International Journal of Information and Communication Sciences
2016; 1(1): 1-8
http://www.sciencepublishinggroup.com/j/ijics
doi: 10.11648/j.ijics.20160101.11

SciencePG
Science Publishing Group

Panda Microring Resonator (PMRR) to Generate 90 GHz Free Spectral Range (FSR) Solitonic Signals Used for Telecommunication Applications

IS Amiri[1], Hamza M. R. Al-Khafaji[2]

[1]Photonics Research Centre, University of Malaya (UM), Kuala Lumpur, Malaysia
[2]Computer Techniques Engineering Department, Al-Mustaqbal University College, Babylon, Iraq

Email address:

irajsadeghamiri@gmail.com (IS Amiri), hamza@mustaqbal-college.com (H. M. R. Al-Khafaji)
[*]Corresponding author

To cite this article:

IS Amiri, Hamza M. R. Al-Khafaji. Panda Microring Resonator (PMRR) to Generate 90 GHz Free Spectral Range (FSR) Solitonic Signals Used for Telecommunication Applications. *International Journal of Information and Communication Sciences*. Vol. 1, No. 1, 2016, pp. 1-8. doi: 10.11648/j.ijics.20160101.11

Received: April 15, 2016; **Accepted**: May 10, 2016; **Published**: June 20, 2016

Abstract: In this work optical solitons carrier generation in a nonlinear waveguide microring resonator (MRR) is simulated and presented. Therefore, a system comprises of a W-band (75 to 110 GHz) optical millimeter wave generation using a Panda microring resonator (PMRR) is presented. A bright soliton with a central frequency of 50 GHz and power of 1 W is introduced into the PMRR. The optical Kerr effect manifests itself temporally as self-phase modulation, a self-induced phase- and frequency-shift of a pulse of light as it travels through a medium. Large bandwidth within the microring device can be generated by using a soliton spectrum input into the nonlinear PMRR. The 90 GHz free spectral range (FSR) solitonic signals were simply generated by adjusting the system parameters. By beating the closely center frequencies of the solitonic signals, we can obtain a center frequency which corresponds to that spacing as millimeter wave used for many applications in signal processing and communications such as wireless cable systems and indoor–outdoor communication.

Keywords: PMRR, Free Spectral Range (FSR), Waveguide Microring Resonator (MRR)

1. Introduction

Nowadays in order to satisfy the increased desire of high-speed data communication, wireless links which can provide multi gigabit-per-second capacities into the core network are getting more attention [1-4]. Optics has become the way by which most information is sent over nearly all the distance that it travels.

The remarkable growth of networks and the Internet over the past decade has been enabled by previous generations of optical technology. Optics is, furthermore, the only technology with the physical headroom to keep up with this exponentially growing demand for communicating information.

Carrier frequency translation can be done whether in electrical or optical domain [5-8]. Passive optical networks (PONs) are the primary broadband optical delivery architecture, providing the shared bandwidth of a fiber to multiple users (16 to 64 users). Generation of mm-wave signal in electrical domain is a challenging issue due to large loss and high cost [9-12].

Propagation attenuation is not purely problematic, however. The added loss at frequencies such as 24GHz and 60GHz can result in a faster drop in the signal power resulting in potentially higher frequency reuse ratio for a cellular implementation, where the same frequency can be used nearby by a different base station. The propagation properties of mm-waves are closer to their yet higher frequency electromagnetic siblings, namely, visible light.

The optically distribution and processing of signals in the mm-wave range is much preferred [13-17]. These schemes of optical millimetre-wave signal generation and up-conversion pave the way for future-proof access networks using all-optical technologies. Recently, several studies are conducted to generate mm-wave signals whether in V-band (57~64 GHz) or for higher data rates, W-band (75~110 GHz) [18-23].

Even some efforts have been done to improve the W-band RoF systems but still practical generation of high data rate

W-band signal is challenging issue and requires more research to improve the system both technically and economically. Table 1 compares some recent works and their methods to generate W-band signal and highlights the drawbacks of each method separately.

As can be concluded from Table I these methods are suffered from spectral efficient modulation or narrow-linewidth laser, which increase the cost, complexity and efficiency of the overall system. Higher spectral efficiency (SE) and better transmission performance can be achieved using systems of microring resonators (MRRs) [31-34]

Table 1. *Comparison of recent techniques on W-band signal generation.*

Method BW (GHz)	Data Rate (Gb/s) and	Drawback
1) Remote Up-conversion with photonic transmitter-mixer [24]	20, 83~103	No spectral efficient Mod
2) Self-coherent heterodyne [25]	40, 87.5~97.5	Laser costly
3) Coherent heterodyne [26-28]	108, 57	Laser costly
4) Multi-input multi-output technology with coherent heterodyne [26, 29]	120, 108, 86.5~113.5	Laser costly
5) Direct-Detection (DD) technology based on optical carrier suppression scheme [30]	40, 98~108	High Frequency LOs

Optical MRRs recently are interesting subject in the area of integrated optics because of their unique aspects such as compactness, low cost, tunability and easy integration on a chip with other photonic devices, having a variety of applications such as optical filter, optical switch, optical modulator, optical delay line, dispersion compensator and optical sensor.

Add/drop filter system which create or filter narrowband wavelength signals from wider optical spectrum and connected to the bus waveguide are generally basic foundations of building blocks in addition to optical communication devices. Furthermore, MRRs have excellent wavelength selection properties and can be used to design tunable filters, modulators, wavelength converters, and switches that are critical components for optical interconnects.

Based on the formulated problems concerned by previous studies, in this work optical solitons carrier generation in a nonlinear waveguide MRR is presented [35, 36]. A Panda Microring Resonator (PMRR) is used to generate W-Band soliton signals with upper and lower optical carriers to be applied for telecommunication systems.

Nonlinear light behaviour inside a PMRR occurs when a strong signal of light is inputted into the ring system; this is used for many applications in signal processing and communication such as wireless cable systems and indoor–outdoor communication [37-39]. The PMRR consists of a centred ring resonator connected to two smaller ring resonators on the right and left sides. The properties of a MRR can be modified via various control methods [40-42].

MRRs can be used as filter devices where trapping of optical frequency or wavelength can be obtained using suitable system parameters [43-45]. Results in this paper show that the system support both single-carrier and multi-carrier optical soliton signals that can be used in W-band transmission/receiver systems.

2. Theory of Soliton Generation

The system of W-Band frequency band generation is shown in Figure 1. Here, a PMRR is used. The filtering process of the input soliton spectrum is performed via the system, where the frequency band ranges of 193–194 THz can be obtained.

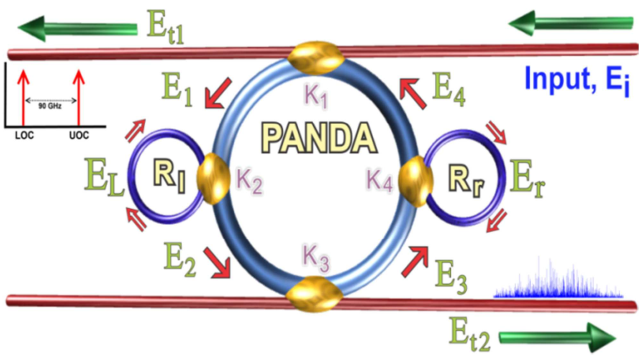

Fig. 1. *Optical frequency band generation system using a PMRR.*

MRRs are simulated using waveguide, where the medium has Kerr effect-type nonlinearity [46]. The Kerr effect, also called the quadratic electro-optic effect (QEO effect), is a change in the refractive index of a material in response to an applied electric field.

The optical Kerr effect manifests itself temporally as self-phase modulation, a self-induced phase- and frequency-shift of a pulse of light as it travels through a medium. This process, along with dispersion, can produce optical solitons. Spatially, an intense beam of light in a medium will produce a change in the medium's refractive index that mimics the transverse intensity pattern of the beam. The Kerr effect causes the refractive index (n) of the medium to vary; it is given by [47-50]

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

where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively, and I and P are the optical intensity and the power, respectively [51-53]. The effective mode core area given by A_{eff} ranges from 0.10 to 0.25 μm^2 in terms of practical material parameters (InGaAsP/InP) [54-56].

A bright soliton is characterized as a localized intensity peak above a continuous wave (CW) background while a dark soliton is featured as a localized intensity dip below a continuous wave (CW) background. It is a well-known fact that the interplay of nonlinearity and dispersion leads to the appearance of localized wave packets moving without distortion.

When the interaction between atoms is attractive, bright solitons can be generated. In this study, a bright soliton with a central frequency of 50 GHz and power of 1 W is introduced into the first ring resonator, R_1, expressed by E_{in}. The input optical field of the optical bright soliton is given by [57-60]

$$E_i = A\sec h\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right)-i\omega_0 t\right], \quad (2)$$

where A and z are the amplitude of optical field and propagation distance, respectively, L_D is the dispersion length of the soliton signal [61, 62], and the carrier frequency of the signal is ω_0.

The soliton signal keeps its temporal and spatial width invariance while it propagates; therefore, it is called a temporal and spatial soliton [63-65]. A balance should be achieved between the dispersion length (L_D) and the nonlinear length ($L_{NL}=1/\Gamma\phi_{NL}$) [66-68]. Here, $\Gamma=n_2\times k_0$ is the length scale over which disperse or nonlinear effects make the beam become wider or narrower; hence, $L_D=L_{NL}$. The interior signals are given as follows [69-72]:

$$E_1 = \sqrt{1-\gamma_1}\left(\sqrt{1-\kappa_1}E_4 + j\sqrt{\kappa_1}E_i\right), \quad (3)$$

$$E_2 = E_L E_1 e^{-\frac{\alpha}{2}\frac{L}{2}-jk_n\frac{L}{2}}, \quad (4)$$

$$E_3 = \sqrt{1-\gamma_3}\times\sqrt{1-\kappa_3}E_2, \quad (5)$$

$$E_4 = E_r E_3 e^{-\frac{\alpha}{2}\frac{L}{2}-jk_n\frac{L}{2}}, \quad (6)$$

where κ is the intensity coupling coefficient [73, 74], γ is the fractional coupler intensity loss [75, 76], α is the attenuation coefficient [77-79], $L=2\pi R_{PANDA}$, and R_{PANDA} is the radius of the PMRR [80, 81]. The electric field of the left and right rings of the PMRR is given by [82-85]

$$E_L = E_1\frac{\sqrt{(1-\gamma_2)(1-\kappa_2)}-(1-\gamma_2)e^{-\frac{\alpha}{2}L_L-jk_nL_L}}{1-\sqrt{1-\gamma_2}\sqrt{1-\kappa_2}e^{-\frac{\alpha}{2}L_L-jk_nL_L}} \quad (7)$$

$$E_r = E_3\frac{\sqrt{(1-\gamma_4)(1-\kappa_4)}-(1-\gamma_4)e^{-\frac{\alpha}{2}L_R-jk_nL_R}}{1-\sqrt{1-\gamma_4}\sqrt{1-\kappa_4}e^{-\frac{\alpha}{2}L_R-jk_nL_R}}. \quad (8)$$

Where $L_R=2\pi R_r$, $R_r=8\mu m$, $L_L=2\pi R_l$, $R_l=18\mu m$. Therefore, the output signals from the through and drop ports of the PMRR can be expressed as [86-89]

$$E_{t1} = \sqrt{1-\gamma_1}\left[\sqrt{1-\kappa_1}E_i + j\sqrt{\kappa_1}E_4\right] \quad (9)$$

$$E_{t2} = \sqrt{1-\gamma_3}\times j\sqrt{\kappa_3}E_2. \quad (10)$$

Here the E_{t1} include two frequency components which are allocated as upper and lower optical solitonic carriers called UOC and LOC respectively shown in Figure 2 [90-92]. The fixed and variable parameters of the PMRR are listed in Table 2.

Table 2. *Fixed and variable parameters of the PMRR.*

Fixed Parameters	Variable Parameters
R_{Panda}=100μm	T_0=Initial propagation time
R_l=18 μm	T=Propagation time
R_r=8 μm	Z=Propagation distance
κ_1=0.35	L_D=Dispersion length
κ_2=0.22	L_{NL}=Nonlinear length
κ_3=0.30	ϕ=Total phase shift
κ_4=0.10	ϕ_{NL}=Nonlinear phase shift
n_0=3.34	ϕ_0=Linear phase shift
n_2=2.2×10^{-17} m^2W^{-1}	A=Optical amplitude
A_{effl}= A_{eff3}=0.50 μm^2	I=Optical intensity
A_{effL}= A_{effR}=0.25 μm^2	P=Optical Power
A=0.5 dBmm^{-1}	E_1= E_2= E_3= E_4= Electric fields
γ=0.1	E_R=Electric field of the right ring
	E_L=Electric field of the left ring
	E_{t1}=Throughput electric field
	E_{t2}=Drop port electric field

3. Results and Discussions

The results of the chaotic signal generation are shown in Figure 2. The input soliton spectrum with a power of 1 W is inserted into the system. Large bandwidth within the microring device can be generated by using a soliton spectrum input into the nonlinear PMRR.

This means that the broad spectrum of light can be generated after the soliton pulse is input into the ring resonator system. The signal is chopped (sliced) into smaller signals spreading over the spectrum; thus, a large bandwidth is formed by the nonlinear effects of the medium. A frequency soliton signals can be formed and trapped within the PMRR with suitable MRR parameters.

Interior soliton signals inside the PMRR can be seen in Figure 2, where the filtering and trapping processes occur during propagation of the input soliton spectrum inside the system. Figure 2(a-d) shows the interior generated signals of the PMRR.

Filtering of the interior soliton signals can be performed when the signals pass through the couplers, κ_1, κ_2, κ_3, and κ_4. The output signals from the throughput and drop ports of the system can be seen in Figure 3, where solitonic optical carriers ranges of 193–194 THz are generated and used in many communication applications, such as wireless personal area networks (WPANs), wireless local area networks (WLANs) and Radio over Fiver (RoF) [93-97].

The throughput output (E_{t1}) shows localized ultra-short soliton signals (LOC and UOC) with an FSR of 90 GHz. The drop port output expressed by E_{t2} is shown in Figure 3(b), where multi-soliton signals could be generated [98-101]. Here, a high capacity of signals can be obtained by generating multi-soliton signals [102-104].

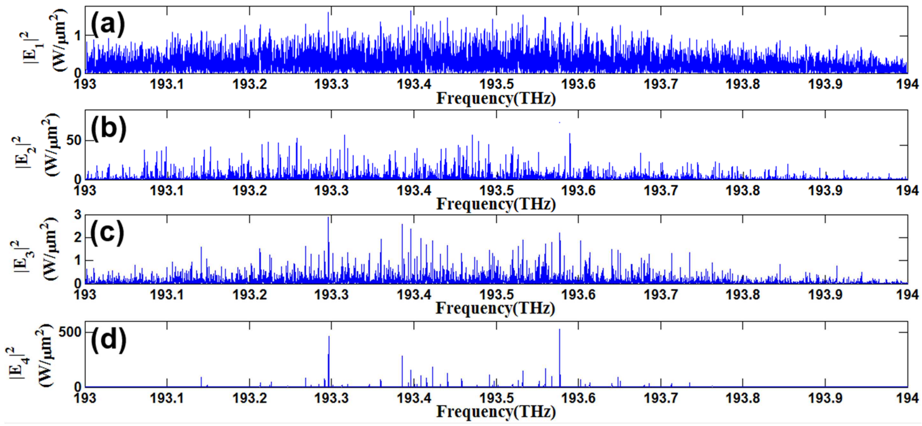

Fig. 2. *Interior soliton power: (a) E_1^2 (W), (b) E_2^2 (W), (c) E_3^2 (W), (d) E_4^2 (W).*

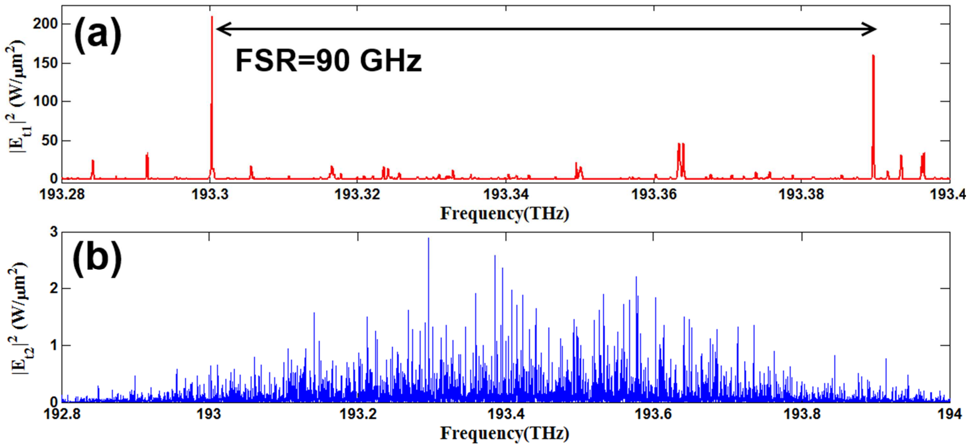

Fig. 3. *Results of upper and lower solitonic optical carriers and multi-solitons: (a) throughput output signal with FSR=90 GHz, (b) multi-soliton signals.*

Based on Figure 1 and presented parameters in Tables 2, the PMRR generates frequencies of 193.3 and 193.39 THz respectively which are 90 GHz apart. By beating the closely center frequencies of the throughput output signals, we can obtain a center frequency which corresponds to that spacing as millimeter wave [105].

4. Conclusions

A Panda Microring Resonator (PMRR) for generating W-band solitonic optical carriers is demonstrated to be used in telecommunication applications. The high-capacity transmission can be obtained using soliton signals with high GHz frequency band carrier. Here the 90 GHz apart soliton signals are generated. Thus, high bitrate data transmissions can be provided, using a broad frequency band of 75 to 110 GHz.

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] 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).

[3] 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).

[4] 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).

[5] 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).

[6] I. S. Amiri, S. Ghorbani, P. Naraei, and H. Ahmad, "Chaotic Carrier Signal Generation and Quantum Transmission Along Fiber Optics Communication Using Integrated Ring Resonators," Quantum Matter 4, 151-155 (2015).

[7] 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).

[8] IS Amiri and A Afroozeh, "Integrated Ring Resonator Systems," in *Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton* (Springer, USA, 2014).

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

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

[11] 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).

[12] Iraj Sadegh Amiri, Sayed Ehsan Alavi, and Sevia Mahdaliza Idrus, *Soliton Coding for Secured Optical Communication Link*, SpringerBriefs in Applied Sciences and Technology (Springer, USA, 2014).

[13] 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).

[14] 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).

[15] 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).

[16] 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).

[17] 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).

[18] 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).

[19] 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).

[20] 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).

[21] 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).

[22] 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).

[23] 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).

[24] F.-M. Kuo, C.-B. Huang, J.-W. Shi, N.-W. Chen, H.-P. Chuang, J. E. Bowers, and C.-L. Pan, "Remotely up-converted 20-Gbit/s error-free wireless on–off-keying data transmission at W-band using an ultra-wideband photonic transmitter-mixer," Photonics Journal, IEEE 3, 209-219 (2011).

[25] A. Kanno, K. Inagaki, I. Morohashi, T. Sakamoto, T. Kuri, I. Hosako, T. Kawanishi, Y. Yoshida, and K.-i. Kitayama, "40 Gb/s W-band (75-110 GHz) 16-QAM radio-over-fiber signal generation and its wireless transmission," in *European Conference and Exposition on Optical Communications*, (Optical Society of America, 2011),

[26] X. Li, Z. Dong, J. Yu, N. Chi, Y. Shao, and G. Chang, "Fiber-wireless transmission system of 108 Gb/sdata over 80 km fiber and 2× 2multiple-input multiple-output wireless links at 100 GHz W-band frequency," Optics letters 37, 5106-5108 (2012).

[27] X. Li, J. Yu, Z. Dong, Z. Cao, N. Chi, J. Zhang, Y. Shao, and L. Tao, "Seamless integration of 57.2-Gb/s signal wireline transmission and 100-GHz wireless delivery," Optics express 20, 24364-24369 (2012).

[28] A. Caballero, D. Zibar, R. Sambaraju, J. Marti, and I. T. Monroy, "High-capacity 60 GHz and 75–110 GHz band links employing all-optical OFDM generation and digital coherent detection," Lightwave Technology, Journal of 30, 147-155 (2012).

[29] J. Zhang, J. Yu, N. Chi, Z. Dong, X. Li, and G.-K. Chang, "Multi-channel 120-Gb/s data transmission over 2x2 MIMO fiber-wireless link at W-Band," (2013).

[30] H.-T. Huang, C.-T. Lin, C.-H. Ho, W.-L. Liang, C.-C. Wei, Y.-H. Cheng, and S. Chi, "High spectral efficient W-band OFDM-RoF system with direct-detection by two cascaded single-drive MZMs," Optics express 21, 16615-16620 (2013).

[31] A. Nikoukar, I. S. Amiri, and J. Ali, "Generation of Nanometer Optical Tweezers Used for Optical Communication Networks," International Journal of Innovative Research in Computer and Communication Engineering 1, 77-85 (2013).

[32] 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).

[33] 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).

[34] 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).

[35] 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).

[36] 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).

[37] 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).

[38] 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).

[39] 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).

[40] 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).

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

[42] 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.

[43] 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).

[44] 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).

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

[46] 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).

[47] I. S. Amiri, H. Ahmad, and Hamza M. R. Al-Khafaji, "A Review of Ultra-Short Soliton Pulse Generation Using InGaAsP/InP Microring Resonator (MRR) System," American Journal of Networks and Communications,, Special Issue: Recent Progresses in Optical Code-Division Multiple-Access (OCDMA) Technology 4, 6-17 (2015).

[48] IS Amiri, H. Ahmad, and Hamza M. R. Al-Khafaji, "Full width at half maximum (FWHM) analysis of solitonic pulse applicable in optical network communication," American Journal of Networks and Communications,, Special Issue: Recent Progresses in Optical Code-Division Multiple-Access (OCDMA) Technology 4(2015).

[49] 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).

[50] 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).

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

[52] 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).

[53] P. Sanati, A. Afroozeh, I. S. Amiri, J.Ali, and Lee Suan Chua, "Femtosecond Pulse Generation using Microring Resonators for Eye Nano Surgery," Nanoscience and Nanotechnology Letters 6, 221-226 (2014).

[54] 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).

[55] 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).

[56] 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).

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

[58] 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).

[59] 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).

[60] 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).

[61] 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).

[62] IS Amiri and A Afroozeh, "Mathematics of Soliton Transmission in Optical Fiber," in *Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton* (Springer, USA, 2014).

[63] Amiri, H Ahmad, and MZ Zulkifli, "Integrated ring resonator system analysis to Optimize the soliton transmission," International Research Journal of Nanoscience and Nanotechnology 1, 002-007 (2014).

[64] 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).

[65] 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.

[66] A. Afroozeh, A. Zeinalinezhad, SE. Pourmand, and IS. Amiri, "Determination of Suitable Material to Control of Light," International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS) 3, 2410-2421 (2014).

[67] 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).

[68] I. S. Amiri and J. Ali, "Optical Buffer Application Used for Tissue Surgery Using Direct Interaction of Nano Optical Tweezers with Nano Cells," Quantum Matter 2, 484-488 (2013).

[69] 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).

[70] 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).

[71] I. S. Amiri, B. Barati, P. Sanati, A. Hosseinnia, HR Mansouri Khosravi, S. Pourmehdi, A. Emami, and J. Ali, "Optical Stretcher of Biological Cells Using Sub-Nanometer Optical Tweezers Generated by an Add/Drop Microring Resonator System," Nanoscience and Nanotechnology Letters 6, 111-117 (2014).

[72] 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.

[73] 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).

[74] 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.

[75] 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.

[76] A. Shahidinejad, S. Soltanmohammadi, I. S. Amiri, and T. Anwar, "Solitonic Pulse Generation for Inter-Satellite Optical Wireless Communication," Quantum Matter 3, 150-154 (2014).

[77] 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.

[78] I. S. Amiri and J. Ali, "Nano Optical Tweezers Generation Used for Heat Surgery of a Human Tissue Cancer Cells Using Add/Drop Interferometer System," Quantum Matter 2, 489-493 (2013).

[79] 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).

[80] 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).

[81] IS Amiri and A Afroozeh, "Introduction of Soliton Generation," in *Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton* (Springer, USA, 2014).

[82] 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).

[83] 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).

[84] I. S. Amiri and J. Ali, "Deform of Biological Human Tissue Using Inserted Force Applied by Optical Tweezers Generated By PANDA Ring Resonator," Quantum Matter 3, 24-28 (2014).

[85] I. S. Amiri, H. Ahmad, and P. Naraei, "Optical Transmission Characteristics of an Optical Add-Drop Interferometer System," Quantum Matter 4, 644-647 (2015).

[86] 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).

[87] 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).

[88] Ali Shahidinejad, Iraj Sadegh Amiri, and Toni Anwar, "Enhancement of Indoor Wavelength Division Multiplexing-Based Optical Wireless Communication Using Microring Resonator," Reviews in Theoretical Science 2, 201-210 (2014).

[89] 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).

[90] 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.

[91] 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).

[92] 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.

[93] 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).

[94] I. S. Amiri and J. Ali, "Nano Particle Trapping By Ultra-short tweezer and wells Using MRR Interferometer System for Spectroscopy Application," Nanoscience and Nanotechnology Letters 5, 850-856 (2013).

[95] 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).

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

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

[98] 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).

[99] 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).

[100] I. S. Amiri, S. E. Alavi, and S. M. Idrus, "Results of Digital Soliton Pulse Generation and Transmission Using Microring Resonators," in *Soliton Coding for Secured Optical Communication Link* (Springer, USA, 2015), pp. 41-56.

[101] I. S. Amiri, S. E. Alavi, and S. M. Idrus, "Introduction of Fiber Waveguide and Soliton Signals Used to Enhance the Communication Security," in *Soliton Coding for Secured Optical Communication Link* (Springer, USA, 2015), pp. 1-16.

[102] I. S. Amiri and J. Ali, "Characterization of Optical Bistability In a Fiber Optic Ring Resonator," Quantum Matter 3, 47-51 (2014).

[103] IS Amiri and A Afroozeh, "Soliton Generation Based Optical Communication," in *Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton* (Springer, USA, 2014).

[104] I. S. Amiri, S. E. Alavi, and S. M. Idrus, "Theoretical Background of Microring Resonator Systems and Soliton Communication," in *Soliton Coding for Secured Optical Communication Link* (Springer, USA, 2015), pp. 17-39.

[105] H. Ahmad, I. S. Amiri, M. R. K. Soltanian, A. A. Latif, S. F. Norizan, and S. E. Alavi, "Multi dual-wavelength generation using InGaAsP/InP passive microring resonator with two sides Apodized gratings," Materials Express (2016).