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Laser apparatus for surgery and force therapy based on high-power semiconductor and fibre lasers

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***Abstract*.** **High-power semiconductor lasers and diode-pumped lasers are considered whose development qualitatively improved the characteristics of laser apparatus for surgery and force therapy, extended the scope of their applications in clinical practice, and enhanced the efficiency of medical treatment based on the use of these lasers. The characteristics of domestic apparatus are presented and their properties related to the laser emission wavelength used in them are discussed. Examples of modern medical technologies based on these lasers are considered.**

Keywords: *semiconductor and fibre lasers, lasers for surgery and force therapy.*

1. Introduction

During the time elapsed since the end of 1960s, the efficient laser surgery methods have been developed for medical treatment of various diseases, and the laser scalpel has become a standard tool of physicians at large medical centres. However, until the mid-1990s, the complexity of laser medicine instruments, the necessity of a permanent qualified engineering service, the need of special operating rooms that would accommodate the bulky laser equipment and high-power electric supplies prevented the application of laser apparatus in surgery and force therapy* in public health.

2. Semiconductor and fibre lasers in surgery apparatus

The situation has changed in the early 1990s due to the improvement of the reliability and the increase in the output power of semiconductor lasers (laser diodes) along with the decrease in their cost. Somewhat later, fibre lasers were developed which generated output powers of a few and then tens and hundreds of watts.

All this permitted the development of medical equipment based on semiconductor and fibre lasers for surgery and force therapy with excellent operating parameters: a small size and weight (about 10 kg) and low energy consumption ($\sim$ 100 W). Because radiation of diode lasers can be rather simply modulated by a power supply, medical apparatus based on these lasers can operate in continuous, pulsed, and repetitively pulsed regimes.

The situation became now qualitatively different. Earlier, a laser operating room was organised around a bulky laser setup and its high-power supply. A high cost of the equipment excluded in fact the possibility of using lasers of different types of medical treatment in one operating room. In addition, surgery laser apparatus required a permanent qualified engineering service.

With the advent of modern portable lasers it became possible, for example, to accommodate in one endoscopic stand several inexpensive apparatus differently acting on biological tissues. It is important that due to the high reliability and simplicity of their control such apparatus do not require any engineering staff for operation. In addition, apparatus based on semiconductor and fibre lasers are cheaper than their analogues based on solid-state or gas lasers, and their operation cost is lower because no preventive maintenance is required.

From the point of view of medical applications, it is also important that the choice of laser wavelengths has expanded. It is known that the penetration depth of laser radiation into biological tissues depends on the radiation wavelength, which strongly affects the character and results of the laser action.

Domestic apparatus based on semiconductor lasers are summarised in Table 1. The apparatus indicated in bold appeared or were approved by the Ministry of Public Health of the Russian Federation during the last two years. For comparison, the characteristics of a laser apparatus produced by one of the world leaders of medical instrument making – the OpusDent British-Israel company are presented**.

Recently interest in the low-cost, low-power laser apparatus was noticeably increased, resulting in the advent of new models. This occurred due to the refinement of medical procedures, which made is possible to reduce the

*The term 'force laser therapy' (as distinct from low-intensity laser therapy) combines here laser medical technologies based on the action of laser radiation on biological tissues which, on the one hand, changes their physical state, and on the other, does not cause any dissection or resection of a biological tissue. Examples of force therapy are the laser interstitial thermal therapy of tumours and laser thermoplastics of a cartilage tissue.

**Data are presented for all apparatus, which were exhibited at exhibitions in Moscow and St. Petersburg in 2004 – 2005.

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Table 1. Apparatus for surgery and force therapy based on semiconductor lasers.

Laser type	Wave-length/μm	Output power/W	Operating regime	Pointer laser	Mass/kg	Dimen-sions/cm	Consumed power/V A	Fibre dia-meter/mm	Manufacturer
ALod-01 ALKOM	0.81 (0.98)	3, 6, 12	Pulsed, cw	Red	7.5		50–600	0.4	RPA ALKOM-medika (St. Petersburg)
Lazon-10P	0.97	10	cw	Green	6.5	12×26×33	70	0.4–0.6	SUE FRPC Pribor (Moscow)
LSP-IRE-Polyus	0.97	5, 10 (20, 30)	Pulsed, cw	Green	6.5 (9)	12×26×33	70 (100)	0.3–0.6	LLC Qualitech (Moscow)
Atkus-15 (**Atkus-3**)	0.81 (0.98)	15 (3)	Pulsed, cw	Red	15	37× 50×17 (26× 32.5×9.5)		0.6	Poluprovodnikovye pribory (St. Petersburg)
Kristall	0.81 (0.98)	7	Pulsed, cw	Red	5	13×26×30	< 100	0.6	LLC Polironik (Moscow)
Lazermed 1-10	1.06	10	Pulsed, cw	Red		50×40×14 в укладке	240	0.6	Russkii inzhenernyi klub (Tula)
LAMI	0.63–1.8 (9 wave-lengths)	25	Pulsed, cw	Red	7	11×29×32	350	0.6; 1.0	LLC Optotekhnika (Moscow)
LAKHTA-MILON	0.63–1.75 (15 wave-lengths)		Pulsed, cw	Red, green	6	17×20×28	200	0.2 (0.1)	LLC MILON Lazer (St. Petersburg)
DIOLAN	0.81, 0.94, 0.98	30	Pulsed, cw	Red	6.5 (9)	45×35×20	400		LLC RPA VOLO (St. Petersburg)
Atkus-3	0.66	2	cw		15	37×50×17		0.6	Poluprovodnikovye pribory (St. Petersburg)
Kristall	0.675	3	Pulsed, cw		20	50×50×120	< 150		RPA Zhiva (Moscow)
Kristall 655 (Kristall 635)	0.655 (0.635)	2 (1.5)	Pulsed, cw						RPA ALKOM-medika (St. Petersburg)
Opus 10	0.81	10 (20)	Pulsed, cw	Red	9.5	24×38×11	200	0.6	Opus Dent (Israel–Great Britain)

required output powers. Note that these apparatus offer a greater number of the emission wavelengths. For example, a Lakhta-Milon apparatus emits at 15 wavelengths in the range from 0.635 to 1.74 μm. However, not all of these wavelengths were used for specific applications.

Table 2 presents medical apparatus based on diode-pumped lasers.

Note that, unlike high-power semiconductor lasers, diode-pumped lasers can be single-mode, which allows one to couple out radiation from them through thin optical

Table 2. Apparatus for surgery and force therapy based on diode-pumped lasers.

Laser type	Active medium	Wave-length /μm	Output power/W	Operating regime	Pointer laser	Fibre diame-ter/mm	Consumed power/V A	Dimen-sions/mm	Mass/kg	Manufacturer
LSP-IRE–Polyus	Yb-doped fibre Eb-doped fibre Tm-doped fibre	1.06 1.56 1.9	5, 10 2.5 (5, 10) 3	cw and pulsed	$\lambda =$ 0.532 μm	0.3 (0.5)–0.6	100 (150)	120×260×330	⩽ 9	LLC Qualitech (Moscow)
Izumrud	Nd : YAG (second harmonic)	0.53	2						⩽ 9	RPA Alkom-medika (St. Petersburg)
Amulet	Nd : YAG (fourth harmonic)	0.266	0.01	Pulsed		0.75	< 200	410×170×360	⩽ 12	LLC Energomash-tekhnika (Moscow)

Table 3. Apparatus based on lasers with two wavelengths.

Laser type	Wave-length/μm	Output power/W	Pointer laser	Mass/kg	Dimen-sions/cm	Consumed power/V A	Output	Manufacturer
LSP-IRE – Polyus	0.97 + 1.56 (1.06, 1.9)	10 + 2.5	Green, red	9	12 × 26 × 33	70 (100)	From one fibre	LLC Qualitech (Moscow)
LAKHTA-MILON	0.65 + 0.81	12 + 2	Red, green	6	17 × 20 × 28	200	From two fibres	LLC MILON Lazer (St. Petersburg)
Atkus-10	0.66 + 0.81	1 + 9		15	37 × 50 × 17		From one fibre	Poluprovodnikovye pribory (St. Petersburg)
Lazon-FT	0.67 + 1 + 06	3 + 8	Green	12	53 × 39 × 16	200	From one fibre	SUE FRPC Pribor (Moscow, development)
Modul'-GF	0.67 + 0.81 (1.06)	10 + 1	–	38	43 × 34 × 46	120	From one fibre	FSUE M.F. Stel'makh RI Polyus (development)

fibres. Thus, the diameter of the fibre core in fibre lasers can be as small as ~ 10 μm. A spot of the same size can be obtained on an irradiated object, which opens up the possibility to manufacture a tool for microsurgery medical treatment. The author pointed out to this circumstance already in [1]; however, this possibility was not realised so far.

The dependence of the action of laser radiation on biological tissues on the radiation wavelength led to the development of medical apparatus providing laser radiation at two wavelengths. These apparatus allow a physician to change the character of action during the operation (procedure) or to use simultaneously radiation at two wavelengths. Such apparatus are presented in Table 3.

The radiation wavelengths of these apparatus show that most of them are intended for photodynamic and thermal therapy (these methods are described below). Preliminary investigations have shown that the combination of these methods is quite promising. The apparatus differ in the methods of radiation coupling – either through one fibre or two separate fibres.

3. Choice of the operation wavelength

Consider the wavelengths that are most often used at present in medicine. For a long time in surgery the 10.6-μm CO_2 lasers and 1.06-μm Nd : YAG lasers were used. (The latter emission wavelength can be also obtained from semiconductor and fibre lasers.) Radiation at 10.6 μm is strongly absorbed in biological tissues (Fig. 1) and although it provides a good cut, the absorption depth is not sufficient for good coagulation. In addition, no efficient fibres are available so far for such radiation, whereas mirror-lens systems for radiation transport can be conveniently used in medicine only for open operations. In the case of cavitary and endoscopic operations such systems are not used, as a rule, because they are very inconvenient.

It is much more convenient for a surgeon to work with thin and flexible fibres, which can be brought into contact with tissues inside the body through the instrumental channel of an endoscope or by means of special instruments. In particular, optical fibres with a silica core, which are available and reliable in operation, can be used to efficiently transfer laser radiation in the range from 0.4 to 2 μm.

Figure 2 presents the absorption spectra of water and whole blood in the spectral range 0.6 – 1.1 μm [2, 3] to which the emission wavelengths of the most-used semiconductor and fibre laser scalpels fall. These spectra can be used to estimate qualitatively the penetration depth of radiation into real biological tissues. Note, however, that the radiation penetration depth also strongly depends on the scattering coefficient, which exceeds the absorption coefficient for the whole blood and amounts to ~ 65 mm^{-1} in this spectral range. Due to scattering, radiation propagates in a biological tissue not only along the initial direction but also to the sides. In addition, the physical state of a biological tissue and, hence, its absorption spectrum change during laser irradiation. Thus, upon heating above 150 °C, the hydrogen is burnt out and the tissue is carbonised, resulting in a drastic increase in absorption.

Radiation at wavelengths of 1.06 μm and 0.81 μm, which is similarly absorbed in tissues, penetrates into soft biological issues by 6 – 10 mm (by attenuating by a factor of e) providing the efficient bulk heating and coagulation.

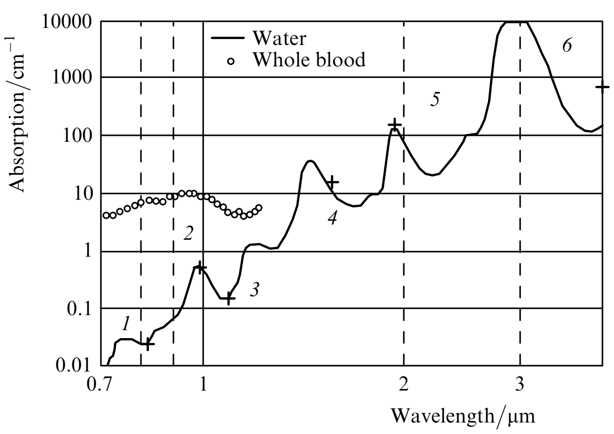

Figure 1. Absorption of radiation by water and blood in the 0.7 – 4-μm range [2, 3] for semiconductor lasers emitting at 0.81 μm (*1*), 0.94 – 0.98 μm (*2*), semiconductor lasers and Yb-doped fibre lasers emitting in the range 1.04 – 1.08 μm (*3*), Yb-doped fibre lasers emitting at 1.56 μm (*4*), Tm-doped fibre lasers emitting in the range 1.9 – 2.1 μm (*5*), and 10.6-μm CO_2 lasers (*6*).

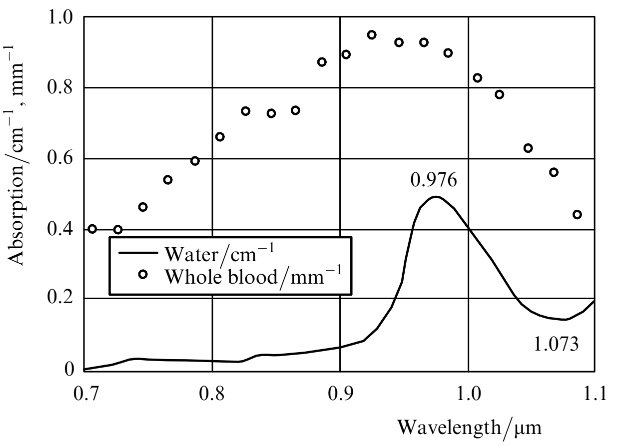

Figure 2. Absorption spectra of water and whole blood in the range 0.7 – 1.1 μm [2, 3].

However, these wavelengths are not optimal for tissue cutting because due to the 'spread' of the radiation power absorbed in the tissue, the radiation power directed to the dissection region should be increased, which can cause the damage of underlying organs during the operation.

For this reason, the contact action by a fibre instrument is used in laser surgery when the distal end of a silica fibre with a removed protective plastic jacket of length ~ 5 mm touches a biological tissue. The physical contact provides a precisely localised action and eliminates the reflection of radiation to the environment. At sufficiently high radiation powers, the fibre end is contaminated by the tissue burning products, which causes its additional heating. In this regime, the tissue is subjected to the simultaneous action of laser radiation and the glowing fibre end.

However, in this case the potential danger of undesired (and sometimes hazardous) action on the underlying organs in the beginning of operation – before the appearance of the carbonised tissue at the contact, also exists.

The radiation of laser diodes at a wavelength of 0.97 μm lying in the region of absorption bands of water and whole blood penetrates into biological tissues by 1 – 2 mm, thereby combining cutting and styptic properties [4] being optimal in most surgery operations.

Note that in the literature, in particular in methodical manuals [5, 6], the different type of action of radiation at wavelengths of 0.81 and 1.06 μm, on the one hand, and at 0.97 μm, on the other, on biological tissues is often neglected, which is incorrect according to the experimental facts presented above. For the same reason, there is little sense in using apparatus with diodes emitting at wavelengths in a broad spectral range, for example, from 0.94 to 1.06 μm.

Radiation at ~ 1.56 μm emitted by a Er-doped fibre laser or semiconductor lasers is absorbed in water more than an order of magnitude stronger than radiation at 0.97 μm, while absorption at these wavelengths in blood is approximately the same, which is important for a number of applications.

Tm-doped fibre lasers can generate radiation in the spectral range from 1.9 to 2.1 μm. The action of such radiation on biological tissues is similar to the action of the 10.6-μm radiation because absorption in soft tissues at these wavelengths is mainly determined by absorption in water. At the same time, unlike the 10.6-μm radiation, radiation at 1.9 – 2.1 μm can be delivered over a flexible silica fibre.

Red radiation is successfully used in photodynamic therapy [7].

An Izumrud apparatus using the second harmonic of a Nd : YAG laser produces radiation in the green spectral region. This radiation is widely used in ophthalmology and dermatology and is also applied for the efficient action on blood.

A domestic Amulet apparatus emits the most short-wavelength UV radiation at 0.26 μm. This radiation is efficiently applied for treatment of tuberculosis of different types immune to medicament treatment, which are more and more spreading at present. Note that the 'solid-state' Amulet apparatus surpasses in its operation parameters (weight, size, supply power, operation convenience) the analogues based on excimer lasers, for example, a Mariya apparatus (Genesto lazer, Estonia).

4. Surgery and force therapy with the use of modern laser apparatus

Consider the examples of efficient application of the apparatus described above (these applications are considered most comprehensively in proceedings of conferences [7] and [8]).

New apparatus have been most rapidly applied in otorhinolaryngology (see, for example, [9]), where they proved to be rather efficient not only in surgery operations but for the force laser therapy such as laser cartilage thermoplastics [10]. The method is based on the ability of a cartilage tissue to change reversibly its elasticity upon after heating up to $\sim 70\,^{\circ}$C, which allows the shaping of the nose septum and wings and conches. The nose septum is shaped by heating the septum cartilage by laser radiation through a mucous membrane to fix the desired shape. After laser heating, the septum cartilage recovers its elasticity during cooling and the septum acquires a new shape. This procedure is almost painless and can be performed under ambulatory conditions, whereas the conventional unpleasant and painful surgery requires a subsequent hospitalisation. Moreover, the spared laser action preserves the growth centres in the cartilage, which allows the use of this procedure for children.

It was already reported [11] that, by using semiconductor and fibre laser apparatus, a new method of medical treatment of otorhinolaryngology pathologies involving simultaneously several endoscopic operations (typically up to six pathologies were eliminated during one intervention) was realised. This became possible because laser operations are bloodless and are not accompanied by a large edema. A weak painfulness of the laser action permits the use of minimal anaesthesia. Due to the use of endoscopic instruments and precise laser exposures, laser operations are weakly invasive and post-operation wounds heal quickly. Because all the infection loci in the nasopharunx are treated simultaneously, the probability of relapses drastically decreases and a minimum of drugs, as a rule, not antibiotics are used during the post-operation period. Laser thermoplastics of cartilages for shaping the nasal septum improves the nasal aerodynamics and ventilation of the nasal sinus, which also enhances the treatment efficiency.

An apparatus with two independently controlled operating radiations at 0.97 and 1.56 μm coupled to one optical fibre proved to be the most universal for applications in otorhinolaryngology [12]. This apparatus allows a physician to vary in a broad range the character of action of laser radiation on biological tissues during the operation.

Laser force therapy methods such as laser interstitial thermal therapy (LITT) and photodynamic therapy (PDT) are now being more and more actively used in practice. LITT is the method for suppressing tumours by thermal action on cells when the cytotoxic action is produced due to the tissue heating by laser radiation. Classical hyperthermia of malignant tumours consists in heating the tumour up to the temperature 42.5 – 45 °C, at which cancerous cells are destroyed, whereas healthy cells are damaged reversibly. In this case, inadmissible are both overheating resulting in the destruction of healthy tissues and underheating, which can stimulate the tumour growth and metastasis. The use of laser radiation simplifies the procedure. Laser radiation is injected into the tumour through a fibre with a special diffuser mounted at its end, which scatters radiation inside the tissue. It is necessary to produce the conditions destructive for cancerous tissues and bearable for healthy tissues only on the tumour boundaries, whereas the tissue near the diffuser can be heated up to higher temperatures. For this reason, LITT can be also used for medical treatment of benign tumours, for example, uterus myoma [13]. Because the LITT method requires the bulk tissue heating, it uses deeply penetrating radiation at 0.81 and 1.06 μm.

In the PDT method, which was initially developed for treating malignant tumours, cytotoxic action on cells is produced by singlet oxygen released upon the interaction of laser radiation with a sensitizer preliminary introduced to the biological tissue. This method in now successfully used for treating not only benign and malignant tumours but also wounds and various skin and otorhinolaryngology diseases. At present, the most promising for PDT is considered radiation in the 0.66 – 0.67-μm range in combination with photosensitizers of the Radochlorine type [7], which are less toxic compared to analogous sensitizers of previous generations. This resulted in the appearance of various commercial medical laser apparatus operating in this wavelength range.

The use of lasers in combination with the modern endoscopic equipment and puncture procedures considerably reduces, as a rule, the traumatic injury of the operation, reduces the medical treatment period, and decreases the probability of post-operational complications. It is important for the convenience of operation that apparatus based on semiconductor and fibre lasers can be mounted on an endoscopic stand and are convenient for operation in combination with X-ray and ultrasonic apparatus.

Laser scalpels operating at a wavelength of 0.97 μm were efficiently used in weakly invasive laparoscopic operations (removal of appendix and ovary cysts) of children [14]. A total number of patients operated for four years exceeded 500. These apparatus are also used in endoscopic operations on the gastrointestinal tract and respiratory system. They are also applied for the treatment of gynecological [5] and practological [15, 16] diseases in clinics or one-day hospitals.

Apparatus based on semiconductor and fibre lasers are also widely used for treating urology diseases [17]. In particular, such an apparatus with a 30-W, 0.97-μm laser was not only successfully used in operations of the benign hyperplasia and surface cancer of a bladder, but also quite efficiently destroyed stones in the bladder upon contact action. Lithoclasty is traditionally performed by using special expensive apparatus based on flashlamp-pumped pulsed solid-state lasers. The possibility to perform lithoclasty without purchasing additional equipment of large dimensions is a considerable advantage of surgery apparatus based on semiconductor lasers.

These apparatus are also used for the medical treatment of intervertebral disc diseases. Such operations are also performed by using laser radiation at 0.97 μm [18] and 1.56 μm [19]. In [18], the method of puncture multichannel laser decompression using the 0.97-μm radiation was developed. In this method, an X-ray-controlled disc is punctured with a guide of diameter 0.5 mm and a puncture needle is inserted through the guide. Then, a fibre is introduced into the needle and the disc is exposed to 3 W of laser radiation for 1 – 1.5 min. A specific feature of this method is that several channels are formed in the disc through one puncture due to the use of specially bent needles. A weak traumatic injury of the method is provided by the use of a thin silica fibre of diameter 0.3 mm through which laser radiation is delivered.

It was found that the action of laser radiation on intervertebral discs was accompanied by the stimulation of the cartilage regeneration, which improves the results of medical treatment.

The stimulation of the regeneration process was also observed during arthroscopic operations on joints [20]. Such operations are weakly invasive, being performed without opening the joint bag, which decreases the possibility of complications and reduces the time of post-operational recovery. Clinical tests performed at N.N. Priorov CITO (Moscow) showed the use of laser radiation at 0.97 and 1.9 μm allows the optimisation of the laser action to obtain the required results at substantially lower laser powers than in the case of the 1.06-μm radiation.

A high radiation power (up to 30 W) at 0.97 μm at the output of a thin silica fibre of diameter 0.4 mm made it possible to use these apparatus for laser osteoperforation treatment of osteomyelitis, bone-joint panaris, and diabetic foot syndrome [21 – 24]. In the case of osteomyelitis, a hole is perforated in the bony tissue (in the inflammation region) by the contact action (through the skin and muscles) of laser radiation delivered through a silica fibre with a special thermally stable jacket. Then, without the fibre removal, thermal therapy (heating) of the bone-brain channel is performed at a low power. About ten of such perforations are produced in the pathology region, and no additional cuts, draining soft tissues and bone-brain channel are performed.

No strong thermal damage of soft tissues and bones was produced at the laser irradiation regimes used in operations. Dynamic bacteriological investigations revealed a rapid sanitation of a pus locus and a decrease in the number of seeded microorganisms below the critical level. A rapid and stable positive effect was observed for all patients after the medical treatment. In the case of chronic osteomyelitis, a stable remission was obtained in more than 90 % of cases and no disease relapses and aggravations were observed. The use of laser osteoperforation in the treatment of bony and bone-joint panaris and diabetic feet syndrome gives similar results.

We can say now that the apparatus described above are already used in clinics for laser revascularization of myocardium in the treatment of ischemia. So far CO_2 lasers were most often used for this operation. However, their application involves a number of problems. First of all, these lasers have all the above mentioned drawbacks, which are typical for conventional surgery lasers of large dimensions. The impossibility of using optical fibres for radiation transport requires operation in the pulsed regime. The pulsed action on a heart should be synchronised, in turn, with heart beatings, which additionally complicates the apparatus. To perform revascularization successfully, it is necessary to form rapidly (for ~ 1 s) a channel in myocardium with the minimum thermal damage of the walls. This is possible in the case of a contact work with a fibre through which cw or repetitively pulse radiation is delivered. Such operations were first performed by using a 0.81-μm semiconductor laser [25]. But, as pointed out above, this wavelength is not optimal for surgery action because of a low absorption in biological tissues. The use of a 0.97-μm semiconductor laser [26] allowed the formation of a channel with the minimal thermal damage of the walls. The overgrowing of this channel, as in the case of the use of CO_2 lasers, is accompanied by the formation of new vessels growing to the surrounding muscular tissue. L.A. Bokeriya reported at the seminar held during the LIK-2005 exhibition (Moscow) that 54 operations on myocardium revascularization were performed by using a 0.97-μm semiconductor laser at A.N. Bakulev Research and Clinical Center of Cardiovascular Surgery. It was pointed out that radiation at this wavelength is more efficient in regions with myocardium regions with fat depositions than the 10.6-μm radiation.

At the same time, many physicians believe that the transformation of the laser channels themselves to vessels would be preferable than the overgrowing of these channels in myocardium even in the case of growing new vessels into the muscular tissue. Such a result was obtained in paper [27] by using a 1.56-μm fibre laser for revascularization. The histograms of sections of laser channels obtained after 34 and 48 days in experiments with dogs showed the preservation of the laser channels and the formation of endothelium on their walls, i.e., the formation of new vessels. Until February 2005, 116 myocardium revascularizations were performed at E.N. Meshalkin Novosibirsk Research Institute of Blood Circulation Pathology by using a 1.56-μm fibre laser. As a rule, such operations are combined with aorta-coronary shunting.

These results suggest that semiconductor and fibre laser scalpels will supplement in the near future the arsenal of cardiosurgeons.

Apparatus based on semiconductor lasers with fibre pigtails proved to be most suitable for stereotaxis operations on the brain [28] and treating of the impassability of the nasal channel [29].

Domestic apparatus based on 0.97-μm lasers are also used in ambulatory stomatology practice. They are successfully applied for treating diseases of soft tissues of the mouth, for example, epulis [30]. By using the contact action of laser radiation, the sterilisation of a root channel and evaporation of granulomas can be performed, and by using a collimating attachment and special gels, to whiten teeth [31].

The important advantages of modern laser apparatus were revealed in treating the widespread varicose veins disease. The traditional medical treatment is performed by the phlebectomy (removal) of the varicose large subcutaneous vein (LSV). However, this operation is often accompanied by the damage of subcutaneous nerves and lymphatic collectors and a long and painful post-operational recovery. The alternative is the use of methods of chemical and thermal therapy, which provide the endo venous obliteration of the LSV. Among thermal methods, the most promising from the point of view of the treatment results, patient's perception and ambulatory conditions is endo venous laser treatment (EVLT) (see, for example, [32]). In this method, an optical fibre is inserted into a vein, and then laser radiation is switched and the fibre is slowly pulled out from the vein simultaneously with its internal coagulation. As a result, LSV column and its large tributaries experience immediately after the operation a spasm in such a degree that they become indiscernible from surrounding tissues. The absence of a pain syndrome, an excellent cosmetic result, and rapid social rehabilitation are obvious advantages of this method. Laser radiation in the region 0.94 – 0.98 μm is considered at present the most efficient for EVLT.

Due to strong absorption in blood, this radiation is efficiently used in dermatocosmetology for treating vascular pathologies – hemangioms, vascular 'stars', and the removal of various newgrowths on the skin (see, for example, [6]).

In the last years the laser ablation methods of skin regeneration have received wide acceptance. In these methods, laser radiation at 2.9 and 10.6 μm, which is strongly absorbed by the skin, removes its thin surface layer. After the skin healing, its texture is renewed and wrinkles disappear. However, a large ablated skin area causes the problem of protection from infection during the healing period and besides due to such a rude intervention the state of the skin becomes, as a rule, after some time worse than before the operation. All this stimulated the permanent search for non-ablative, more sparing and efficient laser methods, and they were found [33].

In a new method, laser radiation absorbed in the surface skin layers without the damage of vessels stimulates thermally the aseptic inflammation resulting in the tissue reconstruction, which leads to the recovery of the skin elasticity and disappearance of wrinkles. In this case, there is no need in the hospitalization of a patient.

This method was develop by American scientists who proposed to use fraxel laser treatment [34] at which instead of irradiation of the whole treated skin area the laser acts on regularly located points. The investigations showed that this was sufficient for triggering the desired process. The apparatus developed by Reliant Technologies Inc. for this method uses a 1.56-μm fibre laser. Thus, it can be expected that this new, more sparing and efficient method, which does not require hospitalization, will cause boom in this segment of laser cosmetology.

Ophthalmology was one of the first fields in medicine where laser radiation was successfully used. This delicate tool is very convenient for the surgery of eye diseases, both operating through the transparent tissues of the eye without their damage (welding of the detached retina) and upon coagulation and perforation of its tissues. Laser apparatus can be excellently combined with a traditional ophthalmology tool such as a slit lamp. The appearance of portable, low-cost and simple apparatus based on laser diodes along with the well-developed eye surgery methods [35] produced prerequisites for wide practical applications of these methods.

In the last years the keratoablation operations, which provide the correction of refraction defects of vision, have received worldwide acceptance. Different variants of this method are based on a change of the cornea profile by removing a part of it by the UV radiation from an excimer laser, which changes in a controllable way the optical properties of the cornea, resulting in the correction of the sight defects. However, a number of post-operational complications can appear (see, for example, [36]), which are quite dangerous because the cornea is irradiated directly in front of the pupil.

A more sparing method is the refraction laser thermokeratoplastics [37]. In this case, laser coagulation points are applied on the eye sclera or cornea over its iris, which produce internal strains in the cornea. As a result, the curvature of the cornea part over the pupil changes. The radiation penetration depth should not exceed 1 mm, which determined the choice of laser radiation at the wavelengths 1.54 μm (LIC-100 setup based on a Er-doped glass laser) and 2.12 μm (Oko-1 setup based on a Ho : YAG laser). The flashlamp-pumped solid-state lasers used in these setups operate in the pulsed regime, emitting ~1-ms pulses. However, it is difficult in this regime to provide the required action on the cornea without its surface erosion.

Apparatus based on fibre lasers can operate in the cw regime, providing a soft action (without erosion). In addition, along with laser applications providing the required stresses, it is possible to 'flatten' the cornea upon its soft laser heating, as in the cartilage shaping by the method of laser thermoplastics. *In vivo* studies of rabbit eyes [38] showed the possibility of reducing a degree of the myopic refraction of the eye. Therefore, fibre apparatus provide a more sparing correction of the refractive defects of vision compared to the ablation laser keratoplastics.

5. Conclusions

The use of semiconductor lasers and diode-pumped lasers qualitatively improved the characteristics of laser apparatus for surgery and force therapy and expanded the possibilities of their applications. These lasers emit at different wavelengths in the visible and near-IR regions, and their proper choice allows one to optimise the action of laser radiation on biological tissues by minimising the undesirable influence on surrounding organs. Medical apparatus based on these lasers are portable, reliable, inexpensive, simple in operation, and do not require a permanent technical service. The advent of such apparatus provided the conditions for applications of lasers in surgery and force therapy in public health. The methods employing these apparatus can be used to treat many diseases, which required earlier hospitalization in clinics or hospitals. In this case, a decrease in the number of complications and relapses as well as painful feelings of patients is combined with the reduction of treatment period and improvement of the treatment quality.

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