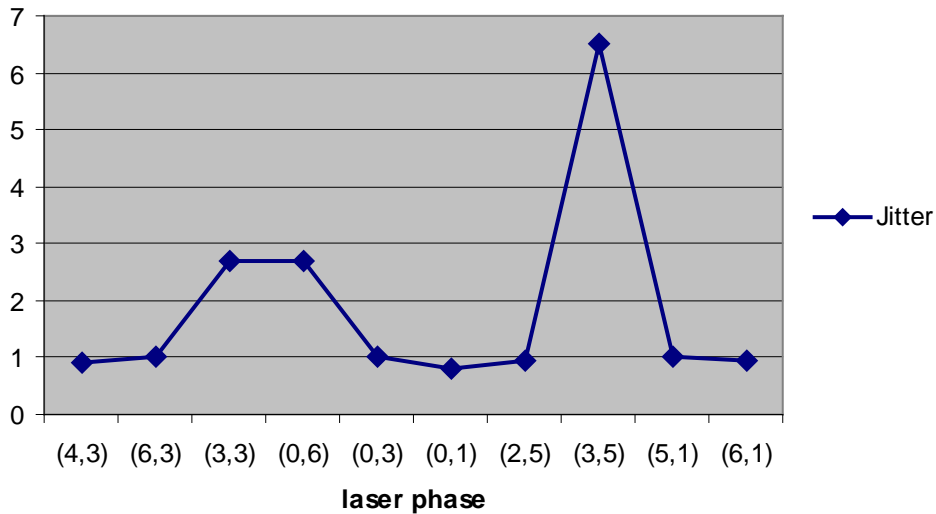


Figure 1.13 Jitter against varying laser phases

Figure 1.13 shows laser phases (4, 3) and (0, 1) gives minimum jitter value that is approximately 0.9 ns. Difference between the two phases is 1 rad.

1.3 Discussion and Conclusion

For $N=3$ peak power increased as compared to $N=1$. pulse evolution in time domain and in frequency domain in fiber along one soliton period for $N=3$. After comparing input and output

figures soliton pulse shapes are same after 30 km distances. FWHM 35 ps and laser phase (4, 3) and (0, 1) gives minimum jitter value approximately 0.9 ns.

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