Data signal processing via manchester coding-decoding method using chaotic signals generated by PANDA ring resonator

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We investigate the nonlinear behaviors of light recognized as chaos during the propagation of Gaussian laser beam inside a nonlinear polarization maintaining and absorption reducing (PANDA) ring resonator system. It aims to generate the nonlinear behavior of light to obtain data in binary logic codes for transmission in fiber optics communication. Effective parameters, such as refractive indices of a silicon waveguide, coupling coefficients (κ), and ring radius ring (R), can be properly selected to operate the nonlinear behavior. Therefore, the binary coded data generated by the PANDA ring resonator system can be decoded and converted to Manchester codes, where the decoding process of the transmitted codes occurs at the end of the transmission link. The simulation results show that the original codes can be recovered with a high security of signal transmission using the Manchester method.

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Chaotic signals have attracted interest in the areas of nonlinear science, communication technology, and signal processing because of their broadband spectrum, as well as orthogonality and complexity properties[1]. The possibility of employing chaotic signals to carry information was first studied in 1993[2]. The interest in chaotic communications is due to the favorable properties of chaotic signals in the fields of security systems or broadband multiple access systems[3]. The nonlinear behavior of light inside a microring resonator (MRR) occurs when a strong pulse of light is inserted into the ring system[4,5]. Chaotic controls have been used in a great number of optical[6−9], engineering[10,11], and biological[12,13] design systems. The theoretical studies of such systems have the same conceptions as those in ring cavities[14−16] and the Fabry–Perot system[17−20].

Another technique[21] used for generating the nonlinear behavior of light in a MRR is through the production of secured codes. The generated binary codes can be encoded and decoded via the Manchester technique[22]. This method is a bi-phase signal-encoding scheme, in which the direction of the mid-interval transition indicates a value (1 or 0) and provides the clocking[23]. Manchester encoding is a synchronous clock encoding technique, wherein the actual binary data to be transmitted over the cable are not sent as a sequence of logic 1's and 0's[24], rather, translated into a slightly different format that has a number of advantages over straight binary encoding. Thus, logic 0 is indicated by a 0 to 1 (upward transition at bit center) transition at the center of the bit, whereas logic 1 is indicated by a 1 to 0 (downward transition at bit center) transition at the center of the bit (Halsall, 1995).

The Manchester code is used in binary search algorithms[25] to determine the location of the collision bits. In the Manchester encoding method, the negative edge of the signal means data-1, whereas the positive edge of the signal means data-0. In the decoding method, the signals are unchanged if collision occurs. Thus, the reader can easily find the unchanged signals to identify the collision and determine where the collision bits are. In this letter, the generation of chaotic signals in a polarization maintaining and absorption reducing (PANDA) ring resonator is presented. The chaotic signal output can be easily controlled because of the interferometric role of this system. This study involves two properties of light, i.e., the chaos behavior of the PANDA ring resonator system was used to generate the demanded binary codes, a suitable technique for encoding and decoding the transmitted information via optical binary signals. The transmitting signals can be secured throughout the propagation during fiber optics communication, whereby the original and initial signals are recovered using the Manchester technique.

The proposed system of chaotic signal generation, known as the PANDA ring resonator (Fig. 1), comprises a centered ring resonator matched to two smaller ring resonators on the right and left sides. This system also has two straight waveguides on the top and bottom sides, where two input signals can be introduced into the system via the input and add ports.

The Kerr effect causes variations in the refractive index (n) of the medium and is given by[26]

$$n = n_0 + n_2 I = n_0 + \frac{n_2}{A_{\mathrm{eff}}} P, \qquad (1)$$

where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively. I and P are the optical intensity and power, respectively. The effective mode core area of the device (A_{eff})[27] ranges from 0.50 to 0.10 μm^2[28]. The input optical fields of the Gaussian pulses are given by[29]

$$E_{\mathrm{i1}}(t) = E_{\mathrm{i2}}(t) = E_0 \exp\left[\left(\frac{z}{2L_{\mathrm{D}}}\right) - \mathrm{i}\omega_0 t\right], \qquad (2)$$

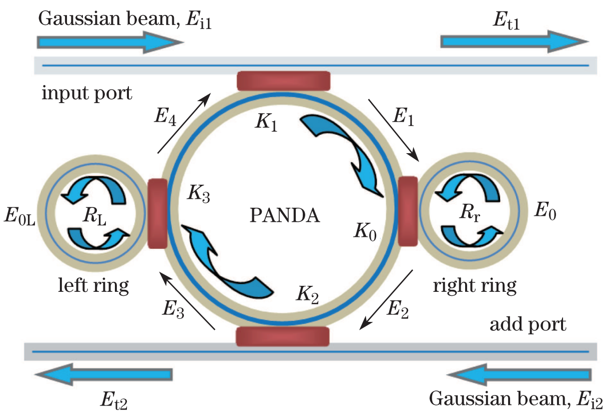

Fig. 1. Schematic of the PANDA ring resonator system.

where E_0 and z are the amplitude of the optical field and propagation distance, respectively; L_D is the dispersion length, and ω_0 is the frequency shift of the signal. A balance should be achieved between L_D and the nonlinear length ($L_{NL}=1/\Gamma\phi_{NL}$)[30], wherein, $\Gamma=n_2\times k_0$ is a length scale. The output signals inside the system are given as[31]

$$E_1 = \sqrt{(1-\kappa_1)(1-\gamma_1)}E_4 + \mathrm{j}\sqrt{\kappa_1(1-\gamma_1)}E_{i1}, \quad (3)$$

$$E_2 = E_0E_1\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}, \quad (4)$$

where κ_1 is the intensity coupling coefficient, γ_1 is the fractional coupler intensity loss, α is the attenuation coefficient, $\kappa_n = 2\pi/\lambda$ is the wave propagation number, λ is the input wavelength light field, and $L = 2\pi R_{PANDA}$. R_{PANDA} is the radius of the PANDA system. The electric field of the right ring of the PANDA system is given as

$$E_0 = (E_1\sqrt{1-\gamma}) \times \frac{\sqrt{1-\kappa_0} - \sqrt{1-\gamma}\mathrm{e}^{-\frac{\alpha}{2}L_1-\mathrm{j}k_nL_1}}{1-\sqrt{(1-\gamma)(1-\kappa_0)}\mathrm{e}^{-\frac{\alpha}{2}L_1-\mathrm{j}k_nL_1}}, \quad (5)$$

where κ_0 is the intensity coupling coefficient, γ is the fractional coupler intensity loss, $L_1 = 2\pi R_r$, and $R_r =$ 180 nm is the radius of right ring. The light fields of the left ring of the PANDA ring resonator can be expressed as

$$E_3 = \sqrt{(1-\kappa_2)(1-\gamma_2)}E_2 + \mathrm{j}\sqrt{\kappa_2(1-\gamma_2)}E_{i2}, \quad (6)$$

$$E_4 = E_{0L}E_3\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}, \quad (7)$$

where the electric field of the left ring of the PANDA system is given as

$$E_{0L} = (E_3\sqrt{1-\gamma_3})\frac{\sqrt{1-\kappa_3} - \sqrt{1-\gamma_3}\mathrm{e}^{-\frac{\alpha}{2}L_2-\mathrm{j}k_nL_2}}{1-\sqrt{1-\gamma_3}\sqrt{1-\kappa_3}\mathrm{e}^{-\frac{\alpha}{2}L_2-\mathrm{j}k_nL_2}}, \quad (8)$$

where $L_2 = 2\pi R_L$ and $R_L = 200$ nm is the radius of left ring. The parameters of x_1, x_2, y_1, and y_2 are defined as: $x_1 = (1-\gamma_1)^{\frac{1}{2}}$, $x_2 = (1-\gamma_2)^{\frac{1}{2}}$, $y_1 = (1-\kappa_1)^{\frac{1}{2}}$, and $y_2 = (1-\kappa_2)^{\frac{1}{2}}$. Thus,

$$E_1 = \frac{\mathrm{j}x_1\left[\sqrt{\kappa_1}E_{i1} + x_2y_1\sqrt{\kappa_2}E_{0L}E_{i2}\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}\right]}{1-x_1x_2y_1y_2E_0E_{0L}\mathrm{e}^{-\frac{\alpha}{2}L-\mathrm{j}k_nL}}, \quad (9)$$

$$E_3 = x_2\left[y_2E_0E_1\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}} + \mathrm{j}\sqrt{\kappa_2}E_{i2}\right], \quad (10)$$

$$E_4 = x_2E_{0L}\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}\left[y_2E_0E_1\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}} + \mathrm{j}\sqrt{\kappa_2}E_{i2}\right]. \quad (11)$$

The electric field output of E_{t1} and E_{t2} is obtained as

$$E_{t1} = AE_{i1} - \frac{G^2BE_{i2}\mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}}{1-FG^2}\left[CE_{i1}+DE_{i2}G\right], \quad (12)$$

$$E_{t2} = \frac{Gx_2y_2E_{i2}\sqrt{\kappa_1\kappa_2}}{1-FG^2}\left[AE_0E_{i1} + \frac{D}{x_1\kappa_1\sqrt{\kappa_2}E_{0L}}E_{i2}G\right], \quad (13)$$

where $A = x_1x_2$, $B = x_1x_2y_2\sqrt{\kappa_1}E_{0L}$, $C = x_1^2x_2\kappa_1\sqrt{\kappa_2}E_0E_{0L}$, $G = \mathrm{e}^{-\frac{\alpha L}{4}-\mathrm{j}k_n\frac{L}{2}}$, $D = (x_1x_2)^2y_1y_2\sqrt{\kappa_1\kappa_2}E_0E_{0L}^2$, and $F = x_1x_2y_1y_2E_0E_{0L}$.

Gaussian beams with a center wavelength of 1.55 μm and power of 0.6 W are introduced into the add and input ports of the PANDA ring resonator. The radius of the centered ring resonator (R_{PANDA}) is 300 nm, and the right and left ring resonators have radii of 180 and 200 nm, respectively. The simulated output signals from the PANDA system are shown in Fig. 2. The coupling coefficients of the PANDA ring resonator are given as $\kappa_1 = 0.35$, $\kappa_0 = 0.2$, $\kappa_2 = 0.1$, and $\kappa_3 = 0.55$, as shown in Fig. 1. The input Gaussian beam from the input and add ports has a power of 0.6 W.

The amplification of signals occurs during light propagation inside the right and left rings. The soliton is stable and observed within the system where the chaotic signals are generated at the throughput port of this system. The temporal form of the throughput output is shown in Fig. 3, where the specific time is indicated for each roundtrip inside the ring system.

Chaotic signals can be used to generate binary code information. The encoding and decoding of the data can be performed via the Manchester technique. This system encodes the binary logic codes of "0" and "1" and transmits these codes via fiber optics communication in the form of Manchester codes, where the decoding process is performed at the end of the transmission link. Figure 4 shows the generated logic codes with respect to the roundtrip of the circulation signal inside the PANDA ring resonator.

Encoding is the process of adding the correct transitions to the message signal in relation to the data to be sent over the communication system. The first step is to establish the data rate to be used. The encoding and decoding system of the transmitting signals is shown in Fig. 5.

The generated logic codes from the PANDA ring resonator system can be inputted into the Manchester system. Therefore, the signals in the form of Manchester codes securely propagate during fiber optics communication and can be finally received, detected, and decoded by the users. Figure 6 shows the forms of the transmitting signals in the communication system.

Therefore, data transmission during fiber network communication uses Manchester codes. The security scheme of the transmission can be obtained via the encoding-decoding of data using a suitable method. A high transmission capacity requires high optical signals such as chaotic signals, which are employed either as optical carrier or optical information.

In conclusion, we present the nonlinear effects of the PANDA ring resonator as optical chaos. The Gaussian beams with a center wavelength of 1.55 μm are inserted into the input and add port of the PANDA system, which generate a high capacity of chaotic signals. The light traveling inside the proposed ring system is analyzed using suitable parameters of the system. The signal transmission can be implemented via a Manchester coding-decoding method, where the encoded signals of the binary codes can be converted to Manchester codes. These codes are secured during the transition of signals along the long distance fiber optics, where the binary codes can be generated from chaotic signals using a PANDA ring resonator system. The binary codes are transmitted in the form of Manchester codes, where the decoding of signals occurs at the end of the transmission link. The length of the transmission link is 125 km, wherein clear and decoded signals are achieved by the users, thereby providing secured and high capacity optical soliton communication.

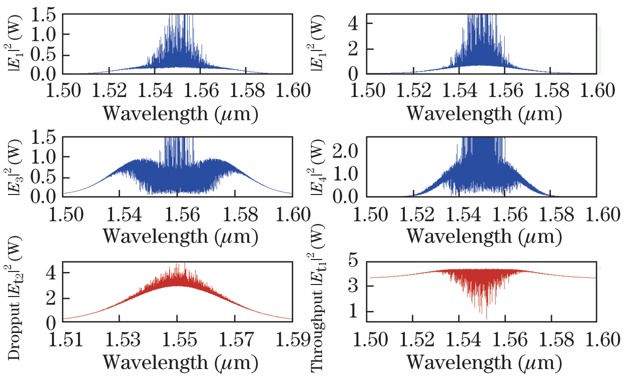

Fig. 2. Optical signals generated inside the PANDA ring resonator system.

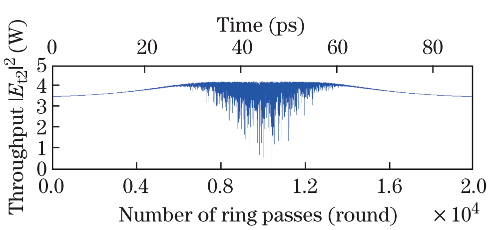

Fig. 3. Chaotic soliton signal generation using the PANDA ring resonator system. E_{t1} is the electric field of the throughput and drop ports of the system.

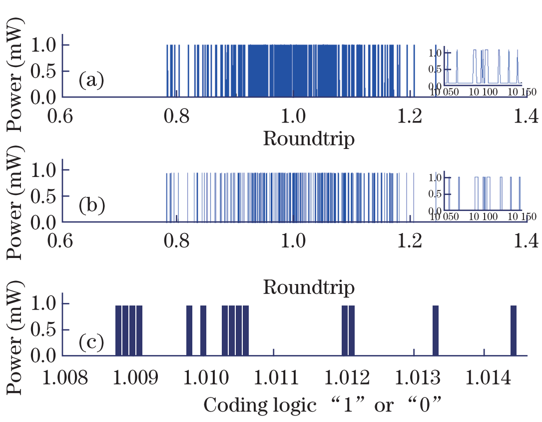

Fig. 4. Generation of logic codes: (a) binary codes, (b) filtered binary codes, and (c) generated logic codes of 00000001111000000010100111100000000000000 1100000000000010000000000010.

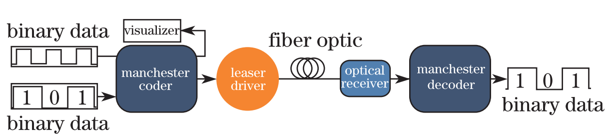

Fig. 5. Encoding and decoding system.

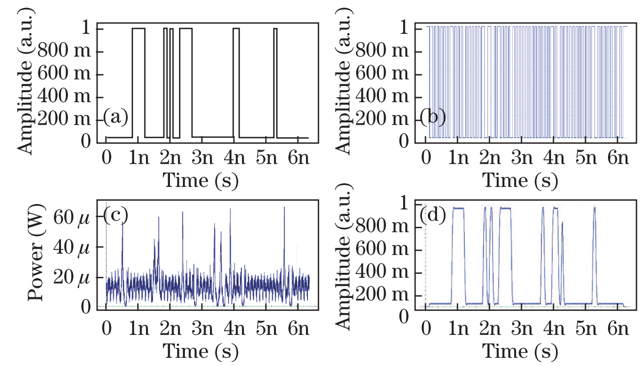

Fig. 6. Generation of transmitting signals: (a) binary codes, (b) converted Manchester codes, (c) transmitted Manchester codes over 125-km fiber optics, and (d) decoded signals into original signals.

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