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Radio Wave Generation Using Dark and Bright Soliton

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Abstract

In this study we propose a new system for radio wave using a soliton pulse within a micro waveguide and nano-waveguide. The system consists of two micro ring resonators and a nano ring resonator that can be integrated into a single system. The input soliton power, coupling coefficients, and ring radii, are used to control the short-wave and millimeter-wave output signals being generated and filtered in a single system. The large bandwidth signal is generated using a soliton pulse within a Kerr-type nonlinear medium. The signals with broad bandwidth or wavelength can then be generated. Results obtained have shown the potential of using this system for a broad light spectra generation.

Keyword: Dark and Bright Soliton,continuous spectra.

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1. Introduction

The interesting results of the nonlinear device known as nano ring resonator have shown potential [1,2] in various applications. Yupapin has reported [1] that the transfer function of an optical output for light pulse propagating within a micro ring resonator at a resonant condition is derived and used. They found that the broad spectrum of light pulse can be transformed to the discrete pulses after filtering. The optical bandwidth can be enlarged or compressed by using the optical soliton propagating within the nonlinear micro ring resonator [2]. Moreover, the superposition of self-phase modulation and cross-phase modulation soliton pulses using either bright or dark [3] solitons within a nano-waveguide can be generated, whereas the large output power is obtained.

The optimum soliton energy is coupled into the waveguide by a lager effective core area device, i.e., ring resonator. The smaller ones are connected to form the amplification. To maintain the soliton pulse propagating within the ring resonator with suitable coupling power pumped into the device. In this paper, we suggest two different optical schemes that can be used to generate the continuous spectrum. First, the white light spectra can be

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formed by using the bright soliton in the proposed system. Secondly, the simultaneous generation of short wave and millimeter wave can be formed by the dark soliton. The use of parameters of the proposed system is discussed based on the practical device parameters [4, 5]. In this study, a hew system for radio wave generation using dark and bright soliton in proposed.

2. Theoretical Simulation

Optical soliton are powerful laser pulses which can be used to expand the optical band width when propagating within the nonlinear nano ring resonator [6]. Many earlier works of soliton applications in either theory or experimental works are found in a soliton application book by Hasegawa *et al.* [7]. The problems of soliton-soliton interactions [8], collision [9], rectification [10] and dispersion management [11] are required to find a solution. In practice, the soliton–soliton interaction would affect the dense wavelength-division multiplexing, however, this problem can be solved by designing suitable system with desirable free spectrum arrangement [12]. , which can be designed [11]. Bright and dark soliton pulses are introduced into the multistage nano ring resonators, as shown in Fig. 1; the input optical field of the bright and dark soliton pulses input are given by (1) and (2) [6–8], respectively,

$$E_{in} = A \sec h\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \tag{1}$$

$$E_{in} = A \tanh\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \tag{2}$$

where A and z are the optical field amplitude and propagation distance, respectively. T is a soliton pulse propagation time in a frame moving at the group velocity $T=t-\beta_1 z$, where β_1 and β_2 are, respectively, the coefficients of the linear and the second order terms of Taylor expansion of the propagation constant. $L_D=T_0^2/|\beta_2|$ is the dispersion length of the soliton pulse, where T_0 is the soliton pulse propagation time at initial input. t is the soliton phase shift time, and the frequency shift of the soliton is ω_0. This solution describes a pulse that keeps its temporal width invariance as it propagates, and thus is called a temporal soliton. When soliton peak intensity $(|\beta_2/\Gamma T_0^2|)$ is given, then T_0 is known. In the nano ring device, a balance should be achieved between the dispersion length (L_D) and the nonlinear length (L_{NL}) for the soliton pulse. The nonlinear length can be described by the relation $(L_{NL} = (1/\gamma\Phi_{NL})$, where γ and Φ_{NL} are coupling loss of the field amplitude and nonlinear phase shift, respectively. The refractive index of a nonlinear optical fiber ring is following the Kerr-type, so is given by

$$n = n_0 + n_2 I = n_0 + (\frac{n_2}{A_{eff}})P, \tag{3}$$

where n_o and n_2 are the linear and nonlinear refractive indexes, respectively. I and P are the optical intensity and optical power, respectively. A_{eff} represents the effective mode core area of the device. The resonant output is formed when a soliton pulse is input and propagated within a nano ring resonator. For the micro-ring and the nano-ring resonators, the effective mode core areas range from 0.10 to 0.50 μm^2 [4], where they found that fast light pulse can be slowed down experimentally after being input into the nano ring.

When a soliton pulse is input and propagated within a micro-ring resonator as shown in Fig. 1, consisting of a series of micro-ring resonators, the resonant output is formed. Therefore, 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 can be described as [13]:

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

The close form of Eq. (3) indicates that a ring resonator in this particular case is very similar to a Fabry–Perot cavity, with an input and output mirror having a field reflectivity (1−κ), and a fully reflecting mirror. κ is the coupling coefficient, and $x=\exp(-\alpha L/2)$ represents a roundtrip loss coefficient, $\varphi_0=kLn_0$ and $\varphi_{NL}=kLn_2|E_{in}|^2$ are the linear and the nonlinear phase shifts, respectively, $k=2\pi/\lambda$ is the wave propagation number in vacuum and L and α are the waveguide length and linear absorption coefficient, respectively. In this work, the iterative method is introduced to obtain the results as shown in Eq. (4), similar to when the output field is connected and input into the other ring resonators.

3. Results and Discussion

In this work , we generate the large bandwidth signals within the micro ring device by either using a bright or dark soliton pulse input in the nonlinear micro ring resonator system. The schematic diagram of the proposed system is shown in Fig. 1.

For the first scheme, a bright soliton pulse with 50-ns pulse width and peak power at 850 mW is input into the system. The suitable ring parameters used are ring radii R_1=10.0μm, R_2=7.0 μm, and R_3=4.0μm . In order to make the system associate with the practical device [4], [5], the selected parameters of the system are fixed to λ_0=1.5 mm, n_0=3.34 (InGaAsP/InP), A_{eff}=0.50, 0.25 and 0.10 μm^2 for a micro-ring and nano-ring resonator, α=0.5 dB mm^{-1} and γ=0.1. The coupling coefficient (kappa, κ) of the micro-ring resonator ranged from 0.50 to 0.9. The nonlinear refractive index is $n_2=2.2\times10^{-13}$ m^2/W. In this case, the wave-guided loss used is 0.5 dB mm^{-1}. The input soliton pulse is sliced into smaller signal spreading over the spectrum as shown in Figs. 3(b), in which the large bandwidth signals are generated within the first ring device. We find that the large bandwidth signal does not occur when the Gaussian pulse is input into the same system. In the second scheme as shown on Figure 2 we have a dark soliton pulse with 50-ns pulse width, maximum power at 2 W is input into the system. The suitable ring parameters are used, for instance, ring radii R_1=5.0μm, R_2=4.0 μm, and R_3=2.0μm. The coupling coefficient (kappa, κ) of the micro-ring resonator ranged from 0.40 to 0.85. The other parameters used are the same as that of the bright soliton case. The coupling coefficients given are as shown in Figs. 1 and 2.

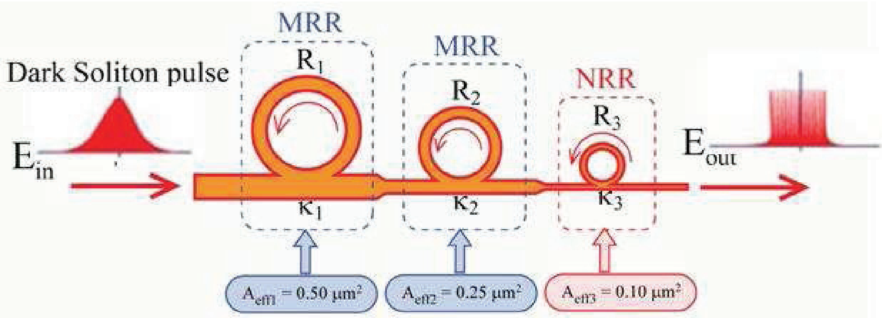

Fig. 1. Schematic of short- and millimeter-wave generations using bright soliton, where Rs : ring radii; κs : coupling coefficients; MRR: micro ring; and NRR: nano ring.

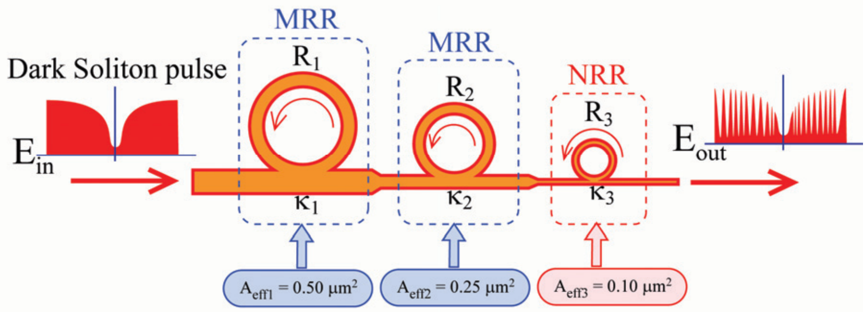

Fig. 2. Schematic of short- and millimeter -wave generations using dark soliton, where Rs : ring radii; κs : coupling coefficients; MRR: micro ring; and NRR: nano ring.

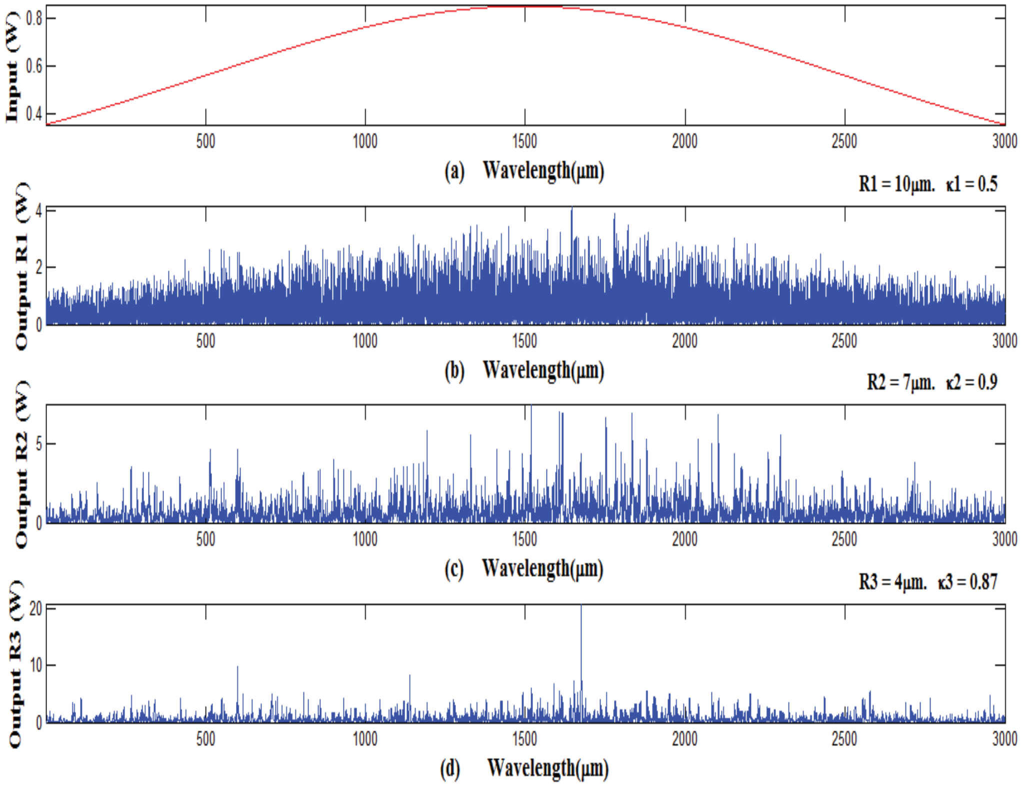

Fig. 3. Result of a millimeter-wave generation using a bright soliton pulse, where the dominant output wavelength are 1.677, 1.142, 0.6023mm.

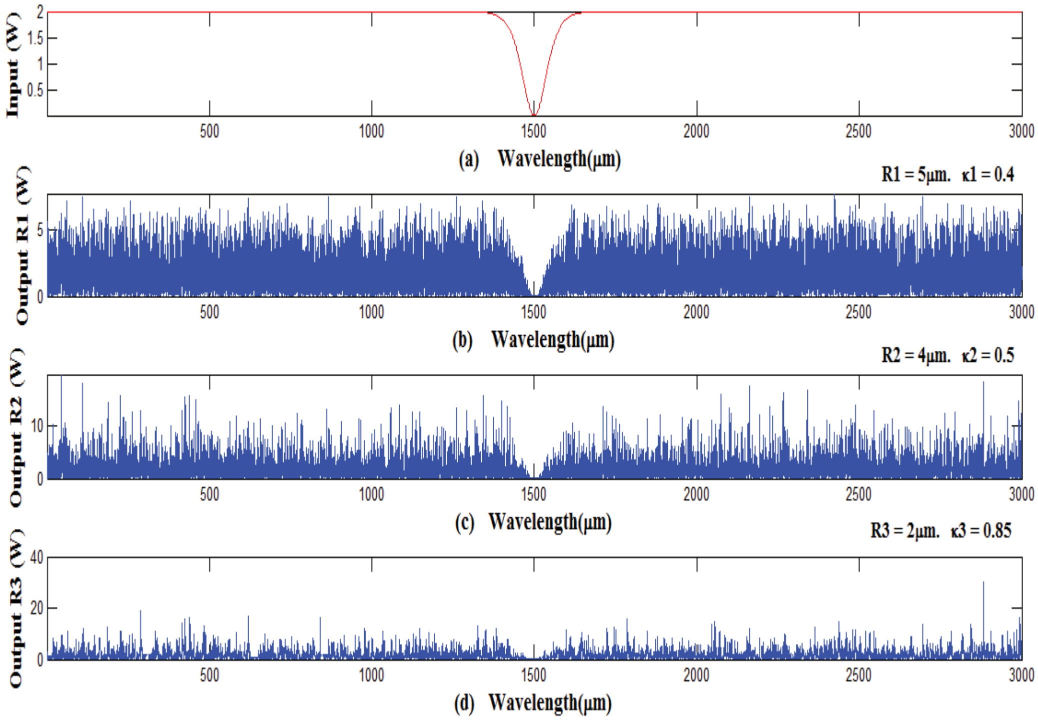

Fig. 4. Result of short- and millimeter -wave generation using a dark soliton pulse, where the dominant output wavelengths at 0.2898, 0.6204, 0.8424, 2.882 mm are obtained.

When the radio signals are input to the system, the millimeter wave can be obtained in which the proposed system to generate the needed results. Various wavelengths of output signals are generated ranging from the short wave to millimeter wave. Results obtained show that the soliton property is confirmed when dense soliton pulses with constant output are formed as shown in Figs. 3(b) and 4(b). Discrete signals are observed when they are filtered using the third ring resonators.

The bright soliton can be input to the first proposed system as shown in Fig. 1 where the continuous (broad) spectrum can be generated as shown in Fig. 3. The generation of optical output within the nano-waveguide with the maximum power of 23 W is achieved. Obtained wavelengths ranges from a few hundred nanometers to millimeters. This means that ring resonators can be used to create the amplified short and millimeter wave. The dark solitons is input in second proposed system shown in Figure. 2. The maximum output power produced is 30 W.

4. Conclusion

Using proposed systems we are able to generate short and millimeter waves where they are several applications in optical communications such as signal security, radio signal transmission and white light source. The ring parameters such as ring radii, coupling coefficients and input power are used to control the output results. When the bright soliton is input to the system, the output wavelengths of 1.677 mm, 1.142 mm and 0.6023 mm are achieved. From the input dark soliton, results obtained are 2.882, 0.8424, 0.6204 and 0.2898 mm. In application, the up-link and down-link of two different frequency carriers can be implemented within the same compact device, for instance, a mobile telephone hand set.

5. Acknowledgement

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