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Several Mode-Locked Pulses Generation and Transmission over Soliton Based Optical Transmission Link

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Abstract

A soliton-based optical communication system is presented to generate and transmits several mode locked laser pulses (generated by fiber laser setup) over 50 km fiber and 120 m wireless link. The passive mode-locking feature of the laser system proposed in this paper is based on nonlinear polarization rotation evolution.

***Keywords**: Optical soliton communication, mode locked laser*

1. Introduction

Transmission of soliton pulses via wired/wireless communication [1-3] link has been presented in many publications in the field of optical communications [4-7]. Mode-locked fiber lasers [8-10] have been shown as the most inexpensive optical light sources for practical generation of ultrashort pulses [11, 12], with actively harmonic mode-locked erbium-doped fiber (EDF) lasers capable of producing transform-limited narrow Gaussian pulses [13-15]. Such systems are especially suitable for high speed [16-18], long distance WDM transmission [19-22]. Fundamental soliton pulses [23-25] are highly important in particular for long-distance optical fiber communications [26-28] and in mode-locked lasers (soliton mode-locking) [29-32]. In this work, a successful transmission of ultra-stable soliton pulses [33-35] over long distance optical links is described along with a subsequent generation of RF multicarriers in the WiFi spectrum range, from which the performance of RF carrier transmission over a 250 m wireless link is measured and analyzed. A method is proposed for generating multiple carrier RF with very low phase noise, limited amplitude fluctuations, and identical time jitter along with negligible interference between carriers [36-38]. The obtained results show that the proposed architecture is a promising scheme for the generation of multiple high purity carriers up to extremely high frequencies (W band) that are far beyond the reach of electronic oscillators [39]. The passive mode-locking feature of the laser system proposed in this paper is based on nonlinear polarization rotation evolution [40-42], whereby an ellipse is resolved into right- and left-hand circular polarization components of separate intensities.

2. Mode-Locked Laser Generation using Fiber Laser Setup

The experimental setup is shown in Figure 1. The laser used a 0.9 m long highly doped Leikki Er80-8/125 EDF as the active gain medium. The EDF was pumped backward by a Lumics 980 nm laser diode through a wavelength division multiplexer (WDM). The isolator connected to the WDM was used to avoid any unwanted back reflection towards the gain medium. This isolator was in turn connected to a polarization controller (PC) and an embedded CNT between two ferrules. The output of the embedded CNT was guided toward a 95:5 coupler, which extracted a portion of the signal for analysis. The 95% port was connected to an isolator, which was then connected to the gain medium. This loop completed the laser cavity. The extracted output was divided into two evenly powered portions using a 3 dB coupler, with one portion being directed to an optical spectrum analyzer (OSA) (model YOKOGAWA AQ6370B,

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with wavelength resolution bandwidth accuracy of ± 0.02 nm (1520 to 1580 nm)) while the other portion led to a photodetector (HP lightwave detector DC-6 GHz) and finally to whether radio frequency-spectrum analyzer (RF-SA Anritsu MS2683A) or oscilloscope (YOKOGAWA DLM2054) in order to be analyzed separately to obtain the average output power, the radio frequency spectrum and the output in the time domain.

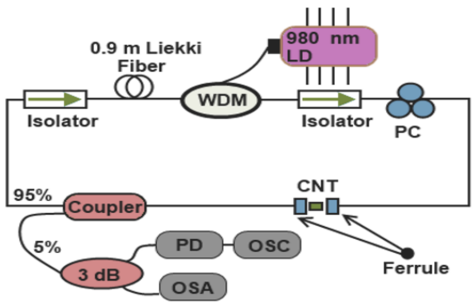

Figure 1. mode-locked laser generation system setup

The all-fiber mode-locked soliton pulses generated via the CNT-based SA as a mode locker have their power across a wavelength range represented in Fig. 2(a). The total length of the laser cavity was approximately 4 m. Aside from the EDF, all fibers used in the cavity were Corning SMF-28 ($\beta 2$ = −22 ps2/km). The observed mode-locked pulses were achieved at a threshold pump power of about 40 mW, with the optical spectrum having a very wide-band output together with multiple sidebands present as observed in the OSA. The presence of these sidebands confirmed that the system was operating in the soliton regime [43]. Fig. 2(b) shows the beating frequency for each of the two modes available in the mode-locked soliton spectrum in 550 MHz scale.

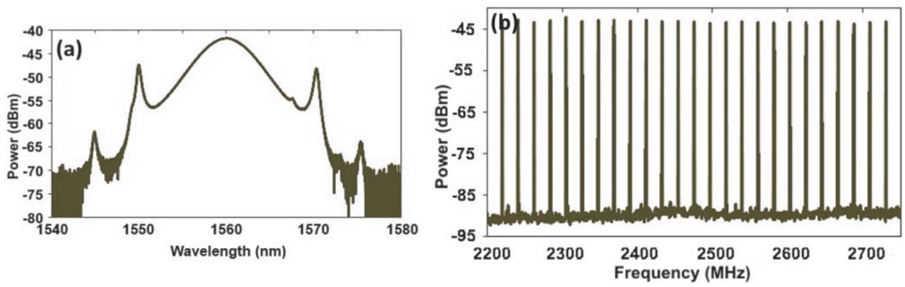

Figure 2. (a) mode-locked spectrum, (b) solitons with FSR of 21.6 MHz and FWHM of 400 KHz

The communication system based on RF signals generated from an optical soliton is shown in Figure 3.

In order to examine the stability of the generated mode locked soliton signal, it was forwarded to 50 km optical fiber. This 50 km optical fiber had an attenuation of 0.2 dB/km, dispersion of 5 ps/(nm.km), differential group delay of 0.2 ps/km, nonlinear refractive index of 2.6×10^{-20} m^2/W, effective area of 25 μm^2 and nonlinear phase shift of 3 mrad. The transmission of the mode locked soliton signal through 50 km of optical fiber can be seen in Figure 4 which show the pulses with FWHM of 670 fs.

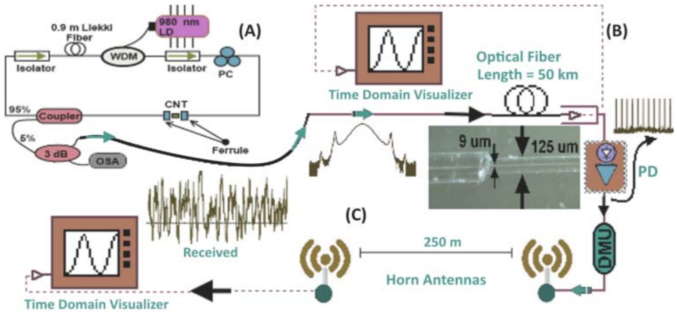

Figure 3. Fi-Wi transmission setup

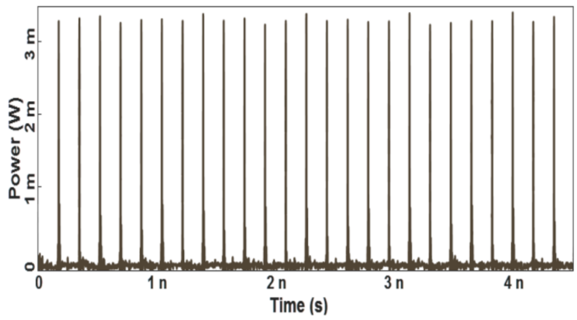

Figure 4. Time-domain trace, mode-locked soliton

A PIN photodetector (PD) was used to convert the solitonic input power to RF band. The generated RF spectrum was a result of beating frequency of wavelengths launched into the PD at the other end of the SMF after photo detection, at the data modulator unit (DMU), as shown in Figure 5, the RF multicarriers are generated in the range of the WiFi frequency and can be modulated to transmit wirelessly along the 250 m wireless link. In order to check the performance of the whole system, one of the RF carriers centered at 2.5 GHz was selected using RF band pass filter (BPF) and this carrier was then used to transmit QPSK /16-QAM data signals. Following amplification, the modulated RF signal was forwarded to the transmitter antenna.

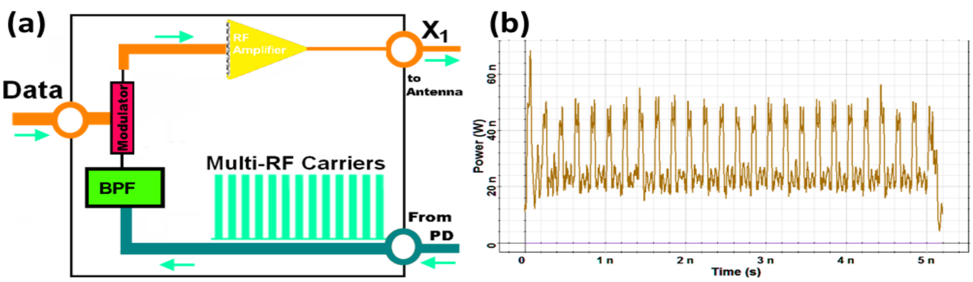

Figure 5. (a) Data modulator unit to dodulate RF carriers, (b) Transmission of 2.5GHz signals over a 250 m wireless link

The power of the detected RF signal after transmission along a 50 km fiber link and within the 250 m wireless link distance can be seen in Figure 5(b). The FWHM of the pulse shown in Figure 5(b) is 80 ps. According to the presented measurements, the proposed system of an RF signal generator based on optical solitonic input with a minimum input power of 10 dBm is applicable for a 50 km optical link and a maximum of 120 m wireless distance with QPSK modulation. The constellation diagram for 16-QAM and QPSK signals transmission are presented in Figure 6.

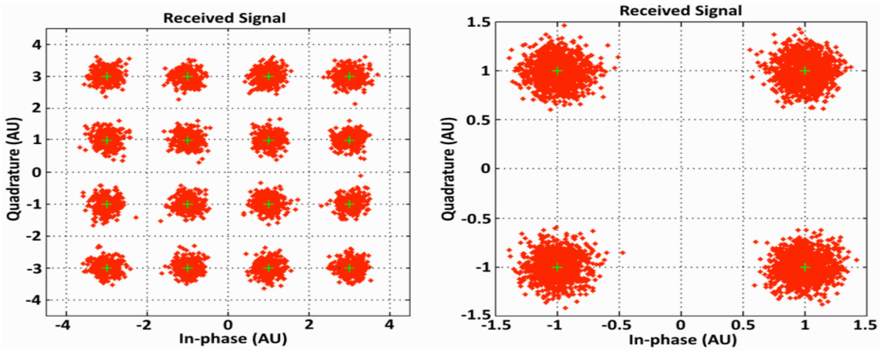

Figure 6. Constellation measurement of 16-QAM (for 40m wireless distant) and QPSK (for 120 m wireless distance)

3. Conclusion

This paper has described a proposal and successful demonstration of a ring laser system to generate soliton pulses. This ring laser system was first used to generate a soliton with differently centered wavelengths passing through a 50 km SMF and impacted on a PIN photodetector at the other end. Consequently RF arrays were generated in the range of WiFi frequencies. The RF spectrum was analyzed following propagation along a 250 m wireless link, and the power variations were measured.

References

[1] Iraj Sadegh Amiri, Abdolkarim Afroozeh, Harith Ahmad. Integrated micro-ring photonics: Principles and Applications as Slow light devices. Soliton generation and Optical transmission. United States: CRC Press. 2015.
[2] I Amiri, H Ahmad. Microring Resonator (MRR) Optical Systems Applied to Enhance the Optical Soliton Communications. Optical Communication Systems: Fundamentals, Techniques and Applications. ed: Novascience Publisher. 2015.
[3] Iraj Sadegh Amiri, Ali Nikoukar, Sayed Ehsan Alavi. Soliton and Radio over Fiber (RoF) Applications. Saarbrücken, Germany: LAP LAMBERT Academic Publishing. 2014.
[4] SE Alavi, IS Amiri, H Ahmad, ASM Supa'at, N Fisal. Generation and Transmission of 3× 3 W-Band MIMO-OFDM-RoF Signals Using Micro-Ring Resonators. *Applied Optics.* 2014; 53: 8049-8054.
[5] IS Amiri, SE Alavi, H Ahmad. Fiber laser setup used to generate several Mode-Locked pulses applied to soliton-based optical transmission link. Horizons in World Physics. USA: Novascience. 2015. 287.
[6] Iraj Sadegh Amiri, Abdolkarim Afroozeh, Alireza Zeinalinezhad. Micro Ring Resonators and Applications: New Technology of Optics. Saarbrücken, Germany: LAP LAMBERT Academic Publishing. 2014.
[7] IS Amiri, SE Alavi, H Ahmad. Optically generation and transmission ultra-wideband mode-locked lasers using dual-wavelength fiber laser and microring resonator system. Horizons in World Physics. USA: Novascience. 2015; 287.
[8] IS Amiri, SE Alavi, SM Idrus. Introduction of Fiber Waveguide and Soliton Signals Used to Enhance the Communication Security. Soliton Coding for Secured Optical Communication Link. USA: Springer. 2015: 1-16.
[9] IS Amiri, SE Alavi, H Ahmad. Microring resonators used to gain the capacity in a high performance hybrid wavelength division multiplexing system. Horizons in World Physics. USA: Novascience. 2015: 287.
[10] IS Amiri, MRK Soltanian, H Ahmad. Optical Communication Systems: Fundamentals, Techniques and Applications. USA: Novascience. 2015.
[11] H Ahmad, MRK Soltanian, IS Amiri, SE Alavi, AR Othman, ASM Supa'at. Carriers Generated by Mode-locked Laser to Increase Serviceable Channels in Radio over Free Space Optical Systems. *IEEE Photonics Journal.* 2015.

[12] H Ahmad, MRK Soltanian, Leila Narimani, IS Amiri, A Khodaei, SW Harun. Tunable S-Band Q-Switched Fiber Laser using Bi2Se3 as the saturable absorber. *IEEE Photonics Journal.* 2015; 7.
[13] IS Amiri, A Afroozeh. Integrated Ring Resonator Systems. Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton. USA: Springer. 2014.
[14] I Amiri, H Ahmad. Optical Soliton Signals Propagation in Fiber Waveguides. Optical Soliton Communication Using Ultra-Short Pulses. USA: Springer. 2015: 1-11.
[15] Iraj S Amiri. Soliton-Based Microring Resonators: Generation and Application in Optical Communication. USA: Amazon. 2015.
[16] A Afroozeh, IS Amiri, K Chaudhary, J Ali, PP Yupapin. Analysis of Optical Ring Resonato. Advances in Laser and Optics Research. New York: Nova Science. 2015.
[17] IS Amiri, A Afroozeh. Introduction of Soliton Generation. Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton. USA: Springer, 2014.
[18] IS Amiri, A Afroozeh. Soliton Generation Based Optical Communication. Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton. USA: Springer. 2014.
[19] N Madamopoulos, V Kaman, S Yuan, O Jerphagnon, RJ Helkey, JE Bowers. Applications of large-scale optical 3D-MEMS switches in fiber-based broadband-access networks. *Photonic network communications*. 2010; 19: 62-73.
[20] E Wong. Next-Generation Broadband Access Networks and Technologies. *Journal of lightwave technology*. 2012; 30: 597-608.
[21] J Chung, Y Yun, S Choi. Prototype implementation of adaptive beamforming-MIMO OFDMA system based on IEEE 802.16 e WMAN standard and its experimental results. *International Journal of Communication Systems*. 2011; 24: 1627-1646.
[22] JD Chen, FB Ueng, PF Lin. A low-complexity adaptive receiver for DS-CDMA systems in unknown code delay environment. *International Journal of Communication Systems*. 2011; 24: 225-238.
[23] IS Amiri, A Afroozeh. Mathematics of Soliton Transmission in Optical Fiber. Ring Resonator Systems to Perform Optical Communication Enhancement Using Soliton. USA: Springer. 2014.
[24] Iraj Sadegh Amiri, Sayed Esan Alavi, Sevia Mahdaliza Idrus, Mojgan Kouhnavard. Microring Resonator For Secured Optical Communication. USA: Amazon. 2014.
[25] IS Amiri, MH Khanmirzaei, M Kouhnavard, PP Yupapin, J Ali. Quantum Entanglement using Multi Dark Soliton Correlation for Multivariable Quantum Router. In: A. M. Moran. *Editors*. Quantum Entanglement. New York: Nova Science Publisher. 2012: 111-122.
[26] I Amiri, H Ahmad. MRR Systems and Soliton Communication. Optical Soliton Communication Using Ultra-Short Pulses. USA: Springer, 2015: 13-30.
[27] Iraj Sadegh Amiri, Sayed Ehsan Alavi, Sevia Mahdaliza Idrus. Soliton Coding for Secured Optical Communication Link. USA: Springer. 2014.
[28] IS Amiri, SE Alavi, SM Idrus. Theoretical Background of Microring Resonator Systems and Soliton Communication. Soliton Coding for Secured Optical Communication Link. USA: Springer. 2015: 17-39.
[29] IS Amiri, SE Alavi, SM Idrus, ASM Supa'at, J Ali, PP Yupapin. W-Band OFDM Transmission for Radio-over-Fiber link Using Solitonic Millimeter Wave Generated by MRR. *IEEE Journal of Quantum Electronics*. 2014; 50: 622-628.
[30] IS Amiri, A Afroozeh. Advances in Laser and Optics Research. USA: Novascience, 2015; 11.
[31] Iraj Sadegh Amiri, Harith Ahmad. Optical Soliton Communication Using Ultra-Short Pulses. USA: Springer. 2014.
[32] MRK Soltanian, IS Amiri. Theoretical and Experimental Method to Control Distributed Denial of Service (DDoS) Attacks. USA: Elsevier. 2-15.
[33] Iraj Sadegh Amiri, Sayed Ehsan Alavi, SM Idrus, Abdolkarim Afroozeh, Jalil Ali. Soliton Generation by Ring Resonator for Optical Communication Application. New York: Novascience Publishers. 2014.
[34] IS Amiri, A Afroozeh. Spatial and Temporal Soliton Pulse Generation By Transmission of Chaotic Signals Using Fiber Optic Link. Advances in Laser and Optics Research. New York: Nova Science Publisher. 2015; 11.
[35] I Amiri, H Ahmad. Ultra-Short Solitonic Pulses Used in Optical communication. Optical Soliton Communication Using Ultra-Short Pulses. USA: Springer. 2015: 47-51.
[36] I Amiri, M Soltanian, H Ahmad. Application of Microring Resonators (MRRs) in Optical Soliton Communications. Optical Communication Systems: Fundamentals, Techniques and Applications. Novascience Publisher. 2015.
[37] Abdolkarim Afroozeh, Iraj Sadegh Amiri, Alireza Zeinalinezhad, Harith Ahmad. Characterization and Controlling of Soliton Signals Generated by Semiconductor Microring Resonators. USA: Springer. 2015.
[38] IS Amiri. Light Detection and Ranging Using NIR (810 nm) Laser Source. Germany: LAP LAMBERT Academic Publishing. 2014.
[39] G Agrawal. Applications of nonlinear fiber optics. Academic press. 2010.

[40] IS Amiri, SE Alavi, SM Idrus. Results of Digital Soliton Pulse Generation and Transmission Using Microring Resonators. Soliton Coding for Secured Optical Communication Link. USA: Springer. 2015: 41-56.
[41] Iraj Sadegh Amiri and Abdolkarim Afroozeh. Ring Resonator Systems to Perform the Optical Communication Enhancement Using Soliton. USA: Springer. 2014.
[42] I Amiri, H Ahmad. Solitonic Signals Generation and Transmission Using MRR. Optical Soliton Communication Using Ultra-Short Pulses. USA: Springer. 2015: 31-46.
[43] IS Amiri, SE Alavi, MRK Soltanian, N Fisal, ASM Supa'at, H Ahmad. Increment of Access Points in Integrated System of Wavelength Division Multiplexed Passive Optical Network Radio over Fiber. *Scientific Reports.* 2015; 5.