Chapter 2
Literature Review

2.1 Introduction

This chapter begins with the historical perspectives of the optical solitons. The bright and dark solitons characteristics are studied. In addition, the historical backgrounds of the ring resonators, including micro- and nanoring resonators are also discussed in details. Finally, the potential applications related to this research work are reviewed.

2.2 Historical Background

A German astronomer, Johannes Kepler was first purposed the radiation pressure theory in 1619 (Chen et al. 2009). Radiation pressure is the pressure associated with the interaction of electromagnetic radiation on any given surface. He managed to explain physical phenomenon of comet tails which always pointing away from the sun because of the radiation pressure exert by sunlight (Svoboda and Block 1994).

In 1873, James Clerk Maxwell proposed the electromagnetism theory (Ashkin 1997) and described the existence of extremely small optical forces associated with electromagnetic fields. He managed to explain the electromagnetism theory precisely. However, the existence of this tiny optical force on absorbing gasses and microscopic objects was described by Russia physicist, Peter Lebedev in 1901 (Ashkin 2000). Since that time, this field has undergone a slow-moving development and innovation due to its feeble magnitude and insignificant impact on particles.

This field of study continues to grow tremendously after the invention of light amplification of stimulated emission of radiation in 1960s (Pralle et al. 2000) known as laser. Laser ensures the high intensities and collimated light which become very useful in enhancing radiation pressure. Advent of laser has enabled numerous of research and developments in this area.

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2.3 Bright and Dark Solitons

Solitons are the localized excitations propagating in a system with constant velocity colliding with each other without change in their shape (Sarapat et al. 2009). Soliton can be divided into two, which are bright and dark solitons.

In the case of self-defocusing, the general form of the bright soliton is given as (Kivshar and Agrawal 2003):

$$u(z, x) = A\,\mathrm{sech}[A(x - vz)]\exp i[vz + (\varphi(z, x))] \tag{2.1}$$

where A is the amplitude of the soliton and v is its velocity.

In the self-defocusing Kerr medium, the continuous-wave plane-wave soliton is always stable against small modulation. The dark soliton can be stated as (Chen et al. 2012):

$$u(z, x) = u_o\{B\tanh[u_o B(x - Au_o z)] + iA\}\exp\left(-iu_o^2 z\right) \tag{2.2}$$

where $A^2 + B^2 = 1$.

In the special case, (when $\phi = 0$) dark soliton doesn't move against the background and it is kept in stationary condition (Masi et al. 2010). In this case, (2.2) reduced to:

$$u(z, x) = u_o\tanh(u_o x)\exp\left(-iu_0^2 z\right) \tag{2.3}$$

The characteristics of the bright soliton depend on the amplitude, A and the velocity, v while the speed of the dark soliton depends on its amplitude through the parameter ϕ.

2.4 Optical Trapping

The field of optical trapping was pioneered introduced by Arthur Ashkin in early 1970 (Ashkin 1997). The usage of intense laser beam has overcome the major problem of extremely small magnitudes of optical forces. Realization of the large magnitudes of optical forces allows this phenomenon to be studied well. His first experimental works are considered as an important breakthrough in this research area. By using forces of radiation pressure from a continuous wave visible laser source, he managed to observe the acceleration of freely suspended micron-size particles. This work have led to the first process of trapping particles in optical potential well which created by using two identical counter propagating laser beams. The stability of the potential well arises from the combination of radiation pressure and gradient force of the laser.

Arthur Ashkin following work is on the optical levitation process. In this work, he has experimentally demonstrated stable levitation of transparent glass sphere by using a laser in different types of medium. During experiment, light beam are directed to strikes a sphere with higher refractive index, n compared to the surrounding medium where it was suspended. This process has successfully proved the existence of another component of force which tends to push the trapped particles towards the center of the beam, which is the region where light intensity is highest. Discovery of the force provides a better understanding on possibilities to create a stable optical potential wells by using a single laser beam.

The potential shown by this technique is the main reason why this technique went into numbers of theoretical and experimental studies over the decades. Levitation of different particles in different medium such as in air and vacuum has been demonstrated in various kinds of research and studies. During those invention years, one of the most important studies has been carried out on optical levitation of liquid drops (Rafizadeh 1997). The study has discovered that not only solid particles can be trapped, but this technique also works on liquid particles. The journal also highlights on some important elements that need to be considered, such as trapping of multiple particle and its restriction.

This technique continues to evolve as time goes by. Finally in 1986, a major breakthrough on this technique has been recorded in history. Ashkin and his co-workers at Bell Labs went into successful discovery on new method to trap a particle by using only single laser beam. This technique is called “single-beam force trap” or commonly referred to as an optical tweezers (Ashkin 2000). Technically, the generation of optical tweezers involves process of focusing a laser beam upon a high numerical aperture microscope objective lens in water immersion. This step allows a strong convergent ray of light to be focused in a small area, which contains very strong electric field gradients compare to the one produced in previous experiment using a normal laser beam. During experiments, it turns out that particles are attracted along the gradient towards the center of the beam with high intensity observed. Geometry of the particle thus allows the forces to be stabilized in transverse direction.

In previous levitation process, axial gradient force is too small that just enough to balanced up with gravitational force to ensure the axial stability. They have shown that by using extremely focused laser beam, magnitude of the force produced is very large that it dominates the axial stability of the trap. By considering geometry of the particle, contributions from both components of forces are enough to ensure the capability of this optical tweezers to hold microscopic particle stable in 3 dimensions. They managed to extend the size regime of trapping for various applications covering macromolecules, colloids, aerosol particles and look into possibility in trapping of biological particles.

However, there are lots of arguments that have been considered on trapping biological specimens since there appear no experimental and theoretical works that have been done on this kind of sample. The main concern of this process was to ensure that the forces used to trap the sample might not cause “opticution”, the term referred to cell damage by interaction with high flux of laser beam. This kind of interaction leads to two major consequences that can cause harms in biological samples especially living cells. First, it will break the covalent bond between biological molecules and second, it will cause excessive heating associated with optical absorption of the samples. Researchers from all over the world continued to put some efforts on this subject and carried out numbers of experiments regarding to this technique. Finally, after years of invention, trapping of biological sample has been performed for the first time in 1987s. They have experimentally reported process of trapping and manipulation of viruses and bacteria by using optical tweezers (Dai et al. 1998). During experiments, single tobacco mosaic virus and *Escherichia coli* (*E. coli*) bacteria were trapped in aqueous chamber filled with water. Observation shows that both samples were successfully confined in the optical trap over period of time with no apparent physical damage detected on the sample. Since this remarkable initiation of optical tweezers in biophysical technique, it has opened up a major breakthrough in the new field which is known as single-molecular research.

Optical tweezers advancing to another level when Svoboda et al. demonstrated an experiment on trapping of metallic particles in 1994. This experiment was unique because they managed to prove that metallic particle was possible to be trapped by using optical tweezers technique. Before this significant finding, metallic object was viewed as poor candidates in optical trapping process due to its relatively large absorption and scattering forces. Magnitudes of these forces are directly proportional to the intensity of light and tend to destabilize the trap. However, in their experiment, they have clearly shown that gold nanoparticles with 36 nm in diameter are trapped with relatively 7 times more stable compared to non-metallic sphere of the same size. This surprising outcome was observed and analyzed. They found out that metallic samples possess a large polarizability, thus producing high magnitude of gradient forces to counterbalance the scattering forces components. This process allows metallic samples to be trapped stable in optical tweezers.

This technique continues to develop as it found its crucial applications in trapping and manipulating neutral particles. In 1997, Ashkin managed to design a new experimental method/set-up by using single laser beam that immediately provides a unique means to precisely control the dynamics of micro-size neutral particles. This achievement plays an important role in the revolutionary of physical and biological sciences. In addition, this research work leads to demonstration of cooling of a neutral atom in context of atomic physics (Ashkin 1997).

In early 2000, a great research work on three dimensional particle tracking for optical tweezers techniques has been carried out. This work successfully provided an insight on high-resolution position sensor for optical trapping process. In this work, lateral displacement and axial position of the trapped sphere are measured by estimating the ratio between the intensity of scattered light towards the total amount of light collected at the detector which is located at the back-focal plane of the microscope. A fluorescent latex bead with radius approximately 300 nm is used as the sample during process of trapping by $Nd:YVO_4$ laser with wavelength at 1.064 nm and 50 mW input power. An inverted microscope with numerical aperture $NA = 1.3$ is implemented in this experiment. This model was successfully used to explain and describe the results obtained from Rayleigh-trapping experiments. Axial displacement of the trapped particle within the Rayleigh length which is calculated to be at z = 150 nm can be measured with percentage of precision less than 10 %. This work is considerably important as it provides a better means/manner to study the dynamics of single membrane molecules.

Advent in nano-manipulation technique manages to extend the use of optical tweezers down to nanometre scale. Frontier research works dealing with nanometre-sized biomolecule has been carried out in 2001 (Agrawal 2001). In this experiment, stiffness of a single actin filament is measured. Beads held by optical trap are attached to both ends of the actin filament. The sample is stretched and the relative displacement between the beads is measured. It is reported that the average displacement of 15–20 nm is recorded corresponding to the stiffness of 65 $pNnm^{-1}$. Basically, this research is considered as one of the pioneer work that operates by combining single molecule imaging with optical manipulation technique for the study of nanometre-scaled molecular motor. Moreover, the unitary processes of mechanical work and energy conversion have been successfully monitored by using this technique. This crucial development has given the opportunity for the other researchers to prolong their experimental research at the single molecular level.

In the following year, Dholakia et al. have reported the use of optical fields to arrange, guide or deflect particles in desired optical lattice geometries. Dholakia in his work entitled “Microfluidic Sorting in an Optical Lattice” managed to perform an optical sorter for micron-size particles that exploit the interaction of particles with dynamically reconfigurable 3-dimensional optical lattice. Sorting process categorized into two types which are sorted by size or refractive index. Efficiency of this sorting process has been calculated in the range of 96–100 %.

Optical trapping, manipulation and sorting techniques have been further improved by upgrading conventional optical trapping system implementing the use of diode laser bars. A single diode laser bar with dimension 100 μm × 1 μm operates at center wavelength of 980 nm and input power of 3 W is multiplexed by ten identical 0.25 NA objective lens along the entire width. This technique maneuvers vast arrays of independently controlled trapping channels which enables trapping of many particles simultaneously. It is reported that 1.8 μm polystyrene beads are trapped along the trapping zone which can be controlled in the range of 1–100 μm without any detectable damage on the sample. This technique directly enhanced the scaling limitation faced by previous laser traps.

The drive toward more sensitive nanoscale-manipulation of optical tweezers led to the development of optical trapping tools that capable to resolve the motion of biological system down to sub-nanometre level. In 2006, spatial resolution of optical tweezers has been successfully improved by using dual traps technique. This approach requires the subject to be held at both ends by using two different optical traps. A single 1.7 μm DNA is tethered between two equal size 860 nm polystyrene microspheres held in optical trap with stiffness of 0.13 $pNnm^{-1}$. Relative distance between polystyrene pair is recorded at the smallest spatial resolution of 2.3 Å (Chen 2006). This work allows the optical-trapping related studies to go beyond sub-nanometer scale with more promising results.

Through all those years, this technique was not only studied experimentally. Some researchers have comes out with modeling investigation on optical tweezers. For instance, Zakharian et al. in 2006 has developed numerical solutions for single-beam trapping of micro-beads in polarized light. In this work, electromagnetic fields distribution including the forces components acting around the spherical geometry of the trapped particle are successfully computed and modelled by using numerical solution of Lorentz law of forces. This model can be used to precisely calculate the stiffness of optical tweezers acting on a particle whether it is immersed in water or suspended in air.

In the following year, computational modelling on optical forces components and its torques has been successfully developed. In detail, a computational toolbox in a proper computer interface system is created to ease the optical tweezers modelling process. The model can be used to trap both spherical or non-spherical samples by using either Gaussian or any other types of trapping beam. For instance, simulation results of optical forces components plotted against relative displacement of the particles from equilibrium point has been demonstrated for the case of Gaussian and Laguerre-Gauss as the trapping beam. These kinds of modelling activity are very important in obtaining quantitative results, thus directly provides a bridge to link between theoretical work and experimental outcomes.

Within the past few years, scope of studies for this particular field is still growing positively either in theoretical and experimental parts. Different techniques and trapping apparatus for optical tweezers generation have been developed starting from a single lens system to a huge and complicated instrument consisting of multiple optical devices. This field evolves when the old lens-based optical tweezers techniques have been substituted by an all-fibre optical tweezers technique. Unlike the conventional tweezers system, this novel approach relies on the unique total internal reflection phenomenon that occurs within the circular core of fibre optics waveguide. This technique requires single-mode fibre probe with tapered hallow tip to produce an intense annular trapping beam as the output. Realization of this technique will greatly improve the design and instrumental part of optical tweezers technique with various potential applications in communication and biology.

However, a single optical fibre device can't form a stable 3-dimensional optical trap because of the weak intensity possessed by the trapping beam. This problem originates from the weak focusing ability possessed by the tapered fibre end which directly induced weak gradient force component that tends to destabilize the trap. This problem has been overcome by the usage of a single fibre probe with an annular light distribution. For this purpose, a tapered, chemically etched and hallow tipped metalized fibre probe are designed to produce the annular light beam. A solid glass bead with diameter of 2 μm surrounded in water has been successfully trapped by an annular light of 1.9 μm diameter produced from a single fibre probe with 20 μm tip. Laser source with input power of 10 mW and centered at $\lambda = 1.32$ μm is used. Scattering force component is recorded at roughly 6×10^{-12} N and the trapped bead is observed moving at the speed of 20 μm s^{-1}. Trapping by this technique can be explained by the balancing condition achieved between the electrostatic force which tends to attract the particle towards the fibre tips and the scattering force component which push the particle in opposite direction. In the following years, a group of scientist from Fukuyama University led by Ikeda reported an interesting phenomenon of optical rotation on a micro-sized plastic bar by using a single-beam optical fibre tweezers system. Such object was observed rotated 360° in 4.8 s by using 20 mW output powers. In addition, they have successfully demonstrated clockwise and anti-clockwise rotation on a bar and cross-shaped plastic micron-size samples. During experiments, manipulation on the sample has been done by tuning the power of the output beam produced by all three tapered optical fibres. This technique is used to precisely control the rotational direction of any trapped particles.

A novel method of optical trapping by using only a single tapered fibre optics probe has been demonstrated in 2006. This unique fibre probe is originally made from a single-mode fibre with core diameter of 9 μm. Fabrication process including heating and drawing techniques are undergone by the waveguide in order to produce a parabola-like profile fibre tip. In this work, trapping of a yeast cell with diameter 6.5 μm immersed in water is performed at the room temperature. Maximum output power supplied by the laser source is 120 mW centered at $\lambda = 980$ nm. Trapping process takes place at the focal plane where the intensity of the laser beam emerged from the fibre tip is highest. This point is located at 1 μm from the fibre tip. Optical field distribution ejected from particular fibre tip is calculated and modelled. Both gradient and scattering forces components are simulated by FDTD method. Result shows that a stable three dimensional trap is plausible for this technique. This breakthrough is important as it makes optical tweezers technique become more convenient in dealing with micron-size particles.

Performance of the single-fibre optical tweezers is examined by Minzioni et al. in one of his paper published in 2008 (Minzioni et al. 2008). In this study, a comparison between all-fibre optical tweezers with conventional tweezers (single beam trap) has been made. Detail numerical computations are performed in Mie regime and performances of both tweezers are compared. A single-mode optical fibre probe with core diameter of 6.5 μm is fabricated. Yb-doped fibre laser at center wavelength of 1,070 nm is launched into the fibre probe with input power of 7 mW.

In the other case, a tightly focused Gaussian beam with the same input power and centered at 1,070 nm corresponding to numerical aperture of 1.25 is considered. Trapping of 5 μm polystyrene sphere immersed in water is performed by both systems and the minimum energy required to escape the traps ε_{esc} are calculated. Result suggests that single-fibre optical tweezers performance is relatively comparable to that obtained by a standard optical trap generated by a strongly focused Gaussian beam as shown in Fig. 2.1. Thus, both systems can be used to deal with micro-scale particle during optical manipulation process.

Recently, Yupapin and Jalil et al. have shown a new methodology to generates optical tweezers by using optical soliton pulse propagates within microring resonator system for several applications such as drug delivery, Alzheimer diagnostic, and blood cleaning (Aziz et al. 2012). Adoption of optical tweezers in microring resonator concept shows that there are still plenty of research and works that can be performed with rising number of new applications in various areas of studies.

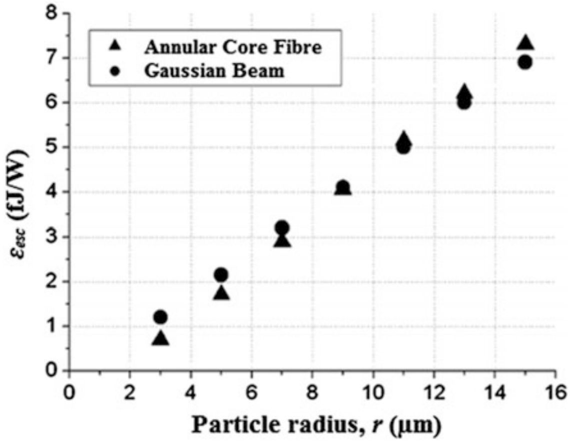

Fig. 2.1 Minimum energy for particle to escape the trap, ε_{esc} plotted against particle radius, r for single fibre optical tweezers and strongly focused Gaussian beam

2.5 Temporal Solitons

In the context of nonlinear optics, soliton can be classified as being temporal or spatial solitons (Wen et al. 2010), depending whether the confinement of light occurs in time or space during the wave propagation. Both types of solitons (temporal or spatial) evolve from a nonlinear change in refractive index of an optical material induced by the light intensity known as the optical Kerr effect (Ishii et al. 2001). The bright and dark spatial solitons form only when the nonlinear effects balanced the diffractive effect precisely. The spatial soliton can form in a self-defocusing nonlinear medium.

The existence of temporal soliton in optical fibre was discovered in 1973 and experimentally proved by the year of 1980 (Agrawal 2001). A balance between the group-velocity dispersion (GVD) and self-phase modulation (SPM) induced by the Kerr nonlinearity caused the formation of temporal soliton inside the optical fibre (Tian and Gao 2005). Temporal soliton represents the optical pulse that maintains its shape, while the spatial soliton is the self-guided beams that remains confined in the transverse direction orthogonal to the direction of propagation. The major nonlinear effects that are responsible for the formation of optical solitons are the spatial self-focusing or self-defocusing and the temporal self-phase modulation (SPM).

Temporal soliton defined as a pulse or wave packet that maintains its shape when propagate at constant speed without any distortion due to dispersion (Yupapin and Suchat 2007). The dispersion effect originates from the dependency of phase velocity towards its frequency and any medium that exhibits such properties is called dispersive media. Every wave packets built from a plane waves with several different frequencies. Due to the dispersive effect, all of these waves travel at different velocities, thus changing the pulse shape over the time. This effect is presented by group delay dispersion parameter, D. D is described as:

$$\Delta\tau \approx DL\Delta\lambda \tag{2.4}$$

where $\Delta\lambda$ is the bandwidth of the pulse in terms of wavelength.

The envelope of optical pulse widens for $\Delta\tau$ after travelling at distance L. On the other hand, the nonlinear Kerr effect induced variation in refractive index. This process directly modified the phase shift in the pulse that leads to a change in frequency spectrum of the pulse. This whole process is referred to SPM.

By considering that a Gaussian beam with intensity I depend on time t, hence:

$$I(t) = I_o \exp\left(\frac{-t^2}{\tau^2}\right) \tag{2.5}$$

where I_o is the peak intensity and τ is the pulse duration of the wave.

Optical Kerr effect produces variation in refractive index of $n(I) = n_o + n_2 I$. As the propagation continues, the intensity at any point of media is changed.

This process yields a time-varying refractive index as:

$$\frac{dn(I)}{dt} = \frac{-2t}{\tau^2} n_2 I_o \exp\left(\frac{-t^2}{\tau}\right) \tag{2.6}$$

The variation of refractive index values is responsible for instantaneous phase shift of the pulse, ϕ. ϕ is given by:

$$\phi(t) = \omega_o t - kx \tag{2.7}$$

$$\phi(t) = \omega_o t - \frac{2\pi}{\lambda_o} L \cdot n(I) \tag{2.8}$$

where ω_o and λ_o represents the frequency and wavelength of the pulse respectively, and L is the propagation distance.

These phase shifts induce the changes in frequency of the pulse and given by:

$$\omega(t) = \frac{d\phi(t)}{dt} \tag{2.9}$$

$$\omega(t) = \omega_o - \frac{(2\pi L)}{\lambda_o} \frac{dn(I)}{dt} \tag{2.10}$$

$$\omega(t) = \omega_o + \frac{4\pi L n_2 I_o}{\lambda_o \tau^2} \cdot t \cdot \exp\left(\frac{-t^2}{\tau}\right) \tag{2.11}$$

Equation (2.11) can be substituted by $\omega(t) = \omega_o + \alpha t$. The second term of the right hand side of this equation clearly states that there is an extra frequency component generated as it propagates in a medium.

This SPM effect broadens the frequency spectrum of the pulse and leading edge is said to be compressed and having a positive chirp. Such optical pulse is stable and propagates undistorted in the form of temporal soliton.

2.6 Microring Resonator System

Marcatili were first demonstrated the concept of light transmission in curved optical dielectric waveguide in 1969. From the experiments done by this group of researchers, different cross sectional diameters of the dielectric waveguides were examined. The bent of light wave within the guided waveguide materials was successfully proved. These findings had been the pioneer work for the development of the studies in the field of guided-wave optics from all over the world.

Weber and Ulrich (1971) reported the characteristics and operational of circulated laser, formed by a circular single mode light-guiding thin film. This system was initially known as ring resonator. This system consisted of a cylindrical glass rod with 5 mm diameter coated with Rhodamine 6G doped with polyurethane film $(n = 1.55)$. The operational of laser pulse from the ring resonator device was successfully developed by this group (Ulrich and Weber 1972).

Haaristo and Pajer proposed and demonstrated the integration of ring waveguide and two tangential straight-channel waveguides on both sides of the ring in 1980 (Moffitt et al. 2006). Both two waveguides were geometrically and intentionally coupled. These straight bus waveguides were made of polymethyl methacrylate (PMMA) doped film on quartz substrate. The most interesting part about this work was that the device has a very small value of coupling loss (about 0.05 dBm/cm). The special properties of low loss and its polarization maintenance were the main reasons why this device was suitable enough for fibre optics interferometers.

In 1982, Stoke et al. successfully demonstrated the optical glass fibre ring resonator (Minzioni et al. 2008). This device consisted of a single-mode fibre and a dielectric coupler. This device was designed to operate at $A = 632.5\,\text{nm}$. The work initiated numerous researchers on glass-based integrated ring resonator.

In early 1990s, a group of researchers have successfully demonstrated the construction of microring resonator from semiconductor based materials (Chu et al. 1993). Through this research, the researchers came out with optical pumped microdisk in both GaInAsP/InP and III-Nitrides materials with smallest disk circumference recorded at 15 μm (Dai et al. 1998). However, one of the weaknesses at this time was, the resonator designed without bus waveguide coupled to the ring geometry. In this configuration, the transmission of light from the resonator relied on the fibre. This draw back has been overcome by Rafizadeh (1997) with the fabrication of integrated microring resonator system where two lateral bus waveguides coupled on the circumference of the ring.

Several configuration of the ring resonator systems have been proposed based on GaAs/AlGaAs materials (Absil 2000). A racetrack-shaped ring resonator has been designed to enhance the coupling efficiency at the coupler region with cross sectional area of 0.5 μm^2 and 400 μm bus waveguide length. The device can perform a wavelength conversion process with 14 % conversion efficiency, quite high percentage compared with other configuration systems. Such results were achieved by using relatively low input power of about 10 mW (Absil et al. 2000) and due to the low-loss and high nonlinear properties possessed by the particular device.

Rabus and Hamacher (2001) demonstrated various ring resonator configurations based on the GaAs/AlGaAs medium. The development of this research area led to a novel integration of a single resonator device made up of GaInAsP/InP material. By using suitable wavelength values, the value of free spectral range (FSR) of 50 GHz with the full width at half maximum (FWHM) of 24 pm were achieved. With integration of semiconductor optical amplifier (SOA), the quality factor, Q up to 65,000 was induced (Rabus et al. 2002a).

A desire output ring resonator transmission can be realized by using multiple-coupled ring resonator system. A new concept of lateral coupling between the ring and bus waveguide has been introduced into different loss-compensated ring resonator configurations to modify the output filter functions. For instance, single, double, and triple multistage optical filter devices were designed. It was reported that such configuration results of FSR with 12.5, 25.0, and 50.0 GHz respectively and on-off ratios greater than 20 dB (Rabus et al. 2002b).

Until this date, record shows that there is no active type ring resonator device that has been fabricated. The first active ring resonator device was constructed from all-active materials. This device was capable to alter the filtering performance. An active ring resonator device was fabricated from indium phosphate material. Such systems showed a relatively high FSR of 10.5 nm with Q of 5,700. Under resonance state, this device was operated at the center wavelength, $\lambda = 1.584$ μm and resulting the output signal transmission, T of 0.1 with finesse, $F = 40$ (Djordjev et al. 2002a). The models of ring resonator which vertically coupled to the bus waveguide have been used with small radius, up to 10 μm (Djordjev et al. 2002b). This successful work becomes a reference for numerous researchers and academicians in this field. In last few decades, this field have rapidly grown and realized in electro-optic polymer, silicon nitride, and silicon oxynitride based materials (Rabiei and Steier 2003; Tan 2004; Geuzebroek 2005).

A complete analysis expression describing the propagation within nonlinear dispersive microring resonator systems has been obtained using matrix approaches. The transfer matrix method can describe precisely a complicated system, such as multiple numbers of coupled ring resonator and others. This method can implement to any structures or geometries of microring resonators. It is also valid for any values of coupling parameters (Poon et al. 2004).

The theoretical analysis on optical microring becomes very important indeed. Details in calculation of loss element in ring resonator device are carried out successfully. The perturbation approach may compute the scattering and radiation losses of components for microring resonator with cylindrical waveguide. The losses in the system which is originated from the shape defect on the ring waveguide and the fluctuation of core refraction index are successfully discussed

(Rabiei 2005). Such analysis provides an insight for a better understanding on microring resonator as discrete loss component impose a serious limitation during fabrication process.

Mahdi (2013) proposed the analytical vernier effect for nanophotonics circuits by using ring resonator systems. It is shown a big contribution about the mathematical calculation especially in physics fields. Amiri (2013) proposed an idea of optical soliton based on communication technology by using microring resonator systems. He has shown that the integrated dark soliton is a useful concept for the communication technology. The dark-bright solitons conversions within add-drop system have been done by Muhammad Arif in 2013. He has shown that the dark-bright solitons can be converted in ring resonator within add-drop system. The research is focussed on the nanotechnology and biomedicine based studies. Muhammad Safwan (2013) proposed the tenability of the optical solitons in micro- and nanoring resonator systems. The electrooptics tenability of the optical solitons interaction within PANDA and double-PANDA system has been investigated.

Due to its potential applications, in the recent years, microring resonator becomes a rapidly developing research interest, especially in photonics devices. Recently, Jalil and Yupapin (2008, 2009, 2011, 2012) have reported a novel idea of PANDA ring resonator configurations which utilized in various applications, especially in communication and medical applications. The development on design and fabrication of microring resonator has been a subject of intense studies among researchers.

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