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Cold laser therapy modeling of human cell/tissue by soliton tweezers

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ABSTRACT

The interferometer system of microring resonator (MRR) can be used to generate soliton tweezers applied for medical applications. This system uses the nonlinear behaviors of light pulse traveling within a fiber optics MRR. The soliton tweezers can be used to contact the biological cells of a human tissue. Here, the non-heat creating laser is required to perform the cold laser (CL) therapy which can be utilized by a generation of low power soliton tweezers using the MRRs. The NIR (near infra-red) laser is used to generate soliton tweezers which are able to penetrate profoundly into tissues in order to improve injury healing and tissue regeneration. The Dark solitons and Gaussian beam with central wavelength of 800 nm collide within the MRR system lead to generate ultra-short soliton tweezers. This type of treatment is effective and based on the photochemical and photobiological effects of the cells and tissues or any biological response by means of power transfer. Thus, the CL using the soliton tweezers provides energy toward the entire body in the form of non-thermal photons of light. In this research soliton tweezers with full width at half maximum (FWHM) of 1.5, 4, 6.8 and 15 nm are generated and used to interact with the living cells and human tissues.

1. Introduction

Laser treatment used for healing is known as low-level beam of light as well as cold-laser (CL) therapy [1]. If the body comes with a harm this cellular material are usually broken in addition to neglect to perform normal parameters [2]. Energies from the CL permeate seriously into the skin and operate by simply restoring regular cell function [3]. This CL utilizes a non-heat creating laser, that is locked with a specific wavelength that is certainly best for treatment which enable it to penetrate profoundly into tissues [4]. The CL or low level laser therapy (LLLT) can be grown as a premiere beneficial modality within the treatment martial arts discipline group [5]. This organic results of LLLT are shown to significantly quicken as well as improve the anatomy's organic defense as well as mend capabilities [6]. By simply minimizing redness and also enhancing particular mend and also recovery processes, LLLT continues to be which could present treatment, minimize cell damage because of the injury and also producing a loss in functionality [7]. The actual LLLT helps the body to get a more rapid restore and stronger cells once recovered [8,9]. The lasers employed for CL therapy variety in energy from 5 to 500 milliwatts (mWs) [10]. Lasers lower than 5 mW do not have enough power to cause a bio-stimulatory effect, whilst lasers over 500 mW could cause excessive heating as well as burn up the skin [11].

CL therapies techniques come in distinctive wavelengths (colors). The range is from green (532 nm) to red (650 nm) to near infra-red (750–950 nm) [12]. Laser light with green color, for instance, is extremely quickly absorbed by the skin and blood vessels and can be utilized simply to assist heal surface injures for instance bedsores or even diabetic ulcers. Red lasers may enter the tissue more deeply, although are still usually applied for surface considerations like burns, acne breakouts, and also hair recovery. IR (infra-red) lasers which penetrate much deeper are used to assist recover muscles, soft tissue supporting muscles, and also bone fragments [13].

Physicists Schawlow and Townes brought the particular laser directly into modern medical fields, where these are being utilized intended for various treatment options [14,15]. The vast majority of lasers used in the healthcare fields are actually high frequency

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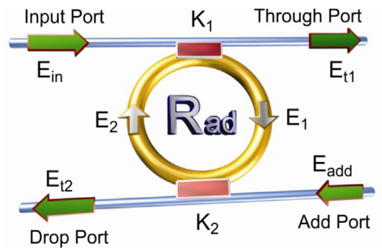

Fig. 1. Schematic diagram of an add/drop interferometer system.

hot lasers, that are catabolic (destructive) in characteristics like the kinds used in the eyesight surgical procedure [16]. The particular CLs are anabolic, or perhaps regenerative (not destructive) within characteristics.

Laser therapy is based on photochemical and photobiological effects of the cells and tissues. With the laser light, cellular functions can be stimulated. The laser beam affects the particular individual tissue over the photoreceptors, causing a physiological influence [17]. Accelerated recovery, the primary aim intended for almost any damage, can be tricky to demonstrate in a laser session.

To speed tissue repair, laser light affects the mitochondria. The mitochondria as a function of the cell responsible for developing ATP (adeno-triphosphate) is the chemical energy of the cell. The laser light may be proven to really speed up the creation of ATP, therefore accelerating the overall activity from the cell [18]. In cells responsible for mending cells, as well as bone fragments, muscle tissue, tendon, skin, and also nerves, this result with a growth rate of repair.

The CL provides energy toward the entire body in the form of non-thermal photons of light. Light will be transmitted through the skin's layers (the epidermis, dermis and the tissue fat under the skin or the subcutaneous tissue) whatsoever wavelengths from the visible range [19]. Nevertheless, light waves in the near infrared ranges penetrate the deepest of all light waves in the visible spectrum. Whenever lower amount laser light permeates significantly into your skin, they enhance the immune system responses of our own bloodstream [20]. It has both anti-inflammatory as well as immunostimulate effects. This can be a medical fact that light transmitted to the blood in this manner possesses positive effects over the whole body, providing crucial oxygen in addition to energy to each cell [21].

Amiri et al. have reported the interesting results of light pulse propagating within a nonlinear MRR system, where the transfer function of the output at the resonant condition is used. Here the interferometric functions of the MRR system which is made of fiber optics have been analyzed. They have shown that the solitonic pulses can be generated by the MRR systems and used in varied applications in medicine and biotechnology studies [22–24].

2. Theory of soliton tweezers propagation

The proposed system to generate soliton tweezers is shown in Fig. 1. This system consists of two input ports (input and add ports) and two output ports (through and drop ports) [25]. The input signals can be inserted into the system via input and add ports, where the output signals will be seen in the through and drop ports.

To form the interferometric functions of this system, here a stationary dark solitons and Gaussian beam are introduced into the system. Input optical fields of the dark solitons and the Gaussian beam are given by [26]

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

$$E_{add} = A \exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \quad (2)$$

A and z are the optical field amplitude and propagation distance, respectively [27]. T is a soliton pulse propagation time in a frame moving at the group velocity, $T = t - \beta_1 \times z$, where β_1 is the linear coefficient of the propagation constant. $L_D = T_0^2/\beta_2$ is the dispersion length of the soliton pulse [28]. The frequency shift of the soliton is ω_0. This solution describes a pulse that keeps its temporal width invariance as it propagates, and thus is called a temporal soliton [29]. When a soliton peak intensity ($|\beta_2/\Gamma T_0^2|$) is given, then T_0 is known [30]. There should be a balance between the dispersion length (L_D) and the nonlinear length ($L_{NL} = 1/\Gamma\phi_{NL}$), where $\Gamma = n_2 \times k_0$, is the length scale over which disperse or nonlinear effects makes the beam wider or narrower, thus $L_D = L_{NL}$ [31,32]. When light propagates within the nonlinear medium, the refractive index (n) of light within the medium is given by [33]

$$n = n_0 + n_2 I = n_0 + \left(\frac{n_2}{A_{\text{eff}}}\right) P, \quad (3)$$

where n_0 and n_2 are the linear and nonlinear refractive indexes, respectively [34]. I and P are the optical intensity and optical power, respectively. The effective mode core area of the device is given by A_{eff} [35]. The effective mode core areas have ranged from 0.10 to 0.50 μm^2. The system in the particular case is similar to a Fabry–Perot cavity, which has an input and an output mirror with a field reflectivity, $(1-\kappa)$, and a fully reflecting mirror [36]. The round-trip loss coefficient can be presented by $x = \exp(-\alpha L/2)$, where L and α are a waveguide length and linear absorption coefficient, respectively [37]. The total phase is $\phi = \phi_0 + \phi_{NL}$, where the $\phi = kLn_0$ and $\phi_{NL} = kLn_2|E_{in}|^2$ are the linear and nonlinear phase shifts, $k = 2\pi/\lambda$ is the wave propagation number in a vacuum. In this work, the iterative method is introduced to obtain the results [38]. The optical fields of soliton pulse and Gaussian beam are inserted into the input and add ports of the interferometer MRR system. Interior optical signals of the system can be expressed by Eqs. (4) and (5).

$$E_1 = \frac{E_{in} \times j\sqrt{\kappa_1} + E_{add} \times j\sqrt{\kappa_2 \times (1-\kappa_1)} \times e^{((-\alpha/2)(L_{ad}/2)) - (jk_n(L_{ad}/2))}}{1 - \sqrt{(1-\kappa_1) \times (1-\kappa_2)} \times e^{(-\alpha L_{ad}/2) - jk_n L_{ad}}} \quad (4)$$

$$E_2 = \frac{E_{in} \times j\sqrt{\kappa_1 \times (1-\kappa_2)} \times e^{((-\alpha/2)(L_{ad}/2)) - (jk_n(L_{ad}/2))}}{1 - \sqrt{(1-\kappa_1) \times (1-\kappa_2)} \times e^{(-\alpha L_{ad}/2) - jk_n L_{ad}}} + \frac{E_{add} \times j\sqrt{\kappa_2 \times (1-\kappa_1) \times (1-\kappa_2)} \times e^{(-\alpha L_{ad}/2) - jk_n L_{ad}}}{1 - \sqrt{(1-\kappa_1) \times (1-\kappa_2)} \times e^{(-\alpha L_{ad}/2) - jk_n L_{ad}}} + E_{add} \times j\sqrt{\kappa_2} \quad (5)$$

where κ_1 and κ_2 are the coupling coefficients, $L_{ad} = 2\pi R_{ad}$ and R_{ad} is the radius of the interferometer MRR system. The through and drop ports output signals of the system are given by [39,40]:

$$E_{th} = E_2 \times j\sqrt{\kappa_1} \times e^{((-\alpha/2)(L_{ad}/2)) - (jk_n(L_{ad}/2))} + E_{in} \times \sqrt{1-\kappa_1} \quad (6)$$

$$E_{drop} = E_1 \times j\sqrt{\kappa_2} \times e^{((-\alpha/2)(L_{ad}/2)) - (jk_n(L_{ad}/2))} + E_{add} \times \sqrt{1-\kappa_2} \quad (7)$$

where E_{th} and E_{drop} represent the optical electric fields of the through and drop ports, respectively [41]. Using specific parameters of the interferometer MRR system, the chaotic noise cancelation can be achieved and the required signals can be retrieved by the specific users.