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Controllable FWM within a PANDA Ring

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Abstract

In this paper, we present the controllable four-wave mixing (FWM) within PANDA ring resonator based-on optical soliton manipulation. After a dark soliton pulse is fed into an input port of the resonator, the FWM can be formed within the system and detected simultaneously at the output ports. Under the resonant condition, the FWM can be controlled by adding Gaussian or bright soliton at the add port. Whenever a soliton(photon) is absorbed by an object, an angular momentum of either + $\hbar$ or $-\hbar$ is imparted to the object, in which two possible soliton states known as soliton spins are seen. In application, the controllable FWM can be used atom/photon manipulation.

Keywords: Four-wave mixing; PANDA ring resonator; Solitons

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1. Introduction

Four-wave mixing (FWM) is a well-known nonlinear parametric process that has been largely studied and investigated in polarized light[1], high-Q silica microspheres [2], coupled-resonator optical waveguides [3, 4, 5], two-component matter waves [6], de Broglie waves: beyond optics [7], and quantum dots [8]. Many systems can be generated and controlled enhancement FWM, but a lot generation based on optical soliton manipulation, which can be applied in many fields such as atom/photon manipulation. The optical soliton have been stronger angular momentum of either + $\hbar$ or $-\hbar$ is imparted to the object, in which two possible soliton states known as soliton spin.

In this paper, we present the new concept of controllable FWM within a PANDA ring resonator [9 - 13] based on dark-bright soliton conversion the FWM can be formed within the system and detected simultaneously at the output ports. Under the resonant condition, the FWM can be controlled by adding

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Gaussian or bright soliton at the add port. Whenever a Soliton (photon) is absorbed by an object, an angular momentum of either + ħ or –ħ is imparted to the object, in which two possible soliton states known as soliton spins are seen. In application, the controllable FWM can be used atom/photon manipulation.

2. PANDA Ring Resonator

In Fig. 1, consists of add/drop optical multiplexing used for generated four-wave mixing (FWM) light pulse and other is add/drop optical filter device for decoded binary code signal. The resonator output field, E_{t1} and E_1 consists of the transmitted and circulated components within the add/drop optical multiplexing system, which can perform the driven force to photon/molecule/atom.

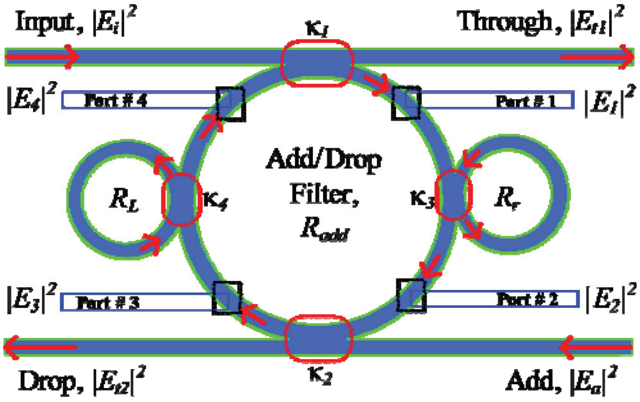

Fig. 1. Schematic diagram of system for used FWM generation

The circulated roundtrip light fields of the right nanoring radii, R_r, are given in Eqs. (1) and (2), respectively [9],

$$E_{r1}=\frac{j\sqrt{1-\gamma}\sqrt{\kappa_0}E_1}{1-\sqrt{1-\gamma}\sqrt{1-\kappa_0}\,e^{-\frac{\alpha}{2}L_1-jk_nL_1}} \tag{1}$$

$$E_{r2}=\frac{j\sqrt{1-\gamma}\sqrt{\kappa_0}E_1e^{-\frac{\alpha}{2}L_1-jk_nL_1}}{1-\sqrt{1-\gamma}\sqrt{1-\kappa_0}\,e^{-\frac{\alpha}{2}L_1-jk_nL_1}} \tag{2}$$

Thus, the output circulated light field, E_0, for the right nanoring is given by

$$E_0=E_1\left\{\frac{\sqrt{(1-\gamma)(1-\kappa_0)}-(1-\gamma)e^{-\frac{\alpha}{2}L_1-jk_nL_1}}{1-\sqrt{(1-\gamma)(1-\kappa_0)}\,e^{-\frac{\alpha}{2}L_1-jk_nL_1}}\right\} \tag{3}$$

Similarly, the output circulated light field, E_{0L}, for the left nanoring at the left side of the add/drop optical multiplexing system is given by

$$E_{0L} = E_3 \left\{ \frac{\sqrt{(1-\gamma_3)(1-\kappa_3)} - (1-\gamma_3)e^{-\frac{\alpha}{2}L_2 - jk_n L_2}}{1-\sqrt{(1-\gamma_3)(1-\kappa_3)}e^{-\frac{\alpha}{2}L_2 - jk_n L_2}} \right\} \tag{4}$$

where κ_3 is the intensity coupling coefficient, γ_3 is the fractional coupler intensity loss, α is the attenuation coefficient, $k_n = 2\pi/\lambda$ is the wave propagation number, λ is the input wavelength light field and $L_2 = 2\pi R_L$, R_L is the radius of left nanoring. From Eqs. (1)-(4), the circulated light fields, E_1, E_3 and E_4 are defined by given $x_1 = (1-\gamma_1)^{1/2}$, $x_2 = (1-\gamma_2)^{1/2}$, $y_1 = (1-\kappa_1)^{1/2}$, and $y_2 = (1-\kappa_2)^{1/2}$.

$$E_1 = \frac{jx_1\sqrt{\kappa_1}E_{i1} + jx_1x_2y_1\sqrt{\kappa_2}E_{0L}E_{i2}e^{-\frac{\alpha}{2}\frac{L}{2} - jk_n\frac{L}{2}}}{1 - x_1x_2y_1y_2E_0E_{0L}e^{-\frac{\alpha}{2}L - jk_n L}} \tag{5}$$

$$E_3 = x_2y_2E_0E_1e^{-\frac{\alpha}{2}\frac{L}{2} - jk_n\frac{L}{2}} + jx_2\sqrt{\kappa_2}E_{i2} \tag{6}$$

$$E_4 = x_2y_2E_0E_{0L}E_1e^{-\frac{\alpha}{2}L - jk_n L} + jx_2\sqrt{\kappa_2}E_{0L}E_{i2}e^{-\frac{\alpha}{2}\frac{L}{2} - jk_n\frac{L}{2}} \tag{7}$$

Thus, from Eqs. (1) to (7), the output optical field of the through port (E_{t1}) is expressed by

$$E_{t1} = x_1y_1E_{i1} + \left(\begin{array}{l} jx_1x_2y_2\sqrt{\kappa_1}E_0E_{0L}E_1 \\ -x_1x_2\sqrt{\kappa_1\kappa_2}E_{0L}E_{i2} \end{array} \right) e^{-\frac{\alpha}{2}\frac{L}{2} - jk_n\frac{L}{2}} \tag{8}$$

The power output of the through port (P_{t1}) is written by

$$P_{t1} = (E_{t1})\cdot(E_{t1})^* = |E_{t1}|^2 . \tag{9}$$

Similarly, the output optical field of the drop port (E_{t2}) is given by

$$E_{t2} = x_2y_2E_{i2} + jx_2\sqrt{\kappa_2}E_0E_1e^{-\frac{\alpha}{2}\frac{L}{2} - jk_n\frac{L}{2}} \tag{10}$$

The power output of the drop port (P_{t2}) is expressed by

$$P_{t2} = (E_{t2})\cdot(E_{t2})^* = |E_{t2}|^2 . \tag{11}$$

3. Results and Discussion

The parameters first are fixed to $\kappa_1 = 0.35$, $\kappa_2 = \kappa_3 = \kappa_4 = 0.1$, $R_{add} = 300\mu m$, $R_r = R_L = 15\mu m$. The input dark soliton pulse train 1W is fed into the input port a PANDA ring resonator. The bright soliton 1W is pumped into the add port at the center wavelength 1400nm for four-wave mixing generates as shown in Fig. 2. Under the resonant condition, the FWM can be controlled by adding Gaussian soliton at the add port. Whenever a Soliton (photon) is absorbed by an object, an angular momentum of either $+\hbar$ or $-\hbar$ is imparted to the object, in which two possible soliton states known as soliton spins are seen. The FWM enhances have been shown at the resonance peak 1383.16, 1388.95, 1393.99, and1411 nm, respectively.

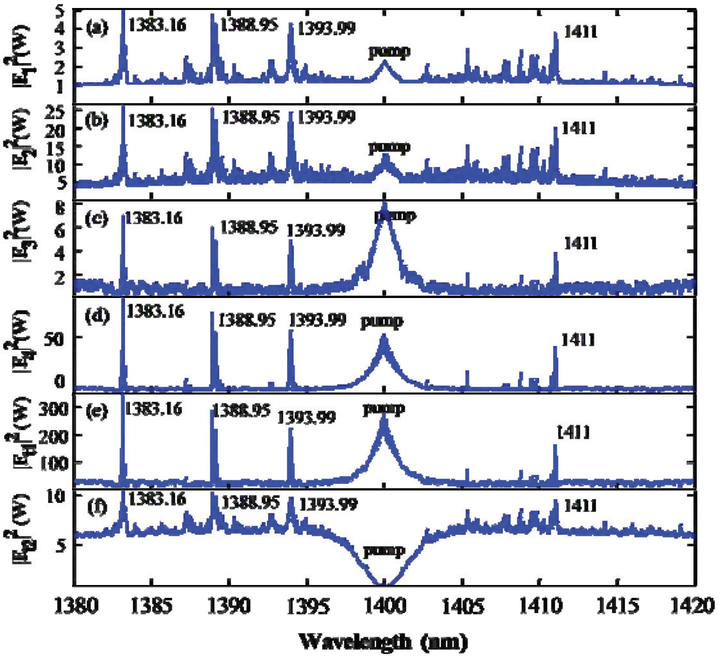

Fig. 2. Numerical results of FWM generation at center wavelength 1400nm, $\kappa_1 = 0.35$, $\kappa_2 = 0.1$ with bright soliton pump at add port, where (a) output port # 1, (b) output port # 2, (c) output port # 3, (d) output port # 4, (e) output at through port and (f) output at drop port

In Fig. 3 when we changes the coefficient of a PANDA ring to $\kappa_1 = 0.1$ and $\kappa_2 = 0.5$, we found that the output power is detected at the through and drop ports comparison in Fig. 2 is decreased. Because the control bright soliton pulse from add port is more fed into circulate a PANDA ring than previous and direct go to the drop port exactly 50%. The resonances peak is shift to 1388.95 and 1393.99 nm, respectively.

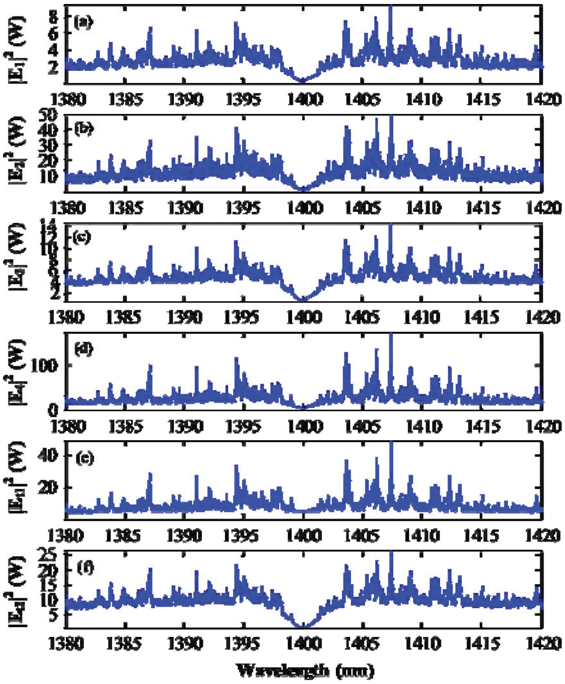

Fig. 3. Numerical results of FWM generation at center wavelength 1400nm, $\kappa_1 = 0.1$, $\kappa_2 = 0.5$ with Gaussian pump at add port, where (a) output port # 1, (b) output port # 2, (c) output port # 3, (d) output port # 4, (e) output at through port and (f) output at drop port

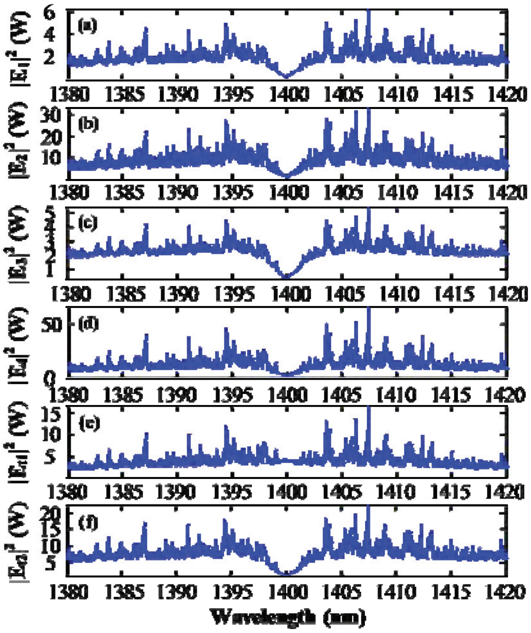

Fig. 4. Numerical results of FWM generation at center wavelength 1400nm, $\kappa_1 = 0.1$, $\kappa_2 = 0.75$ with Gaussian pump at add port, where (a) output port # 1, (b) output port # 2, (c) output port # 3, (d) output port # 4, (e) output at through port and (f) output at drop port

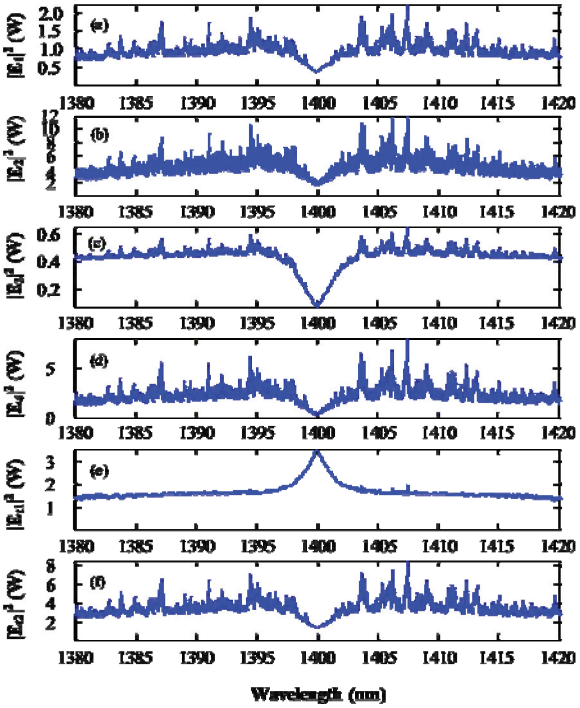

Fig. 5. Numerical results of FWM generation at center wavelength 1400nm, $\kappa_1 = 0.1$, $\kappa_2 = 0.95$ with Gaussian pump at add port, where (a) output port # 1, (b) output port # 2, (c) output port # 3, (d) output port # 4, (e) output at through port and (f) output at drop port

Certainly, when we increases the second coupling coefficient a PANDA ring resonator to 0.75 and 0.95 as shown in Figs. 4 and 5, we found that the output power detected at the through port is decreased, on the other hand, the drop port is increased compared in Figs. 2 and 3, respectively. In Fig. 5, when the coupling coefficient of coupler 2 (κ_2) is given to 0.95, the output signal at the drop port is higher output power than through port. Under the resonant condition, the FWM can be controlled by adding Gaussian or bright soliton at the add port. Whenever a Soliton (photon) is absorbed by an object, an angular momentum of either $+\hbar$ or $-\hbar$ is imparted to the object, in which two possible soliton states known as soliton spins are seen again, which is realized using a optical memory [13].

4. Conclusion

We present the controllable four-wave mixing (FWM) within PANDA ring resonator based-on optical soliton manipulation. After a dark soliton pulse is fed into an input port of the resonator, the FWM can be formed within the system and detected simultaneously at the output ports. We can conclude that the output power of drop port is increasing when the second coupling coefficient which is realized optical memory [13]. Under the resonant condition, the FWM can be controlled by adding Gaussian or bright soliton at the add port. Whenever a Soliton (photon) is absorbed by an object, an angular momentum of either $+\hbar$ or $-\hbar$ is imparted to the object, in which two possible soliton states known as soliton spins are seen. In application, the controllable FWM can be used atom/photon manipulation.

References

[1] C. Li, Y. Zhang, Z. Nie, Y. Du, R. Wang, J. Song, and M. Xiao. Controlling enhancement and suppression of four-wave mixing via polarized light. *Phys Rev A* 2010;**81:**033801.

[2] I. H. Agha, Y. Okawachi, M. A. Foster, J. E. Sharping, and A. L. Gaeta. Four-wave-mixing parametric oscillations in dispersion-compensated high-*Q* silica microspheres. *Phys Rev A* 2007;**76**:043837.

[3] A.a Melloni, F. Morichetti, and M. Martinelli. Four-wave mixing and wavelength conversion in coupled-resonator optical waveguides. *J Opt Soc Am B* 2008;**25**:C87-C97.

[4] L.G. Helt, Z. Yang, M. Liscidini, and J. E. Sipe. Spontaneous four-wave mixing in microring resonators. *Opt Lett* 2010;**35**:3006-3008.

[5] P. Dong, S. F. Preble, J. T. Robinson, S. Manipatruni, and M. Lipson. Inducing photonic transitions between discrete modes in a silicon optical microcavity. *Phys Rev Lett* 2008;**100**:033904.

[6] D. Pertot, B. Gadway, and D. Schneble. Collinear four-wave mixing of two-component matter waves. *Phys Rev Lett* 2010;**104**:200402.

[7] V. Krachmalnicoff, J.-C. Jaskula, M. Bonneau, V. Leung, G. B. Partridge, D. Boiron, C. I. Westbrook, P. Deuar,P. Zin´, M. Trippenbach, and K.V. Kheruntsyan. Spontaneous four-wave mixing of de Broglie waves: beyond optics. *Phys Rev Lett* 2010;**104**:150402.

[8] D. Nielsen and S. L. Chuang. Four-wave mixing and wavelength conversion in quantum dots. *Phys Rev B* 2010;**81**:035305.

[9] T. Phatharaworamet, C. Teeka, R. Jomtarak, S. Mitatha, and P. P. Yupapin. Random Binary Code Generation Using Dark-Bright Soliton Conversion Control Within a PANDA Ring Resonator. *J Lightw Techn* 2010;**28**:2804-2809.

[10] N. Suwanpayak, M. A. Jalil, C. Teeka, J. Ali, and P. P. Yupapin. Optical vortices generated by a PANDA ring resonator for drug trapping and delivery applications. *Biomed Opt Express* 2011;**2**:159-168.

[11] M. Tasakorn, C. Teeka, R. Jomtarak, and P. P. Yupapin. Multitweezers generation control within a nanoring resonator system. *Opt Eng* 2010;**49**:075002.

[12] B. Jukgoljun, N. Suwanpayak, C. Teeka, and P.P. Yupapin. Hybrid Transceiver and Repeater using a PANDA Ring Resonator for Nano Communication. *Opt Eng* 2010;**49**:125003.

[13] P. Youplao, T. Phattaraworamet, S. Mitatha, C. Teeka, and P. P. Yupapin. Novel optical trapping tool generation and storage controlled by light. *JNonlin Opt Phys Mater* 2010;**19**:371–378.