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Widely Wavelength-Tunable Solitonic Pulse Generation Using InGaAsP/InP Microring Resonators

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Abstract: Multi-optical solitonic carriers suitable for use in optical communication systems and telecommunications have been generated via microring resonators (MRRs) incorporating an add/drop filter system. The generated multi solitonic carriers utilizing the MRRs were sufficiently stable for transmitting in a free space channel while experiencing very low dispersion during propagation. Moreover, the technique used which is iterative method using MRRs allowed for greater number of channels as multi-channel generation that could be utilized in a wavelength division multiplexing (WDM) system. Solitonic carriers were created, with each carrier possessing a free spectral range (FSR) of 12.45 GHz and a full width at half maximum (FWHM) of 250 MHz.

Keywords: Microring Resonator, Soliton, Wavelength Division Multiplexing (WDM)

1. Optical Multicarrier Generation Principals

The system of THz frequency band generation is shown in Figure 1. Here, a series of MRRs are incorporated with an add/drop filter system. In this study the MRRs are simulated using waveguides, where experimentally they can be produced via fabrication technology. The III/V semiconductors (InGaAsP/InP) on the basis of InP with a direct bandgap are used to simulate these ring resonators [1-4]. The input pulse of the Gaussian goes through the filtering process within the MRRs, therefore THz frequency band can be generated and used in many applications in optical communications [5-8]. The function of the MRRs is to filter out the resonance modes when the input pulse of Gaussian or any other types of lasers round trip the MRR's circumference, therefore the intensity within the MRRs can be built up in which the MRRs having bigger radius or cross section are connected to the next MRRs with smaller radius [9, 10]. The self-phase modulation behavior caused by the nonlinear effect is responsible to obtain a large output gain within the MRRs, where solitons can be formed by balancing the linear effect as dispersion and the nonlinear effect as self-phase modulation [11-14]. Figure 1 shown the system consisting of series of MRRs integrated with an add/drop filter system. The directional couplers are used to couple the waveguide to the MRRs.

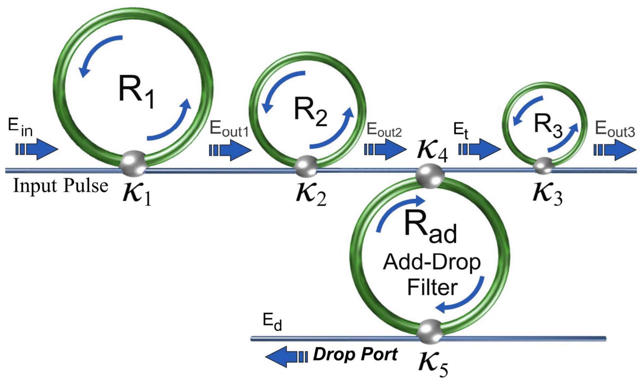

Fig. 1. *MRR system with R: ring radii, κ: coupling coefficients, R_{ad}: add/drop ring radius, E_{in}: input powers, E_{out}: Ring resonator output, E_t: throughput output, and E_d: drop port output.*

The medium of the ring resonator has Kerr effect-type nonlinearity [15-18]. The Kerr effect causes the refractive index (n) of the medium to vary, and is given by [19-22]

$$n = n_0 + n_2 I = n_0 + \frac{n_2}{A_{eff}} P \quad , \tag{1}$$

where n_0 and n_2 are the linear and nonlinear refractive indices respectively [23, 24], and I and P are the optical intensity and the power respectively [25-27]. The effective mode core area is given by A_{eff} and ranges from 0.10 μm^2 to 0.50 μm^2 in terms of material parameters (InGaAsP/InP) [28-31]. A Gaussian pulse having a central wavelength of 1.55 μm and power of 1 W is introduced into the input port, E_{in}, of the system [32]. The input optical field of the Gaussian pulse is given by [33, 34]

$$E_{in}(t,z) = E_0 \exp\left[\left(\frac{iz}{2L_D}\right) - i\omega_0 t \right] \tag{2}$$

where E_0 and z are the amplitude of the optical fields and propagation distance respectively [35-37], L_D is the dispersion length of the soliton pulse [38-40], and the carrier frequency of the signal is ω_0 [41, 42]. The soliton pulse keeps its temporal width invariance while it propagates, and is therefore it referred to as a temporal soliton [43-46]. A balance should be achieved between the dispersion length (L_D) and the nonlinear length ($L_{NL} = 1/\Gamma\phi_{NL}$) [47-49], so that the condition $L_D = L_{NL}$ is achieved [50]. Here, $\Gamma = n_2 \times k_0$ is the length scale over which dispersive or nonlinear effects cause the beam to become wider or narrower [51, 52]. In the case of the add/drop system, the nonlinear refractive index is neglected [53]. The normalized output intensity of the light field, which is the ratio between the output and the input fields for each round trip, can be expressed by [54, 55].

$$\left| \frac{E_{out1,out2,out3}(t)}{E_{in,out1,out2}(t)} \right|^2 = (1-\gamma) \times \left[1 - \frac{(1-(1-\gamma)x^2_{1,2,3})\kappa_{1,2,3}}{(1-x_{1,2,3}\sqrt{1-\gamma}\sqrt{1-\kappa_{1,2,3}})^2 + 4x_{1,2,3}\sqrt{1-\gamma}\sqrt{1-\kappa_{1,2,3}}\sin^2(\frac{\phi_{1,2,3}}{2})} \right] \tag{3}$$

κ is the coupling coefficient, and $x = \exp(-\alpha L/2)$ represents the round trip loss coefficient, where the ring resonator length and linear absorption coefficient are given by L and α respectively [56-58]. $\phi_{1,2,3} = \phi_0 + \phi_{NL1,2,3}$ where $\phi_0 = kL_{1,2,3}n_0$ is the linear phase shift. The nonlinear phase shift for the first MRR is [59-61],

$$\phi_{NL1} = kL_1 n_2 |E_{in}|^2 = kL_1 n_2 \left| \frac{P_{in}}{A_{eff1}} \right| \tag{4}$$

Due to the optical intensity enhancement experienced in each MRR, the nonlinear phase shift for the second and third MRRs can be expressed by [62-64],

$$\phi_{NL2} = kL_2 n_2 |E_{out1}|^2 = kL_2 n_2 \left| \frac{P_{out1}}{A_{eff2}} \right|, \tag{5}$$

$$\phi_{NL3} = kL_3 n_2 |E_{out2}|^2 = kL_3 n_2 \left| \frac{P_{out2}}{A_{eff3}} \right|, \tag{6}$$

The wave propagation number in a vacuum and the fractional coupler intensity loss are given by $k = 2\pi/\lambda$ and γ respectively [65-67]. The Gaussian pulse is input into the MRRs, and a chaotic signal can be formed via applying appropriate parameters [68, 69]. The throughput and drop port electrical fields of the add/drop system can be expressed by [70-72].

$$\frac{E_t}{E_{out3}} = \frac{-\kappa_4\sqrt{1-\kappa_5}e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}} + \sqrt{1-\kappa_4} - (1-\kappa_4)\sqrt{1-\kappa_5}e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}}}{1-\sqrt{1-\kappa_4}\sqrt{1-\kappa_5}e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}}} = \frac{-\sqrt{1-\kappa_5}e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}} + \sqrt{1-\kappa_4}}{1-\sqrt{1-\kappa_4}\sqrt{1-\kappa_5}e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}}} \tag{7}$$

$$\frac{E_d}{E_{out3}} = \frac{-\sqrt{\kappa_4 . \kappa_5}\, e^{\frac{-\alpha}{2}\frac{L_{ad}}{2} - jk_n\frac{L_{ad}}{2}}}{1-\sqrt{1-\kappa_4}\sqrt{1-\kappa_5}\, e^{\frac{-\alpha}{2}L_{ad}-jk_nL_{ad}}} \;, \tag{8}$$

where κ_4 and κ_5 are the coupling coefficients, $L_{ad} = 2\pi R_{ad}$, and R_{ad} is the radius of the add/drop system. The normalized optical outputs of the add/drop system can be expressed by [73, 74]

$$\frac{|E_t|^2}{|E_{out3}|^2} = \frac{(1-\kappa_4) - 2\sqrt{1-\kappa_4}\cdot\sqrt{1-\kappa_5}e^{-\frac{\alpha}{2}L_{ad}}\cos(k_nL_{ad}) + (1-\kappa_5)e^{-\alpha L_{ad}}}{1+(1-\kappa_4)(1-\kappa_5)e^{-\alpha L_{ad}} - 2\sqrt{1-\kappa_4}\cdot\sqrt{1-\kappa_5}e^{-\frac{\alpha}{2}L_{ad}}\cos(k_nL_{ad})} \tag{9}$$

$$\frac{|E_d|^2}{|E_{out3}|^2} = \frac{\kappa_4 \kappa_5 e^{-\frac{\alpha}{2}L_{ad}}}{1+(1-\kappa_4)(1-\kappa_5)e^{-\alpha L_{ad}} - 2\sqrt{1-\kappa_4}\cdot\sqrt{1-\kappa_5}e^{-\frac{\alpha}{2}L_{ad}}\cos(k_n L_{ad})} \tag{10}$$

where $|E_t|^2$ and $|E_d|^2$ are the output intensities of the through and drop ports, respectively [75-77], whereas the output electric field from the third ring is given by E_{out3}. In this work, the iterative method is introduced to obtain the resonant results and similarly, when the output field is connected and input into the other MRRs [78, 79].

2. Results of Soliton Generation

Simulated MRRs have the specific parameters as shown in Table 1.

Table 1. *Specific parameters of the MRRs.*

R_{ad}	R_1	R_2	R_3
1.14 mm	50 µm	30 µm	10 µm
n_0	n_2(m^{2}W^{-1})	A_{eff1}(µm^2)	A_{eff2}(µm^2)
3.34	2.2×10^{-17}	0.25	0.10
A_{eff3}(µm^2)	$A_{eff4,5}$ (µm^2)	κ_1	κ_2
0.10	0.10	0.5	0.3
κ_3	$\kappa_4 = \kappa_5$	α (dBmm^{-1})	γ
0.1	0.08	0.5	0.1

The chaotic signal can be generation by round tripping the input within the MRRs shown in Figure 2. The Gaussian pulse used as input pulse has power of 1 W and it is inserted into the system. By using the nonlinear conditions within the MRRs, we could generate large bandwidth frequencies. The input pulse was filtered to many smaller and narrow bandwidth pulses spreading out throughout the spectrum, therefore a large bandwidth could be obtained utilizing the nonlinear conditions. As conclusion, the frequencies of soliton pulses could be formed and performed within the system, while suitable MRR parameters have been selected in order to optimize the functionality of the resonator system. Figure 2(a) shows the input Gaussian pulse, Figure 2(b) shows generation of chaotic signals as output results for the firat MRR due to existing of nonlinear condition, Figure 2(c) shows the outputs from the second MRR presenting less chaotic signals due to the filtering process. Soliton pulses ranged from 190 to 196 THz could be generated successfully.

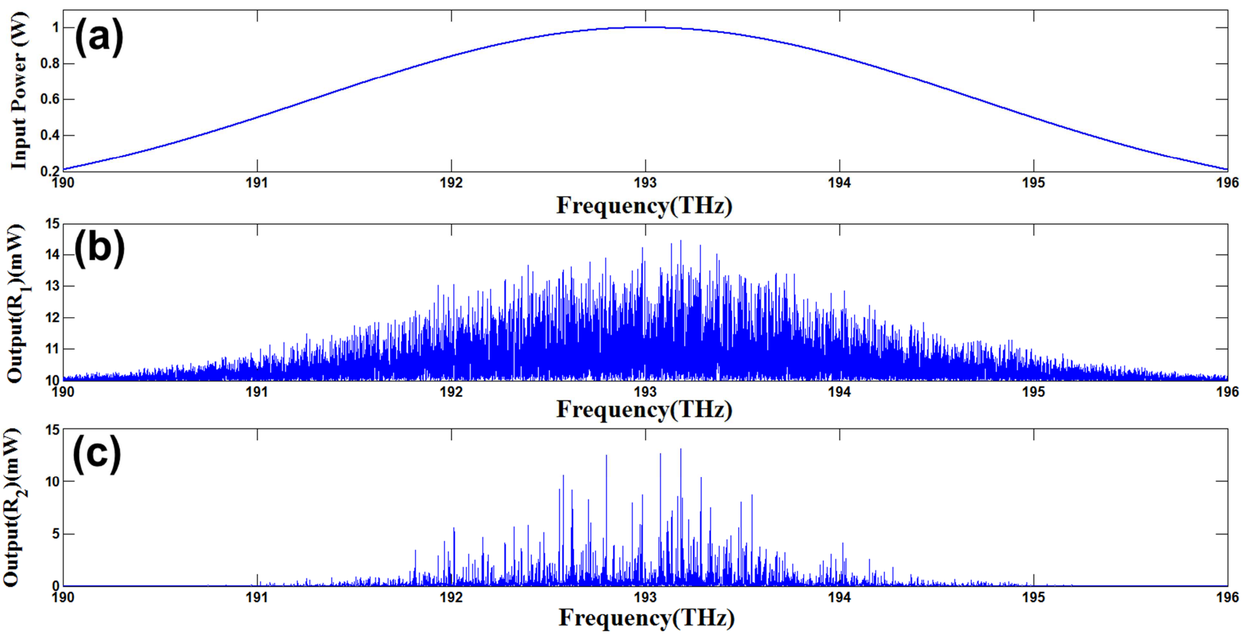

Fig. 2. *Chaotic signals generation, (a) input Gaussian pulse, (b) output from the first MRR, (c) output from the second MRR.*

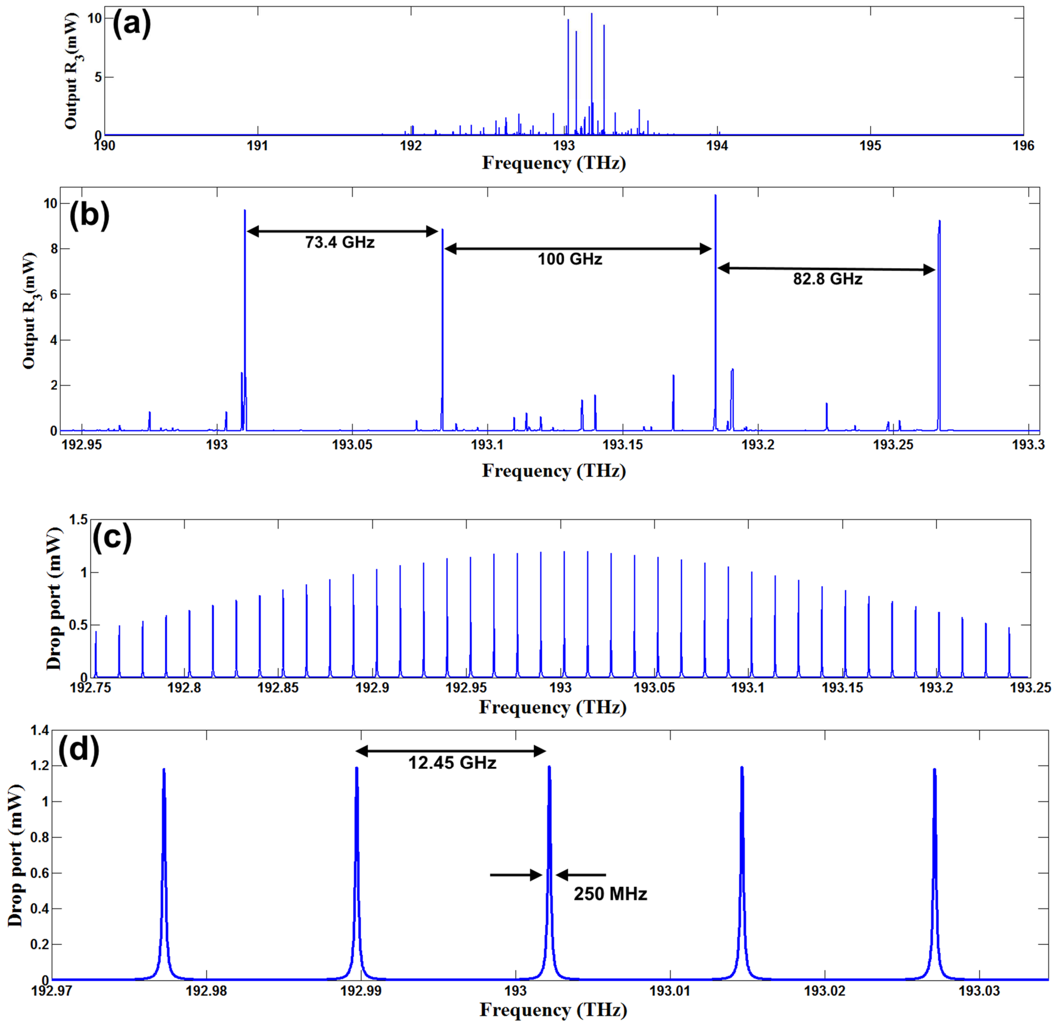

***Fig. 3.** Multi-solitons output from the drop port, with FSR as 12.45 GHz and FWHM as 250 MHz.*

Generated multi-soliton pulses ranging from 192.95 to 193.3 THz, are performed and shown in Figure 3(b), were they are as consequence of the short bandwidth Gaussian pulse inserted into the third MRR. The drop port of the add/drop filter system show generation of solitonic pulses in the range of 192.75 to 193.25 THz (Figure 3(c)). Since the input signal to the add/drop filter system did not roundtrip in the system, the dispersion effect is negligible. The free spectral range (FSR) of the pulses is 12.45 GHz, where the full width at half maximum is 250 MHz as shown in Figure 3(d). The advantage of using the add/drop system lay in generating spatially uniform multi-solitons.

We have calculated the finesse (F), given by the ratio FSR/FWHM, approximately 49.8, and the Q-factor, defined as the ratio of the resonant wavelength to the 3-dB bandwidth (FWHM), as ~7.7×10^5. The presented finesse and Q-factor are ideal impacts in order to design and fabricate an optical transmitter system based on MRRs, applicable in optical communication systems. Therefore, such results established manifest of this newly suggested and presented system having high performance and efficiency. When the input pulse with specific wavelength and power intensity propagates within the simulated MRRs waveguide, the resonance condition occurs and the resonating optical modes will pass through the MRRs and they could be detected in the drop port of the system due to the successful constructive interferences between the signals in the system. The modes result from destructive interferences will be removed from the resonance system and will not be detected due to high loss. Such functionality of the MRRs is in particular well suited for filtering and shifting both wavelength division multiplexing (WDM) optical signals and multiple-wavelength optical packets.

3. Conclusion

A series of microring resonators with an incorporated add/drop filter was utilized to generate stable optical solitonic carriers to be used in a communication system. The generated solitonic carriers had great stability and low dispersion, and thus were highly suitable for transmission across a free space channel. The method of generation furthermore increased the number of channels applicable for servicing within an optical communication system. Multi carriers, each with FSR and FWHM of 12.45 GHz and 250 MHz respectively, were generated. The proposed method, which was successfully demonstration as described in this paper, therefore can be used to service more channels in telecommunication systems and so enhance broadband capacity.

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References

[1] IS Amiri, S. Alavi·, M. Soltanian·, R. Penny·, A. Supa'at, N. Fisal·, and H Ahmad, "2×2 MIMO-OFDM-RoF Generation and Transmission of Double V-Band Signals Using Microring Resonator System," Optical and Quantum Electronics (2015).

[2] A. Afroozeh, I. S. Amiri, K. Chaudhary, J. Ali, and P. P. Yupapin, "Analysis of Optical Ring Resonator," Journal of Optics Research 16(2015).

[3] H Ahmad, MRK Soltanian, IS Amiri, SE Alavi, AR Othman, and ASM Supa'at, "Carriers Generated by Mode-locked Laser to Increase Serviceable Channels in Radio over Free Space Optical Systems," IEEE Photonics Journal 7(2015).

[4] Iraj Sadegh Amiri, Abdolkarim Afroozeh, and Harith Ahmad, *Integrated micro-ring photonics: Principles and Applications as Slow light devices, Soliton generation and Optical transmission*, CRC Press (CRC Press, United States, 2015).

[5] M Soltanian, IS Amiri, SE Alavi, and H Ahmad, "All Optical Ultra-Wideband Signal Generation and Transmission Using Mode-locked laser Incorporated With Add-drop Microring Resonator (MRR)," Laser Physics Letters 12(2015).

[6] IS Amiri, SE Alavi, N Fisal, ASM Supa'at, and H Ahmad, "All-Optical Generation of Two IEEE802.11n Signals for 2×2 MIMO-RoF via MRR System," IEEE Photonics Journal 6(2014).

[7] IS Amiri, SE Alavi, MRK Soltanian, H Ahmad, N Fisal, and ASM Supa'at, "Experimental Measurement of Fiber-Wireless (Fi-Wi) Transmission via Multi Mode Locked Solitons from a Ring Laser EDF Cavity," IEEE Photonics Journal 7(2015).

[8] Iraj Sadegh Amiri and Abdolkarim Afroozeh, *Ring Resonator Systems to Perform the Optical Communication Enhancement Using Soliton*, SpringerBriefs in Applied Sciences and Technology (Springer, USA, 2014).

[9] A. Afroozeh, I.S. Amiri, K. Chaudhary, J. Ali, and P. P. Yupapin, "Analysis of Optical Ring Resonator," in *Advances in Laser and Optics Research* (Nova Science, New York, 2015), pp. 133-146.

[10] I. Amiri, M. Soltanian, and H. Ahmad, "Application of Microring Resonators (MRRs) in Optical Soliton Communications," in *Optical Communication Systems: Fundamentals, Techniques and Applications* (Novascience Publisher, 2015), pp. 25 - 44.

[11] I. Amiri, S. Alavi, A. Supa'at, J. Ali, and H. Ahmad, "The Analysis of Phase, Dispersion and Group Delay in InGaAsP/InP Microring Resonator," Jurnal Teknologi (Sciences and Engineering) (2015).

[12] I. S. Amiri, J. Ali, and P. P. Yupapin, "Enhancement of FSR and Finesse Using Add/Drop Filter and PANDA Ring Resonator Systems," International Journal of Modern Physics B 26, 1250034 (2012).

[13] S. E. Alavi, I. S. Amiri, S. M. Idrus, and A. S. M. Supa'at, "Generation and Wired/Wireless Transmission of IEEE802.16m Signal Using Solitons Generated By Microring Resonator," Optical and Quantum Electronics 47, 975-984 (2014).

[14] I. S. Amiri, S. E. Alavi, Sevia M. Idrus, A. Nikoukar, and J. Ali, "IEEE 802.15.3c WPAN Standard Using Millimeter Optical Soliton Pulse Generated By a Panda Ring Resonator," IEEE Photonics Journal 5, 7901912 (2013).

[15] I. S. Amiri, R. Ahsan, A. Shahidinejad, J. Ali, and P. P. Yupapin, "Characterisation of bifurcation and chaos in silicon microring resonator," IET Communications 6, 2671-2675 (2012).

[16] I. S. Amiri and J. Ali, "Generating Highly Dark–Bright Solitons by Gaussian Beam Propagation in a PANDA Ring Resonator," Journal of Computational and Theoretical Nanoscience (JCTN) 11, 1092-1099 (2014).

[17] I. S. Amiri, S. E. Alavi, and J. Ali, "High Capacity Soliton Transmission for Indoor and Outdoor Communications Using Integrated Ring Resonators," International Journal of Communication Systems 28, 147–160 (2015).

[18] Iraj Sadegh Amiri, Sayed Esan Alavi, Sevia Mahdaliza Idrus, and Mojgan Kouhnavard, *MICRORING RESONATOR FOR SECURED OPTICAL COMMUNICATION*, Amazon (Amazon, USA, 2014).

[19] I. S. Amiri, S. E. Alavi, and H. Ahmad, "Analytical Treatment of the Ring Resonator Passive Systems and Bandwidth Characterization Using Directional Coupling Coefficients " Journal of Computational and Theoretical Nanoscience (JCTN) 12, 418-424 (2015).

[20] I. S. Amiri, H. Ahmad, and A. Shahidinejad, "Generating of 57-61 GHz Frequency Band Using a Panda Ring Resonator," Quantum Matter 4, 469-473 (2015).

[21] I. S. Amiri and J. Ali, "Optical Quantum Generation and Transmission of 57-61 GHz Frequency Band Using an Optical Fiber Optics " Journal of Computational and Theoretical Nanoscience (JCTN) 11, 2130-2135 (2014).

[22] I. S. Amiri, A. Afroozeh, and M. Bahadoran, "Simulation and Analysis of Multisoliton Generation Using a PANDA Ring Resonator System," Chinese Physics Letters 28, 104205 (2011).

[23] I. S. Amiri, A. Nikoukar, and J. Ali, "GHz Frequency Band Soliton Generation Using Integrated Ring Resonator for WiMAX Optical Communication," Optical and Quantum Electronics 46, 1165-1177 (2013).

[24] IS Amiri, MRK Soltanian, SE Alavi, and H. Ahmad, "Multi Wavelength Mode-lock Soliton Generation Using Fiber Laser Loop Coupled to an Add-drop Ring Resonator," Optical and Quantum Electronics 47, 2455 - 2464 (2015).

[25] S. E. Alavi, I. S. Amiri, S. M. Idrus, A. S. M. Supa'at, and J. Ali, "Cold Laser Therapy Modeling of Human Cell/Tissue by Soliton Tweezers," Optik 126, 578–582 (2015).

[26] I. S. Amiri and J. Ali, "Femtosecond Optical Quantum Memory generation Using Optical Bright Soliton," Journal of Computational and Theoretical Nanoscience (JCTN) 11, 1480-1485 (2014).

[27] I. Amiri and H. Ahmad, "MRR Systems and Soliton Communication," in *Optical Soliton Communication Using Ultra-Short Pulses* (Springer, USA, 2015), pp. 13-30.

[28] S. E. Alavi, I.S.Amiri, A. S. M. Supa'at, and S. M. Idrus, "Indoor Data Transmission Over Ubiquitous Infrastructure of Powerline Cables and LED Lighting," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 599-604 (2015).

[29] I. S. Amiri, S. E. Alavi, M. Bahadoran, A. Afroozeh, and H. Ahmad, "Nanometer Bandwidth Soliton Generation and Experimental Transmission within Nonlinear Fiber Optics Using an Add-Drop Filter System," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 221-225 (2015).

[30] I. S. Amiri, A. Nikoukar, A. Shahidinejad, and Toni Anwar, "The Proposal of High Capacity GHz Soliton Carrier Signals Applied for Wireless Commutation," Reviews in Theoretical Science 2, 320-333 (2014).

[31] Iraj S. Amiri, *Soliton-Based Microring Resonators: Generation and Application in Optical Communication*, Amazon (Amazon, USA, 2015).

[32] I. Amiri and H. Ahmad, "Microring Resonator (MRR) Optical Systems Applied to Enhance the Optical Soliton Communications," in *Optical Communication Systems: Fundamentals, Techniques and Applications* (Novascience Publisher, 2015), pp. 1 - 23.

[33] IS Amiri, MRK Soltanian, SE Alavi, AR Othman, MZA Razak, and H. Ahmad, "Microring Resonator for Transmission of Solitons via Wired/Wireless Optical Communication," Journal of Optics (2015).

[34] I. S. Amiri and A. Afroozeh, "Spatial and Temporal Soliton Pulse Generation By Transmission of Chaotic Signals Using Fiber Optic Link " in *Advances in Laser and Optics Research* (Nova Science Publisher, New York, 2015), pp. 119-131.

[35] IS Amiri, SE Alavi, and H. Ahmad, "Microring resonators used to gain the capacity in a high performance hybrid wavelength division multiplexing system," in *Horizons in World Physics* (Novascience, USA, 2015).

[36] I. S. Amiri and J. Ali, "Picosecond Soliton pulse Generation Using a PANDA System for Solar Cells Fabrication," Journal of Computational and Theoretical Nanoscience (JCTN) 11, 693-701 (2014).

[37] I. Amiri, S. Alavi, A. Supa'at, J. Ali, and H. Ahmad, "Temporal Soliton: Generation and Applications in Optical Communications," Jurnal Teknologi (Sciences and Engineering) (2015).

[38] I. S. Amiri and H. Ahmad, "Multiplex and De-multiplex of Generated Multi Optical Soliton By MRRs Using Fiber Optics Transmission Link," Quantum Matter 4, 463-468 (2015).

[39] IS Amiri, SE Alavi, and H Ahmad, "Optically generation and transmission ultra-wideband mode-locked lasers using dual-wavelength fiber laser and microring resonator system," in *Horizons in World Physics* (Novascience, USA, 2015).

[40] Iraj Sadegh Amiri, Sayed Ehsan Alavi, S. M. Idrus, Abdolkarim Afroozeh, and Jalil Ali, *Soliton Generation by Ring Resonator for Optical Communication Application*, Novascience (Novascience Publishers, New York, 2014).

[41] SE Alavi, IS Amiri, MRK Soltanian, R Penny, ASM Supa'at, and H Ahmad, "Multiwavelength generation using an add-drop microring resonator integrated with InGaAsP/InP sampled grating distributed feedback (SG-DFB)," Chinese Optics Letters 14, 021301 (2016).

[42] S. E. Alavi, I. S. Amiri, M. Khalily, A. S. M. Supa' at, N. Fisal, H. Ahmad, and S. M. Idrus, "W-Band OFDM for Radio-over-Fibre Direct-Detection Link Enabled By Frequency Nonupling Optical Up-Conversion," IEEE Photonics Journal 6(2014).

[43] IS Amiri, SE Alavi, and H Ahmad, "Increasing Access Points in a Passive Optical Network," Optics and Photonics News (2015).

[44] I. S. Amiri, S. E. Alavi, H. Ahmad, A.S.M. Supa'at, and N. Fisal, "Numerical Computation of Solitonic Pulse Generation for Terabit/Sec Data Transmission," Optical and Quantum Electronics 47, 1765-1777 (2014).

[45] I. S. Amiri, P. Naraei, and J. Ali, "Review and Theory of Optical Soliton Generation Used to Improve the Security and High Capacity of MRR and NRR Passive Systems," Journal of Computational and Theoretical Nanoscience (JCTN) 11, 1875-1886 (2014).

[46] I. S. Amiri, A. Nikoukar, J. Ali, and P. P. Yupapin, "Ultra-Short of Pico and Femtosecond Soliton Laser Pulse Using Microring Resonator for Cancer Cells Treatment," Quantum Matter 1, 159-165 (2012).

[47] IS Amiri, SE Alavi, MRK Soltanian, N Fisal, ASM Supa'at, and H Ahmad, "Increment of Access Points in Integrated System of Wavelength Division Multiplexed Passive Optical Network Radio over Fiber," Scientific Reports 5(2015).

[48] Iraj Sadegh Amiri and Harith Ahmad, *Optical Soliton Communication Using Ultra-Short Pulses*, SpringerBriefs in Applied Sciences and Technology (Springer, USA, 2014).

[49] A. Afroozeh, A.Zeinalinezhad, I. S. Amiri, and S. E. Pourmand, "Stop Light Generation Using Nano Ring Resonators for Read Only Memory," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 468-472 (2014).

[50] A Afroozeh, IS Amiri, Y Farhang, and A. Zeinalinezhad', *Microring resonators: fabrication and applications in soliton communications*, Amazon (Amazon, USA, 2015).

[51] I. Amiri and H. Ahmad, "Optical Soliton Signals Propagation in Fiber Waveguides," in *Optical Soliton Communication Using Ultra-Short Pulses* (Springer, USA, 2015), pp. 1-11.

[52] SE Alavi, MRK Soltanian, IS Amiri, M Khalily, ASM Supa'at, and H Ahmad, "Towards 5G: A Photonic Based Millimeter Wave Signal Generation for Applying in 5G Access Fronthaul," Scientific Reports 6(2016).

[53] MRK Soltanian, IS Amiri, WY Chong, SE Alavi, and H Ahmad, "Stable dual-wavelength coherent source with tunable wavelength spacing generated by spectral slicing a mode-locked laser using microring resonator," IEEE Photonics Journal 7(2015).

[54] MRK Soltanian, IS Amiri, SE Alavi, and H Ahmad, "Dual-Wavelength Erbium-Doped Fiber Laser to Generate Terahertz Radiation Using Photonic Crystal Fiber," Journal of Lightwave Technology (JLT) 33, 5038-5046 (2015).

[55] I. Sadegh Amiri, M. Nikmaram, A. Shahidinejad, and J. Ali, "Generation of potential wells used for quantum codes transmission via a TDMA network communication system," Security and Communication Networks 6, 1301-1309 (2013).

[56] Abdolkarim Afroozeh, Mahdi Bahadoran, Hooman Moradpour, Alireza Zeinalinezhad, and Iraj Sadegh Amiri, "Effect of Voltage on the Optical Properties of Liquid Photonic Crystal Fiber," Buletin Optik 1(2016).

[57] IS Amiri, SE Alavi, and H Ahmad, "Fiber laser setup used to generate several Mode-Locked pulses applied to soliton-based optical transmission link," in *Horizons in World Physics* (Novascience, USA, 2015).

[58] I. S. Amiri and J. Ali, "Single and Multi Optical Soliton Light Trapping and Switching Using Microring Resonator," Quantum Matter 2, 116-121 (2013).

[59] A. Afrozeh, A. Zeinalinezhad, S. E. Pourmand, and I. S. Amiri, "Attosecond Pulse Generation Using Nano Ring Waveguides," INTERNATIONAL JOURNAL OF CURRENT LIFE SCIENCES 4, 7573-7575 (2014).

[60] I. S. Amiri, M. H. Khanmirzaei, M. Kouhnavard, P. P. Yupapin, and J. Ali, "Quantum Entanglement using Multi Dark Soliton Correlation for Multivariable Quantum Router," in *Quantum Entanglement* A. M. Moran, ed. (Nova Science Publisher, New York, 2012), pp. 111-122.

[61] I. S. Amiri, M. Ebrahimi, A. H. Yazdavar, S. Gorbani, S. E. Alavi, Sevia M. Idrus, and J. Ali, "Transmission of data with orthogonal frequency division multiplexing technique for communication networks using GHz frequency band soliton carrier," IET Communications 8, 1364 – 1373 (2014).

[62] A. Afroozeh, I. S. Amiri, S. E. Pourmand, A. Zeinalinezhad, S. E. Alavi, and H. Ahmad, "Comparison of Control Light using Kramers-Kronig Method by Three Waveguides," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 1864-1868 (2015).

[63] I. S. Amiri and A. Afroozeh, "Spatial and Temporal Soliton Pulse Generation By Transmission of Chaotic Signals Using Fiber Optic Link" Journal of Optics Research 16, 121-133 (2015).

[64] MRK Soltanian, H Ahmad, A Khodaie, IS Amiri, MF Ismail, and SW Harun, "A Stable Dual-wavelength Thulium-doped Fiber Laser at 1.9 µm Using Photonic Crystal Fiber," Scientific Reports (2015).

[65] I. S. Amiri and J. Ali, "Data Signal Processing Via a Manchester Coding-Decoding Method Using Chaotic Signals Generated by a PANDA Ring Resonator," Chinese Optics Letters 11, 041901(041904) (2013).

[66] I. S. Amiri, S. E. Alavi, M. R. K. Soltanian, A.S.M. Supa'at, N. Fisal, and H. Ahmad, "Generation of Femtosecond Soliton Tweezers Using a Half-Panda System for Modeling the Trapping of a Human Red Blood Cell," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 10-18 (2015).

[67] I. S. Amiri, S. E. Alavi, and H. Ahmad, "Radio Frequency signal generation and wireless transmission using PANDA and Add/drop systems," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 1770-1774(1775) (2015).

[68] S. E. Alavi, I. S. Amiri, H. Ahmad, N. Fisal, and ASM. Supa'at, "Optical Amplification of Tweezers and Bright Soliton Using an Interferometer Ring Resonator System," Journal of Computational and Theoretical Nanoscience (JCTN) 12, 624-629 (2015).

[69] I. S. Amiri and J. Ali, "Simulation of the Single Ring Resonator Based on the Z-transform Method Theory," Quantum Matter 3, 519-522 (2014).

[70] SE Alavi, IS Amiri, H Ahmad, ASM Supa'at, and N Fisal, "Generation and Transmission of 3× 3 W-Band MIMO-OFDM-RoF Signals Using Micro-Ring Resonators," Applied Optics 53, 8049-8054 (2014).

[71] I. S. Amiri, S. Soltanmohammadi, A. Shahidinejad, and j. Ali, "Optical quantum transmitter with finesse of 30 at 800-nm central wavelength using microring resonators," Optical and Quantum Electronics 45, 1095-1105 (2013).

[72] H Ahmad, MRK Soltanian, Leila Narimani, IS Amiri, A Khodaei, and SW Harun, "Tunable S-Band Q-Switched Fiber Laser using Bi2Se3 as the saturable absorber," IEEE Photonics Journal 7(2015).

[73] IS Amiri, MZ Zulkifli, and H Ahmad, "Soliton comb generation using add-drop ring resonators," International Research Journal of Telecommunications and Information Technology 1, 002-008 (2014).

[74] I. Amiri and H. Ahmad, "Ultra-Short Solitonic Pulses Used in Optical communication," in *Optical Soliton Communication Using Ultra-Short Pulses* (Springer, USA, 2015), pp. 47-51.

[75] P. P. Yupapin, M. A. Jalil, I. S. Amiri, I. Naim, and J. Ali, "New Communication Bands Generated by Using a Soliton Pulse within a Resonator System," Circuits and Systems 1, 71-75 (2010).

[76] I. Amiri and H. Ahmad, "Solitonic Signals Generation and Transmission Using MRR," in *Optical Soliton Communication Using Ultra-Short Pulses* (Springer, USA, 2015), pp. 31-46.

[77] I. S. Amiri, S. E. Alavi, S. M. Idrus, A. S. M. Supa'at, J. Ali, and P. P. Yupapin, "W-Band OFDM transmission for radio-over-fiber link using solitonic millimeter wave generated by MRR," Quantum Electronics, IEEE Journal of 50, 622-628 (2014).

[78] S. E. Alavi, I. S. Amiri, S. M. Idrus, ASM Supa'at, J. Ali, and P. P. Yupapin, "All Optical OFDM Generation for IEEE802.11a Based on Soliton Carriers Using MicroRing Resonators " IEEE Photonics Journal 6(2014).

[79] MRK Soltanian, IS Amiri, SD Emami, and H Ahmad, "Yagi-Uda nanoantenna in the near-field optical domain," in Optical Communication Systems: Fundamentals, Techniques and Applications (Novascience Publisher, New York, 2015), pp. 91 - 96.