Force of optical tweezers by micro ring resonator system

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Abstract. This research was to design optical tweezers for nanometer scale. The principle of absorption and reflection of light passing through the optical theory of four wave mixing (FWM) caused a phenomenal optical nonlinearity. The principle is the importance of design a small device, the light device micro ring resonator for use in various applications. The parameter can be variable the couple coefficient (κ) of the cavity resonance light from 0.2 - 0.8 and the size of the radius of the cavity resonance small (r) is between 10 -150 microns is applied in the near future. The wavelength is 1,550 micrometers and the resulting intensification two forces are the gradient force equal to 2.00 x 10^{-18} newton and scattering force equal to 5.44 x 10^{-30} newton, in this case with particles 10 - 20 microns into the pure water. This system, optical devices micro ring resonator is small nanometer scale. We can application to such as medical and devices for quantum computing in the near future.

1. Introduction

In this technology about the detection of optical scattering and gradient forces on micron sized particles was first reported in 1970 by Ashkin, a scientist working at Bell Labs.[1] Years later, Ashkin and colleagues reported the first observation of what is now commonly referred to as an optical tweezer: a tightly focused beam of light capable of holding microscopic particles stable in three dimensions [2].Optical tweezers have proven useful in other areas of biology as well. For instance, in 2011, the review summarizes the recent advances in the emerging field of plasmon-based optical trapping and discusses the details of Plasmon tweezers along with their potential applications to bioscience and quantum optic [3]. Optical tweezers have also been used to probe the cytoskeleton, measure the visco-elastic properties of biopolymers,[4] and study cell sperm competition and motility[5]. A dynamic multiple-beam optical tweezers [6], laser tweezers for atomic solitons[7], holographic optical tweezers[8] and experimentally demonstrated optical tweezers[9].

In this paper, we combine laser trapping for optical tweezers with computer software Optiwave and Matlab to study the micro ring resonator for optical tweezers nano scale for find the force of optical trapping and confirm the result by experiment the polymer in water for find the gradients force and scattering force [10].

2. Theory and background

The purpose of this research is to simulate the effect of the length of the ring resonance phenomenon that affects non-linear cavity resonance of ring. Considering that the radius of the ring is a 5 -12 microns and diameters of core equipment ring resonance with 250 nm by changing the phase linear static (ϕ_L= 0) , the coupling coefficient ratio of light (κ) are 0.2 -0.9 and a refractive index of a nonlinear n_2 = 2.69 x 10^{-17} m^2/W [11].

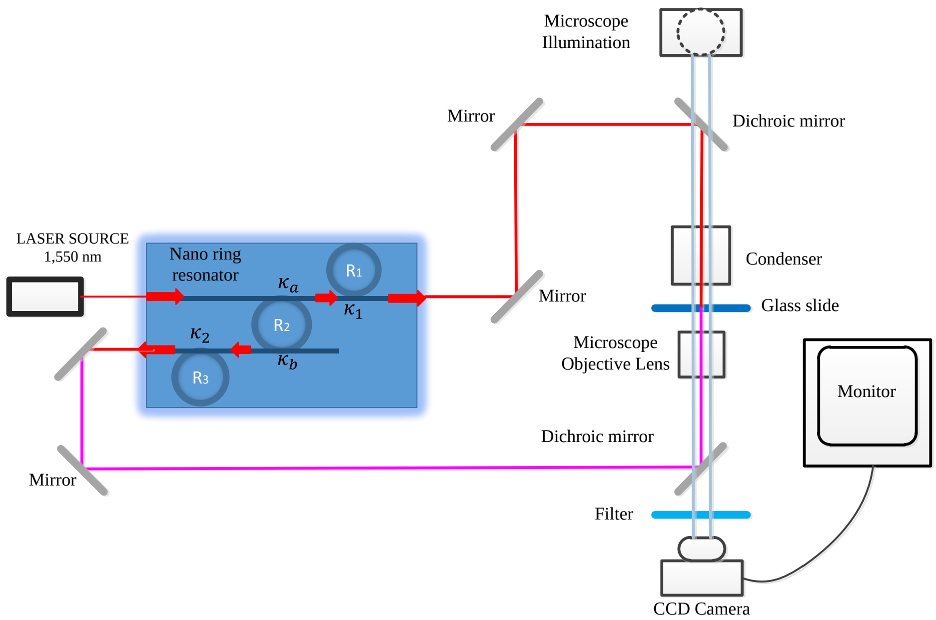

Fig. 1 system design optical tweezers for passing light through small molecules. The device is a small cavity resonance wavelength 1.550 micrometre. The systems that have been designed by computer program such results.

When the input light Gaussian pulse into the cavity resonance devices smaller and the third ring, which is a phenomenal rise is not linear. (Kerr-effect) is called chaos and optical isolation add / drop Filter serves to separate the optical signal into multiple wavelengths, as shown in Figure 4.15 of such relationships. The input and output is ($E_{out}(t)$ and $E_{in}(t)$) as shown in equation (1) [12].

$$E_{in}(t) = E_0\, e^{j\phi_0(t)} \tag{1}$$

where E_{in} is input electric field , E_0 is output electric field and ϕ_L is linear phase shift and non-linear phase shift optical waveguide loop in the ring is

$$\phi = \phi_L + \phi_{NL} \tag{2}$$

$$\phi_{NL} = \frac{2\pi n_2 L}{\lambda_0 A_{eff}} \left| E_1(t) \right|^2 \tag{3}$$

λ_0 is the wavelength of the light traveling in a vacuum and A_{eff} is cross section area of core in the waveguide by equation (2) and equation (3) and a written form of the equation iteration is time-dependent.

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

From Equation (4) is based on the principle of Fabry-Perot cavity which input to use mirrors to reflect back and forth in a systematic manner(1-κ), κ is Coupling coefficient and $x=\exp(-\alpha L/2)$ is roundtrip loss coefficient, $\phi_0 = kLn_0$ and $\phi_{NL} = kL(\frac{n_2}{A_{eff}})P$ are linear phase shift and non-linear phase shift optical waveguide and $k = 2\pi/\lambda$ is wave propagation number in a vacuum and L is waveguide length and α is linear absorption coefficient.

In this paper used the equation (4) in the experiment for signal integrity and the suitable in design and multi-channel optical isolation use to Add / drop filter device. Similarly, we can connect to the micro ring resonator system to input signal. Input field of the optical signal is shown in Equation (1) Gaussian beam, which the optical signal is linear. from equations with variable causes the signal is non-linear. The chaos signal from equation (2), which can create chaos and filtering by wavelengths, with many uses the supplied splitter multi-wavelength by Add / drop filter device [12].

The force of optical tweezers to Ray Leigh particle consist of two forces that force is the force gradient and a scattering force. The gradient force is the force caused by electromagnetic induction cause separation between the positive and negative charge inside. The particles become dipole, which drawn to the point where the intensity of light, which is the focus point has a strong gradient values.

$$F_{grad} = \frac{\alpha}{2}\nabla\langle E^2\rangle \tag{7}$$

and

$$\alpha = n_m^2 r^3\left[\frac{m^2-1}{m^2+1}\right] \tag{8}$$

where $\nabla\langle E^2\rangle$ is The average result of electric field squared n and n_m are the refractive index of the particles and the refractive index of medium and m = n/n_m is refractive index ratio of particles and medium, r is radius of particles

Scattering force is the particles absorb light (absorption) and scattering of light from the particles in all directions (scattering) causes transfer momentum to the particle momentum scattering a line with the emission of light but is less over the force gradient at large. The object is likely to be pushed into focus the disorder is

$$F_{scatt} = n_m\frac{\langle S\rangle\sigma}{c} \tag{9}$$

where

$$\sigma = \frac{8}{3}\pi\left(kr^4\right)r^2\left[\frac{m^2-1}{m^2+1}\right]^2 \qquad (10)$$

and $\langle S \rangle$ is the results of the point vectors ***c*** is velocity of light and $k = \dfrac{2\pi}{\lambda}$ is the wave number of the laser in practice, the particles are trapped in size 100 nm to 10 µm, which is between particle Ray Leigh and Mears, so to bring the two together and calculations algebra.

3. Result and Discussion

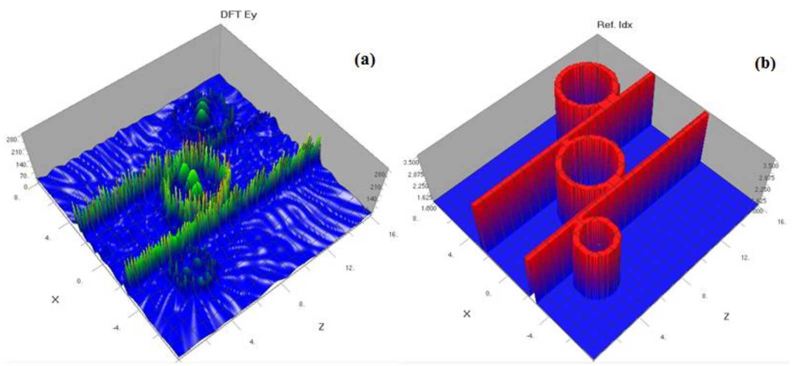

Fig. 2 show the input signal is 0.40 W and the radius of micro ring resonator R_1 and R_2 are 2 µm, and R_3 is 1 µm.

In Fig. 2 show the ring resonator design by the ***Optiwave program version 2013*** the material is InAlGaAs/InP, which have non refection index (n_2) is = 2.69 x 10^{-17} m^2/W. Output signal in through put port have 250 mW and Drop port 240 mW and gallery mode in first ring is 160 mW show in Fig. 2 (a) and Fig. 2 (b) show the waveguide have a size 16 x16x10 µm.

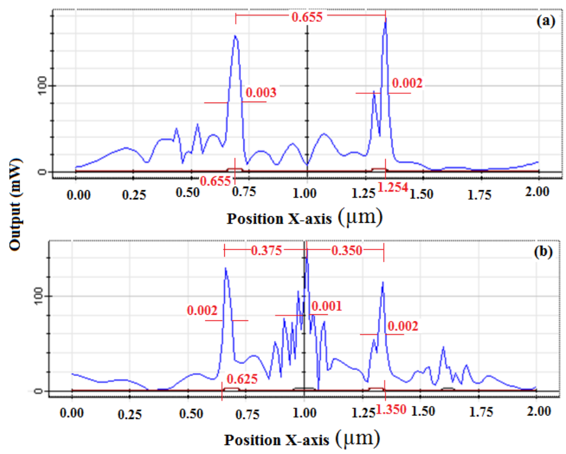

Fig. 3 shows the output gallery mode ring resonator system.

In Fig. 3 show the gallery mod in ring resonator system have output intensity are 160 mW and 180 mW has the range of signal to signal between 0.655 µm, which have 2 peaks for first ring (R_1) show in Fig. 3 (a) and output intensity are 140 mW, 125 mW and 119 mW for second ring (R_2), which have 3 peaks show in Fig. 3 (b).

4. Conclusion

The research presents the design principles and optical tweezers small nanometer scale using the principle of non-linearity effect, which is formed with a semiconductor used in the design is InAlGaAs/InP based on with so many variables, such as the refractive index of a non-linear (n_2) the reflection coefficient of the cavity resonance, the third ring reflective index of ring resonator and the reflection coefficient of the cavity resonance, the two sides the reflective index of Add / Drop device are κ_a and κ_b, which can be seen from the trial. We can use of new transportation equipment to link organisms with computers and communications have been cut to a smaller size. Optical tweezers is lighting equipment and accessories, small particles or storage. As well as the selection of the particles to store and allocate the camber to collect cells and genes in a stable condition.

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