



OPTICAL SOLITON PULSE GENERATION TO REMOVAL OF TISSUE

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ABSTRACT

The effect of femto second pulse through a nonlinear nanoring system for refractive removal tissue is studied. The generation of femto second pulse using bright soliton which pass through multistage Hydrogenated-amorphous Silicon (a-Si:H) nano ring resonator is reported. The laser pulse treatment through a system of N nano ring resonator is analytically studied. Simulated results show the generation of ultra short pulse with FWHM of 150 fs which is practical for correcting short-sightedness and far-sightedness in removal tissue surgery.

Keywords: Femtosecond Pulse, Ring Resonators, Hydrogenated Amorphous Silicon

INTRODUCTION

Femtosecond lasers have an amazing array of possible applications, and this is especially true in the health and medicine industry [1]. The low average power limits the amount of thermal damage to biological organisms, while the intensity and peak power are high enough to enable nonlinear processes for a range of medical uses from high-resolution microscopy to precise surgical procedures [2].

The ultrafast lasers have found multifunctional usage in biology and medicine [3, 4]. The ability of precise ablation and accurate cutting quality on different materials makes the femtosecond laser a promising multifunctional surgery tool for refractive surgery [5], surgery on the inner ear [6], dentistry [7, 8], and cardiovascular surgery [9]. Femtosecond laser near infrared (FLNIR) is used in

multiphoton microscopy (MPM) for high-resolution fluorescence imaging in intact tissues or live animals. FLNIR have also been used in cell transfection biology [10] morphogenetic movements [3] neurosciences [11] and corneal surgery [12]. In this study, a novel technique based on scattering matrix method is used for generation of femtosecond pulse from a set of nanoring resonators. An input bright soliton with nanosecond pulsewidth is fed into the system of a-SiHnanoring resonator. The ultra short femtosecond pulse is generated through the proposed system which is applicable in removal tissue surgery.

Proposed System

Nano ring device can be constructed with radius in the size of nano [13]. Hydrogenated-amorphous silicon (a-Si:H) is a proper candidate for integration of silicon photonics. It provides vertical stacking of optical interconnections with low loss waveguides including horizontal slot waveguides and cavity resonators [14].

Function of System

In order to generate femtosecond light pulse, the optical bright soliton is fed into the series of a-Si:H nano ring resonators. The input optical field in the form of temporal bright soliton pulse can be expressed by [15].

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

where the amplitude of optical field shows by A and the propagation distance demonstrated by z . The propagation time for soliton pulse which moves at the group velocity in a frame shows by $T = t - \beta_1 \times z$. Here, t is the soliton phase shift time, and ω_0 is the frequency shift of the soliton. $L_d = T_0^2 / |\beta_2|$ represents the dispersion length of the soliton pulse, where T_0 shows soliton pulse propagation time at the initial input. The coefficients of the linear and the second order terms of the Taylor's expansion of the propagation constant are shown by β_1 and β_2 , respectively. For the soliton pulse in the nanoring device, a balance should be achieved between the dispersion length (L_d) and the nonlinear length $L_{NL} = 1 / \Gamma \phi_{NL}$, where $\Gamma = n_2 K_0$, is the length scale over which dispersive or nonlinear effects makes the beam becomes wider or narrower. For a soliton pulse, there is a balance between dispersion and nonlinear lengths, hence $L_d = L_{NL}$ [16].

Based on the coupling coefficient of nano ring resonator (NRR), a fraction of input soliton pulse is coupled into the NRR. For long dispersive path E_{in} causes the nonlinearity effect to be built up inside the NRR due to change of the refractive index with optical power. Here, the power

dependence of refractive index is responsible for the Kerr effect [17]. The refractive index can be written by [18]

$$n = n_0 + \left(\frac{n_2}{A_{eff}}\right)|E_{in}(t)|^2 \dots\dots\dots(2)$$

where n_0 and n_2 are the linear and nonlinear refractive indices respectively and A_{eff} shows the effective mode core area of the waveguide. In each round trip a phase shift of $\xi = \exp(-\alpha L_i/2 - iKnL_i)$ is added into the soliton pulse while propagating via NRR. One roundtrip loss coefficient considered as $x = \exp(-\alpha L_i/2)$ where L_i is the circumference of the NRR and α is the waveguide absorption coefficient. The vacuum wave number and refractive index of the waveguide are represented by K and n , respectively. Interference occurs between the pulse passes through the NRR and input soliton pulse after each round. The optical outputs from the first ring resonator is given by

$$E_{out}^1 = E_{in} \left(\frac{C_1 - (1 - \gamma_1)\xi_1}{1 - C_1\xi_1} \right) \dots\dots\dots(3)$$

where $C_1 = \sqrt{(1 - \kappa_1)(1 - \gamma_1)}$ is the fraction of input pulse that is coupled into the NRR, κ_1 is the coupling coefficient of the first ring and γ_1 shows the fractional intensity loss of the first coupler. The output pulse from each NRR in proposed system (**Figure 1**) should feed into the next NRR, so the output pulse from a system of N nano ring resonator can determine by

$$E_{out}^N = E_{in} \prod_{j=1}^N \frac{C_j - (1 - \gamma_j)\xi_j}{1 - C_j\xi_j} \dots\dots\dots(4)$$

The output power from each ring can be determined by

$$P_{out}^j = (E_{out}^j) \cdot (E_{out}^j)^* = |E_{out}^j|^2 \dots\dots\dots(5)$$

RESULTS AND DISCUSSTION

Hydrogenated amorphous silicon can be used to construct nano ring resonator, where the ring radii of the system are chosen as 150, 100, 50, 10 and 5nm for R_1 , R_2 , R_3 , R_4 , and R_5 respectively. In order to generate fs pulse a soliton pulse with power at 30 W is fed into the system as shown in **Figure 3(a)**. The nonlinear refractive index of the system is fixed to $n_0 = 3.48$ and the nonlinear refractive index is $n_2 = 4.2 \times 10^{-17} (m^2/W)$. The wave guided loss and coupler intensity loss are $\alpha = 0.2 (dB/mm)$ and $\gamma = 0.2$, respectively. The coupling coefficients of the nano ring resonator vary between 0.1-0.5. The effective mode core areas of the nanoring resonators are varied in the range from 0.1 to 0.5 μm^2 . When the input optical pulse meets the resonance condition of each nanoring resonator, it will couple into the ring and travel around inside it. Based on the imposed phase shift and resonant mode numbers of each nanoring resonator the optical pulse affects a constructive and destructive interference. Therefore the signals are suppressed over frequency interval and the overall intensity in this frequency domain is amplified according to the superposition principle. Since the energy per area for optical breakdown decreases with the pulse duration, reduction in the

pulse energy were postulated and has been recognized with lasers operating in the ultrashort (femtosecond) pulse duration regime [19]. Here the input bright soliton pulse is sliced and amplified into a smaller signals over the spectrum as shown in **Figure 2(b), 2(c), 2(d) and 2(e)**. **Figure 2(f)** shows the generated femtosecond of 150 fs with output power of 1150W. The generated femtosecond pulse with pulse width of 150 fs is shown in **Figure 3**.

Tissue Modification and Nano Surgery

Femtosecond laser pulse commercially have been used as ultraprecise nanosurgical tools in removal tissue with cut sizes between 70 nm and 100 nm [20]. The unique properties of ultrashort pulse lasers that make them effective for nano-processing are also highly useful for performing complex or delicate surgical procedures. Femtosecond lasers allow precise removal of tissue with little or no damage to the surrounding areas.

The unique ablation characteristics of femtosecond lasers render higher precision in micromachining while minimizing the size of the heat affected zone, as well as a reduction in debris, recast, and burrs. Additionally, they allow cutting, drilling, and welding of transparent materials with less collateral damage to the work piece. These unique processing capabilities are utilized in the semiconductor industry as well. The remarkably clean ablation stems

from the extremely short deposition of the laser pulse energy, which ablates the material effectively before the absorbed laser energy dissipates as heat to the surrounding area of the ablation.

This process is very important for manufacturing medical devices such as vascular stents, where fine, clean cuts, produced without altering the properties of the surrounding material by heat transfer, are required to improve the performance of the device and its lifetime inside the body.

In many types of biomedical imaging, an excitation laser source causes a target molecule in a biological sample to fluoresce. Some types of naturally occurring biological cells will fluoresce when excited by the appropriate wavelength. In other cases, a fluorescent molecule can be introduced into the tissue which targets and attaches itself to specific cells. Using nonlinear absorption, only the region of the laser focus has sufficient intensity to excite fluorescence. This fluorescence can be used to map the tissue by scanning the laser focus across a 3-dimensional grid in the sample. **Figure 4** shows the removal tissue. The ultrashort pulse duration of femtosecond lasers allows for strong nonlinear excitation without photo damage caused by high average laser power. Efforts are being made to transition the R&D optical imaging system to a clinically deployable one.

IMRA's stable, robust and helping with this transition, providing the compact Femtosecond Fiber Lasers are best reliability in the industry.

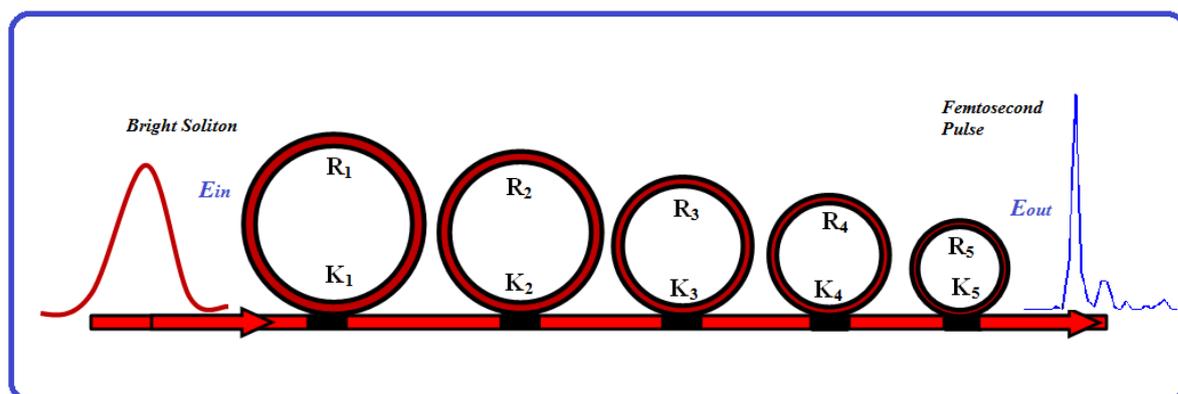
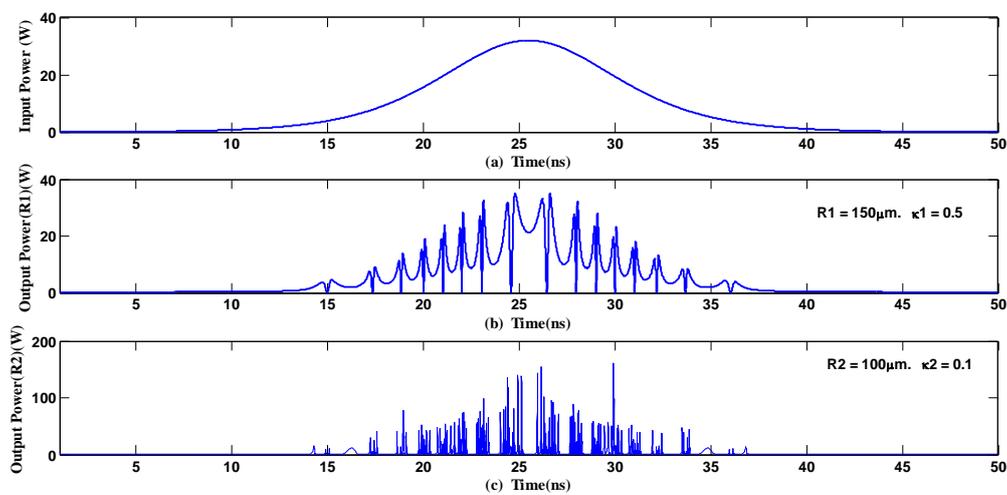


Figure 1: Schematic of multistage nano ring resonators



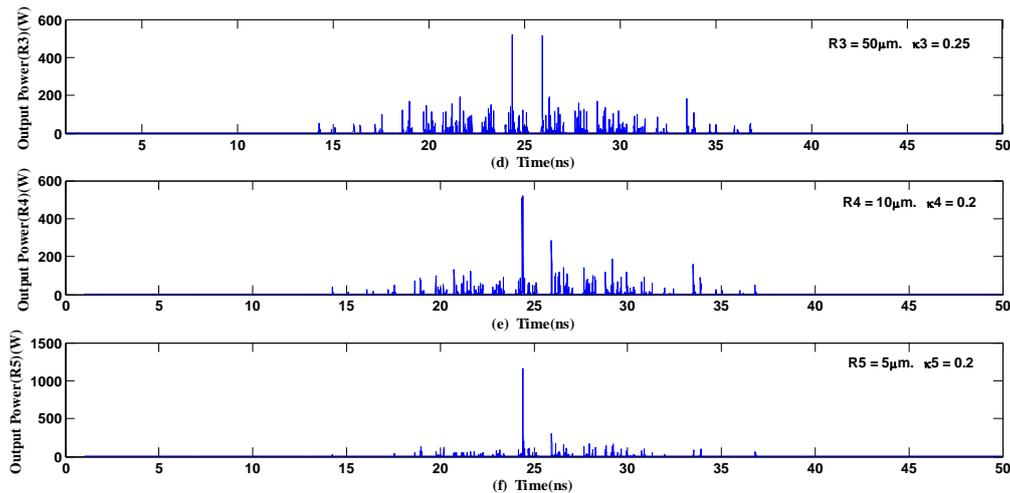


Figure 2: Result of the output signals from proposed system where (a) shows the input bright soliton pulse, (b) and (c) the chaotic signals generation, (d) and (e) the amplifying and filtering signals, (f) the generated femtosecond pulse.

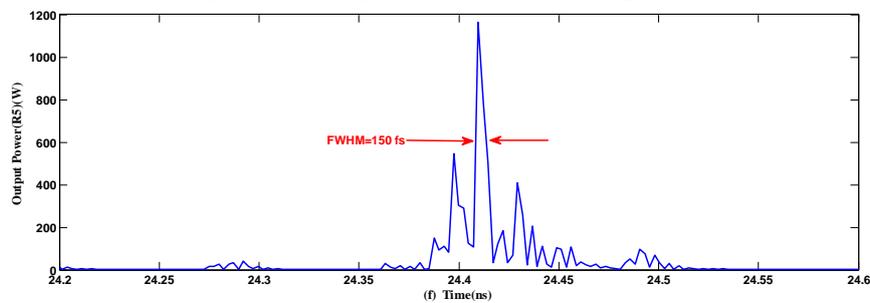


Figure 3: The generated femtosecond pulse for nano surgery

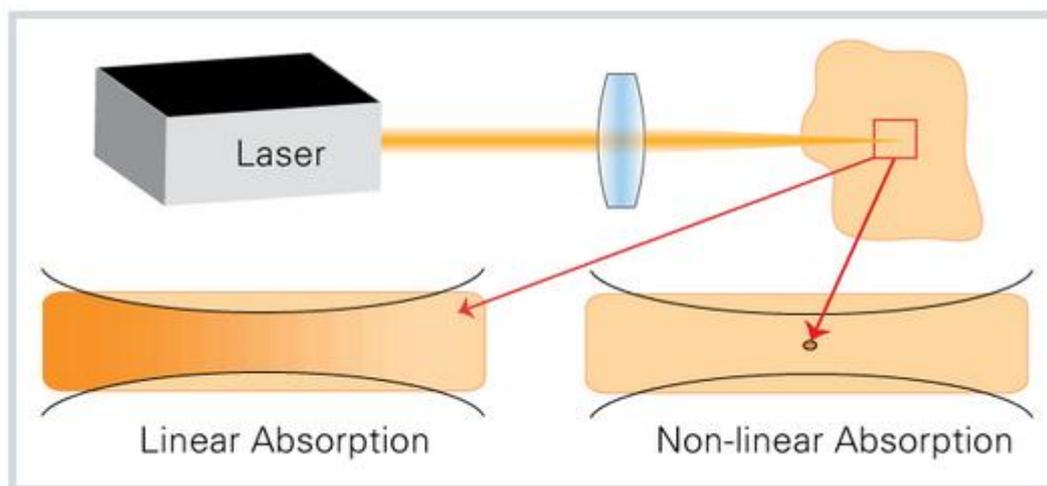


Figure 4: Removal Tissue method in nano surgery

CONCLUSION

We have proposed the novel system to generate interesting results of femtosecond soliton pulse using

nanosecond laser which pass through multistage a-Si:H nano ring resonators. The light behavior through a system of N nano ring resonator is analytically

studied. Simulated results show the generation of ultra short pulse with FWHM of 150 fs which is useful for removal tissue in nano surgery.

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