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Research Article

Enhanced continuous-wave four-wave mixing using Hybrid Modulation Technique

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Abstract

Dense wavelength division multiplexing mainly used in Optical fiber communication channel. Among the non-linear effect four wave mixing is generated new frequency components among existing frequency standards. Existing FWM reduction technique used for channel density and limits the capacity of Wavelength division Multiplexing systems. In this paper we have discussed the hybrid modulation techniques for Enhancements of the continuous-wave four-wave mixing conversion efficiency suppressing FWM non-linear effect in dense wavelength division multiplexing are accomplished through the application of plasma-assisted photoresist reflow to reduce the sidewall roughness of sub-square-micron-modal area waveguides with uncoated sidewalls and anti-reflection coatings that show group velocity dispersion of +0.22 ps2/m.

Keywords: *BER, MUX, FWM (Four wave mixing), DWDM (dense wavelength division multiplexing)*

1. Introduction

Fiber optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The optical fiber is designed in such a way that all the nonlinearities inside the fiber have to be minimized and optimized to reproduce the original signal at the receiver. The non-linearity in optical fiber falls into two categories: Inelastic Stimulated Scattering and Kerr Effect.

WDM is nothing but N independent optically formatted information streams each transmitted at a different wavelength are combined with optical multiplexer and send over the same fiber. The wavelength in WDM must be properly spaced to avoid inter-channel interference. Dense Wavelength Division Multiplexing (DWDM) is a technology that puts data from different sources together on an optical fiber, with each signal carried at the same time on its own separate light wavelength (T. Sabapathi *et al*, 2014). Using DWDM, up-to 64 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a light stream transmitted on a single optical fiber.

In CDWM system channel spacing is above 200 GHz. The channel spacing in the DWDM system is less than 200 GHz. (T. Sabapathi *et al*, 2014). In the Dense Wave length division multiplexing system (DWDM) the nonlinear effects plays important role due to limited channel spacing. The optimized design and application of optical fiber are very important for the transmission quality of optical fiber transmission system. So, it is necessary to investigate the transmission characteristics of optical fiber. There are several nonlinear effects in WDM systems, such as Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering (SBS), Self-phase Modulation (SPM), cross-phase modulation (XPM), and four-wave mixing (FWM). In this paper we have discussed the hybrid modulation techniques for Enhancements of the continuous-wave four-wave mixing conversion efficiency suppressing FWM non-linear effect in dense wavelength division multiplexing are accomplished through the application of plasma-assisted photoresist reflow to reduce the sidewall roughness of sub-square-micron-modal area waveguides with uncoated sidewalls and anti-reflection coatings that show group velocity dispersion of +0.22 ps2/m.

There are some barriers in DWDM related to data rate and capacity. These barriers are linear and nonlinear effects. Out of these barriers, linear effects such as attenuation and dispersion can be easily compensated using soliton and dispersion compensating fiber but there is an accumulation of nonlinear effects. The nonlinear effects occur in optical system are Self-Phase Modulation (SPM), Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), Cross Phase Modulation (XPM), And Four-Wave Mixing (FWM). Out of which SBS and SPM

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is examined in single channel link whereas SRS, XPM and FWM is introduced in multi-channel link (Ami R. Lavingia *et al* 2015) Using DWDM, multiple channel of information can be transmitted on single fiber. In DWDM based optical communication systems, fiber nonlinearities are limiting factors that limit the data rate and capacity. Besides this the nonlinear optical effects also degrade the system performance. Among the nonlinear effect four wave mixing (FWM) is a nonlinear process that generates new frequency components from existing frequency components (PisekKultavewutietal2011). Demonstration of enhanced FWM-based wavelength conversion in a Q=7500 AlGaAs- Nano-waveguide resonator with conversion efficiency of -43 dB which accounts for 12 dB enhancement compared to FWM in a straight waveguide (T. Sabapathi *et al*, 2014)demonstrate enhanced FWM-based wavelength conversion in a Q=7500 AlGaAs-Nano-waveguide resonator with conversion efficiency of -43 dB which accounts for 12 dB enhancement compared to FWM in a straight waveguide.

2. Four wave mixing

FWM can be compared to the intermodulation distortion in standard electrical systems. When three wavelengths (λ_A, λ_B, and λ_C) interact in a nonlinear medium, they give rise to a fourth wavelength (λ_D), which is formed by the scattering of the three incident photons, producing the fourth photon. This effect is known as Four Wave Mixing (FWM) and is a fiber-optic characteristic that affects WDM systems (T. Sabapathi *et al*, 2014).

$\lambda_D = \lambda_A \pm \lambda_B \pm \lambda_C$ here, $A \neq B \neq C$

FWM Reduction technique

In this stage the hybrid modulator portion is the combination of optical PM modulator followed by an optical AM modulator. The optical PM modulator introduces the phase mismatch in each wavelength which then adds constructively or destructively by the AM modulator

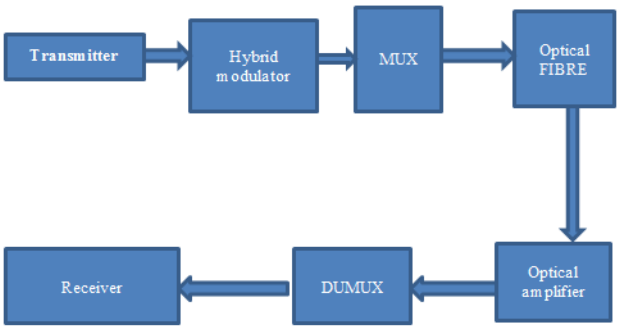

Fig.1 Block Diagram for FWM Reduction technique

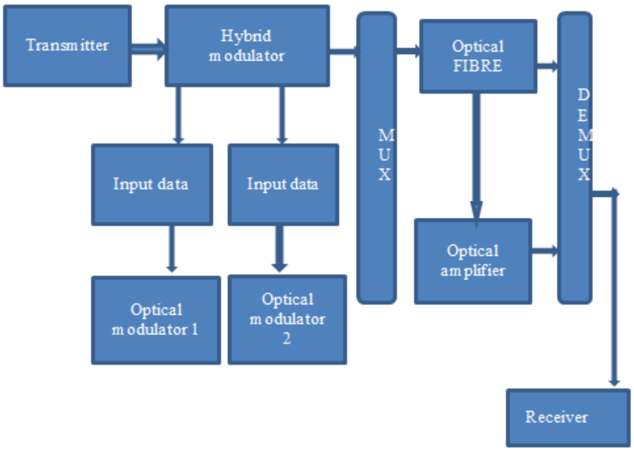

Fig 2. Block Diagram for Continuous Wave four Wave Mixing conversions

The continuous wave FWM reduction method uses the hybrid combination of one electrical and three optical modulators. The electrical modulator is CPFSK whose output is connected with optical Dual Port Dual Drive Mach Zehnder modulator followed by Dual Drive Mach Zehnder and AM Optical modulator respectively. The electrical CPFSK modulator is responsible for generating the distortion in the signal. This technique can be employed for short distances and low power consuming system.

3. DWDM topologies and simulation setup

There are 4 nodes fiber link are 8 and number of node level are 1.8-channel 2.5 Gbps WDM system, sample rate of 160 GHz, sequence length of 128 bits, 64 samples per bit, bit rate of 2.5 Gbps, operating at normal mode, NRZ pulse generator with hybrid modulation schemes. Fiber:-non- zero dispersion fiber, length of 50-100 Km, dispersion value of 16.75 ps/nm/km and a reference wavelength of 1550 nm, Optical amplifier:- EDFA with operating wavelength of 1550 nm. The filter used on the receiving side is a Low Pass Bessel Filter with a cut-off frequency of 0.75*Bit rate.

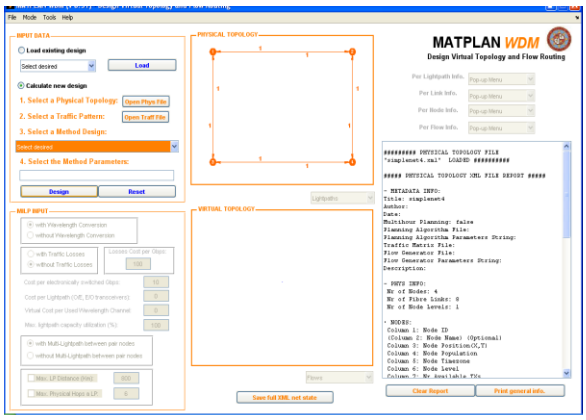

Table 1 Nodes simulation setup

Node ID	Node Position(X,Y)	Node Population	Node Timezone	Node Level	Nr Available TXs	Nr Available RXs	Nr Available TWCs
1	(0.50,1.50)	8393	1	1	10	10	0
2	(1.50,1.50)	5002	1	1	10	10	0
3	(0.50,0.50)	6539	1	1	10	10	0
4	(1.50,0.50)	8127	1	1	10	10	0

Table 2 Fibre links

Fibre Link ID	Origin Node ID	Destination Node ID	Link Length (Km)	Nr Available Wavelengths
1	1	2	1	40
2	2	1	1	40
3	2	4	1	40
4	4	2	1	40
5	4	3	1	40
6	3	4	1	40
7	3	1	1	40
8	1	3	1	40

Lightpath Capacity (Gbps)	40
Level Matrix	1
Traffic File "simplenet4.traff" LOADED	4
FILE 1	0.000 0.750 0.400 0.500
FILE 2	0.450 0.000 0.100 0.900
FILE 3	0.150 0.600 0.000 0.100
FILE 4	0.300 0.350 0.800 0.000

FWM Reduction Technique

Table 3 Variation of FWM reduction technique factor with input power

Available FMW Power			
Input Power (dBm)	Q-Factor	Eye-Height Power (dB)	FWM (dBm)
-10	63.897	0.023	0
-5	111.927	0.032	0
0	161.720	0.034	-89.42
5	416.741	0.037	-81.93
10	283.421	0.035	-74.98
15	256.064	0.036	-68.90
20	99.532	0.034	-59.89

Continuous Wave Four Wave Mixing Algorithm

Table 4 Variation of Continuous wave four wave mixing Algorithm

Available FMW Power			
Input Power (dBm)	Q-Factor	Eye-Height Power (dB)	FWM (dBm)
-10	5.28	0.012	0
-5	5.34	0.022	0
0	5.87	0.028	0
5	5.67	0.033	-91.98
10	5.83	0.034	-82.09
15	5.80	0.036	-78.21
20	2.86	-0.056	-65.76

The simulation results for hybrid technique shows that as comparison to input power-factor, Eye height power FWM power decreases in FWM reduction technique and in Continuous wave four wave mixing Algorithm the Q-factor is very low.

FIG-5 FIG-6 and FIG-7 show these variations with Q-factor eye height FWM power.

4. Comparison

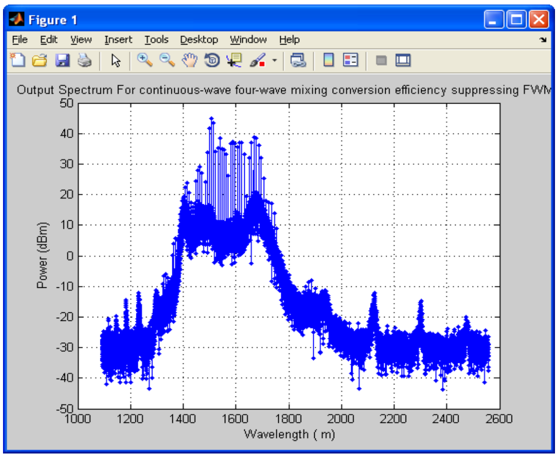

Fig.3 wavelength vs power output spectrum for continuous wave four wave mixing conversion

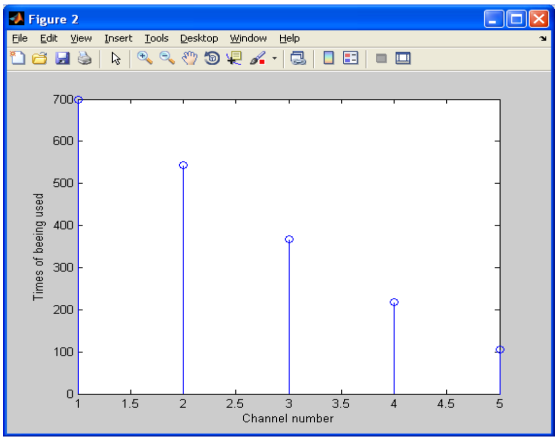

Fig.4 Number of channel used in FWM reduction and time being used

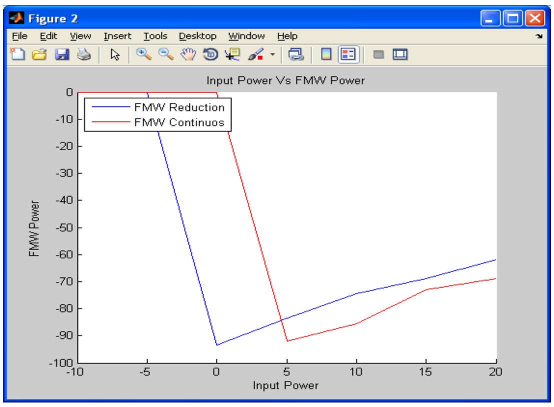

Fig.5 input power vs FWM power in FWM reduction and FWM continuous

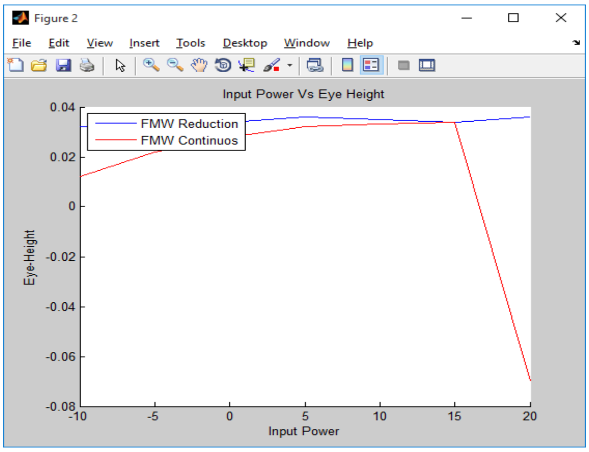

Fig.6 Input power vs eye height in FWM reduction and FWM continuous

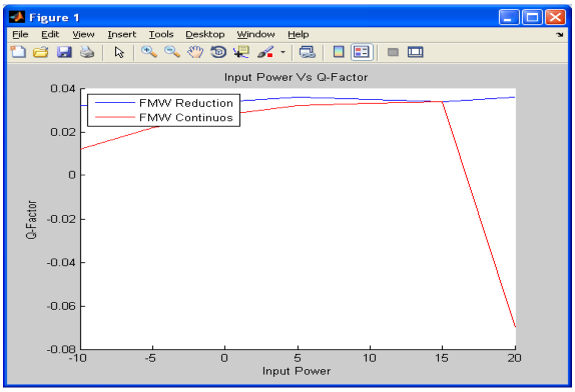

Fig.7 Input power vs Q-Factor in **FWM** reduction and FWM continuous

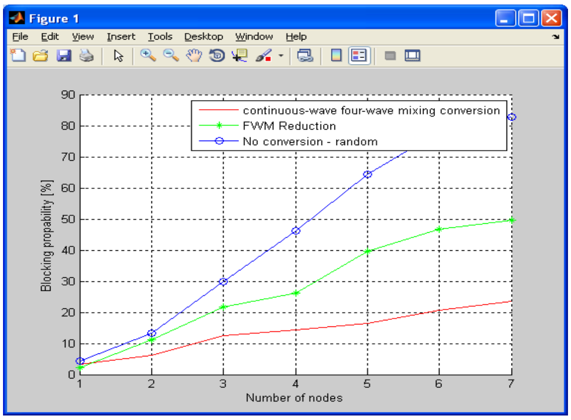

Fig. 8 No of Nodes vs. Blocking Probability

Conclusion

This paper presents the analysis of FWM effects for different hybrid modulators in Enhancements of the continuous-wave four-wave mixing conversion efficiency Enhancements of the continuous-wave four-wave mixing conversion efficiency suppressing FWM non-linear effect in dense wavelength division multiplexing are accomplished through the application of plasma-assisted photoresist reflow to reduce the sidewall roughness of sub-square-micron-modal area waveguides with uncoated sidewalls and anti-reflection coatings that show group velocity dispersion of +0.22 ps2/m.

The BER analyzer gives efficient result in this reduction technique. FWM products are greatly reduced with high level reduction but there are distortions in Eye diagram. Comparative study shows that intermediate level for Enhancements of the continuous-wave four-wave mixing conversion is more efficient.

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