ZOND–1 LASER LITHOTRIPTOR

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Laser lithotriptor for crumbling calculi (stones) in the urinary or biliary system is discussed. The source of a power optical radiation is a flashlamp-pumped dye laser using iminocoumarin G-283 and operating at 530 nm wavelength in the repetitively pulsed regime with the pulse duration of 1 to 2 μs, pulse repetition rate of 1 to 10 Hz, and average power up to 2 W. The optical waveguide with 400-microne core is used.

In the most developed countries the tendency has recently become evident to support scientific and technical programs aimed at improving living standards and human health. Therefore the latest achievements in high-energy physics, super-high frequency physics, quantum radiophysics, etc. find wider and wider applications into different branches of ecology and medicine. In particular, coherent sources of optical radiation – lasers – are used for both treatment and prophylaxis of human diseases and numerous medico-biological investigations.

Crumbling calculi in human internals by the method of laser lithotripsy[1] without traditional surgical intervention is one of most promising directions in the application of laser radiation to medicine. According to the Candela Laser Company which has developed one of the first industrial setups for laser lithotripsy on the basis of the MDL–1 type dye laser, the stones are destroyed with the efficiency reaching 85% under the exposure to repetitively pulsed radiation.[2] The experience of applying first devices of such a type shows that they can shorten the period needed for absolute recovery by some days, whereas the traditional surgical intervention requires 1.5–2 months of the postoperative care.[3]

The aim of our investigations was to develop and create devices for intracorporal laser lithotripsy. For this purpose it was necessary to solve the following problems:

– to choose and validate the values of the most important laser radiation parameters which must provide the effective destruction of calculi in ureter and other human organs;

– to choose the type of the laser emitter, develop its construction and test its main characteristics;

– to create the device for intracorporal laser lithotripsy.

The analysis of scientific and technical literature available shows that the photoacoustic method, i.e., the generation of sound waves at resonance frequencies of a calculus under absorbtion of repetitive laser radiation pulses by its surface, appears to be the most suitable for laser lithotripsy.[4–6] As a result of such an irradiation, a stone is gradually destroyed mechanically and its fragments go out from organism in a natural way. According to the data available, this method provides rather effective treatment of the human cholelithiasis with minimal injuries of the surrounding tissues.[4,6]

The above-mentioned factors determined the choice of the photo-acoustic method for destroying calculi by the created device as well as of the values of the main parameters of the optical radiation. Of the greatest importance are the following.

1. The wavelength of laser radiation $\lambda = 500–530$ nm. The radiation of this portion of the visible range is rather effectively absorbed by a surface of the most widespread stones observed in a ureter with minimal injuries to the surrounding tissues.[4,6]

2. The optical pulse energy $W = 30...150$ mJ (depending on the type and size of a stone), the pulse duration $\tau = 1...2$ μs, and the repetition frequency $f = 1...10$ Hz. These values are determined by the compromise demands: they must guarantee the effective generation of the shock acoustic waves in stones to be destroyed but ablation is undesirable and the formation of plasma is not allowed.

The above-mentioned parameters can be most completely achieved by means of a repetitively pulsed flashlamp-pumped dye laser what is in accordance with the developments of now known laser lithotriptors.[2] This has determined the final choice of the source of optical radiation. The ethanol solution of the G–283 dye[7] providing effective generation in the green range of the spectrum ($\lambda = 530$ nm) was decided to be used as an active medium of the laser. For the excitation of the active medium, we have developed a pump system on the basis of a pulsed tubular xenon-filled flash lamp and a reflector of the ellyptic profile. The main

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elements of the discharge circuit and geometrical dimensions of the pumping lamp were calculated from the conditions of electrical and spectral matching obtained earlier.[8] A scheme for supporting the duty discharge[9] was provided in the electric circuit for rising stability and increasing service lifetime of the pump lamp.

The tests of the developed laser in the single pulse mode showed that the maximum generation energy is about 800 mJ at the pulse duration $\tau = 1.5$ μs at the wavelength $\lambda \approx 530$ nm. The tests of the same laser in the repetitively pulsed mode were conducted with the aim to find experimentally the duration of the continuous treatment at a given average power without renewal of the active medium. The results obtained imply that the generation mode with the frequency $f = 10$ Hz and average power $P_a = 2$ W is ensured by the gradual rise of the output voltage of the high-voltage rectifier up to its maximum value during 7.5 min if the volume of the active medium is 1 liter.

The characteristics obtained demonstrates that the described laser can be used in development and construction of a medical device for laser lithotripsy. If necessary, the wavelength of the laser radiation can be changed by changing the active medium and some elements of the laser cavity.

ZOND–1 medical device intended for the destruction of calculi in the ureter and other human organs was created on the basis of the above-described repetitively pulsed flashlamp-pumped dye laser. The device comprises of the following parts:

1. a flashlamp-pumped dye laser consisting of the following units:
   - emitting unit,
   - circulating and cooling unit,
   - power supply:
   - control unit,
   - switch pedals;
2. a high-voltage power source;
3. a catheter with an optical fiber tract.

The high-voltage power source is made as a specialized module (220/380 V, 50 Hz). It permits establishing the operating voltage across the storage capacitor in the range 8...20 kV with the step of 0.1 kV. The reflector of the emitter is made using an INP–5/250 lamp.

The control unit provides the operation of the laser lithotriptor in a repetitively pulsed mode at given values of energy, repetition frequency, and pulse series duration. The choice of the mode is carried out by an operator before the beginning of treatment by pressing the corresponding keys on the control desk near the digital indicators of modes. The device is equipped with a built-in instrumentation permitting the visual control of its main parameters.

ZOND–1 specifications:

radiation wavelength, nm	504 ± 5%
spectral bandwidth, nm	5...10
pulse energy (after the waveguide), mJ	20...150, with the step of 10 mJ
pulse duration, μs	1...2
repetition frequency, Hz	1...10, with the step of 1 Hz
duration of the pulse series, s	0.2, 0.5, 1, 2, 5, 10; continuous
permissible duration of the continuous pulse series at the frequency of 5 Hz, min	no less than 15
overall dimensions, mm	1120×650×900
weight, kg	no more than 135

Preliminary laboratory *in vitro* investigations on the interaction of the repetitively pulsed radiation with ureter stones of the oxalat type which are most widespread in the Khar'kov region showed that samples of stones with dimensions less than 8 mm are destroyed during some seconds under the average radiation power about 1 W.

ZOND–1 medical device developed by YUNIKS Company (15, Petrovskogo St., Khar'kov, Russia 310002, phone/fax (0572) 455 123) can be applied in both urology and other branches of medicine.

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