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Therapeutic processes for eradicating cancerous or benign tumours by laser beams using the excitonic approach of peptide groups

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ABSTRACT

The aim of the present study was to develop a protocol for the treatment of cancerous or benign tumours making use of laser rays, also demonstrating that the destruction process remains exclusively confined in the defective organ.
Thermal effects of lasers on biological tissue have been elucidated using vibrational excitations approach of peptide groups (PGs). It was proposed a Hamiltonian which integrate excitations induced by laser pulses and it was shown that the system is governed by a nonlinear equation with strong nonlinearity. It was also exactly described what happens in polypeptide chain once the unwanted organ is irradiated by the Neodymium-doped yttrium aluminium garnet, chosen as incident laser.
It was shown that, the advent of incident laser beams contributes to a sudden reinforcement of the vibrational excitations of PGs frequencies and amplitudes.
It was also demonstrated that the heating process leads to transverse and longitudinal deformation of the polypeptide chain and these sudden changes lead to the denaturation and subsequently to the destruction of the bulky organ. The drawn curves make it possible to estimate the spatial expansion of the denaturation, in order to effectively control the spread of the heat. Laser irradiation leads to a drastic increase in the vibration amplitudes of the PGs and subsequently results in the destruction of the undesirable tissue. An appropriate choice of the laser can make it possible to circumscribe the destruction only in the defective zone and to protect healthy cells.

Key words: Cancer, radiotherapy, heat transport in biological tissues, protein denaturation, peptide groups

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Peptide groups laser excitonic approach for cancer treatment
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Introduction

Radiotherapy is a fascinating topic tackled by researchers in several directions, with the common objective to easily and effectively remove the excess substance from the body, alleviate the suffering of the patient and even completely overcome the disease. Schnelzer and coll. (1) took into consideration smoking on radon-associated risk for lung cancer mortality among German uranium miners: they investigated the increase in risk with a linear excess relative risk model while considering smoking as a multiplicative factor and concluded that lung cancer mortality risk increased essentially with radon exposure increasing and also that the impact of smoking led only to marginal changes.
Cancers manifest themselves in different forms and, whatever the mode of treatment, the primary wish of doctors is to achieve an early diagnosis and screening. Diagnosis is a crucial step in the process of eradication of all forms of cancer and it fundamentally determines what happens later on. In this spirit, Hamim and coll. (2) developed an automated system for diagnosing oral lesions at initial stages with the result to be able to quickly intervene and save the patient's life. A quick assessment of the extent of the damage can make doctors be more efficient and, according to these authors, early diagnoses can significantly reduce the mortality resulting from oral cancer.
As earlier mentioned, the main object is to rid the body of foreign and unwanted substances as well as to protect healthy cells against collateral damages.
The present work represents a platform for the description of biological tissue thermal process under laser pulsed radiation and, in this contribution, it intends to exactly describe what happens in polypeptide chain once the unwanted organ is irradiated by a pulsed laser. In this context, a complete diagnosis must be made to determine, with precision, the exact size of the unwanted organ to eliminate and it is important to clearly define the framework of this operation. As soon as these conditions are fulfilled, the physician could easily remove the unwanted substance and, at the same time, protect healthy cells from the violence of laser beams. In fact, special care must be taken so that heat does not reach healthy substances. Thus, the development proposed in this paper will make it possible to determine:

- The most suitable type of laser that will allow the operation to be efficiently carried out;
- The required intensity of the selected laser;
- The duration of the laser irradiation.

Such predictions could be done only if the transfer process of heat generated by laser beam through biological tissue as well as the mode of degradation of the tissue under heat action are fully understood.
In this model the process of denaturation and total destruction of biological tissue based on the formalism of vibrational excitations of PGs is described. Indeed, the long polypeptide chain is made up of PGs which, thanks to the vibrations to which they are subjected, generate the energy necessary for the proper functioning of the organism.
It turns out that, during laser beam surgery, PGs receive an energy excess and this is likely to excessively multiply the frequencies and amplitudes of vibrational excitations, leading inevitably to uncontrollable situations.
Radiotherapy is a very delicate and risky exercise and precautions should be taken to avoid or limit unwanted effects. In this sense, a survey by a Korean group (3) was performed in view of improving the risk management system of radiation therapy departments in the Republic of Korea. It should be noted, in passing, that collateral damages which could occur during radiation therapy are of two types: they are inherent to the patient, as we have just underlined but they could also concern physician. Indeed, physician faces great risks while manipulating laser beams and this aspect of the problem has been very well developed by Fadi and coll. (4) in a quite interesting contribution.
Our model was built following laser treatment processes developed by Simo in a very recent book (5): in this contribution, he proposed protocols for overcoming certain diseases making use of the technique of radiotherapy, namely, the angioma, the condyloma and the tracheal tumours. In the same vein, Simo and coll. (6) proposed an innovative model of laser production using the technics of high-order harmonic generation. Given that, lasers so generated could also be used in the medical area.

Materials and methods

The denaturation process of human tissue that occur during laser beam surgery can be explained using vibrational excitations approach.

Tissue functioning in normal mode, without irradiation

The PGs constituting the giant polypeptidic chain are in perpetual vibrational movement around their equilibrium positions. The biological tissue consists of protein molecules with long chains of polypeptidic giant molecules, the constitutes of which being the PGs. PGs are constantly vibrating in our body and the idea is that energy is stored as vibrational energy in the C=O stretching mode (amide-I) of a polypeptidic chain. This vibrational excitation propagates from one group to the next because of the dipole-dipole interaction between the neighbouring groups [7-12]. Indeed, energy which results from these vibrations ensures the good functionality of the human body. These vibrations are permanently in progress since they are at the origin of the life. Indeed, these vibrations generate energy which punctuates the life of the human being. Human beings need energy to cover various functionalities that condition their existence. All the vital functions of human beings require energy for a perfect accomplishment of the tasks which are devoted to them. We can list, for instance, breathing activities, walking, muscle contraction, etc. The organism is therefore installed in a regime of residual vibrational excitations which maintain life.
The overall Hamiltonian of the system is made up of two essential components: the phonon Hamiltonian and the exciton Hamiltonian:

(i) The phonon Hamiltonian describes the pure lattice vibrations. This reflects the slow movements of the entire molecule around its equilibrium position. The expression of which is given by:

$$H_{ph} = \sum_n \left[\frac{P_n^2}{2M} + \frac{M\omega_0^2}{2}(Q_n - Q_{n-1})\right] \qquad (1)$$

Where Q_n, P_n, m, are the displacement of the n^{th} low frequency vibration from the equilibrium position, the momenta and mass of the molecules respectively. ω_0 is the characteristic frequency,

(ii) The exciton Hamiltonian describes intramolecular vibrational excitations. This Hamiltonian takes the following form:

$$H_{ex} = \sum_n [J_0\, B_n^+ B_n + M_0(B_n^+ B_{n+1} + H.C)] \quad (2)$$

$\boldsymbol{B_n^+}$ and $\boldsymbol{B_n}$ are the corresponding creation and annihilation operators. M_0 is the dipole-dipole interaction energy between nearest-neighbour molecules. J_0 is the free-molecule excitation energy due to an intramolecular vibration.

The biological tissue is subjected to laser irradiation

As we mentioned earlier, prior to tissue irradiation, PGs are subjected to a continuous vibration mode naturally maintained. The sudden absorption of laser pulses corresponds to a sharp and highly significant increase in the energy of the PGs. The additional supply of laser energy strengthens vibrational excitations and generates an excess of energy which causes increased heating. So, the occurrence of the laser energy causes the PGs to oscillate with very high amplitudes and frequencies. This could subsequently subject these PGs to critical resonances which obviously gives rise to the process of denaturation. Consequently, a drastic collapse of the unwanted tissue can be observed. At the same time, healthy cells must be protected.
Finally, as soon as the PG absorbs photonic energy, it accelerates the vibrating process from its equilibrium position. Therefore, the amplitudes of vibrational excitations are rapidly amplified over time. The heat source involved in surgical operation is derived from the Beer-Lambert Law: according to the latter, the intensity of the incident radiation decreases exponentially with the penetration depth [13-14]. Let's notice in passing that, we consider collimated irradiation at normal incidence and irradiation is assumed to be constant over time.
Then, the Hamiltonian of the vibrational excitations induced by pulsed laser is given by

$$H_{lex} = \sum_n (1-R)\mu_a E_v e^{-\mu_a Q_n}\, B_n^+ B_n \qquad (3)$$

where E_{ν} stands for the incident energy flux at tissue surface and μ_a is the absorption coefficient. The parameter R represents the Fresnel tissue surface reflectance. Thus, H_{lex} describes the coupling between laser manifestations and vibrational excitations.

In this context, the total Hamiltonian of the system is determined by the contribution of the three components described by the formulas (1-3):

$$H = H_{ph} + H_{ex} + H_{lep} \quad (4)$$

Next, we introduce state vectors which are products of a normalized one-exciton state and a coherent phonon state,

$$|\Psi(t)> = \sum_n \beta_n(t) B_n^{+}|0>_{ex} \left[exp\left(\frac{1}{i\hbar}\sum_n (u_n(t)P_n - \pi_n(t)Q_n)\right)\right]|0>_{ph} \quad (5)$$

Discrete equations of motions satisfied by β_n and u_n are given as

$$i\hbar\frac{\partial\beta_n}{\partial t} = J_0\beta_n + M_0(\beta_{n+1} + \beta_{n-1}) + (1 - R)bE_{\nu}e^{-bu_n}\beta_n \quad (6)$$

$$M\frac{\partial^2 u_n}{\partial t^2} = (u_{n+1} + u_{n-1} - 2u_n)M\omega_0^2 - (1 - R)bE_{\nu}e^{-bu_n}|\beta_n|^2 \quad (7)$$

$$J_0 = 0{,}205\ eV \equiv 0{,}328.10^{-19}\ J;$$
$$M_0 = -7{,}8\ cm^{-1} \equiv -1{,}549.10^{-22}\ J;$$
$$v_0 = a\omega_0 = 4{,}6.10^3\ ms^{-1};$$
$$v = 4{,}5.10^3\ ms^{-1}; R = 2{,}4\%$$

$$E_{\nu} = 50031\ Wcm^{-2};$$
$$\mu_a = 20\ cm^{-1} \equiv 3{,}971.10^{-22}\ J;\ \ M = 114\ m_p \quad (8)$$

Exact analytical solutions of the nonlinear coupled differential-difference equations are unobtainable.

In the rest of this work, we will be interested in smooth waves or waves with long wavelengths compared with the lattice constant, a. In this context, we may adopt a continuum approximation and Eqs. (6-7) turn into:

$$i\beta_t = -A_0\beta_{xx} - \mu\beta + (1 - R)bE_{\nu}e^{-bu}\beta \quad (9)$$

$$mu_{tt} = C_0u_{xx} - (1 - R)b^2E_{\nu}e^{-bu}|\beta|^2 \quad (10)$$

The subscripts *t* and x denote partial differentiation with respect to time and space, respectively. Now, we differentiate Eq. (10) once with respect to the spatial coordinate. After replacing u_x by η, we arrive at these two equations:

$$i\beta_t = -A_0\beta_{xx} - \mu\beta + (1 - R)bE_{\nu}e^{-b\int\eta dx}\beta \quad (11)$$

$$m\eta_{tt} = C_0\eta_{xx} - (1 - R)b^2E_{\nu}\ \left[e^{-b\int\eta dx}|\beta|^2\right]_x \quad (12)$$

In order to propose a solution to these master equations governing the system, we introduce the ansatz

$$\beta = \Phi(s)exp[i(kx - \omega t)], \eta = \eta(s), s = x - v \quad (13)$$

Substituting Eq. (13) into Eqs. (11-12), we obtain after some algebras:

$$\Phi_{ss} = a_1\Phi + a_2e^{-b\int\eta dx} \quad (14)$$

$$\eta_s = b_1e^{-b\int\eta dx}\Phi^2 \quad (15)$$

Here,

$$a_1 = -\frac{\omega + \mu - A_0k^2}{A_0};\ \ a_2 = \frac{\mu_a(1 - R)E_0}{A_0};$$
$$A_0 = -\frac{M_0a^2}{h} \quad (16)$$

$$b_1 = -\frac{(1-R)b^2E_0}{mv^2 - C_0}; \mu = -\frac{J_0 + 2M_0}{h} \quad (17)$$

The above system of equations (14–15) is not easy to solve. We will approach it following the work done by Simo and coll. [8] in biological models. So, for the sake of simplicity, we assume that η is of the form:

$$\eta = Nsech^2\left(\frac{s}{\Delta}\right) \quad (18)$$

where $\boldsymbol{N}$ is the amplitude of the pulse solution and Δ is its width. The numerical values considered in the computations being: N=1.24 and Δ= 2.32 Å.

This will significantly easier the process under consideration. Substituting (18) into (14-15) we obtain, after some algebras:

$$\Phi_{ss} = a_1\Phi - \frac{2a_2N}{\Delta b_1} sech^2\left(\frac{s}{\Delta}\right) tanh\left(\frac{s}{\Delta}\right)\frac{1}{\Phi^2} \quad (19)$$

Results and discussion

Numerical analyses of the action of laser rays on biological tissues: search for conditions for effective treatment preserving healthy cells

Studies are made on the basis of master equation (19). The starting point is the irradiation of the biological tissue by a laser ray, followed by the absorption of the photonic energy by the matter.

This energy reinforces the vibrational motility of the PGs forming the polypeptide chain and these strong vibrations are accompanied by a significant release of heat. So, the energy carried by photons is converted into thermal agitation of the molecules and the thermal energy so released is transported into the tissue by dipole-dipole interaction. So, these reinforced vibrations move along the polypeptide chain producing important damages throughout its course. In this study, we consider as incident lasers the Neodymium-doped yttrium aluminium garnet (Nd:YAG).

The capital fact that should be emphasized is that tissue degradation must be formally controlled in order to protect healthy tissues during this operation.

The incident heat that arrives at the site, n, via the laser beam does not stagnate at this position but it is intended to propagate along the polypeptide chain and this is called heat contamination. Once the appropriate type of laser has been chosen, we want to examine the impact of the intensity and the duration of the irradiation on the extent of the heated tissue. The calculations proposed in this contribution make it possible to determine, beforehand, the set of physical parameters associated to each configuration. Thus, we determine the intensity and the time period that allow the heat to be confined exactly in the defective tissue thickness.

It is therefore a technique which makes it possible to treat the patient while protecting its healthy cells. The expansion of forced vibrations is visible on Fig. (1). Three typical situations are deeply analysed.

Here, the thickness of the tissue impacted by heat is indicated for three different values of the intensity of the incident laser. These are specifically:

$I_1 = 1{,}5\ W/cm^2$; $I_2 = 1{,}75\ W/cm^2$ and $I_3 = 2{,}0\ W/cm^2$.

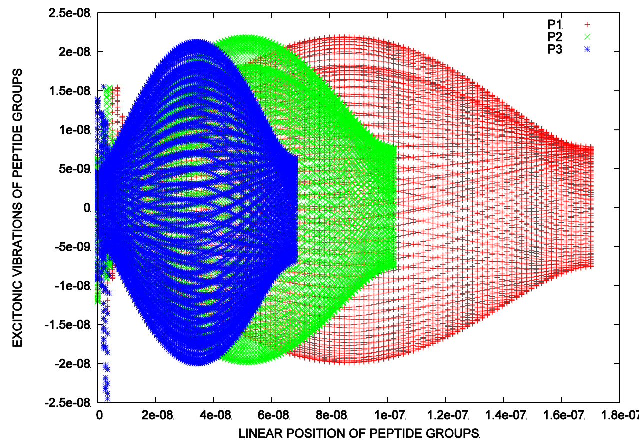

Fig. 1. Thickness of the tissue impacted by heat for three different values of the intensity of the incident laser: $I_1 = 1{,}5\ W/cm^2$ (curve in blue), $I_2 = 1{,}75\ W/cm^2$ (curve in green) and $I_3 = 2{,}0\ W/cm^2$ (curve in red).

It clearly appears that the thickness of the heated tissue increases with the intensity increase.

It should also be noticed that, following the irradiation of biological tissues, the amplitudes of vibrational excitations are rapidly amplified over time.

Fig. (2) depicts the abrupt change of vibrational excitation amplitudes with time as soon as the irradiation starts. In this figure, are first represented the typical vibrational excitations, in a normal and natural situation of life. Amplitudes suddenly increase almost exponentially, this leading to a chaotic process and subsequently to the degradation and destruction of the tissue.

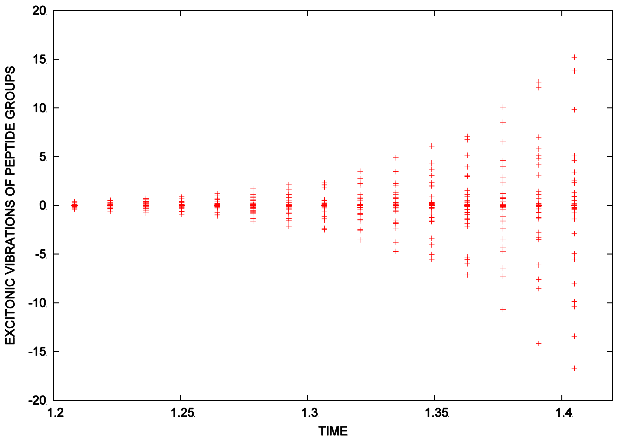

Fig. 2. The variation of vibrational excitation amplitude as a function of time after the initiation of laser beam irradiation. Here, the time period is multiplied by $1{,}5.10^{12}s$ while the amplitude of vibrations is multiplied by $1{,}25.10^{7}m$.

The heating process is also accompanied by a strong elongation of the chain. Figs. (3-5) depict the rate of change in chain length of the biological tissue for three different values of the laser intensity: For the value $I_1 = 1{,}5\ W/cm^2$, the rate of length variation is around 1.2; For $I_2 = 1{,}75\ W/cm^2$, it is around 2.5. While, for a somewhat higher value $I_3 = 2{,}0\ W/cm^2$, it turns to the value 3.5. These results tell us that the rate of length change grows as the intensity of the incident laser grows.

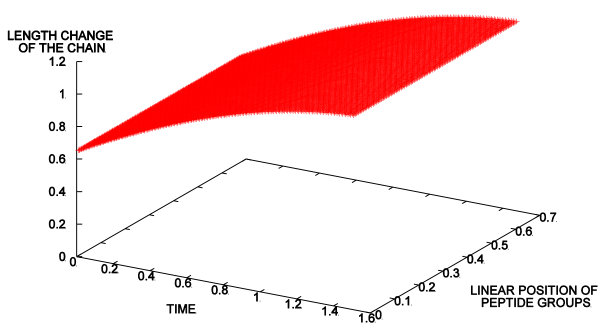

Fig. 3. The rate of change in chain length for a laser intensity $I_1 = 1{,}5\ W/cm^2$. Here, the time period is multiplied by $1{,}5.10^{12}s$ while the position of the PG is multiplied by $1{,}25.10^{7}m$.

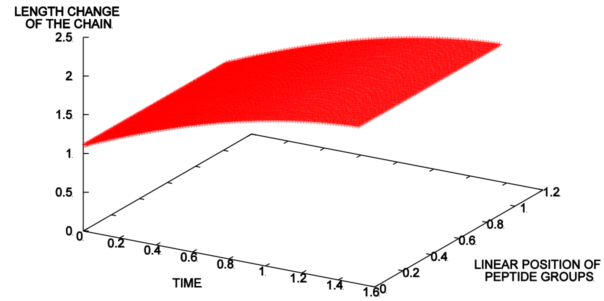

Fig. 4. The rate of change in chain length for a laser intensity $I_2 = 1{,}75\ W/cm^2$. Here, the time period is multiplied by $1{,}5.10^{12}s$ while the position of the PG is multiplied by $1{,}25.10^{7}m$.

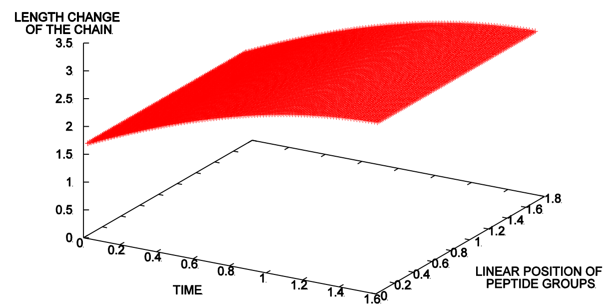

Fig. 5. The rate of change in chain length for a laser intensity $I_3 = 2{,}0\ W/cm^2$. Here, the time period is multiplied by $1{,}5.10^{12}s$ while the position of the PG is multiplied by $1{,}25.10^{7}m$.

Our investigations demonstrates that heat input causes both transverse and longitudinal deformation of the chain and these abnormal increases in the amplitudes of motion result in denaturation and total destruction of the tissue, as we mentioned earlier.
The ambition pursued while carrying out these calculations can be summed up as follows: In the presence of a perfectly determined and elucidated anomaly, we must be able to select the appropriate incident laser and all the corresponding physical parameters.

Conclusions

The therapies proposed in this paper use laser beams to overcome certain forms of cancers. The main objective here is to destroy the mass of undesirable, inconvenient or cumbersome organ making the carrier of this default uncomfortable.
The PGs constituting the giant polypeptidic chain are in perpetual vibrational movement around their equilibrium positions. So, in a normal life condition, the biological tissue is constantly submitted to the primary heating resulting from natural vibrational excitations of PGs. These vibrations release energy which ensures various functionalities of the organism. So, the main function of these vibrations is to give life to the cell and subsequently to the organism. It is clear that energy concerns are at the heart of the life. Life ceases as soon as the energy disappears. There is a source of persistent energy in the human body which allows one to exist. The local energy recorded around the PG irradiated by the laser beam is extremely high, to abruptly multiply the amplitudes of the vibrational excitations. The occurrence of a dramatic increase in the amplitudes and the frequencies of vibrational excitations gives rise to the process of denaturation. Consequently, a drastic collapse of the unwanted tissue can be observed. Therefore, denaturation occurs in an abnormal situation and alters the protein molecule.
It becomes imperative to protect healthy cells while confining heat only in the defective area.
The formalism developed in this paper aims to display a total control on the process of heat diffusion in human tissue. We have built a Hamiltonian describing the action of laser rays on biological tissue. We have obtained that; higher values of laser intensity are associated with higher length change of the biological tissue. The results presented in this paper also show that the heated area is a function of the intensity and the period of irradiation. This survey enables one to determine the type of appropriate laser for this operation, its physical characteristics and the duration of irradiation. By doing so, we could eradicate the unwanted substance while protecting healthy cells.

The novelty that can be highlighted in this model is the coupling of the energy induced by irradiations of biological tissues with the natural energy generated by the hydrolysis of the ATP molecule.
And this, in order to elucidate the denaturation and the destruction of the undesirable organs by making use of the excitation concept of PGs.
This model obviously has some limitations. Indeed, risks cannot be completely eradicated. We can only strive to limit them as much as possible and reduce them to their minimum portion. First of all, we must point out that laser beams are dangerous and difficult to handle. Possible risks can be recorded not only for the patient but also for the doctors.
Moreover, it is an expensive technique, not within everyone's reach; especially if we refer to Third World countries where people live below the poverty line, in indescribable precariousness. They cannot afford this type of care.
This model has been built by nourishing the wish that the proposed analyses will improve the protocols of treatment of certain anomalies by laser rays. Doctors should do their utmost to treat while preserving healthy organs.

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Conflict of interest
The authors declare no conflict of interest.

References

[1] Schnelzer M, Hammer MGP, Kreuzer M, Tschense A, Grosche B. Accounting for Smoking in the Radon-related Lung Cancer Risk Among German Uranium Miners: Results of a Nested Case-control Study. Health Physics 2010; 98: pp. 20-28.
[2] *Mohammed H, Ismail EM, Mohan, Hicham DP, Mustapha HM.* A Hybrid Gene Selection Strategy Based on Fisher and Ant Colony Optimization Algorithm for Breast Cancer Classification. iJOE 2021; 17: pp. 148-63.
[3] Ahn S, Shin DO, Choi SH, Koo J, Lee SS, Park D, Oh Y, Park S, Kim DW. Status and Perception of Risk Management in Radiation Therapy Survey Among Korean Medical Physicists. Health Physics 2018, 114; pp. 77-83.
[4] Asma F, Khadija FL, Jabran D, Said B, Said B, Fatima ZR, Hassane K. Contribution of Simulation

in the Development of the Competences of Future Radiology Technicians in the Framework of the Management of the Risks Associated with the Medical Radiology Techniques. International Journal of Online and Biomedical Engineering 2021; 17: pp. 135-52.

[5] Simo E. Therapeutic Processes to Overcome Angioma, Condyloma and Trachea tumours in the Frame work of the Numerical Analysis of Heat Transfer in Biological Tissues Irradiated by Pulsed Laser. Ed. Generis Publishing, 2021, ISBN: 9798598496664

[6] Simo E, Caputo JG. High-order harmonic generation by double-photoionization accounting for the correlation between continuum electrons. Optik 2011; 122: pp. 247-55. Int. J. Light Electron Opt.

[7] Cruzeiro L. The Davydov/Scott Model for Energy Storage and Transport in Proteins. J. Biol Phys. 2009; 35(1): pp. 43-55.

[8] Simo E, Kofane TC. On nonlinear Effects in Molecular Chains with one Type of Intramolecular Vibrations. Phys. Scipta 1994; 49: 543.

[9] Georgiev DD, Glazebrook JF. Thermal stability of solitons in protein α-helices. Chaos, Solitons and Fractals 2022; **155**: 111644.

[10] Georgiev DD, Glazebrook JF. On the quantum dynamics of Davydov solitons in protein α-helices. Physica A: Statistical Mechanics and Its Applications 2019; 517: pp. 257-69.

[11] Georgiev DD, Glazebrook JF. Launching of Davydov solitons in protein alpha-helix spines. Physica E Low-dimensional Systems and Nano-structures 2020; 124: 114332.

[12] Peyrard M. Nonlinear excitations in biomolecules. Springer-Verlag Berlin Heidelberg and Les Editions de Physique Les Ulis, 1995.

[13] Manns F, Borja D, Parel JM, Smiddy W, Culbertson W. Semianalytical thermal model for sub ablative laser heating of homogeneous nonperfused biological tissue: application to laser thermo-kerato-plasty. Journal of Biomedical Optics 2003; 8: pp. 288-97.

[14] Tung MM, Lopez Molina JA, Rivera MJ, Berjano EJ. Modeling the heating of biological tissue based on the hyperbolic heat transfer equation. Mathematical and Computer Modelling 2009; 50(5-6): pp. 665-72.

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