CRYPTOGRAPHY SCHEME OF AN OPTICAL SWITCHING SYSTEM USING PICO/FEMTO SECOND SOLITON PULSE

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ABSTRACT
We propose a system of microring resonators (MRRs) incorporating with an add/drop filter system. Optical soliton can be simulated and used to generate entangled photon, applicable in single and multiple optical switching. Chaotic signals can be generated via the MRRs system. Therefore continuous spatial and temporal signals are generated spreading over the spectrum. Polarized photons are formed incorporating the polarization control unit into the MRRs, which allows different time slot entangled photons to be randomly formed. Results show the single soliton pulse of 0.7 ps where the multi soliton pulse with FSR and FWHM of 0.6 ns and 20 ps are generated using the add/drop filter system. Here Ultra-short single soliton pulse with FWHM=42 fs can be simulated. These pulses are providing required communication signals to generate pair of polarization entangled photons among different time frame where the polarization control unit and polarizer beam splitter (PBS) are connected to the ring resonator system.

KEYWORDS: *Microring Resonator, Photon, Spatial and Temporal Soliton.*

I. INTRODUCTION

Photon switching is concerning field of optical communication [1], where it employs quantum cryptography in a mobile telephone network, which is described by Yupapin [2]. Quantum key distribution supplies the perfect communication security [3-4]. Hence quantum cryptography can be performed through an optical-wireless link [5]. Research works have shown that techniques of continuous variable quantum cryptography are aimed and applied on the micro ring resonators [6]. Entangled photon pairs are an important resource in quantum optics [7], and are essential for quantum information [8] applications such as quantum key distribution [9-10] and controlled quantum logic operations [11]. Furthermore, control over the pair generation time is essential for scaling many quantum information schemes beyond a few gates. New quantum key distribution protocol points that data can be encoded on continuous variables of a single photon [12]. In order to give rise a range of light throughout a wide range, an optical soliton signal is suggested as an improved laser pulse used to make chaotic filter characteristics when propagate inside MRRs [13-16]. The capacity of the system can be increased when the chaotic packet switching is employed [17-20]. We propose a system that purposes localized soliton pulses [21] to figure the high capacity and security communication [22-25]. It is used to trap optical solitons to generate entangled photon pair [26-27]. Furthermore, the continuous variable quantum codes can be generated using the polarizer and beam splitter systems

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II. THEORY AND SYSTEM

Schematic diagram of the proposed system is as shown in figure 1. A soliton pulse with 20 ns pulse width, peak power at 500 mW is inserted into the system. The parameters of the system are fixed to λ_0=1.55μm [29], n_0=3.34 (InGaAsP/InP) [30-32], A_{eff}=0.50, 0.25μm^2 and 0.12μm^2 for the different radii of microring resonators respectively, α=0.5dBmm^{-1}, γ=0.1 [33-36]. The coupling coefficient (kappa, κ) [37] of the micro ring resonator ranged from 0.50 to 0.975 [38-39].

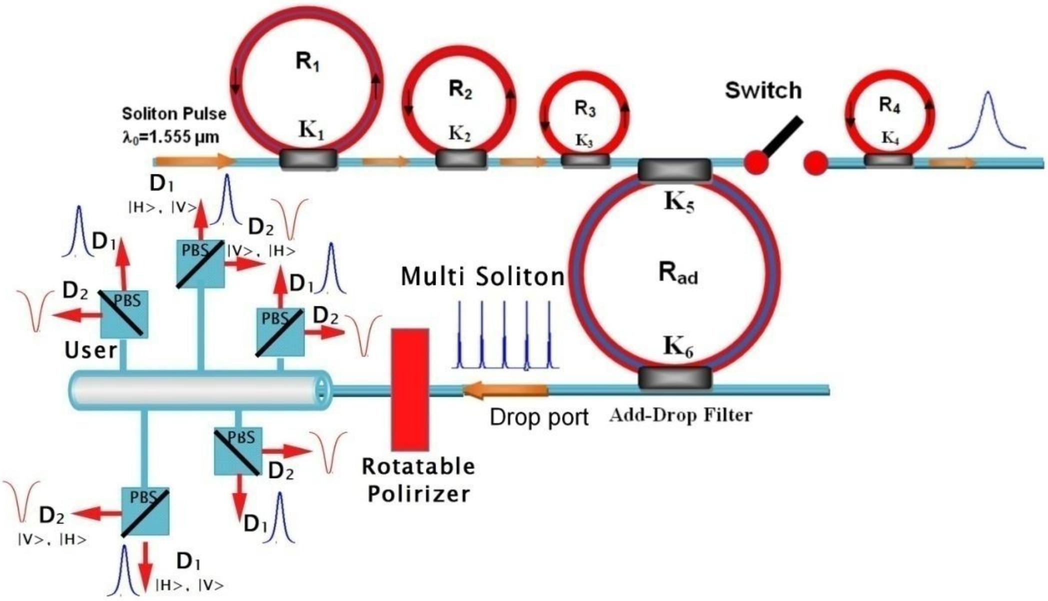

Fig.1: Schematic diagram of a single and multiple narrow pulse switching generation for continuous variable quantum key distribution with the different time slot, where PBS, polarizing beam splitter, Ds, detectors, Rs, ring radii and κs, coupling coefficients

Input optical field (E_{in}) of the bright soliton pulse can be expressed as [40-41],

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

A and z are the optical field amplitude and propagation length, respectively [42-43]. T is a soliton pulse propagation time in a form proceeding at the group speed [44-45], T = t-β_1×z, where β_1 and β_2 [46] are the coefficients of the linear and second order terms of Taylor expansion of the propagation constant [13]. $L_D = T_0^2/|\beta_2|$ is the dispersion length of the soliton pulse [47]. The frequency carrier of the soliton is w_0 [48-50]. When soliton peak intensity $\left(|\beta_2/\Gamma T_0^2|\right)$ is given, and then T_o is known [51-52]. The nonlinear length is given by $L_{NL} = 1/\Gamma\varphi_{NL}$ where Γ = n_2×k_0 is the length scale, thus $L_{NL} = L_D$ should be satisfied [53]. The refractive index (n) of light within the medium is given by [54]

$$n = n_0 + n_2 I = n_0 + (\frac{n_2}{A_{eff}})P, \tag{2}$$

where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively. *I* and *P* are the optical intensity and optical power, respectively. The effective mode core area of the device is shown by A*eff*. The effective mode core areas range from 0.50 to 0.10 μm^2 [54]. The resonant output is formed, thus, the normalized output [55] of the light field is the ratio between the output and input fields E_{out} (t) and E_{in} (t) in each roundtrip, which can be expressed as [56]

$$\left|E_{out}(t)\right|^2 = \left|E_{in}(t)\right|^2 \times (1-\gamma) - \frac{(1-x^2+2\gamma x^2-\gamma-\gamma^2 x^2)\kappa}{(1-x\sqrt{1-\gamma}\sqrt{1-\kappa})^2+4x\sqrt{1-\gamma}\sqrt{1-\kappa}\sin^2(\frac{\phi}{2})} \tag{3}$$

Here the particular case of a Fabry-Perot cavity, which has an input and output mirror with a field reflectivity, $(1-\kappa)$, and a fully reflecting mirror is presented [57-58]. κ is the coupling coefficient, and $x=\exp(-\alpha L/2)$ represents a roundtrip loss coefficient, $\Phi_0=kLn_0$ and $\Phi_{NL}=kLn_2|E_{in}|^2$ are the linear and nonlinear phase shifts, $k=2\pi/\lambda$ is the wave propagation. L and α are a waveguide length and linear absorption coefficient, respectively [59]. The simulated results are based on the solution of the nonlinear Schrödinger Equation (NLSE) for the case of ring resonators using MATLAB programming.

III. Simulation of Result and Discussion

The large bandwidth within the micro ring device can be generated where required signals can perform the fix communication network. The nonlinear refractive index is $n_2=1.5 \times 10^{-20}$ m^2/W. In this case, the wave guide loss used is 0.5dBmm^{-1}. As shown in figure 2, large bandwidth is formed within the first and second rings device. The compress bandwidth is obtained within the ring R_3 and R_4. The attenuation of the optical power within a microring device is required in order to keep the constant output gain. The ring radii R_1=10 µm, R_2=7µm, and R_3=5µm and R_4=2µm.

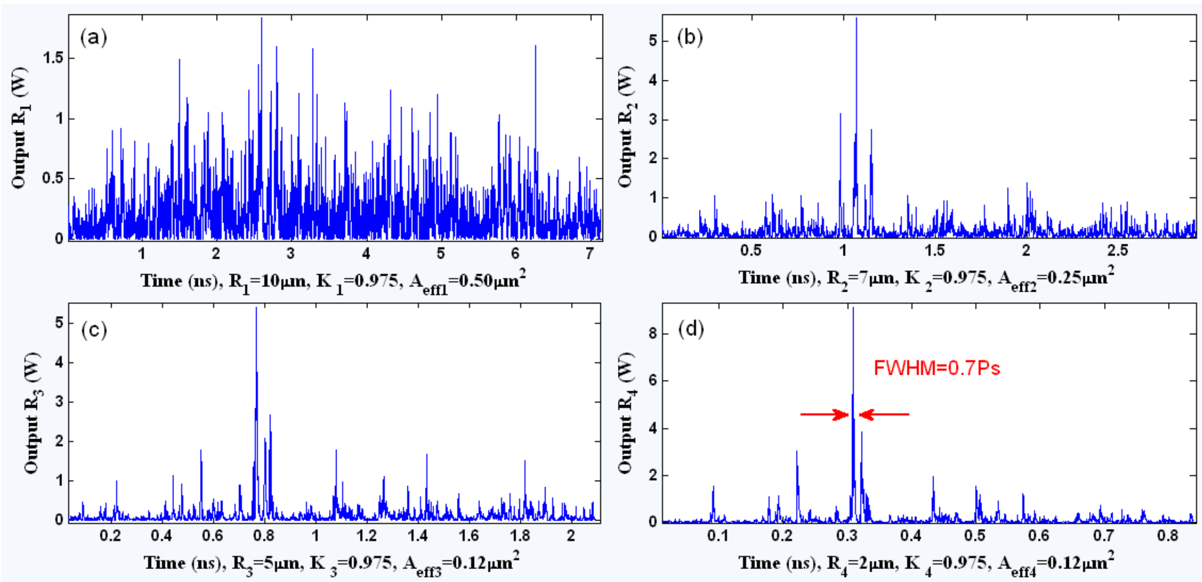

Fig. 2: Results obtained when temporal soliton is localized within a microring device with 20,000 roundtrips, where (a): Chaotic signals from R_1, (b): Chaotic signals from R_2, (c): Trapping of temporal soliton, (d): Localized temporal soliton with FWHM of 0.7 ps

Figure 3 shows the results when temporal and spatial optical soliton pulses are localized within a microring device and add/drop filter system with 20,000 roundtrips, where the single soliton with FWHM=42fs is generated. The multi soliton can be generated with FWHM and FSR of 20 Ps and 0.6 ns respectively. Here, the ring radii and their coupling coefficients are the same and R_{ad}= 200 µm with coupling coefficient of $\kappa_1 = \kappa_2 = 0.1$.

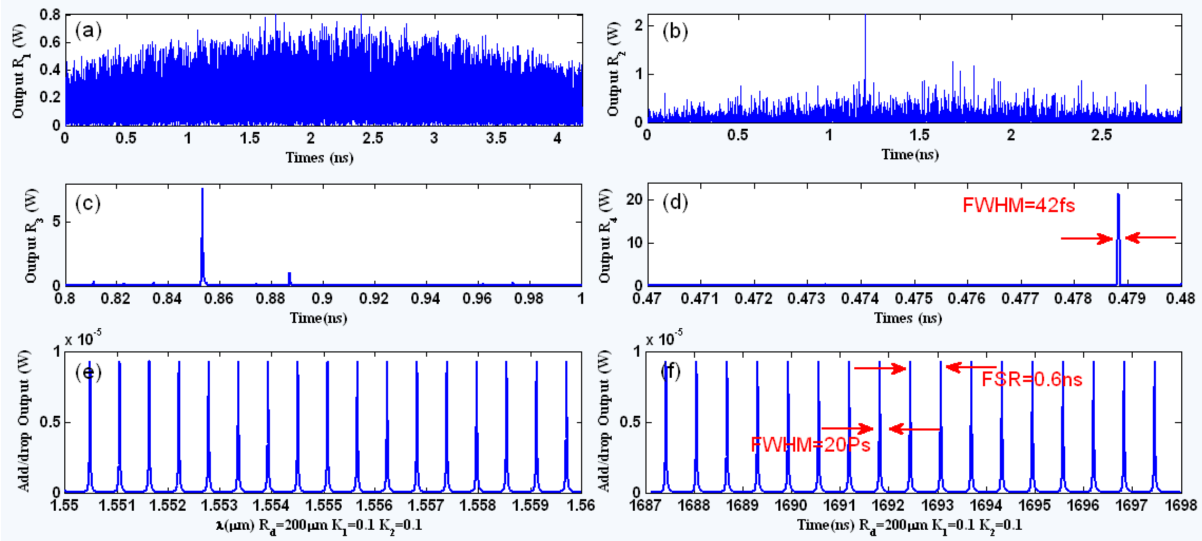

Fig. 3: Results of temporal and spatial soliton generation, where (a): Chaotic signals from R_1, (b): Chaotic signals from R_2, (c): filtering signals, (d): Localized temporal soliton with FWHM of 42 fs, (e): Spatial soliton pulses, (f): Temporal soliton with FSR=0.6 ns and FWHM=20 ps

Thus each pair of polarization entangled photons can be made among different time frame by applying the polarization control unit and polarizer beam splitter (PBS) demonstrated in figure1. They can be constituted by the two polarization orientation angles as [0°, 90°] [60]. Here we bring in the technique that is used to generate the photon. A polarization device distinguishes the basic vertical and horizontal polarization states represent to an optical switch between the short and the long pulses. We presume those horizontally polarized pulses with a temporal separation of Δt. The coherence time of the consecutive pulses is larger than Δt. Then the pursuing state at time t_1 is produced by equation (4).

$$|\Phi\rangle_p = |1, H\rangle_s |1, H\rangle_i + |2, H\rangle_s |2, H\rangle_i \tag{4}$$

In the formula $|k, H\rangle$, k is determined as the number of time slots (1 or 2), where it announces the state of polarization [horizontal $|H\rangle$ or vertical $|V\rangle$] [61]. The subscript identifies the signal (s) or the idler (i) state. The delay circuit comprises of a coupler and the difference between the round-trip times of the micro-ring resonator, which is equal to Δt [62]. The $|H\rangle$ can be converted into $|V\rangle$ at the delay circuit output that is the delay circuits convert

$$r|k, H\rangle + t_2 \exp(i\Phi) |k+1, V\rangle + rt_2 \exp(i_2\Phi) |k+2, H\rangle + r_2t_2 \exp(i_3\Phi) |k+3, V\rangle \tag{5}$$

Where t and r is the amplitude transmittances to cross and bar ports in a coupler. Then equation (4) is convinced into the polarized state by the delay circuit as

$$\begin{aligned} |\Phi\rangle =& [|1, H\rangle_s + \exp(i\Phi_s) |2, V\rangle_s] \times [|1, H\rangle_i + \exp(i\Phi_i) |2, V\rangle_i] \\ &+ [|2, H\rangle_s + \exp(i\Phi_s) |3, V\rangle_s \times [|2, H\rangle_i + \exp(i\Phi_i) |2, V\rangle_i] = \\ &[|1, H\rangle_s |1, H\rangle_i + \exp(i\Phi_i) |1, H\rangle_s |2, V\rangle_i] + \exp(i\Phi_s) |2, V\rangle_s |1, H\rangle_i + \\ &\exp[i(\Phi_s+\Phi_i)] |2, V\rangle_s |2, V\rangle_i + |2, H\rangle_s |2, H\rangle_i + \exp(i\Phi_i) |2, H\rangle_s |3, V\rangle_i + \\ &\exp(i\Phi_s) |3, V\rangle_s |2, H\rangle_i + \exp[i(\Phi_s+\Phi_i)] |3, V\rangle_s |3, V\rangle_i \end{aligned} \tag{6}$$

As an outcome, we can get the following polarization entangled state as

$$|\Phi\rangle = |2, H\rangle_s |2, H\rangle_i + \exp[i(\Phi_s+\Phi_i)] |2, V\rangle_s |2, V\rangle_i \tag{7}$$

Because of the Kerr nonlinearity of the optical device, the strong pulses acquire an intensity dependent phase shift throughout propagation [63]. The polarization angle adjustment device is utilized to investigate the orientation and optical output intensity depicted [64]. Therefore, signal of solitons can be used to generate photon which is secured and unknown during propagation within communication systems [65]. Generated secured photons can be transferred via a wireless access point, and network communication system shown in figure 4.

Fig.4: System of optical photon transmission using a router and wireless access point

A wireless access system transmits data to different users via wireless connection [66-67]. The transmission of information can be sent to the Internet using a physical, wired Ethernet connection [68]. This method also works in reverse, when the router system used to receive information from the Internet, translating it into an analog signal and sending it to the computer's wireless adapter.

IV. FUTURE WORK

It is very difficult to construct a useful quantum key distribution system based on the entanglement photon generation and switching. To overcome this problem, a quantum memory can be used to store the quantum state of light. A ring resonator system can act as a quantum memory in which a quantum state of a photon will transfer to another quantum system. So, after the storage has been done for a very short time of nano or picosecond, the quantum state can be converted back to a photon state at an arbitrary time. Therefore, the probability of entanglement switching can be improved and the decay of the entanglement photon generation rate is avoided. The technique of quantum entanglement photon switching is called a quantum repeater which uses entangled states stored in quantum memories.

V. CONCLUSION

Photon can be performed using single and multiple temporal and spatial soliton pulses generated by MRR system. We have shown that a large bandwidth of the arbitrary soliton pulses can be generated and compressed within a micro waveguide. The chaotic signal generation using a soliton pulse in the nonlinear micro ring resonators has been presented. Localized light of soliton perform secure and high capacity of optical communication. Localized spatial and temporal soliton pulse is useful to generate entangled photon pair providing quantum key applicable for communication wireless networks. In this study ultrashort of single optical soliton with FWHM=0.7 ps and 42 fs and multi optical soliton which FWHM and FSR of 20 ps and 0.6 ns were generated propagating along the entangled photon generation system which is connected to the drop port of the add/drop filter system connecting to series of microring resonators. Thus we have analyzed the entangled photon generated by chaotic signals in the series MRR devices applicable in optical wireless communication systems.

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