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Design and Implementation of All-optical Demultiplexer using Four-Wave Mixing (FWM) in a Highly Nonlinear Fiber (HNLF)

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Abstract- All-optical demultiplexer of 10Gb/s channel dropped out of 40Gb/s data stream is demonstrated by using the method of four-wave mixing (FWM) and an optical filter. Demultiplexing of optical time division multiplexed (OTDM) signal is based on the effect of nonlinearities in a highly nonlinear fiber (HNLF).We describe our experiment of all-optical demultiplexer and bit error rate (BER) measurements.

Index Terms- Optical time division multiplexing (OTDM) , four-wave mixing (FWM) , wavelength conversion , optical components.

I. Introduction

Demultiplexing is based on the effect of four-wave mixing (FWM) in a highly nonlinear fiber.Most common demultiplexers are cross-phase modulation (XPM) in a fiber [1]-[3] , SOA [2] , nonlinear optical loop mirror (NOLM) [4]-[5], mach-zehnder interferometer (MZI) [6].Other method is four-wave mixing (FWM) in a dispersion shifted fiber (DSF) or an SOA [7]-[8], electroabsorption modulator (EAM) .

In this paper , we demonstrate a new research for all-optical demultiplexer using a highly nonlinear fiber with four-wave mixing (FWM) method.This method is induced by beating between two or more channels cause the generation of one or more new frequencies at the expense of power depletion of the original channels.Very low bit error rate (BER) ($<10^{-12}$) is illustrated with 10Gb/s demultiplexed channel from 40Gb/s data stream.The main part of our proposed system is that we utilize an optical band pass filter that is choosed the desired channel to demultiplex .This research results in higher and amplified output signal received.

II. Principle of DEMULTIPLEXER BY FOUR-WAVE MIXING

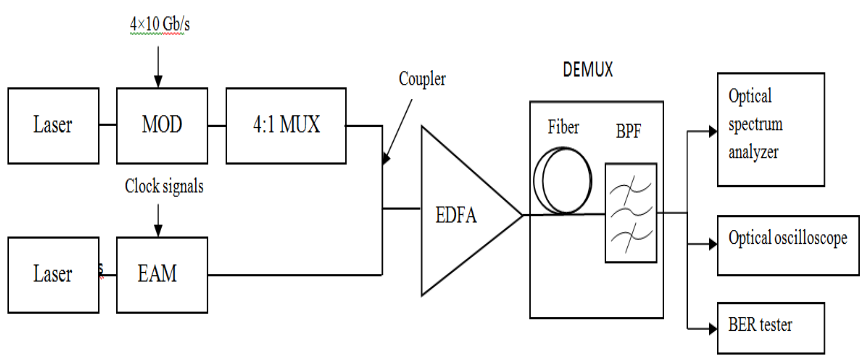


Figure1:Proposed block diagram of 40Gb/s to 10Gb/s all-optical demultiplexer

The operation principle of the proposed design work is illustrated in Fig [1].It includes signal transmission, signal amplification and demultiplexing. In signal transmission, four 10Gb/s channels are aggregated to 40Gb/s data stream.The clock signal and the data stream are amplified in an erbium doped fiber amplifier.To demultiplex the desired channel by means of four-wave mixing based on fiber and optical bandpass filter. In spectrum broadening, dispersion is done by highly nonlinear fiber after passing 0.4Km long. At the output of the HNLF, an optical bandpass filter (OBPF) is used to choose the demultiplexed channel.

III. SIMULATION SETUP AND RESULTS

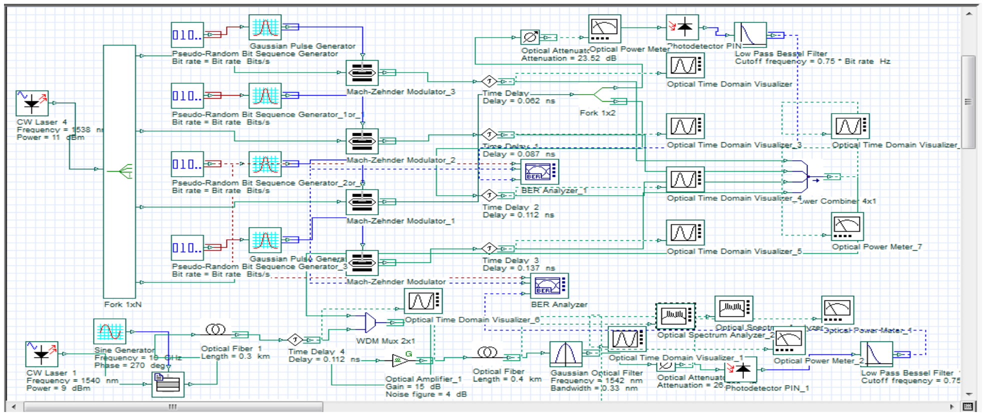


Fig2: Simulation setup of the proposed system

The simulation setup is shown in fig [2].A continuous wave laser diode emitted in optical pulses at a 1538 nm wavelength with a repetition bit rate of 10GHz.The data which is transmitted from 10 Gb/s PRBS is combined with CW laser output in an Mazchender modulator.The output data of modulator is tuned by appropriate four optical delay to get four channels within a 100ps time slot.With the help of power combiner , 40Gb/s data stream is evolved. The clock signals were generated by combining optical pulses and sine generator in an electroabsorption modulator well known as optical intensity modulator.The combined signals were amplified in an erbium-doped fiber amplifier (EDFA) with 15 dB gain.The amplified output signal is launched into the 0.4km long highly nonlinear fiber with a dispersion of -0.08ps/nm/km and a dispersion slope of 0.032 $ps/nm^2/km$.Nonlinear interaction of the two signals occurred in the applied fiber.The peak power of the clock signal into the fiber was 1.659mW , while the power of the signal was 1.039mW.Due to the effects of FWM , the generation of side bands were appeared according to the following equations

$$M = N^2 (N-1) / 2$$

Where N is the number of channels and M is the number of newly generated side bands.Fig [3] shows an example of mixing of two waves at frequency ω_1 and ω_2. After passing through the fiber , the optical spectrum was broadened.So , the desired 10Gb/s channel of 40Gb/s data stream was demultiplexed by using a 0.33-nm optical BPF adjusted to a center wavelength of 1542nm.The demultiplexed channel was used to various receiver operations such as optical spectrum analyzer , optical oscilloscope and BER tester.

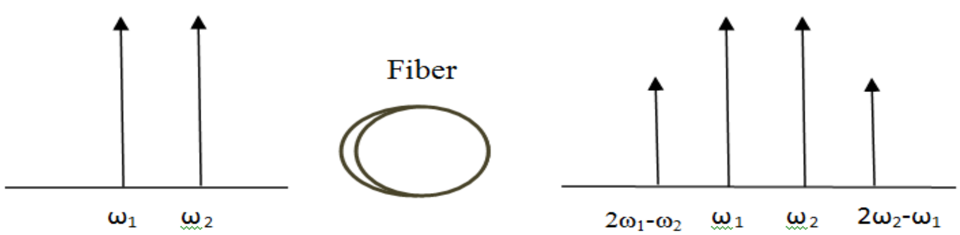


Figure3:Degenerate four-wave mixing

Table 1. Simulation parameters in the proposed system

Signal	Wavelength	1538nm
	Laser Power	11dBm
Clock	Wavelength	1540nm
	Laser Power	9dBm
SMF	Length	0.3km
	Attenuation	0.2dB/km
	Dispersion	-80ps/nm/km at λo=1540nm
EDFA	Gain	15dB
HNLF	Wavelength	1550nm
	Fiber Length	0.4km
	Attenuation	0.2dB/km
	Dispersion Slope	0.032ps/nm^2 /km
	Nonlinear coefficient γ	12.6W^{-1}km^{-1}
BPF	Bandwidth	0.33nm

Fig[4] shows the spectrum of the combination of clock and data signals before highly nonlinear and after highly nonlinear fiber.After passing fiber, the optical spectrum was broadened.To demultiplex the desired channel without containing the amplified spontaneous emission (ASE) noise, the proper choosing of optial bandpass filter is important.

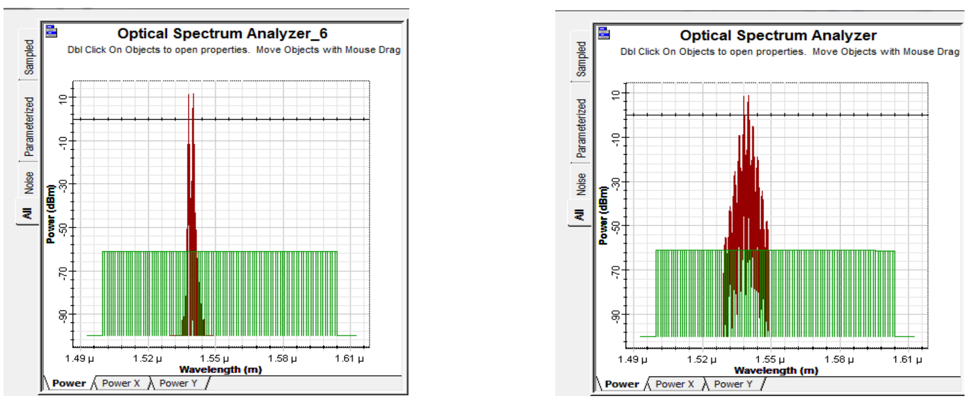
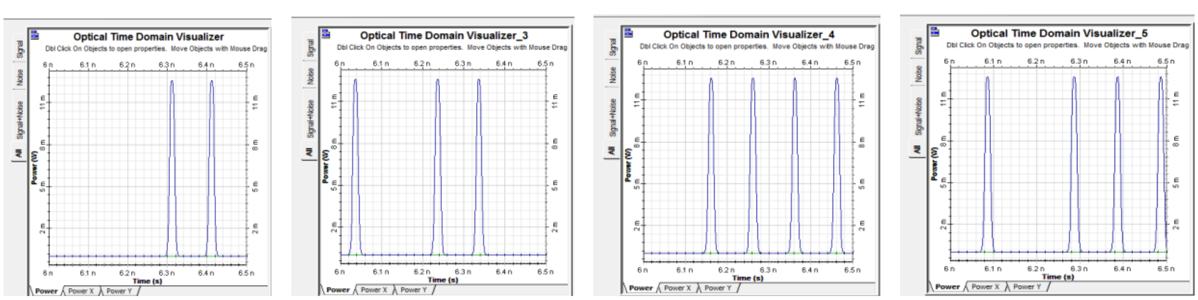
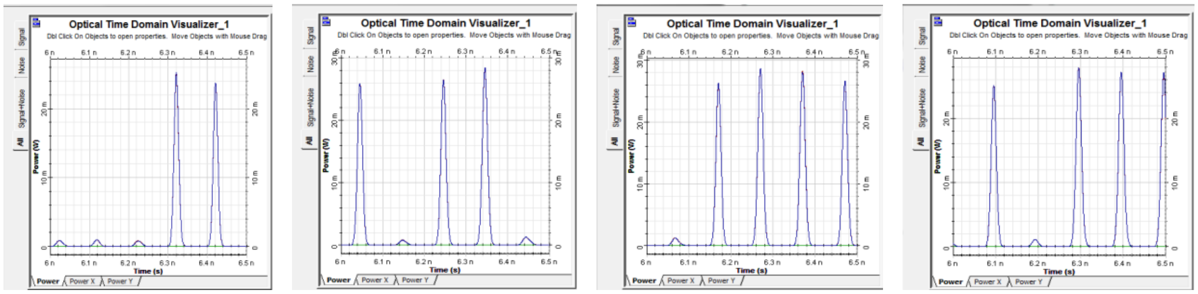


Fig4: (a) The spectrum of the combined signal before fiber, and (b) The broadened spectrum induced by FWM effect after fiber

Fig[5] shows the input signal waveforms and the demultiplexed output waveforms.As a result , the peak power of output waveforms is better than that of the input. But , there has a few zero level noise that is the effect of other channels.There is still need to regenerate the peak power of '1' level.



(a) (b) (c) (d)



(e) (f) (g) (h)

Fig 5:Input signals of(a)CH 1,(b)CH 2,(c)CH 3,(d)CH 4,Output signals of (e)CH 1,(f)CH 2,(g)CH 3,(h)CH 4

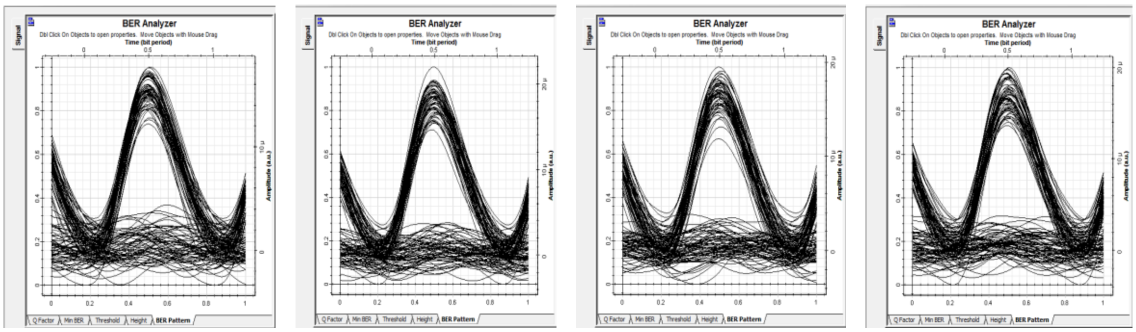


Fig6: (a)-(d) Demultiplexed 10Gb/s channels

Eye patterns of the demultiplexed 10Gb/s channels are shown in Fig.6.As seen in Fig.7, the power penalty of the demultiplexed channels are about <1 dB at standard BER of 10^{-9}.

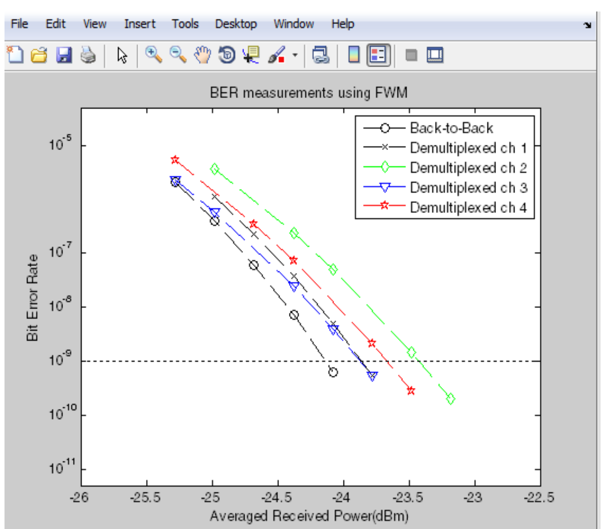


Fig7:BER measurements for 40-10Gb/s demultiplexing

IV. CONCLUSION

In this paper , we have showned a new method for OTDM demultiplexing based on FWM in a highly nonlinear fiber.40Gb/s data channel was demultiplexed to 10Gb/s with <1dB power penalty successfully. . According to the simulation results, regeneration of ‘1s’ in output signal is required for better demultiplexing.

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