Micro-ring Embedded Devices and System for Big Data and IoT High Capacity and Security

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Abstract: Micro-ring resonator (MRR) can be fabricated and integrated into many forms for various applications. Such a form of a device can be made by the combination of linear and nonlinear materials and metal, for an instant, silicon, GaAs, graphene, gold, silver, and ferromagnetic material, from which the new forms of devices can be constructed, where they are optical, plasmonic, spintronic and quantum electronics. These forms of devices cannot be seen by naked eyes, which can lead to applying in many functions and forms of applications. The use of such a device for the internet of thing (IoT) is also the interesting and available aspects, which can provide a huge information capacity, while the system reliable and redundancy are the other main advantages. In this paper, there are many forms of such a device discussed and interpreted, while the system designs and useful applications presented.

Keywords: Micro-ring embedded system; IoT; Big data; Communication security; Emerging technologies

1. Introduction

Material science and technology have been the key technology that involved in various applications for the decades [1-4], which are especially in the nanotechnology. The new technique and material have been used for many types of research and applications. One of the techniques is the ion-exchange method that has been widely used for nanomaterial improvement [5], while the use of graphene material has also been using for the new era of electronic circuit called plasmonic electronics [6]. IoT has become the current platform for 5G technology, in which the large volume of data known as the big data can transmit via the current transmission system [7-9]. However, it seems that the existed system is required the large space, which gives some difficulties for expansion, therefore, the new devices and systems are required to reduce the current system dimension, while the transmission capacity increased. The searching of new suitable devices are continued, we have found that the use of microring resonators can offer this requirement. Apparently, MRR has shown the very interesting aspects of applications [10-12], where there are many forms of them can be available for the embedded devices within the large system, where finally, the large system can be redundant, while the transmission ability is increased. MRR has been widely investigated and used in many applications, where there are many forms of MRR that can be adapted and employed. MRR can be fabricated and formed the small-scale devices that can replace the large scale fiber optic system, while the channel capacity is increased, where moreover the capacity expansion can also available. The evidence of the use of MRR is found in the references [13-15], where the use of channel capacity increasing, information security, image transmission and system redundancy are seen. In this paper, several types of MRR are proposed and implied to use as the system redundancy, channel capacity, and security. Several forms of MRRs and theoretical concerns are given, from which the related applications are described and discussed in details. Moreover, the possible security scheme for IoT transmission using the embedded MRR is also given.

2. General Concept

The mathematical formalism is one of the most important tools for the successful design and applications. The use of MRR has shown the very promising aspects of applications, from which the device characteristics is required to make the device having more completely featured, wherein all aspects of the devices can be used and performed in either light or photon behaviors consideration. When light propagates within the device, the used mathematical methods are the Meson's rule, wave equation, Schrodinger equation, while the use of path integral and Dirac approach are required when the photon aspect is considered. The photon aspect will be the generalized method for all-optical, plasmonics, even spintronic electronics, while the latter one is the electron movement, which is also a particle behavior.

One of the concepts is that when a photon is represented by the form of energy with massless particle, the oscillation frequency is v, where in terms of mathematics can be used the product of constant amplitude (A), a Gaussian pulse and the oscillation function, which is given by the equations (1) – (3)[16].

$$\psi(t) = \bar{A}\tanh\left[\frac{T}{T_0}\right] exp\left[\left(\frac{Z}{2L_D}\right) + i\varphi(t)\right] = Ae^{-i\frac{E}{\hbar}t}; \quad (1)$$

Given $A = \bar{A}\tanh\left[\frac{T}{T_0}\right]\exp\left(\frac{Z}{2L_D}\right)$ (2)

whereE= nhv; n = 1,2,3......, and

$$\mathbf{V} = \begin{bmatrix} a & : White\ \ spirit \\ 0: & Emptiness \\ -ka & : Black\ spirit \end{bmatrix}, where\ t_1 \geq t \leq t_2 \quad (3)$$

Where such a wave function can hold the photon concept, when the concept of a wave packet is applied, which is described by the wave packet is satisfied the slowly varying amplitude, otherwise, it is not the wave-particle duality. Where the potential function V is the spirit transient energy introduced by the personal passion or craving, the spirit signal is formed by a soliton pulse at the same time with the origin of time. In which A and z are the spirit signal amplitude and the circulation distance within the being brain, respectively, where the spirit signal is formed by the soliton pulse, therefore, the other parameters are the same as the soliton parameters in the previous section.

Microring resonator is made by the nonlinear material family, which is the transparency that can be categorized to be the devices for various applications. Such forms of the devices can be and benefits for the modern signal processing and communication, which are as following details as shown in Figure 1. Such a device can be embedded into the existed large scale system, for instant, the optical devices and systems. This is allowed to use and combine the device into the system, where the system band width can also be increased, while the system dimension is decreased, which is the other advantage. Moreover, the various functions such as channel increasing ability, secure communication, sensors, data communications, etc., which can also available to connect and use by the existed system to fulfill the huge data capacity, which is known as the big data, where the capacity is reach 40 petabyte, which is the definition. Finally, the concept of the internet of things is now possible. In practice, the system can be constructed by the land line such as a fiber optic network or a free space light transmission, which is called a light fidelity (LiFi) [7-9], where the hybrid system of them for transmission is also available.

MRR Device Types

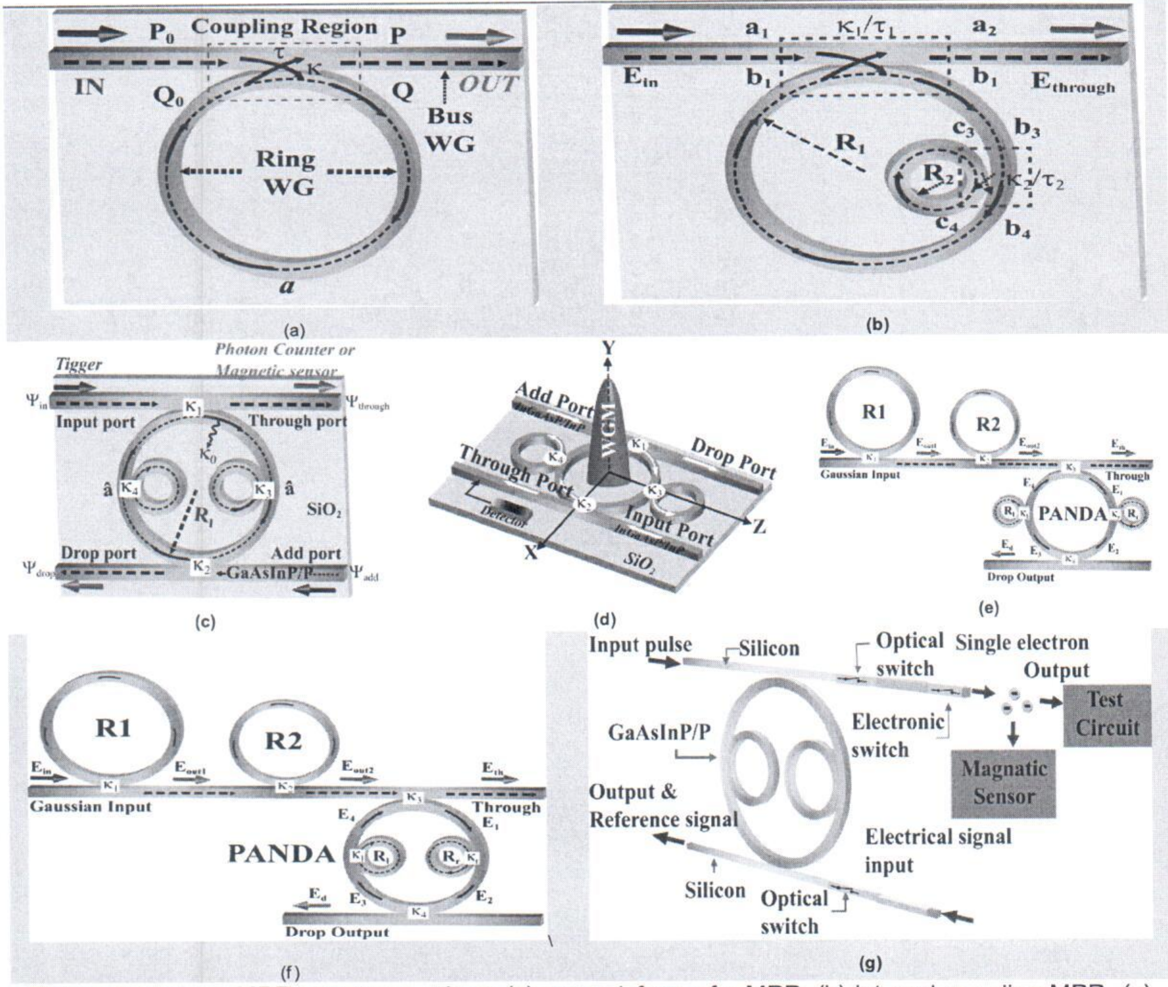

Figure 1: Various MRR structures, where (a) general form of a MRR, (b) internal coupling MRR, (c) Photon aspect of internal coupling MRR, (d) a MRR antenna, (e) Fast and slow light using MRR, (f) Quantum interferometer uding MRR, (g) Group velocity acelleration

3. Signal Processing in a MRR

In Figure 1, one of the embedded devices can be configured as the quantum entangled source, which is suitable for quantum communication, from which the highly secure communication can be implemented. In this form, the information can be modulated by the carrier and transmitted via the antenna, in which the propagation of modulated signals can be linked to the target users, where the transmission of the up-down link information is formed by the transmission cone similar to the wireless or satellite communication.

Principally, the quantum bit (qubit) can be presented by the polarization components of polarized light, which are parallel and vertical components, is the entangled pair generated by the forms of laser pulses. In practice, the common laser pulse, for instance, a Gaussian pulse is mostly used for various aspects of application, while the laser with higher output power and power stability can be obtained by the soliton pulse, which can be given by the Equations(4) to (6), respectively [17].

$$E_i = A_i \exp[\frac{z}{2L_d} - i\omega_0 t] \quad (4)$$

and an output pulse from image plane s given by

$$E_s = A_s \exp[\frac{z}{2L_d} - i\omega_0 t] \quad (5)$$

where the amplitude of optical fields are represented by A_i and A_s respectively. The propagation distance is demonstrated by z. The propagation time for soliton pulse moving with a group velocity in a frame is $T = t - \beta_1 \times z$. Here, soliton phase shift time is t, and ω_0 is the frequency shift of the soliton. $L_d = T_0^2/|\beta_2|$ represents the dispersion length of the soliton pulse, where T_0 shows soliton pulse propagation time at the initial input. The coefficients of the linear and the second order terms of the Taylor's expansion of the propagation constant are β_1 and β_2, respectively. For the soliton pulse in the micro ring device, a balance should be achieved between the dispersion length (L_d) and the nonlinear length $L_{NL} = 1/\Gamma\phi_{NL}$, where $\Gamma = n_2 K_0$, is the length scale over which dispersive or nonlinear effects alter the beam diameter. For a soliton pulse, there is a balance between dispersion and nonlinear lengths, hence $L_d = L_{NL}$ [18].

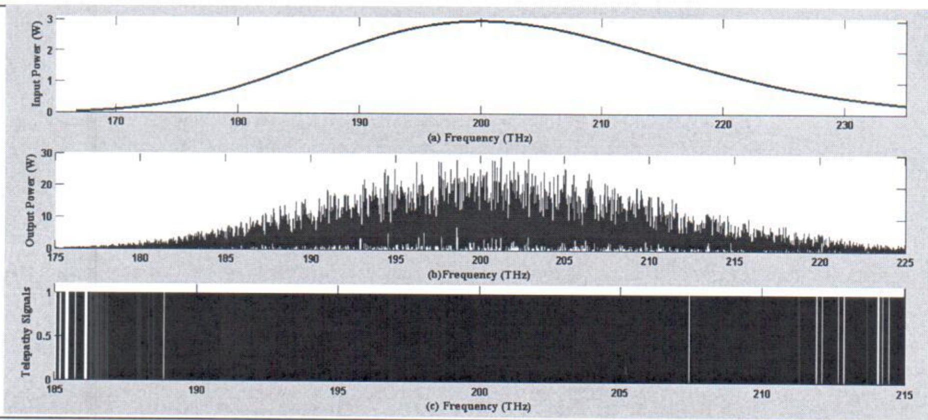

Figure 2: Result of the output signals from proposed system where (Top) shows the input Gaussian pulse, (Middle) the chaotic signals generation, (Bottom) the average discrete signals

Based on the coupling coefficient of micro-ring resonator (MRR), a fraction of input soliton pulse is coupled into the MRR. For long dispersive path, E_i causes the nonlinearity effect built inside the MRR due to change of the refractive index with optical power. Here, the power dependence of refractive index is responsible for the Kerr effect. The refractive index can be written as [19]

$$n = n_0 + (\frac{n_2}{A_{eff}})|E_s(t)|^2 \quad (6)$$

where n_0 and n_2 are the linear and nonlinear refractive indices respectively and A_{eff} shows the effective mode core area of the waveguide. In each round trip a phase shift of $\xi = \exp(-\alpha L_i/2 - iKnL_i)$ is added into the soliton pulse while propagating via MRR. One round trip loss coefficient is considered as $x = \exp(-\alpha L_i/2)$ where L_i is the circumference of the MRR and α is the waveguide absorption coefficient. The vacuum wave number and refractive index of the wave-guide are represented by *K* and *n*, respectively. The pulse passes through the MRR and input soliton pulse after each round interfere with each other. The optical outputs from the first ring resonator is given as

$$E_{out}^{1} = E_s\left(\frac{C_1 - (1-\gamma_1)\xi_1}{1 - C_1\xi_1}\right) \tag{7}$$

where $C_1 = \sqrt{(1-\kappa_1)(1-\gamma_1)}$ is the fraction of input pulse coupled to the MRR, κ_1 is the coupling coefficient of the first ring and γ_1 shows the fractional intensity loss of the first coupler. The output pulse from each MRR in proposed system (Figure 1) is fed to the next MRR. The output pulse from a system of N micro ring resonator can determine as

$$E_{out}^{N} = E_s \prod_{j=1}^{N} \frac{C_j - (1-\gamma_j)\xi_j}{1 - C_j\xi_j)} \tag{8}$$

The output power from each ring can be determined as

$$P_{out}^{j} = (E_{out}^{j}).(E_{out}^{j})^{*} = \left|E_{out}^{j}\right|^{2} \tag{9}$$

In Figure 2, in order to generate the pulse code for interpretation, a Gaussian pulse with power at 3W is injected into the ring resonator as shown in Figure 1. The linear refractive index of the system is fixed to n_0 = 3.48 and the nonlinear refractive index is $n_2 = 4.2 \times 10^{-17} (m^2/W)$. The waveguide loss and coupler intensity loss are α= 0.2 (*dB/mm*) and γ = 0.2, respectively. The coupling coefficients of the micro ring resonator vary between 0.1-0.5. The effective mode core areas of the micro-ring resonators are varied ranging from 0.1 to 0.5 μm^2. When the input optical pulse meets the resonance condition in each micro-ring resonator, it couples to the ring and travel inside it. Here telepathy pulse can be achieved based on the normalized pulse and resonant mode numbers of micro-ring resonator optical pulse act as constructive and destructive interference. Therefore, signals are suppressed over frequency interval and the overall intensity in this frequency domain is amplified according to the superposition principle. The energy per unit area for optical breakdown decreases with the pulse duration which is recognized with lasers operating in the telepathy pulse duration regime.

4. Conclusion

The use of a small scale device and system based on an MRR is modeled and proposed for the use in modern information transmission that can serve the huge demands of using in the near future. By using the MRR in various forms, the increasing in bandwidth capacity orbit rates and the system redundancy can be achieved. Such a form of the devices can be integrated into a current transmission system and provided the large bandwidth for the 40 petabyte channel capacity, which is known as a big data transmission, which is suitable for the internet of thing (IoT), which can lead to the 5G technology requirement.

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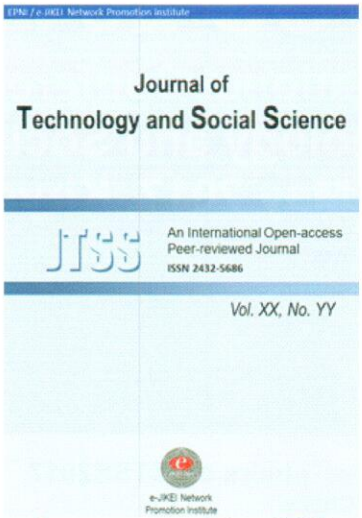

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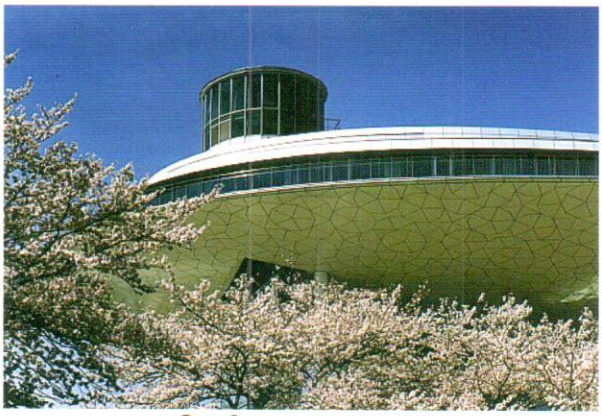

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