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THE OPTIMAL VALUES OF LASER PARAMETERS FOR SOME APPLICATIONS IN CLINICAL PRACTICE

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Abstract: Laser radiation is nowadays applied in various fields of medicine. However, the efficiency of its application is particularly determined by the appropriated choice of values of laser radiation physical parameters. Within this paper, the authors notify the optimal values of laser parameters in clinical applications of Ar laser in ophthalmology, CO_2 laser in neurosurgery and He-Ne soft laser for biostimulation.

1. Introduction

Molecules involved in biologic system are extremely complex and can maintain vital activity only in very specific configurations. Thus, depending on the wavelength, widely different interactions are observed [1]

The effects of laser radiation on tissue depend primary on the wavelength, power delivered per unit area of tissue, and duration of exposure [2]. Photons in the ultraviolet region are so energetic that interaction with a biologic system leads to disruption or alteration of DNA and RNA into abiotic forms, and cell death follows. The effects are predominantly photochemical, and in this wavelength region, chemical changes may be produced directly by the laser beam. Photons in the visible part of the spectrum lead to two forms of interaction. First, the photons can provide energy for photochemical reaction, such as photosynthesis and those that take place in the visual process. Second, the energy of the photons that are absorbed is degraded into heat, and since temperature is a very critical parameter in the normal operation of a living cell, a small increase in temperature can lead

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to thermal damage. At longer wavelengths, thermal effects predominate, resulting in coagulation, vaporisation and carbonisation [3]. When a very high-power laser beam is focused into a very small area, then absorption is by nonlinear processes, with the generation of thermoacoustics shock waves.

An extreme degree of caution is required in selecting the physical parameters of laser radiation, which are used in successful realization of clinical treatments.

2. Ar ion laser in ophthalmology

Interaction of Ar laser beam with the retina has been studied by a number of investigators. Because the Ar laser usually emits several wavelengths in blue-green part of the spectrum, all the wavelengths of this laser are located in a relatively narrow part of the spectrum that is almost optimally located for effective interaction with both the pigment epithelium and choroid. Experimental evidence in rhesus of monkeys has shown that vessels can be occluded with the Ar laser beam by a power 10 times less than that used with Xe-arc radiation. The wavelengths of the Ar laser appear to be extremely effective for photocoagulation of both the pigment epithelium and the choroid and for interaction with blood vessels.

The type of damage caused in photocoagulation is thermal in nature. This damage is associated with denaturation of proteins or the inactivation of enzymes [1,3]. The temperature rise is required for this type of damage is only in the range 10-30°C for the retinal damage associated with minimal to heavy clinical exposures.

It has been shown that at the power levels used for interaction of minimal damage and for clinical applications, only small amount of energy is absorbed by the photopigments of the eye. The majority of the energy that reaches the fundus is absorbed by the pigment epithelium and choroid. The resulting interaction results in thermal damage of the tissues in the fundus of the eye [1].

Because of its high density of melanin granules, the pigment epithelium is the place where the highest absorption per unit volume takes place. The highest temperature rise in the back of the eye will thus take place near or inside the pigment epithelium layer. Because of the geometry of the absorbing layers and since thermal conduction can take place away from the interaction region, the size of the interaction area plays a very important role as far as temperature rise and decay of the exposed site are concerned.

In case of small spot size the temperature quickly rises and reaches a constant value. This temperature is the point of equilibrium where the heat introduced into the interaction region is equal to the heat being conduced away to the surrounding tissues. In larger spot sizes it takes longer for equilibrium to be reached; more important, a higher temperature is reached (even though the power density is the same) because the thermal conduction of heat from a small spot size is more effective than that from a large spot size. In a small spot size one has a small absorbing area; as the heat is absorbed and the temperature begins to rise, there will be thermal relaxation or conduction of heat away from the site. In a small area the central part of the absorbing area, which is the part that becomes the hottest, can cool in virtually all directions, so that the cooling of a small spot is fairly effective. In contrast, in a large spot the entire central area begins to heat up simultaneously, so that the center part of the region cannot cool as effectively because its immediate neighbors are also heating up. Thus, in a large area it takes less photon absorption per unit area to generate a certain temperature than in a small area.

Table 1. The optimal values of **Ar ion laser parameters for some applications in ophthalmology.**

Clinical treatment	Wavelength $\lambda(nm)$	Power $P(mW)$	Operation	Pulse duration $t_{imp}(s)$	Spot size $d(\mu m)$	Max. spot number
Photocoagulation of normal blood vessels	**488 and 514**	**200-400**	**pulsed**	**0.1-0.2**	**100**	**1500**
Panretinal photocoagulation	**488 and 514**	**200-600**	**pulsed**	**0.1-0.2**	**50-500**	**1500**
Trabeculoplasty	**488 and 514**	**700-1000**	**pulsed**	**0.1-0.2**	**50**	**36-42**
Iridoplasty	**488 and 514**	**300-500**	**pulsed**	**0.5-1.0**	**50-500**	/

Since in photocoagulation the goal is to generate the same temperature rise at the center of any lesion, the power density used must be correspondingly reduced as the spot size is increased.

At very short exposure times the power requirement varies in a way that is proportional to the area size. Thus, if the spot size is increased by a factor of two, the area correspondingly increases by a factor of four, and four times as much power will be required to reach the same temperature. In this exposure time regime the heating of the tissues takes place in a short time in comparison with the thermal relaxation time; that is, no cooling takes place because of conduction. However, at long exposures, which is the regime where most clinical Ar laser exposure are made, the situation is quite different. Here, we see that if the spot size is increased by a factor of two, the power required increases only by a factor of two instead of four, because smaller spot is more efficiently cooled by conduction than larger one. Thus, whenever the spot size is adjusted, the power must always be correspondingly adjusted [1,3].

At the Clinic of Ophthalmology in Niš Ar ion laser (COHERENT 920 Medical Group-class IV, P_{max}= 9W - CW) is successfully applied with the adequate values of parameters. Previous experience has shown that values of parameters should be selected as given in Tab. 1. The presented data coincide with the results quoted by other authors [4,5,6].

3. CO_2 Laser in neurosurgery

CO_2 laser have been widely used in neurosurgery due to excessive potentials of incision and vaporisation of tumor tissue. Applying CO_2 laser on the nerve tissue, very precise lesions may be performed without disturbing the functions of surrounding tissue [7].

Table 2. The optimal values of CO_2 **surgical laser** parameters for some applications in neurosurgery.

Clinical treatment	Wavelength $\lambda(\mu m)$	Power $P(W)$	Operation	Exposure duration t(min)	Spot size $d(mm)$	Application mode
Soft tissue vaporisation	10.6	5-20	CW	3-30	0.45-0.77 at working dist. 200-400 mm	Free-hand surgery
Soft tissue incision	10.6	5-20	CW	3-30	0.09 and 0.22	Free-hand surgery

Specialists at the Clinic of Neurosurgery in Niš successfully apply CO_2 laser (SHARPLAN 733A Surgical laser-class IV, P_{max}=50 W -CW) with the adequate values of parameters. Previously obtained results shown that the values of parameters should be chosen as presented in Tab. 2.

4. He-Ne soft laser for biostimulation

Many studies have reported on the beneficial effects of soft laser irradiation in the treatment of non-healing ulcers and wound healing. However, most of reports are open to serious scientific criticism. Even after almost 20 years, the role of laser biostimulation in wound healing has not become established [2,5]. Controversy exists whether or not any laser biostimulatory effects, if it exists, is due to properties specific to laser light, i.e. coherence and polarisation.

Table 3. The values of **He-Ne soft laser** parameters for biostimulation of wound healing and therapy of ulcerous lesions.

Clinical treatment	Wavelength $\lambda(nm)$	Power $P(mW)$	Operation	Exposure duration t(min)	Spot size $d(mm)$	Application mode
Wound healing	632.8	1	CW	10 a day 7 days	2-3	Circular motion at working distance 20-25 cm
Therapy ulcerous lesions	632.8	1	CW	5 a day 7 days	2-3	Circular motion at working distance 20-25 cm

Some experiments with experimental animals carried out at the Institute of Biophysics of Medical Faculty in Niš (He-Ne soft laser PL-9 class II, P=1 mW -CW) have proved the existence of a strong biostimulating effect during the therapy of surgical wound healing and ulcerous lesions induced by acid acetic [8,9]. Table 3 presents the values of physical parameters being for biostimulation.

5. Conclusion

Laser radiation is widely used in medicine. The application efficacy depends on values of laser radiation physical parameters. In this paper the authors give the optimal values of laser radiation physical parameters which have been obtained on the basis of many years of clinical practice and experimental studies.

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OPTIMALNE VREDNOSTI LASERSKIH PARAMETARA ZA NEKE PRIMENE U KLINIČKOJ PRAKSI

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Sadržaj: Lasersko zračenje danas se primenjuje u mnogim granama medicine. Međutim, efikasnost primene je naročito uslovljena pravilnim izborom vrednosti fizičkih parametara laserskog zračenja. U ovom radu autori daju optimalne vrednosti laserskih parametara za kliničke primene Af lasera u oftamologiji, CO_2 lasera u neurohirurgiji i He-Ne soft lasera za biostimulaciju.