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A new technique generation ghost-signal by microring resonator for 1.3 µm security communication

U. Dunmeekeaw\textsuperscript{a*}, S. Sririsina\textsuperscript{a}, N. Pornsuwancharoen\textsuperscript{a}, S. Chaiyasoonthorn\textsuperscript{b}, P. P. Yupapin\textsuperscript{c}, R. Phromloungsrit\textsuperscript{d}

\textsuperscript{a}Nano Photonics Research Group, Department of Electrical Engineering, Faculty of Industry and Technology, Rajamangala University of Technology Isan Sakhon Nakon Campus, Sakhon Nakon 47160, Thailand.

\textsuperscript{b}Department of Electronic Technology, Faculty of Science, Ramkhamhaeng University Bangkok 10240, Thailand

\textsuperscript{c}Advance Research Center for Photonics, Faculty of Science, King Mongkut’s Institute of Technology Ladkrabang, Bangkok 10520, Thailand

\textsuperscript{d}Department of Electronics Engineering, Faculty of Technology, Udonthani Rajabhat University, Udonthani, 41000, Thailand

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Abstract

We present a new system of signal security using nonlinear micro ring resonators for optical communication system. When a Gaussian pulse (1.3\,\mu{}m) is input into the system, the chaotic signal is generated and multiplexed into the optical communication. The chaotic waveform can be canceled using an add/drop device connected into the transmission link. In application results from the fact that the fast and slow light behaviors can be presented and can be seen using the add/drop filter. We can generate signal to obtain the two identical “signal” and “ghost” signals, which are observed in a different time frame. In this application, communication security can be performed when the required information is multiplexed and performs the link using the chaotic signal, signal and ghost signals, where the original signal can be retrieved and randomized by the known user.

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1. Introduction

The generation ghost-signal by microring resonator for 1.3 \,\mu{}m security communication on application from soliton communication band for optical networking redundancy using a Gaussian soliton

* Corresponding author. E-mail address: au_electric09@hotmail.com, jeewuttinun@gmail.com.
generation, generalized optical filters using a nonlinear micro ring resonator system, multi-variable quantum tweezers generation using photon entanglement, multi-wavelength generation of an extremely narrow pulse using a ring resonator system for bio-cells microscopy, New wavelength division multiplexing bands generated by using a Gaussian pulse in a microring resonator system and trapping a dark soliton pulse within a nano ring resonator [1-6]. The ghost reduction system for television receivers, coding for the optical channel: the ghost-pulse constraint, development of a ghost cancel reference signal for TV broadcasting, optical encryption with compressive ghost imaging and Coupling-mediated ghost resonance in mutually injected lasers [7-11]. Furthermore, the Gaussian pulse generator is a simple, easily and compact design, making it more commercially viable.

In this paper, we present the theoretical background in the physical model concept, where design can be use to 1.3 µm security communication system design by microring resonator system. In application, the high capacity channel, this is available for high security and high capacity via optical communication application.

2. Theory and Background

The light from a monochromatic light source is launched into a ring resonator with constant light field amplitude (\(E_0\)) and the router quantum key distribution as shown in Fig. 1, which is the combination of terms in attenuation (\(\alpha\)) and phase(f0) constants, which results in temporal coherence degradation. Hence, the time dependent input light field (\(E_{in}\)), without pumping term, can be expressed as [12]

\[
E_{in}(t) = E_0 e^{-\alpha L + j f_0 t}.
\]  

Here \(L\) is a propagation distance (waveguide length).

We assume that the nonlinearity of the optical ring resonator is of the Kerr-type, i.e., the refractive index is given by

\[
n = n_0 + n_2 I = n_0 + \left(\frac{n_2}{A_{eff}}\right) P,
\]  

where \(n_0\) and \(n_2\) are the linear and nonlinear refractive indexes, respectively. \(I\) and \(P\) are the optical intensity and optical power, respectively. The effective mode core area of the device is given by \(A_{eff}\). For the microring and nanoring resonators, the effective mode core areas range from 0.10 to 0.50 µm².
Fig. 1 show optical signal and ghost generation by microring resonator system to drop port by the first ring generated the chaotic signal and second ring filtering the chaotic signal from first ring, which the third ring filtering again with the chaotic cleaning and cancellation chaotic by add/drop filter. The signal and ghost signal can be variable by change the parameter of couple coefficient ($\kappa_1$) and ($\kappa_2$).

When a Gaussian pulse is input and propagated within a fiber ring resonator, the resonant output is formed, thus, the normalized output of the light field is the ratio between the output and input fields ($E_{out}(t)$ and $E_{in}(t)$) in each roundtrip, which can be expressed as [13-14].

\[
\frac{|E_{out}(t)|}{|E_{in}(t)|} = (1-\gamma) \left[ \frac{(1-(1-\gamma)x^2)\kappa}{(1-x\sqrt{1-\gamma\sqrt{1-\kappa^2}})^4 + 4\kappa \sqrt{1-\gamma\sqrt{1-\kappa^2}} \sin^{2}\left(\frac{\phi}{2}\right)} \right]
\]  

Equation (3) indicates that a ring resonator in the particular case is very similar to a Fabry-Perot cavity, which has an input and output mirror with a field reflectivity, (1-\kappa), and a fully reflecting mirror. k is the coupling coefficient, and 

\[\phi = \exp(-\alpha L / 2)\]

represents a roundtrip loss coefficient, $\phi_0 = kLn_0$ and $\phi_{nl} = kL(n_{nl})P$ are the linear and nonlinear phase shifts, $k = 2\pi / \lambda$ is the wave propagation number in a vacuum. Where $L$ and $\alpha$ are a waveguide length and linear absorption coefficient, respectively. In this work, the iterative method is introduced to obtain the results as shown in equation (4), similarly, when the output field is connected and input into the other ring resonators.

The input optical field as shown in equation (1), i.e. a Gaussian pulse, is input into a nonlinear microring resonator. By using the appropriate parameters, the chaotic signal is obtained by using equation (2). To retrieve the signals from the chaotic noise, we propose to use the add/drop device with the appropriate parameters. This is given in details as followings. The optical outputs of a ring resonator add/drop filter can be given by the equations (4) and (5).

\[
\frac{|E_{out}|^2}{|E_{in}|^2} = \frac{(1-\kappa_1) - 2\sqrt{1-\kappa_1} \cdot \sqrt{1-\kappa_2} e^{-\frac{\alpha L}{2}} \cos(k_x L) + (1-\kappa_2) e^{-\alpha L}}{1 + (1-\kappa_1)(1-\kappa_2) e^{-\alpha L} - 2\sqrt{1-\kappa_1} \cdot \sqrt{1-\kappa_2} e^{-\frac{\alpha L}{2}} \cos(k_x L)}
\]  

Equation (4) indicates that a ring resonator in the particular case is very similar to a Fabry-Perot cavity, which has an input and output mirror with a field reflectivity, (1-\kappa), and a fully reflecting mirror. k is the coupling coefficient, and 

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represents a roundtrip loss coefficient, $\phi_0 = kLn_0$ and $\phi_{nl} = kL(n_{nl})P$ are the linear and nonlinear phase shifts, $k = 2\pi / \lambda$ is the wave propagation number in a vacuum. Where $L$ and $\alpha$ are a waveguide length and linear absorption coefficient, respectively. In this work, the iterative method is introduced to obtain the results as shown in equation (4), similarly, when the output field is connected and input into the other ring resonators.
Here $E_t$ and $E_d$ represents the optical fields of the throughput and drop ports respectively. The transmitted output can be controlled and obtained by choosing the suitable coupling ratio of the ring resonator, which is well derived and described by reference.

Here $\beta = kn_{\text{eff}}$ represents the propagation constant, $n_{\text{eff}}$ is the effective refractive index of the waveguide, and the circumference of the ring is $L = 2\pi R$, here $R$ is the radius of the ring. In the following, new parameters will be used for simplification, where $\phi = \beta L$ is the phase constant. The chaotic noise cancellation can be managed by using the specific parameters of the add/drop device, which the required signals at the specific wavelength band can be filtered and retrieved. $k_1$ and $k_2$ are coupling coefficient of add/drop filters, $\alpha = 2\pi / \lambda$ is the wave propagation number for in a vacuum, and the waveguide (ring resonator) loss is $\alpha = 0.5$ dBmm$^{-1}$. The fractional coupler intensity loss is $\gamma = 0.1$. In the case of add/drop device is linear device.

3. Result

In Fig. 2 show the signal and ghost signal of microring resonator system.

![Fig. 2](image)

In Fig. 2 show the input power 2 W by Gaussian pulse (CW) have wavelength is 1.3 $\mu$m in Fig. 2(a). By the microring resonator system consist of 3 microrings and one add/drop filter show in Fig. 1. When the Gaussian pulse into the first ring, which have nonlinear effect (chaotic signal) in ring resonator show...
chaotic signal in Fig. 2(b) and Fig. 2(c-d) can be filter the nonlinear effect by second ring and third ring. The output through put port has many wavelengths show in Fig. 2(e) and expansion between 1.300-1.303 μm in Fig. 2(f). Drop port has multi-wavelength with we can be control light by variable coupling coefficient (κ₁₁) and (κ₂₂) of add/drop filter are 0.3 in Fig. 2(g). The signal and ghost signal created by ring resonator system and we can choose the signal or ghost signal by the wavelength first or second it show in Fig. 2(h).

Fig. 3. Show the signal and ghost signal for design by microring resonator system

In Fig. 3 show the input signal by Gaussian pulse is 1.3 μm in Fig. 3(a) and show the chaotic signal first, second and third ring in Fig. 3(b-d). The multi-wavelength created by the add/drop filter with show in through put port and drop port in Fig. 3 (e and d). The Fig. 3(f) shows the expansion of through port with into optical system, which normal signal for optical communication. In the Fig. 3(h) show the signal and ghost signal on drop port with we can choose the signal by position of wavelength such as the signal have position wavelength are 1.30180 μm ,1.30510 μm and The ghost signal have position wavelength is 1.30348 μm. The free spectrum range (FSR) between “Signal” to “Ghost” is 0.00168 and FSR between “Signal” to “Signal” is 0.00330.

4. Conclusion

We present the new technique for security optical communication of generation signal –ghost signal by microring resonator for 1.3 μm security communication. The optical communication important security system consists of a very simple, smallest system and comfortable for use, which can be application on normal system. In this time, the microring resonator system can be fabricated in chip and smallest equipment for connect optical system with data security channel, encrypts channel, encoding signal and
military channel. In near future we can used the 1.3 μm security communication more than optical communication for application on millimeter wave and THz communication.

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