New Communication Bands Generated by Using a SolitonPulse within a Resonator ystem

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Abstract

With a common soliton pulse (i.e., with a centre wavelength of 1.55 m) propagating through a nonlinear microring and nanoring resonators system, we offer a novel system of a broadband source generation. The large bandwidth signals can be generated, stored, and regenerated within the system, which comprises of a micro ring resonator system with an add/drop filter. We discovered that the obtained multi-soliton pulses have the potential for application for dense wavelength division, while the different centre wavelengths of the soliton bands can be obtained via the add/drop filter, which can be used to increase the channel capacity in communication networks, by using the appropriate parameters relating to the practical device, such as micro ring radii, coupling coefficients, linear and nonlinear refractive index

Keywords: Ring Resonator, Photonic Device, Optical Waveguide

1. Introduction

Throughout the past three years, there has been a major growth in the need for communication channels and network capacity, but the high user demand has persisted up to this point. As a result, the development of new methodologies that are network and communication channel-focused is required. The technique that can be used to meet the high demand was recently reported by Pornsuwancharoen et al. [1] as having produced some very interesting results. They have shown that the signal bandwidth can be stretched and compressed by using the nonlinear micro ring system [2- 4]. By using such a scheme, the increasing in communi- cation channels using soliton communication is plausible. Furthermore, the long distance communication link is also available. However, several problems are required to solve and address, for instance, the problem of soliton-soliton interaction and collision [5], and the waveguide structure that the broadband soliton can be confined [6]. In this letter, we propose the technique that can be used soliton bands at the required center wavelengths can be stored [7] and filtered by using the add/drop filter [5]. In application, the use of super dense wavelength multi- plexing, with the long distance link is available. Fur- thermore, the personnel channel and network may be plausible due to the very available bandwidths. However, the problem of the soliton interaction and collision is required to solve, which can be avoided by the specific free spectrum range design [5].

2. Theoretical Background

To maintain the soliton pulse propagating within the ring resonator, the suitable coupling power into the device is required, whereas the interference signal is a minor effect compared to the loss associated to the direct passing through. A soliton pulse, which is introduced into the multi-stage micro ring resonators as shown in **Figure 1**, the input optical field (E_{in}) of the soliton input is

given by an Equation (1) [7].
to generate the new soliton communication bands (wave- $E \; t \; \; A\mathrm{sech}\; T \;$ exp
$i \; t$ z

1)
length bands), whereas the common soliton pulse, *i.e.*, a soliton source is at the center wavelength of 1.55 m. The

0
D in T 2L 0

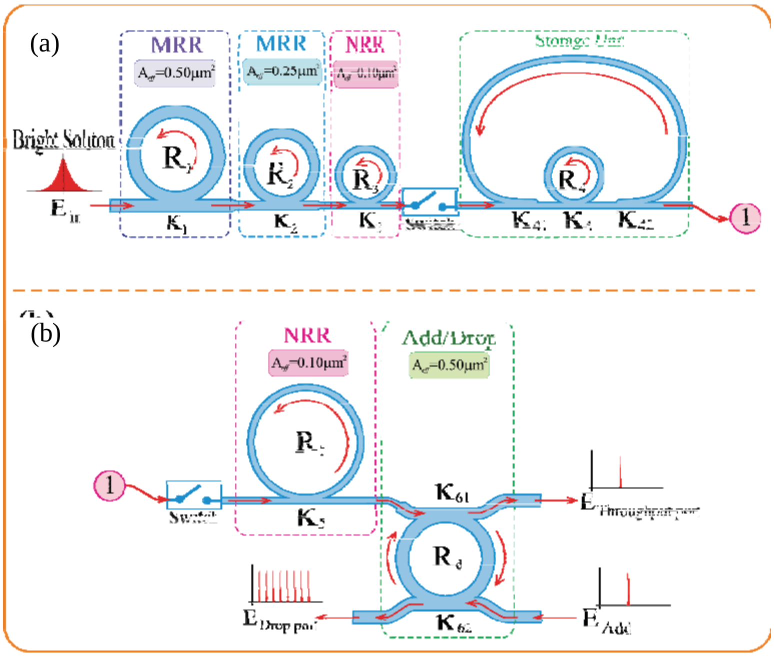

Figure 1. A broadband generation system. (a) a broadband source generation and a storage unit; (b) a soliton band selector, where R_s: ring radii, □$_s$: coupling coefficients, □$_{41}$, □$_{42}$: coupling losses, k_{61} and k_{61} are the add/drop coupling coefficients.

where *A* and *z* are the optical field amplitude and propa- gation distance, respectively. *T* is a soliton pulse propa- gation time in a frame moving at the group velocity, $T = t - \beta_1 * z$, where β_1 and β_2 are the coefficients of the linear and second order terms of Taylor expansion of the pro- pagation constant, $L_D = T_0^2/|\beta_2|$ is the dispersion length of the soliton pulse. T_0 in equation is a soliton pulse propagation time at initial input. Where *t* is the soliton phase shift time, and he frequency shift of the soliton is
ω_0. This solution describes a pulse that keeps its tempo- ral width invariance as it propagates, and thus is called a temporal soliton. When a soliton peak intensity

micro ring and nano ring resonators, the effective mode core areas range from 0.50 to 0.1 □m^2 [8], where they found that fast light pulse can be slow down experimen- tally after input into the nano ring.

When a soliton pulse is input and propagated within a micro ring resonator as shown in **Figures 1(a)** and **(b)**, which consists of a series micro ring resonators. 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

2

□ □ / □ T^2 □ is given, then T is known. For the soliton $\frac{E_{out}(t)}{E_{in}(t)}$ □
2 0 0

pulse in the micro ring device, a balance should be achieved between the dispersion length (L_D) and the □ □

nonlinear length (L
(1/ □ □
), where □ = n *k , is the □
(1□ (1□ □) x^2)□ □

2 0 NL NL
(1□ □) □1□

length scale over which dispersive or nonlinear effects □ □
□ (1□ x
1□ □
1□ □ $)^2$ □ 4 x
1□ □
1□ □ $\sin^2$( ) □

makes the beam becomes wider or narrower. For a soli- □ 2
□

ton pulse, there is a balance between dispersion and nonlinear lengths, hence L_D □ L_{NL} .

When light propagates within the nonlinear material (medium), the refractive index (n) of light within the medium is given by

(3)

The close form of 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-), and a fully reflecting mirror. □

n □ n □ n I □ n
□ ($\frac{n_2}{A_{eff}}$)P,

(2)

is the coupling coefficient, and x □ exp□ □ □ L / 2□ re-

0 2 0

presents a roundtrip loss coefficient,

□$_0$ □ kLn_0

and

where n□ and n□ are the linear and nonlinear refrac-

□ □ kLn E 2

are the linear and nonlinear phase

tive indexes, respectively. I and P are the optical in-tensity and optical power, respectively. The effective

NL 2 in

shifts, k □ 2□ / □

is the wave propagation number in a

mode core area of the device is given by A_{eff} . For the vacuum. Where L and area waveguide length and

linear absorption coefficient, respectively. In this work, the iterative method is introduced to obtain the results as shown in Equation (3), similarly, when the output field is connected and input into the other ring resonators.

After the signals are multiplexed with the generated chaotic noise, then the chaotic cancellation is required by the individual user. To retrieve the signals from the cha- otic noise, we propose to use the add/drop device with the appropriate parameters. This is given in details as followings. The optical circuits of ring-resonator add/ drop filters for the throughput and drop port can be given by Equations (4) and (5), respectively [9].

as shown in **Figure 1**. A soliton pulse with 50 ns pulse width, peak power at 2 W is input into the system. The suitable ring parameters are used, for instance, ring radii R_1 = 15.0 µm, R_2 = 10.0 µm, $R_3 = R_s$ = 5.0 µm and $R_5 = R_d$
= 20.0 µm. In order to make the system associate with the practical device [8], the selected parameters of the system are fixed to □$_0$ = 1.55 □m, n_0 = 3.34 (In- GaAsP/InP), A_{eff} = 0.50, 0.25 □m^2 and 0.10 □m^2 for a micro ring and nano ring resonator, respectively, □ = 0.5 dBmm^{-1}, □ = 0.1. The coupling coefficient (kappa, □) of the micro ring resonator ranged from 0.1 to 0.95. The nonlinear refractive index is $n_2 = 2.2 \times 10^{-13}$ m^2/W. In

$$\left|\frac{E_t}{E_{in}}\right|^2 \square$$

□ 1□ □ $_1$□$\sqrt{□\ 2}$ 1$\sqrt{□\ □_1}$□

□$\frac{□}{}$ L

1□ □ $_2 e$ 2

cos□ $k_n L$□ □ □ 1□ □ $_2$ □ e

$-\ L$ □

□□ L

this case, the wave guided loss used is 0.5 dBmm^{-1}. The input soliton pulse is chopped (sliced) into the smaller signals spreading over the spectrum (*i.e.*, broad wave- length) as shown in **Figures 2(b)** and **2(g)**, which isshown that the large bandwidth signal is generated

1□ □ 1□ □ $_1$□ □ 1□$^{\alpha L}$□ $_2$ $\sqrt{1 e\kappa_1}$ $\sqrt{1 2\kappa_2}$ □

$$\left|\frac{E_d}{E_{in}}\right|^2 \square$$

□ L

^{2} cos□ $k_n L$□

(4)

within the first ring device. The biggest output amplifi- cation is obtained within the nano-waveguides (rings R_3 and R_4) as shown in **Figures 2(d)** and **2(e)**, whereas the maximum power of 10 W is obtained at the center wave- length of 1.5 □m. The coupling coefficients are given as shown in the figures. The coupling loss is included due

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ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

1 1 $_1$ 1 $_2$
 e $_1$$_2$e 2

L 2 $\sqrt{1-\kappa_1}$ $\sqrt{1-\kappa_2}$

e 2 L

cos k_n L

(5)

to the different core effective areas between micro andnano ring devices, which is given by 0.1 dB.

We have shown that a large bandwidth of the opticalsignals with the specific wavelength can be generated

where E_t and E_d represents the optical fields of thethroughput and drop ports respectively. kn_{eff} is the

within the micro ring resonator system as shown in **Fig-ure 1**. The amplified signals with broad spectrum can be

propagation constant, n_{eff} is the effective refractive

generated, stored and regenerated within the nano-

index of the waveguide and the circumference of the ring is L 2 R , here R is the radius of the ring. In the following, new parameters will be used for simplification:

   L is the phase constant. The chaotic noise cancel- lation can be managed by using the specific parameters of the add/drop device, which the required signals can be retrieved by the specific users. $_1$ and $_1$ are coupling coefficient of add/drop filters, k_n 2 / is the wave propagation number for in a vacuum, and where the waveguide (ring resonator) loss is = 0.5 dBmm^{-1}. The fractional coupler intensity loss is = 0.1. In the case of add/drop device, the nonlinear refractive index is ne-glected.

3. Results and Discussion

In operation, the large bandwidth signal within the micro ring device can be generated by using a common soliton pulse input into the nonlinear micro ring resonator. This means that the broad spectrum of light can be generated after the soliton pulse is input into the ring resonator system. The schematic diagram of the proposed system is

waveguide. The maximum stored power of 10 W is ob- tained as shown in **Figures 2(d)** and **2(e)**, where the av- erage regenerated optical output power of 4 W is achi- eved via and a drop port of an add/drop filter as shown in **Figures 2(h)-2(k)**, which is a broad spectra of light cover the large bandwidth as shown in **Figure 2(g)**. However, to make the system being realistic, the wave- guide and connection losses are required to address in the practical device, which may be affected the signal ampli- fication. The storage light pulse within a storage ring (R_s or R_4) is achieved, which has also been reported by Ref. [7]. In applications, the increasing in communication channel and network capacity can be formed by using the different soliton bands (center wavelength) as shown in **Figure 2**, where **2(h)** 0.51 m, **2(i)** 0.98 m, **2(j)** 1.48 m and **2(k)** 2.46 m are the generated center wave- lengths of the soliton bands. The selected

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

wavelength center can be performed by using the designed add/drop filter, where the required spectral width (Full Width at Half Maximum, FWHM) and free spectrum range (FSR) are obtained, the channel spacing and bandwidth are represented by FSR and FWHM, respectively, for in

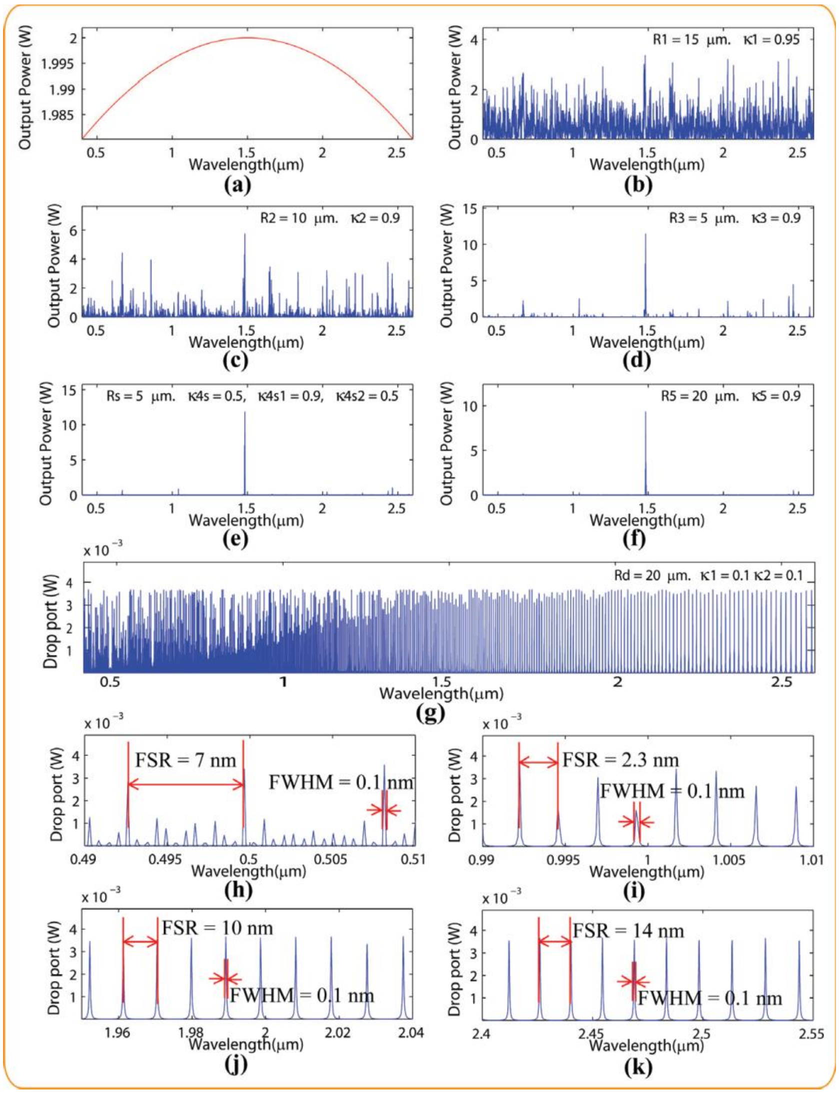

Figure 2. A soliton band with center wavelength at 1.5 □m, where (a) input soliton; (b) ring R_1; (c) ring R_2; (d) ring R_3; (e) storage ring (R_s); (f) ring R_5; (g) drop port output signals. The output of different soliton bands (center wavelength) are as shown, where (h) 0.51 □m; (i) 0.98 □m; (j) 1.99 □m; (k) 2.48 □m.

stance, the FSR and FWHM of 2.3 nm and 100 pm are obtained as shown in **Figure 2(i)**.

4. Conclusions

In conclusion, apart from communication application, the idea of personnel wavelength (network) being realistic for the large demand user due to un-limit wavelength discrepancy, whereas the specific soliton band can be generated using the proposed system. The potential of soliton bands such as visible soliton (color soliton), UV- soliton, X-ray soliton and infrared soliton can be generated and used for the applications such as multi color holography, medical tools, security imaging and trans- parent holography and detection, respectively.

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