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Wavelength Conversion of Dispersion Managed Solitons at 100 Gbps through Semiconductor Optical Amplifier

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Abstract**—**All optical wavelength conversion is essential in present day optical networks for transparent interoperability, contention resolution, and wavelength routing. The incorporation of all optical wavelength convertors leads to better utilization of the network resources and hence improves the efficiency of optical networks. Wavelength convertors that can work with Dispersion Managed (DM) solitons are attractive due to their superior transmission capabilities. In this paper, wavelength conversion for dispersion managed soliton signals was demonstrated at 100 Gbps through semiconductor optical amplifier and an optical filter. The wavelength conversion was achieved for a 1550 nm input signal to1555nm output signal. The output signal was measured in terms of BER, Q factor and system margin.

Keywords**—**All optical wavelength conversion, dispersion managed solitons, semiconductor optical amplifier, cross gain modulation.

I. Introduction

ALL optical wavelength conversion (AOWC) is a process through which information contained by one wavelength is transferred to other wavelength in optical domain only. AOWC is pivotal in reducing the access blocking probability and hence increasing the utilization efficiency of the network resources [1]. Wavelength conversion is required for wavelength routing in WDM networks and is also used in ultrafast OTDM networks [2]. AOWC relieves the optical networks from the speed constraints of electronic circuits and reduces the power consumption as compared to electronic counterparts.

Various methods have been used to realize high bit rate AOWC utilizing different nonlinear optical effects. Broadly AOWC's can be of two types optical gating based AOWCs and wave-mixing based AOWCs [3]. AOWC using Semiconductor optical amplifier makes use of processed such as cross gain modulation, cross phase modulation and Four wave mixing in SOA [3]. AOWC using SOA is attractive because of their low power consumption, potential for integration and compactness [2].

As the technology is evolving, the need for other modulation formats that employ the phase information as well are being investigated, such as RZ-DPSK (Return-to-Zero Differential Phase Shift Keying), RZ-QPSK (Return-to-Zero Quadrature Phase Shift Keying), etc. [4]. AOWC had been demonstrated for different data transmission formats such as NRZ pulses, RZ pulses and soliton pulses. Among many optical transmission formats, an optical soliton offers a great potential to realize an advanced optical transmission system as soliton pulse can maintain its waveform over long distances. Ideally a soliton pulse can exist in a lossless fiber with a constant dispersion. But there are losses and varying dispersion due to which quality of the soliton pulse degrades. These limitations can be reduced by incorporation of dispersion compensation [5]. DM strategy in soliton systems gives rise to a new class of pulses known as DM soliton pulses which can be employed as potential information carrier [6]. DM solitons are different from standard soliton as its shape, width and peak power are not constant. These parameters repeat from period to period at any location within the map. Hence, DM solitons can be used in optical communication systems. DM solitons have remarkable characteristics which make them the preferred choice for use in high capacity systems [7].

In this paper, AOWC was demonstrated for DM soliton pulses through SOA and an optical filter. To the best of our knowledge this is for the first time that wavelength conversion for DM soliton pulses is achieved at 100 Gbps.

II. DM Solitons

Dispersion management came into limelight to meet the demands of WDM networks. In periodic dispersion maps even though the GVD of each section is large, the average (GVD) of the whole link reduces which helps in suppressing four wave mixing and third order dispersion effects [8]

The most significant advantages of DM solitons are Enhancement of pulse energy and Reduction of Gordon-Haus timing jitter, which are discussed below:

a) Enhancement of pulse energy DM solitons undergoes periodic expansion and compression in pulse width during propagation. When the pulse is broadened the intensity of the pulse is reduced, so is the nonlinearity that the pulse experiences. This reduces the effect of SPM in the propagation of DM solitons as compared with standard solitons having the same peak power and same width. The DM solitons thus requires more pulse energy than the standard solitons to achieve the steady state achieved by balance between the nonlinearity and (average) dispersion. The enhanced pulse energy of DM solitons helps in raising the SNR and/ or reducing the average

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fiber dispersion which leads to lower noise induced Gordon-Haus timing jitter [7].

b) Reduction of Gordon-Haus timing jitter: Timing jitter induced by frequency modulations caused by various perturbations is a major hurdle in increasing transmission distance and speed of solitons. The frequency modulation induces a modulation in group velocity through the GVD. Thus, if GVD were close to zero, the frequency modulation would not induce significant timing jitter [9].

The shape of DM solitons is similar to Gaussian pulses, so in numerical simulations, the evolution of DM soliton is assumed as [8]

$$B(z,t) = ae^{[-(1+iC)\frac{T^2}{2T^2}+i\Phi]} \quad (1)$$

where a= amplitude of pulse, T= width of pulse, C= Chirp of pulse and ϕ is phase of soliton pulse.

The periodicity of soliton's behavior which is their unique characteristic becomes vital when the aim is to provide the backbone of an All-optical network. Important issues regarding the periodicity of soliton transmission are discussed below [9]. DM solitons are very attractive for Dense wave division multiplexed (DWDM) systems as they allow the formation of ultra- long haul Tera bit level optical networks. By using DM solitons these networks can operate in all-optical mode thereby obtaining transparency over vast geographical regions. [10].

III. Principle of Operation

The nonlinearities in SOA can be exploited to perform wavelength conversion and other all optical processing functions used in present day all optical networks. The cross gain modulation (XGM) in SOA can be used for wavelength conversion. The most elementary XGM schematic is shown in Fig. 1 where a weak CW probe light and a strong data signal is injected into the SOA [11]. The modulated data signal is imposed on the probe, which implies that wavelength conversion is accomplished.

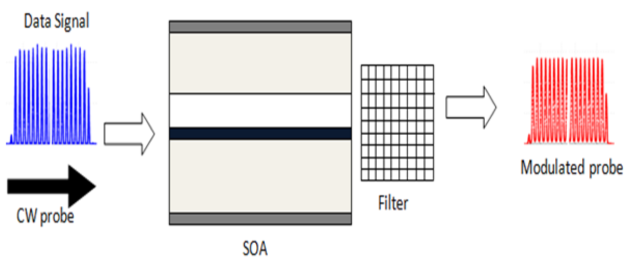

Fig. 1 Wavelength Conversion schematic using XGM in SOA

As shown in Fig. 1, the modulated optical DM soliton pulses together with CW probe were injected into the SOA. The data signal and the CW signal should be at a different wavelength. The data signal was at 1550 nm and the pump signal was at 1555 nm. [9].

As shown in Fig. 2, the relative location of the pump and the probe in the wavelength spectrum obtained after SOA implies that probe spectrum is broadened. The frequency origin is corresponding to 1550 nm in Fig. 2

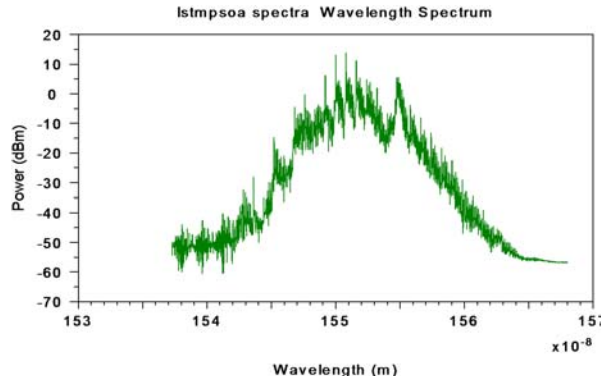

Fig. 2 Broadened wavelength spectrum after SOA

Due to cross gain modulation the falling edge of the probe is shifted towards longer wavelengths and the rising edge is shifted towards shorter wavelength, which leads to a broadened probe spectrum as shown in Fig. 2. The data pulse introduce spectral blue shift for probe light and the optical filter present after SOA rejects central wavelength of probe light and selects the blue shifted spectrum so that probe can only pass through the optical filter when the control signal is present [12]. This principle is utilized for achieving AOWC.

IV. Simulation Setup

The simulation of wavelength conversion of DM soliton pulses employing SOA and an optical filter as shown in Fig. 3 was done using optical communication simulation software.

Mode locked laser was employed to generate multiple soliton pulses of Sechyperbolic (Sech) shape. The Sech pulses were made to pass through a dispersion management bloc which is actually a recirculating small dispersion map. The behavior of DM solitons deteriorates at 100 Gbps but by proper optimization of dispersion map parameters, DM solitons can be generated. After passing through Dispersion management bloc the pulses acquire the characteristics of DM soliton pulses which was verified through their pulse spectrum.

The wavelength of high powered data signal was 1550 nm and the wavelength of probe was 1550 nm. The main parameters that were used in the proposed wavelength convertor are listed in Table I.

TABLE I
Simulation Parameters

S.No	Parameter	Value
1	Bit rate	100 Gbps
2	Data Signal Power	50 mW
3	Probe Signal Power	0.6mW
4	Data Signal Wavelength	1550 nm
5	Probe Signal Wavelength	1560nm
6	SOA pump power	0.7 A
7	Optical filter central wavelength	1555 nm

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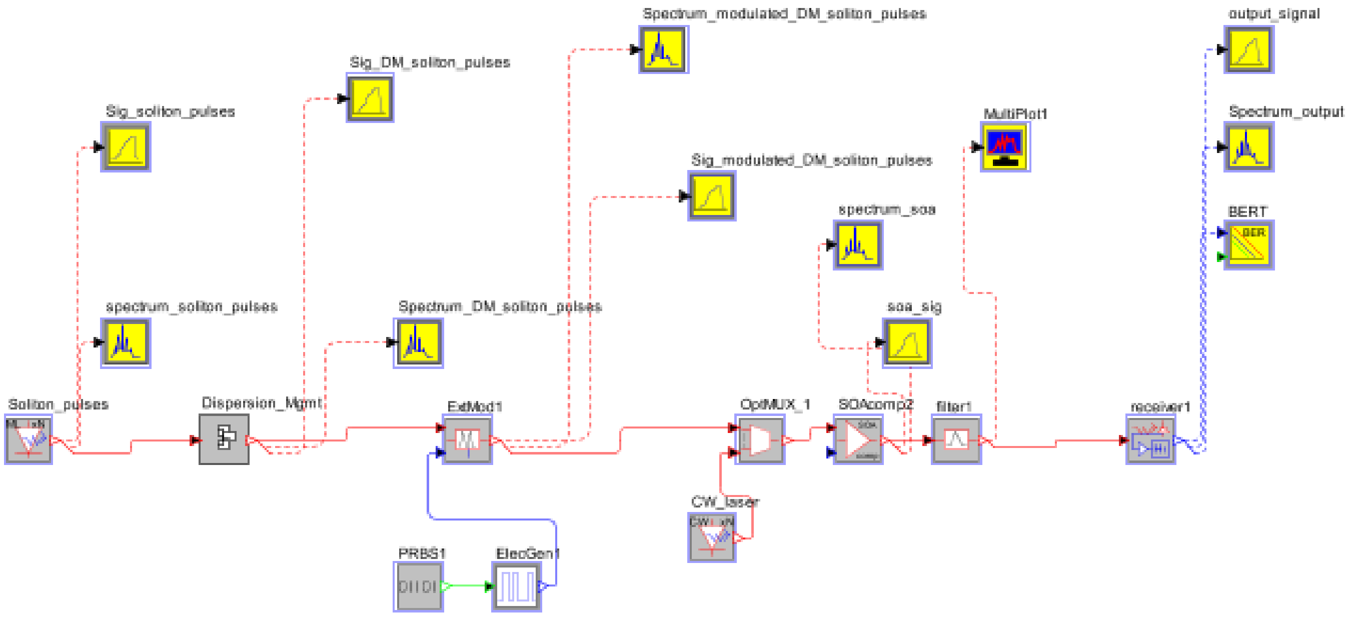

Fig. 3 Simulation Setup for wavelength conversion for DM soliton pulses

The DM soliton pulses were modulated according to the data provided by PRBS generator at a bit rate of 100 Gbps. The modulated DM soliton pulses and the optical signal from CW probe was sent to a multiplexer. The output of the multiplexer was connected to SOA which is further connected to an optical filter. The CW signal i.e. the probe was also coupled into the SOA through the multiplexer. The probe and the data signal were simultaneously injected into SOA. Due to XGM the information in the data signal was superimposed on the probe signal. After SOA the signal was passed to an optical filter. The central wavelength of optical filter was taken as 1560 nm. The optical filter filters the spectrally broadened probe light. The wavelength converted pulses were obtained after the optical filter. The output pulses were sent to the receiver so that analysis could be done in terms of Q factor and BER.

V. Results and Discussion

The soliton pulses generated from mode locked laser and the DM soliton pulses generated at 100 Gbps after dispersion management block were compared through their pulse spectrum. The wavelength spectrum of the soliton pulses as obtained in the case of fundamental soliton is shown in Fig. 4. The wavelength spectrum of the DM soliton pulse obtained for fundamental DM soliton pulse is shown in Fig. 5.

As seen from the wavelength spectrum in Figs. 4 and 5, the characteristics of soliton pulses changes and the soliton pulse acquire the characteristics of DM soliton pulses. As observed from wavelength spectrums in Figs. 4 and 5, the pulse spectrum changes from Sech to Gaussian.

The wavelength spectrum of DM modulated soliton pulses is shown in Fig. 6, and the output wavelength spectrum obtained after the filter is shown in Fig. 7. By observing the input and output spectra from Figs. 6 & 7, it is inferred that the data signal shifts from 1550 nm to 1555nm. Hence, the process of wavelength conversion was accomplished at a bit rate of 100 Gbps.

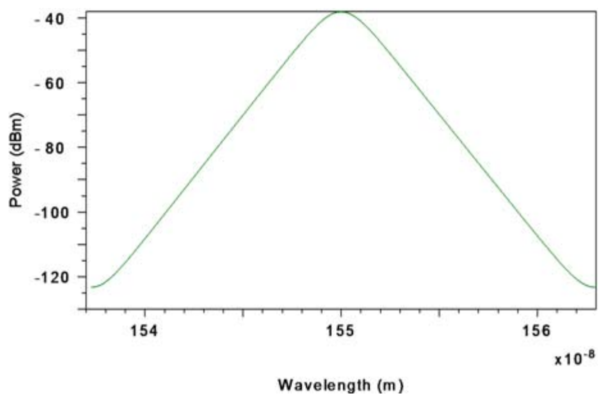

Fig. 4 Wavelength spectrum of fundamental soliton pulse

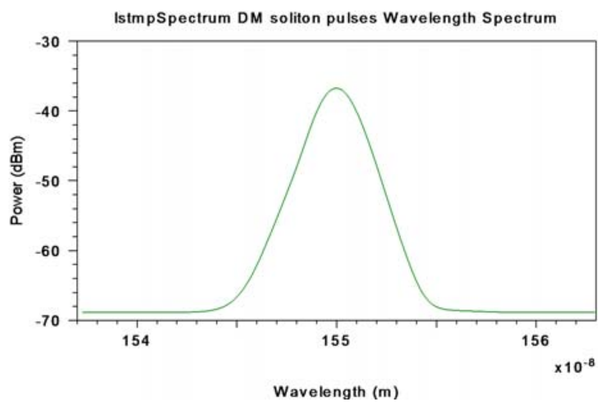

Fig. 5 Wavelength spectrum of fundamental DM soliton pulse

The performance of the system was analyzed through various analysis blocks such as BER tester, Signal analyzer and eye diagram analyzer. The simulated Q factor and BER

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obtained were 17.38 and $6.91*10^{-14}$ respectively. The XGM process was used for wavelength conversion; hence the extinction ratio achieved was 7.18 dB. The system margin of the proposed system was obtained as 1.82. The performance parameters obtained for output signal were summarized in Table II.

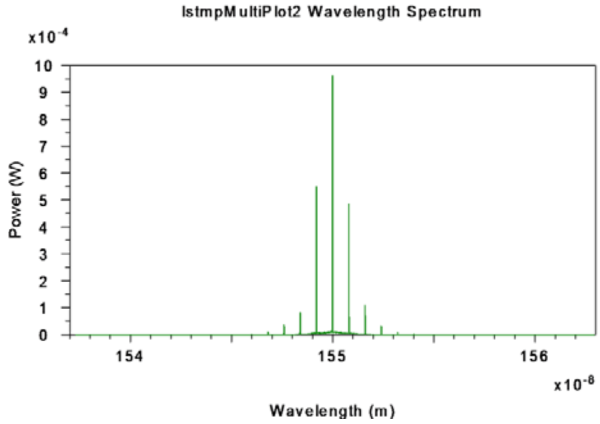

Fig. 6 Wavelength spectrum of input data signal

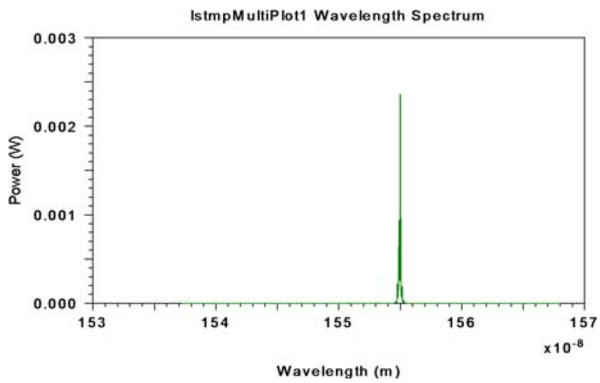

Fig. 7 Wavelength spectrum of output data signal

TABLE II
PERFORMANCE PARAMETERS OF THE PROPOSED SYSTEM

S. No	Parameter	Value
1	Q factor	17.38
2	Required Q	15.56
3	BER	$6.91*10^{-14}$
4	Required BER	$1*10^{-9}$
3	System Margin	1.82
4	Extinction ratio	7.18 dB

As seen from Table II, the values of Q factor and BER of the converted stream i.e. output signal was above the minimum threshold, which signifies fair performance of the convertor.

VI. CONCLUSION

The wavelength conversion for a 100 Gbps DM soliton pulse stream was achieved with a Q factor of 17.38 and a BER of $6.91*10^{-14}$. The system margin achieved for the proposed system was 1.82. Thus, realization of proposed wavelength convertor which can handle DM solitons at 100 Gbps will enhance future optical signal processing applications at high bit rates which is the need of the hour.

REFERENCES

[1] Y. Liu, E. Tangdiongga, Z. Li, S. Zhang, H. de Waardt, G. D. Khoe, and H. J. S. Dorren, “160 Gbit/s wavelength conversion using ultra-fast dynamics in SOA,” in *31st European Conference on Optical Communications (ECOC 2005)*, 2005, vol. 2005, pp. v3–367–v3–367.

[2] H. Ishikawa, *Ultrafast all-optical signal processing devices*. Wiley, 2008.

[3] S. J. B. Yoo, “Wavelength conversion technologies for WDM network applications,” *Journal of Lightwave Technology*, vol. 14, no. 6, pp. 955–966, Jun. 1996.

[4] P. J. Winzer and R.-J. Essiambre, “Advanced Optical Modulation Formats,” *Proceedings of the IEEE*, vol. 94, no. 5, pp. 952–985, May 2006.

[5] M. Nakazawa, H. Kubota, K. Suzuki, and E. Yamada, “Recent progress in soliton transmission technology,” vol. 10, no. 3, pp. 486–514, 2000.

[6] http://photonicssociety.org/newsletters/feb99/solit.htm, accessed Mar. 2016.

[7] L. F. Mollenauer and J. P. Gordon, *Solitons in Optical Fibers*. Elsevier, 2006.

[8] G. P. Agrawal, *Fiber-Optic Communications Systems, Third Edition.*, vol. 6. 2002.

[9] A. Hasegawa and M. Matsumoto, *Optical Solitons in Fibers*. Springer Berlin Heidelberg, 2003.

[10] B. Anjan, D. Milovic, and M. Edwards, *Mathematical theory of Dispersion-managed optical Solitons*. Higher Education Press, Springer, 2010.

[11] M. J. Connelly, *Semiconductor optical amplifiers*. Boston: Kluwer Academic Publishers.

[12] Z. Li, Y. Liu, S. Zhang, H. Ju, H. de Waardt, G. D. Khoe, H. J. S. Dorren, and D. Lenstra, “All-optical logic gates using semiconductor optical amplifier assisted by optical filter,” *Electronics Letters*, vol. 41, no. 25, p. 1397, 2005.