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Polarized soliton pulses generation using nonlinear micro ring resonators for multi- and long distance links

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Abstract

We propose a new concept of quantum soliton pulses generation using a soliton pulse in the micro ring resonators. Firstly, the chaotic soliton pulses are generated and circulated within the integrated micro ring resonators. Secondly, the specific second harmonic pulses are selected by using the appropriate ring parameters. The superposition of the second harmonic pulses within the micro ring devices introduces the randomly polarized photons within the micro ring device. The entangled photon visibility of the polarized photon is seen after passing the polarization control devices and projecting on the detectors. The optimum entangled photon visibility is obtained. The advantage of such a system is that the quantum repeater unit can be redundant for long distance quantum communication link, whereas the use of the system for multi-entangled photon sources and links is also available. The system degradation via the entangled photon states timing walk-off is also discussed.

Keywords: Quantum soliton; Chaotic quantum; Quantum communication; Quantum information

1. Introduction

Quantum security has shown the promising indication of the realistic application for perfect security, whereas the message (i.e. telephone conversation) in the classical channel could be multiplexed with the secure quantum codes (qubits). Some research works in several techniques have shown the potential of applications [1–3]. They have shown that the entangled photon pair can be used as the quantum bits, where the random entangled states can be used to generate the random codes (0 and 1). However, the problem of the system degradation due to walk-off effects [4,5] and power loss in long distance link remains. Furthermore, the problem of polarization dispersion causes the entangled photon a problem which is called entangled state timing walk-off, which is become a problem in the recovery process. In practice, to solve such a problem, a technique called walk-off compensation and a quantum repeater are recommended to implement into the long distance link. To date, the searching of new device for mobile telephone hand set that capable to implement the said technology within the device is very attractive, i.e. quantum encoding. Fortunately, it seems that the scale of such a device (i.e. micro ring) is dramatically decreased, where

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the device scale of few microns is fabricated and available [6,7]. One of the promising aspects is that such a device can be fabricated to process the signal processing within the small device, where the secured message, i.e. security, can be performed [8]. Some techniques such as chaos [9,10], quantum entanglement [1] and chaotic quantum [11] have shown the potential of applications for communication security, however, the problem of signal taping and signal degradation remains in long distance link. Recently, Khunnan and Yupapin [12] have shown that the entangled photon recovery i.e. regeneration using fiber optic ring resonator incorporating an EDFA, which is useful for long distance link. In this paper, we propose the system that can be implemented for secure long distance link. Firstly, the chaotic signals are generated by a soliton pulse within the micro ring resonators. Secondly, the quantum codes are generated by a micro ring device and a polarization control unit. The high-power second harmonic pulses can be performed the strong entangled photon pair, which is capable for long distance link. Further, the multi-entangled photon sources are also available, which also discussed in details.

2. Operating principle

To generate the ultra short pulse, the optical soliton is introduced into the multi-stage micro ring resonators. The input optical field in the form of soliton pulse is expressed by an Eq. (1) [13].

$$E_{\text{in}} = A\,\text{Sech}\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right)\right] \tag{1}$$

where A and z are the optical field amplitude and propagation direction, respectively. $L_D = T_0^2/|\beta_2|i$ is the dispersion length of the soliton pulse. This solution describes a pulse that keeps its temporal width invariant as it propagates and thus is called a temporal soliton. T_o is known, once we can find the proper peak intensity $(|\beta_2|/\gamma T_0^2)$ that will make this pulse a soliton. For example, when the micro ring resonator at the 1550 nm wavelength, with a 12 W peak power, then $T_0 = 50$ ps long, which is a pulse of about 2 mm length (in z). For the soliton pulse in the micro ring device, a balance should be achieved between the dispersion lengths $L_D = (T_0^2/|\beta_2|)$ and the nonlinear length $L_{NL} = (1/\gamma\psi_0)$, which are the length scales over which dispersive or nonlinear effects make the beam become wider or narrower. For a soliton pulse, there is balance between the two and hence $L_D = L_{NL}$.

When the optical field (i.e. soliton pulse) is input into the nonlinear micro ring resonator, the relationship between the output and input optical fields is given by Eq. (2) [9].

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

A close form of Eq. (2) indicates that a ring resonator in the particular case to very similar to a Fabry–Perot cavity, which has an input and output mirror with a field reflectivity, $1-\kappa$, and a fully reflecting mirror, where n_0 and n_2 are the linear and nonlinear refractive indices, the coupling coefficient is κ. Where $x = \exp^{-(\alpha L/2)}$ represents the one round-trip losses coefficient, $\phi_0 = kLn_0$ and $\phi_{NL} = kLn_2|E_1|^2$ are the linear and nonlinear phase shifts, respectively, $k = 2\pi/\lambda$ is the wave propagation number in vacuum.

The remarkably simple system of the intense short pulse generation using a serial micro ring resonator is

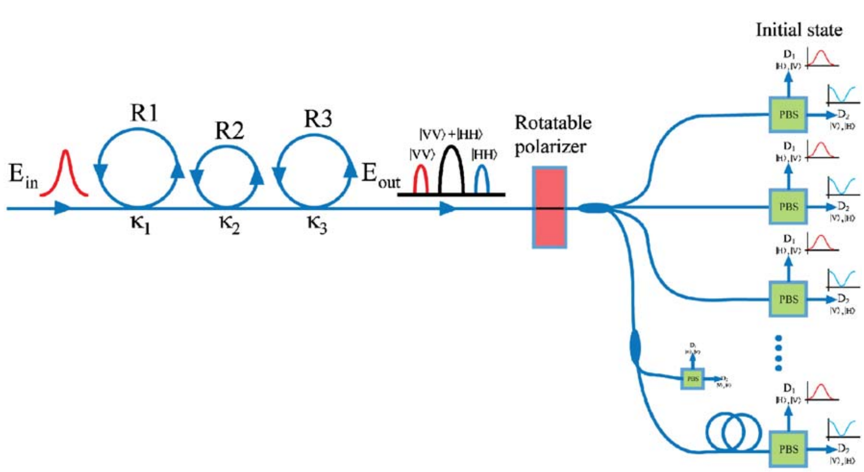

Fig. 1. Show a schematic diagram of the micro ring resonators for long distance link, where PBS is a polarizing beam splitter and Ds are the avalanched detectors.