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Performance Comparison of Various Optical Sources in 40 Gbps Soliton Transmission

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Abstract—*This paper presents performance comparison of various optical sources for different amplifier spacing in 40 Gbps system. CW laser, Raised Cosine, Super Gaussian and Optical Soliton are the various optical sources which are compared in this paper. Their performance of various optical sources is based on the factors such as Quality factor, Bit error rate (BER), Timing Jitter, Eye opening and Eye closure. It has been studied that in all the sources optical Soliton gives the highest value of Q factor and BER.*

Keywords*: BER; Optical Soliton; OptSim; Raised Cosine; Supergaussian.*

1. INTRODUCTION

In optical fiber transmission system, to meet the increasing demands of high data rates at long distances; optical Soliton transmission has become the main area of research. Dispersion and fiber nonlinearities are the two phenomenon which degrades the performance of an optical system. Dispersion and fiber nonlinearities depend on the pulse shape. So the selection of the proper optical source becomes very deciding factor. Non linear effects are intensity dependent and occur in fiber because of change in refractive index with change in input power as given by eq 1.1.

$$n = n_0 + n_2 \left(\frac{P}{A_{eff}}\right) \quad \dots (1.1)$$

Here n_0 is refractive index of the core, n_2 is non linear refractive index coefficient, P is optical power in watt and A_{eff} is fiber core's effective area. The different types of optical sources such as CW laser, Raised Cosine, Super Gaussian and Soliton have different properties and advantages based on their pulse shape.

A. *CW Laser Source*

Laser is a device that emits based on the stimulated emission of electromagnetic radiation light through a process of optical amplification. Lasers are distinguished from other light sources by their coherence.

The CW laser has higher spectral component than the Lorentzian Laser in the low frequency range, due also to the fact that the Rate Equation laser model do not only emit phase noise, but also intensity noise (RIN).

B. *Optical Soliton*

The existence of Solitons in optical fibers is the result of a balance between the group velocity dispersion (GVD) and self-phase modulation (SPM). An optical Soliton is not distorted due to dispersion or other effects. Nonlinear effects (such as the Kerr effect in optics) may modify the phase shift across the pulse and thus create new frequency components in the specter of the pulse (in optics this effect is known as self-phase modulation. Nonlinear effects may exactly cancel dispersion thus producing a pulse with a constant shape, if the original pulse has the right shape.

The mathematical description of solitons employs the nonlinear Schrodinger (NLS) equation (1.6) and satisfied by the pulse envelope $A(z, t)$ in the presence of GVD and SPM. This equation can be written as

$$\frac{\partial A}{\partial z} + i.\frac{\beta_2}{2}.\frac{\partial^2 A}{\partial t^2} - \frac{\beta_3}{6}.\frac{\partial^3 A}{\partial t^3} = i.\gamma.|A|^2.A - \frac{\alpha}{2}.A \quad \dots (1.2)$$

Where fiber losses are included through the α parameter while β_2 and β_3 account for the second- and third-order dispersion effects. The nonlinear parameter $\gamma = 2\pi\ n_2/(\lambda.A_{eff})$ is defined in terms of the nonlinear-index coefficient *n*2, the optical wavelength λ , and the effective core area A_{eff} .

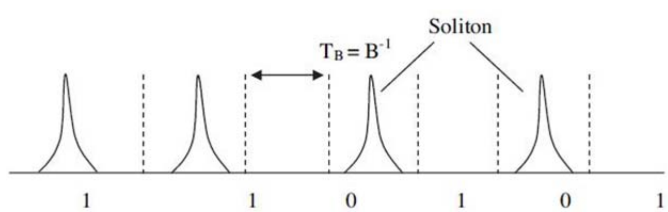

Fig. 1: Optical Soliton for RZ Data Format

C. *Raised cosine*

The parameter *α* determined the shape of the raised cosine, where $0 \le \alpha \le 1$. The bandwidth occupied by the pulse and the rate at which the pulse decay is also defined by α.

At α = 0, the bandwidth obtained is minimum, but the slowest rate of decay in the time domain. The bandwidth becomes 1/*T* when α = 1, but the time domain tails decay rapidly. It is interesting to note that α = 1 case offers a double-sided bandwidth of $2/T$. Thus a tradeoff between increased data rate and time-domain tail suppression is provided by the parameter α.

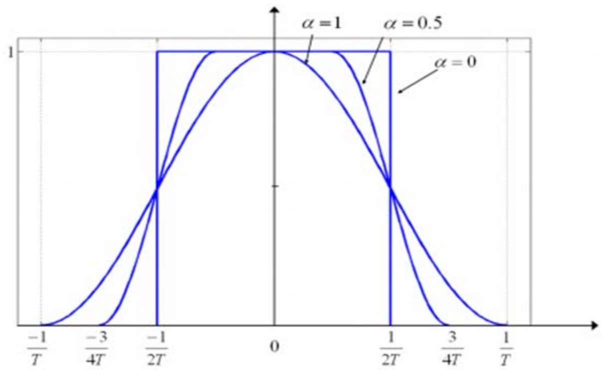

Fig. 2: Shape of the Raised Cosine with variable Parameter α

D. Super Gaussian

The simplest type of laser beams are Gaussian beams are and their properties makes them most desirable type of beam provided by a laser source.

They have better extraction from saturated laser amplifiers. Non-linear conversion for same peak intensity is better in case of super Gaussian beam.

2. SIMULATION MODEL

To obtain the optimum result a very precise mathematical tool is required which takes into account all important phenomena including fiber loss, chromatic dispersion, polarization mode dispersion (PMD) and Kerr non-linearity and amplified spontaneous emission accumulation. Using OptSim, it is possible to model very closely a real long haul system to achieve realistic results. For performance comparison of different modulation formats at 40 Gbps bit rate an optical Soliton transmission system is set up as shown in Fig. 1.

Transmitter section as shown in the fig. 1 is a compound component and consists of the data source, modulator driver, optical source and external sine amplitude modulator. RZ Soliton is used as the modulator driver due to its advantages over NRZ modulator driver. For performance comparison various optical sources such as CW laser, Raised Cosine, Super Gaussian and Optical Soliton are used.

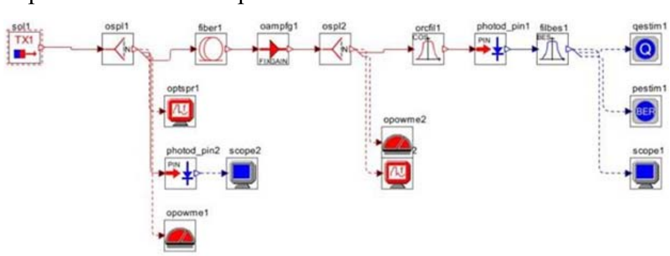

Fig. 3: Schematic for 40 Gbps Optical Soliton Transmission

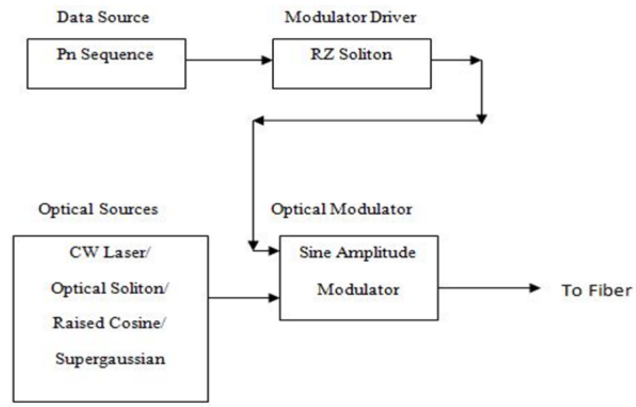

Fig. 4: Transmitter Section with Different Optical Sources

The data source is generating signal of 40 Gbps with pseudo random sequence. Modulator driver converts logical input into electrical input. Different optical source of center emission wavelength of 1550 nm, center emission frequency 193.4149 THz are used. Optical Soliton source is used at Full width half maximum (FWHM) of 20 ps and peak power of 30 mW to generate optical pulses of "sech" shape. The time between two pulses is taken to be 25 ps. A sine amplitude modulator is used to modulate the optical signal according to pseudo noise sequence. A fixed gain amplifier having gain 12 dB with fiber of varying lengths (50,100,150,200,250 km) is used. Fiber taking all non linear effects into account and dispersion of 0.2 ps/nm/km is used. The quantum efficiency of PIN photo detector used0.7and it is having responsivity of 0.875 A/W and dark current of 0.1 nA.

3. RESULTS AND DISCUSSION

The performance of CW Laser, Optical Soliton, Raised Cosine and Supergaussian optical sources for variable lengths at 40 Gbps optical communication system is analyzed. Table given below present the summary of different parameter values for various optical sources at 40 Gbps system.

Table I: Comparative Analysis of Different Optical Sources

Parameter	Length (km)	CW LASER	Raised Cosine	Super Gaussian	Soliton
Q factor(dB)	50	24.6618	29.9322	29.9932	32.708
BER		1.e-40	1.e-40	1.e-40	1.e-40
Eye opening		0.0093	0.052	0.08767	0.2104
Eye closure		0.7345	0.3228	0.3165	0.2281
Jitter		0.0004	0.0003	0.0002	0.0002
Q factor(dB)	100	13.7102	21.1497	22.2411	25.7285
BER		1.08e-06	3.56e-28	5.11e-36	1.e-40
Eye opening		0.00055	0.0056	0.02343	0.0194
Eye closure		3.2344	1.0864	0.9989	0.5783
Jitter		0.0027	0.0004	0.0004	0.0002

Q factor(dB) BER Eye opening Eye closure Jitter	150	6.0206 0.02275 7.08e-07 20.7558 0.0066	11.8744 0.000161 0.000192 6.3531 0.0021	12.9895 1.81e-05 0.00034 4.6882 0.0034	16.9886 5.66e-30 0.00092 2.6792 0.0008
Q factor(dB) BER Eye opening Eye closure Jitter	200	6.0206 0.02275 2.43e-07 21.3538 0.0053	6.0206 0.02275 7.21e-07 20.7686 0.0051	6.0206 0.02275 1.041e-06 19.8960 0.0052	7.6228 0.0106 0.0002 18.7865 0.0042

Fig. 5 shows the variation of quality factor at different lengths for different optical sources. The optical Soliton source shows the highest value of the Q-factor which is 32.708 dB followed by super Gaussian, raised cosine and CW laser source with the Q values 29.9932, 29.9322 and 24.6618 dB respectively. The bit error rate variation of the various sources with variable length before the amplifier is used is shown in the figure 6. For 50 km length all the data formats show the minimum bit error rate. But for 100 km and 150 km BER values of the optical Soliton is much better than other formats as shown in Table 1. By further increasing the length, performance of the system degrades to very large extent and BER becomes very high.

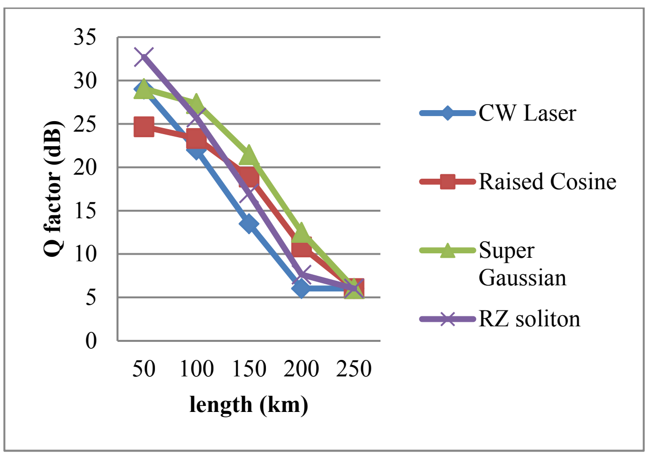

Fig. 4: Q-factor vs Length

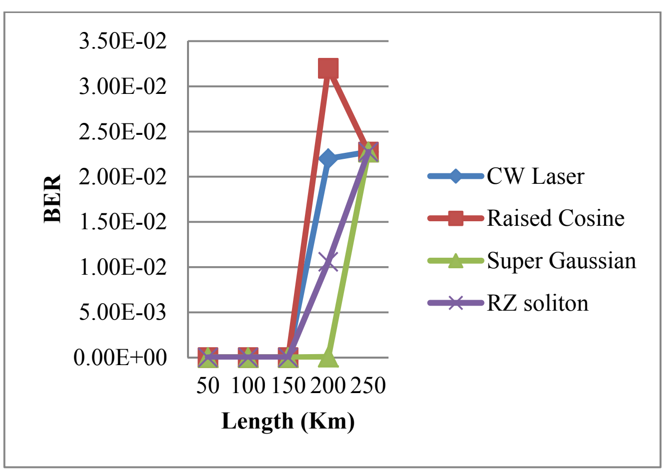

Fig. 5: BER vs Length

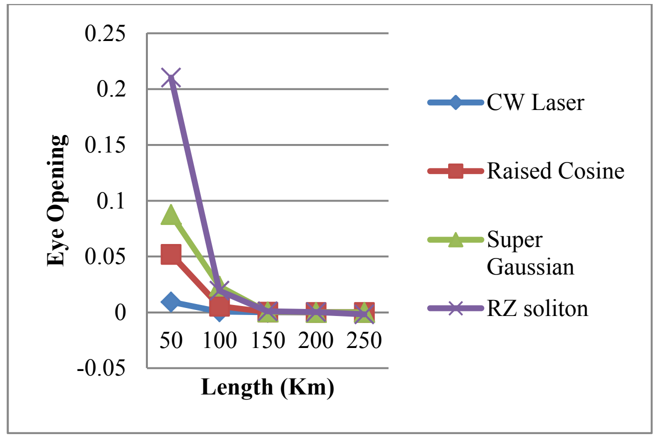

Fig. 6: Eye Opening Vs Length

For better results, value of Eye opening must be high. From the results it is observed that Soliton gives the highest value of the eye opening. The comparison chart of eye opening with varying lengths is shown in fig. 7.

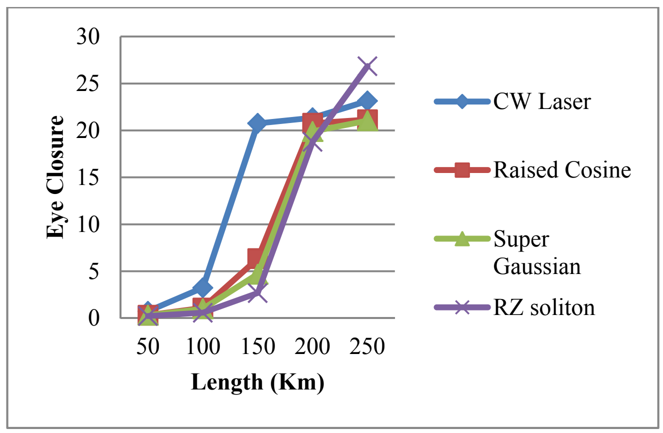

Fig. 7: Eye Closure vs Length

Figure 8 shows the variation of eye closure with lengths of the fiber for different optical sources. From the results it is noted that optical Soliton shows the minimum value of the eye closure as shown in Table 1.

4. CONCLUSION

In this paper, the performance of various optical sources has been studies for variable lengths. The results for different optical sources such as CW laser, optical Soliton, Raised Cosine and Super Gaussian has been presented in Table 1. In case of Optical Soliton, the highest value of Q (32.708 dB), good eye opening, lowest eye closure, lowest BER and lowest value of Jitter has been reported, which makes it the best choice among all the data formats at 40 Gbps transmission. In the comparative study, it is noted that parameter values are reasonably good for Super Gaussian but they are reported to be the best for Optical Soliton.

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