MICRO RING RESONATOR FOR COMMUNICATION SECURITY

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To my beloved parents and my brother (Morteza)
“Your encouragement & all you have supported me”

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ABSTRACT

A novel system of dark soliton array (DSA) for secured communication generated by using the multiplexed dark soliton pulses is proposed. The multi soliton pulses with relevant parameters are input into the micro ring resonators system with the radii of $10\mu m\ and\ 5\mu m$, where the dynamic dark solitons can be controlled and generated. The DSA are obtained by using a series micro ring resonators with parameters where in the wavelength range of λ_1 is 1.56 , λ_2 is 1.58 and λ_3 is 1.60. For security applications, the DSA can be tuned and amplified. Thus, the use of DSA for high capacity which can be realized by using proposed secured system. In transmission, the long distance link of the multi variable network can be performed by this DSA.

ABSTRAK

Satu sistem baru dari susunan soliton gelap (DSA) untuk keselamatan komunikasi yang dihasilkan dengan beberapa denyutan soliton gelap dicadangkan. Denyutan multi soliton dengan parameter yang tepat dimasukkan ke dalam sistem penyalun cecincin mikro dengan jejari 10 μm and 50 μm dimana soliton gelap dinamik boleh dikawal dan dijanakan. DSA ini diperoleh dengan menggunakan siri penyalur cecincin mikro dengan beberapa parameter yang sesuai dimana julat panjang gelombang adalah λ_1=1.56 μm, λ_2=1.58 μm, dan λ_3=1.60 μm. Untuk aplikasi keselamatan, DSA boleh diselaraskan dan digandakan. Maka, penggunaan DSA untuk kapasiti yang tinggi dapat diwujudkan dengan menggunakan sistem yang dicadangkan. Dalam penghantaran, laluan jarak jauh dari rangkaian multi pembolehubah boleh dilakukan dengan menggunakan DSA yang dicadangkan.

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CHAPTER 1

1.1 Introduction

Soliton has been known as a nonlinear solitary wave for year[1]. In general the common property of soliton is known as the self-phase modulation (SPM) which is the chaotic and challenging behavior. The non-dispersive behavior of the soliton is the main advantage .It may be used in long distance communication link where the long distance link without a repeater can be employed. The other interesting behavior is the localization effect where the soliton pulse can be trapped and stored within a periodic medium which is useful in many area of applications[2]. In the context of nonlinear optics, soliton are classified as being temporal or spatial, depending on whether confinement of light happen in time or space during the wave propagation.

Temporal soliton represents optical pulses that maintain their shape however spatial solitons represent self-guide beams that remains confined in the transverse directions orthogonal to the direction of propagation. Both types of soliton evolve from nonlinear change in the refractive index by the light intensity. This is known as optical Kerr effect [3]. This occurs, when the intensity of light pulses are strong enough to modify the refractive index (n) of the fiber.

$$n = n_0 + n_2 I = n_0 + (\frac{n_2}{A_{eff}})P \qquad (1.1)$$

where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively. I and P are the optical intensity and optical power, correspondingly and A_{eff} is the effective mode core area of the fiber.

In terms of intensity, soliton is classified as dark and bright soliton where dark soliton are characterized by being formed from a localized reduction of intensity compared to a continues wave while a bright soliton is characterized as a localized intensity peak above a continues wave (CW) background, so the dark soliton is featured as a localized intensity dip below a continues wave (CW) background.

1.2 Background of study

Solitons has been considered as solitary wave[4-5]. It was first observed by a Scottish engineer, John Scott Russell in 1834, when he saw a rounded, smooth and well-defined heap of water separated itself from the prow of barrage brought to rest and proceed without changing of its shape or reduction in speed for over two miles along the union canal linking Edinburgh with Glasgow. This observation contradicts the nonlinear theory of airy published in 1845, which predicted that the wave with evaluation of finite amplitude cannot propagate without change of its form. According to his theory the wave should get steeped and eventually break. The controversy of Russell's observation arises because the nonlinear shallow-water theory neglects the dispersion. Generally it prevents wave steepening. The problem was solved by Joseph Boussinesq [6] in 1871 and Lord Rayleigh[8]in1876 independently. They made the important contributions to the topic of solitary wave by showing that if one ignores dissipation, the increase in local wave velocity associated by finite amplitude is balanced by the decrease associated with dispersion leading to the wave of permanent form. In 1895,Korteweg de Vries derived a model equation which describe the unidirectional propagation of the waves of long wavelength in water of relatively shallow depth [7]. This equation is known as Kortage de Vries equation (KdV) which shows the periodic solution of that equation. They name cnodial waves can be found in closed form and without further approximation.

In the same year that the operative fiber transmission systems were developed, Hasegawa predicted the short optical at the wavelength for anomalous dispersion can propagate in the fiber as an optical soliton [8]. Continuously, in 1974 the existence of soliton (spatial soliton) was reported by Ashkin and Bjorkholm in a cell filled with sodium vapor [9]. It was more than ten years ago this field was revisited in experiments, at Limoges University in liquid carbon disulphide [10]. After all these experiments spatial solitons have been demonstrated in glass, semiconductors and polymers [11-12]. The historical perspectives of the solitary wave are shown in Table 1.

Table 1.1: Historical Review of Soliton

year

- **Historical perspectives**

1808-1882

- Soliton was first described by John Scott Russe.

1965

- Norman Zabusky of Bell Lab and Martin Kruskal of Princeton University first demonstrated soliton behavior in media subject to Kortewag-de Varies (kdv) in equation which is nonlinear partial differential equation of the third order.

1967

- Gardner,Greene,Kruskal and Miura discovered an inverse scattering transform enabling analytical solution of kdv equation.

1973

- Akira Hasegawa of AT&T Bell labs was the first to suggest that solitons could exist in optical fibers.

1998

- Linn Mollenauer and his team transmitted soliton pulse over 4,000 kilometers using Raman effect ,named after the Indians scientist Sir C.V. Raman

1991

- Bell Lab research team transmitted soliton error-free at 2.5 GB over more than 14000 kilometers,using erbium optical fiber amplifiers (EOFA).

1998

- Thierry Georges and his team at France Telecom R&D Center,combining optical solitons of diffrent wavelengths (wavelength division multiplexing).

2001

- The practical use of soliton became a reality when Algety Telecom deployed submarine telecommunications equipment in Europe carrying real traffic using John Scott Russell's solitary wave

2002

- Alexander V. Buryak study on Optical solitons due to quadratic nonlinearities from basic physics to futuristic applications

2003

- Kivshar Agrawal published a book by the title of Optical solitons : From fibres to photonic crystals

2004

- Akira Hasegaw studied on the Effect of polarization mode dispersion in optical soliton transmission in fibers

2005

- M. F. Ferreira worked on optical Solitons in Fibers for Communication Systems to solve a long distance transmission

2006

- Mishra.M writing a book about Interaction of Solitons in a Dispersion Managed Optical Communication System with Asymmetric Dispersion Map

1.3 Problem Statement

In order to understand why optical solitons are needed in optical fiber communication system, the problems that limit the distance and/or capacity of optical data transmission should be considered. A fiber-optic transmission line consists of transmitter and a receiver connected with each other by a transmission optical fibers which have chromatic dispersion, losses (attenuation of signal), and nonlinearity that lead to distortion of signal [13]. Due to the fact that optical receiver has a finite sensitivity, the signal should have a high-enough level to achieve error-free performance of the system. On the other hand by increasing the signal level, nonlinear effect in the fiber also increase. To compensate these problem, the optical amplifiers is needed along the transmission line therefore, a new source of errors will be introduced to the system [14].

To keep the signal to noise ratio (SNR) high enough for the error-free system performance, one has to increase the signal level and hence reduce the potential problems caused by the nonlinear effects. The idea of soliton transmission is to guide the nonlinearity to the desired direction and used it for the desired benefit. When the soliton pulses are used to as an information carrier, the effect of dispersion and nonlinearity balance or compensate each other which can be satisfy by using dark soliton, then pulses propagate through the fiber without changing their spectral and temporal shapes.

In addition, in the area of communication security, the power attenuation of the output signal becomes a problem in terms of network security over the long distance link, thus the high quality of the pulses again and return to zero (RZ) nature of the data suggest dark soliton to be suitable candidate for all optical communication network [15].

1.4 Objective

To propose the use of dark soliton in dark soliton array resonators for secured communication link

1.5 Scope of Research

We propose a system of dark soliton array (DSA) generated by using the multiplexed darks soliton pulses which are input into micro ring resonator where the dynamic dark solitons are controlled and the required array generated. The stable DSA are obtained by using a series microring and nanoring resonators with some suitable parameters. The various areas of applications such as dark-bright soliton conversion and power amplification will be proposed and dark soliton array will be developed.

1.6 Significance of study

One of the interesting applications is optical communication which can be secured by using the dark soliton input to the micro ring resonator. Also the ability to slow down the propagation speed of the light, and stop or store optical pulses is achieved.