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Multi-Wavelength Optical Network Security generated by Modified add-drop filter

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***Abstract*—The multi-wavelength optical network security system generated by using an optical nonlinear material within the modified add-drop optical filter for network security is proposed. By using the dark-bright nonlinear pulse control, the optical multi-wavelength can be constructed and applied to securely transport within the network. The advantage is that the dark and bright nonlinear pair (components) can securely propagate for long distance without electromagnetic interference. In operation, the optical intensity from modified add-drop optical filter is established.**

Keywords—optical network; network security; multi-wavelength optical;

I. INTRODUCTION

A multiple access scheme is required for multiplexing and DE multiplexing traffic on a shared physical medium [1]. The three major multiple access schemes are described pictorially in Fig. 1. Digital communication allows the possibility of time division multiple access (TDMA). In a TDMA system, each channel occupies a time slot, which interleaves with the time slots of other channels. In a wavelength division multiple access (WDMA) system, each channel occupies a narrow bandwidth around a center wavelength or frequency. The modulation format and speed at each wavelength can be independent of those of other channels. A channel in a CDMA system occupies the same frequency-time space as all the other CDMA channels. The multi-wavelength optical networking (MONET) program was established to define, demonstrate, and help drive industry consensus of how best to achieve multi-wavelength optical networking.

However, the multi-wavelength has been heavily studied in communications and has proven itself as a viable technology, it is a relatively new technology in the network security.

This paper present of MONET system is to integrate network architecture for high traffic capacity, high performance and high security in long distance transport networks.

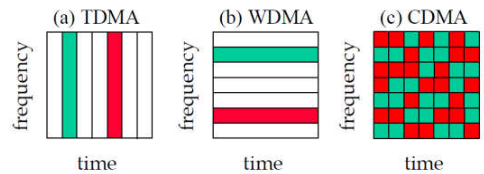

Fig. 1. Time-frequency space usage in (a) TDMA, (b) WDMA, (c) CDMA

II. OPERATING PRINCIPLE

The modified add/drop filter shown in Fig. 2. The coupling region is defined by the coupling factor κ. The equations describe the coupled electric fields are given by references [2]-[5].

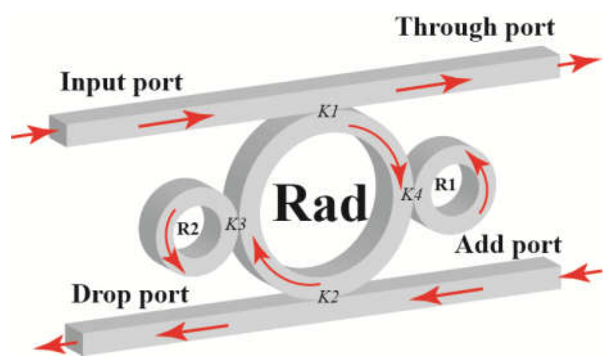

Fig. 2. The Panda Ring Resonator

The input and control fields at the input and add ports are formed by the dark and bright optical soliton pulses, which are given by reference [6] as shown in (1) – (2).

$$E_{in}(t) = A_0 \tanh\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \tag{1}$$

$$E_{in}(t) = A_0 \operatorname{sec}h\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \tag{2}$$

A is the amplitude of optical field and z is a distance propagation, T is a soliton pulse propagation time in a moving frame at group velocity, $T=t-\beta_1 x$, t is the soliton phase shift time, T_0 is a soliton pulse propagation time at initial input, $L_D = T_0^2/|\beta_2|$ is the dispersion length of the soliton pulse, where β_1 and β_2 are the linear and second-order terms of Taylor expansion coefficients of the propagation constant, and ω_0 is the soliton frequency shift.

When light propagates within the nonlinear material (medium), the refractive index (n) of light within the medium is given by (3), which is given by references [7]-[9].

$$n = n_0 + n_2 I = n_0 + \frac{n_2}{A_{eff}} P \tag{3}$$

Where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively, I is the optical intensity, P is the optical power.

III. MULTI-WAVELENGTH OPTICAL

In simulation, the parameters of add-drop optical multiplexer and both micro ring on the left and right hand sides of the PANDA ring for MATLAB simulation are listed in Table I. The waveguide is made of ***InGaAsP/InP***, in which the refractive index value is 3.14 [10]–[11], where the wavelength is defined to be at λ_0=1400, 1425, 1450, 1475, 1500, 1525, 1550, 1575, 1600 nm. In the PANDA ring section, a dark soliton light pulse with 10 mW peak power is input into the input port, while a bright soliton with 1 mW peak power is fed in the Add port to control the device function. Afterward, the dark and bright soliton pulses are entered into through port and circulated within the system, a flow diagram is shown in Fig. 1, where finally the optical field is obtained at E_1, E_2, E_3 and E_4 positions as illustrated in Fig. 3. The Through port and Drop port soliton spins are obtained in Fig. 4. As a result, it is shown that many soliton spins can be produced from PANDA ring resonator. Therefore, the soliton spin array can be generated and controlled by the proposed system, which offers the required multi-wavelength optical spin generation.

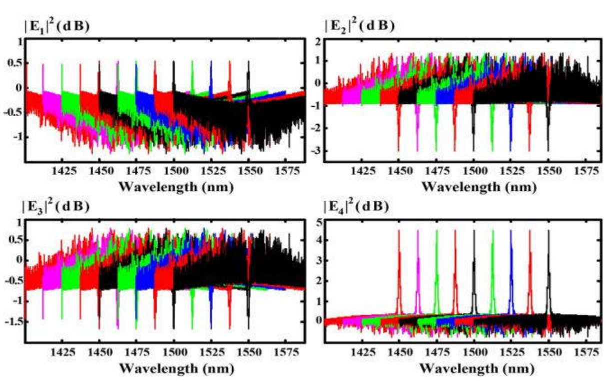

Fig. 3. Many soliton spins within a PANDA ring are generated using a dark-soliton pump input at center wavelength 1400, 1425, 1450, 1475, 1500, 1525, 1550, 1575, and 1600 nm.

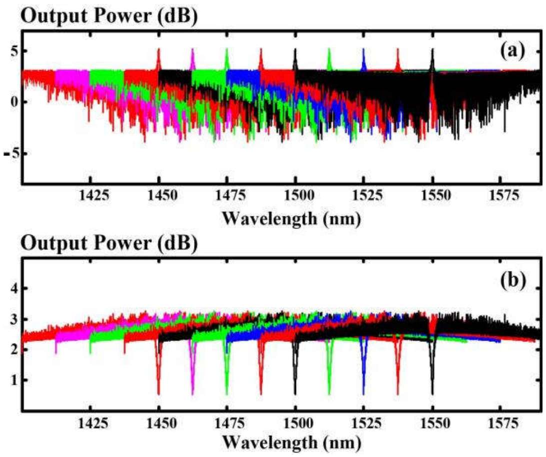

Fig. 4. A set of spins obtained at Through port and drop ports.

TABLE I. List of waveguide and system parameters

	R_{ad}	R_1	R_2	R_{th}	κ_1	κ_2	κ_3
Waveguide parameters	30μm	2.5μm	2.5μm	15 μm	0.5	0.5	0.3
	κ_4	κ_5	κ_6	A_{eff} (μm^2)	n_0	α ($dBmm^{-1}$)	γ
	0.3	0.5	0.5	0.25	3.34	0.1	0.01

Variable parameters	
E_1- E_4	Center ring electric fields
E_{R1}	Left ring electric fields
E_{R2}	Right ring electric fields
E_T	Through port electric fields
E_D	Drop port electric fields
E_{t1}	Through add-drop electric fields
E_{d1}	Drop port add-drop electric fields
P_T	Through port optical power
P_D	Drop port optical power
P_{t1}	Through add-drop optical power
P_{d1}	Drop port add-drop optical power
I	Optical intensity
L_D	Dispersion length
L_{NL}	Nonlinear Dispersion length
ϕ_{NL}	Nonlinear Phase shift
x	Propagation distance
A	Optical amplitude
T	Propagation time

IV. DESIGN AND SIMULATION

The user add-drop filters are employed to retrieve the required signals, where the different wavelength signals (spins) can be obtained using the wavelength selectors (add-drop filters) at the end of the drop port. On the other hand, the modified data can be input into the network via the add port of each user in the transmission networks, which is shown in Fig. 5. The received signals of each user 1-4 from add-drop filters at the through and drop ports are shown Figs. 6 and 7, in which the spin wavelength selectors are employed as the key instrumental components. The certain or a narrow band wavelength can be obtained before the required spin signals being detected via the end users. In terms of signal quality, the simulated free spectral range (FSR) transmission = 25 nm and full width half maximum (FWHM) = 4 nm are achieved as shown in Fig. 8, where the output optical spins with different wavelengths can be obtained.

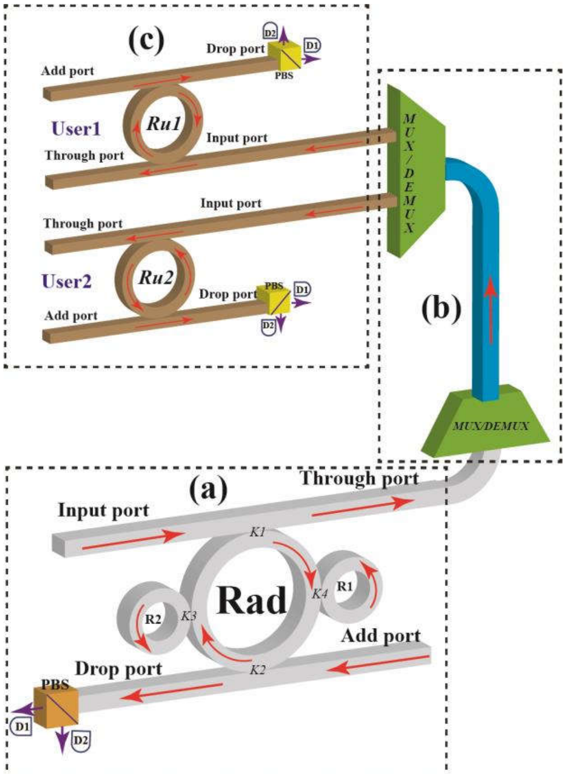

Fig.5. A schematic diagram of spin distributed networks using the multi-wavelength optical spins, where Di: detectors, PBS: polarizing beam splitter, Rgs: output ring radii (users)

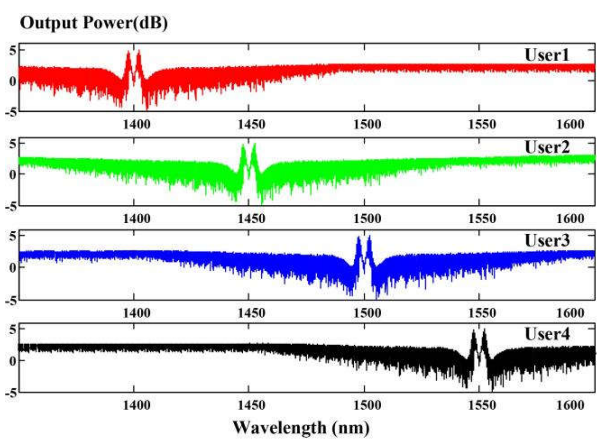

Fig. 6. Shows the results that received by each user 1-4 from add-drop filter at Through port.

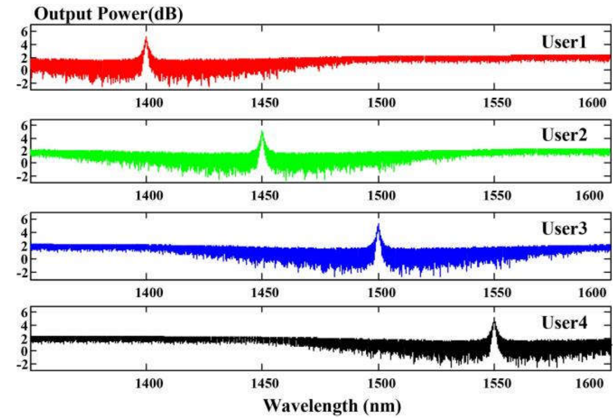

Fig. 7. Shows the results that received by each user 1-4 from add-drop filter at Drop port.

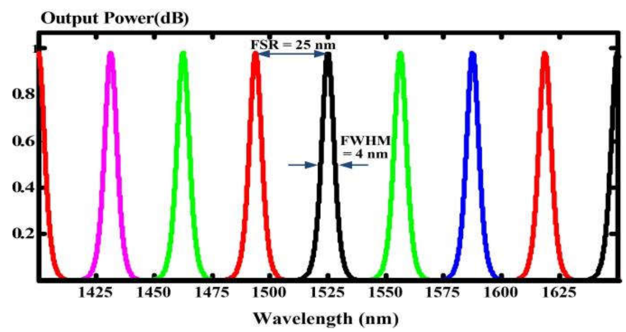

Fig. 8. Simulated transmission FSR= 25 nm and FWHM = 4 nm.

In simulation, the optical multi-wavelength can be generated, as shown in Fig. 4. Hence, the proposed system in Fig. 5, a polarizing beam splitter (PBS) is used to distinguish the data and reference signals at the required destination in part (a). After that, data from the device enters into the multiplexing device (multiplexer, MUX) to encrypt data and transmit into the optical network. The generated optical multi-wavelength (many optical spins) can be used to form the wavelength division multiplexing data transmission, which offers the advantage of a long journey without interference and safely arrives at the destinations. Finally, the required signals can be retrieved (decoded by the DE multiplexing, DEMUX) in part (b). After travelling through the DEMUX, the information will also be sent to the end users using the add-drop filters is generated to identify the required data in part (c).

Generally, the long distance link means the soliton output power that can be useful for > 1,000 km via an optical fiber link [12]-[13], where the proposed system power of 10 dBm is obtained, which can be transmitted over 4,000 km for nine-channel transmission [14], while the time jitter in a soliton communication can be reduced by using the periodic optical phase conjugation (OPC) device [15]. By using the small waveguide effective area, the polarization-dependent loss of

< 0.1dB at 1550 nm can be achieved [16]-[17], where the spin detection can be realized in the form of polarization mode by using the polarizing beam splitter and detected by the end users. The minimum detuning of the two signals (solitons) can be obtained, where in this case the detuning of 6.8 THz can be obtained between two signals (bands), where more details can be found in reference [18]. However, this is a simulation work in practice, if the propagation loss varies with wavelength, then the solitons away from the center (peak) wavelength (1500 nm) will not be valid for long distance propagation.

V. CONCLUSION

In this work, multi-wavelength optical network system is proposed using the orthogonal dark-bright nonlinear conversion pulses within a modified add/drop ring resonator that can be separated using the add-drop filter and PBS for reference source and required signals at the destinations (end users). The results obtained have shown that multi-wavelength optical in the optical networks by nonlinear pulse pair within the optical. In addition, the multi-wavelength nonlinear pulse may be benefit for optical network communication and cryptography. The advantage of the multi-wavelength optical network is appropriate for high security in long distance link.

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