A Nd:YAG LASER FOR MICROSURGICAL PROCEDURES IN OPHTHALMOLOGY

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Abstract. A surgical laser system used in ophthalmology for posterior capsulotomy and pupil membranectomy (iridotomy) is presented. BIOLASER allows stereoscopic examination of eye's transparent medium and the execution of the microsurgical procedures in the anterior and posterior chambers. This paper presents also some results obtained in order to optimize laser parameters required in medical application of BIOLASER. One of the important parameter is the specific energy for a specific application. So, for the capsulotomy operation an energy of about 3 mJ is enough and for iridotomy operation an energy of about 7–9 mJ is necessary.

Key words: Nd:YAG laser, medical applications, ophthalmology, capsulotomy, iridotomy surgical procedures.

INTRODUCTION

BIOLASER system allows stereoscopic examination of eye's transparent medium and the execution of the microsurgical procedures in the anterior and posterior chambers. The system produces a beam of infrared light at 1064 nm (a Q-switch Nd:YAG laser has been designed for BIOLASER-1) and this laser delivers a chosen amount of energy to a focal point of approximately 10 microns diameter which causes an acoustic wave [1, 2, 3]. The wave disrupts adjacent tissue. This is known as the photodisruptive effect. As the treatment energy is increased the size of plasma formatted also increases, causing a larger acoustic wave and also a stronger effect. The system works in mono pulse regime. The laser beam was spatial filtered in order to obtain the TEMoo and it is focused at 150 microns behind the optical plane to reduce the risk of pitting of the intraocular lens when performing posterior capsulotomy.

This system was made in association with Romanian Optical Enterprise – IOR and it provides sufficient energy density to create a small ionization site

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Received July 2005;
in final form December 2005.

ROMANIAN J. BIOPHYS., Vol. 16, No. 1, P. 69–75, BUCHAREST, 2006

(plasma) which causes an acoustic wave which disrupts adjacent tissue. The laser system is adapted to an ophthalmic stereomicroscope used in ophthalmology.

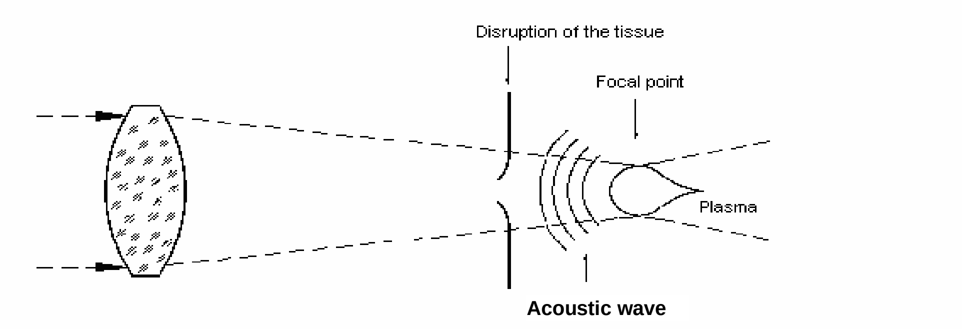

Fig. 1. Photodisruptive effect scheme.

MATERIALS AND METHOD

The system yields an infrared laser beam of 1064 nm wavelength (Fig. 2). A Q-switch Nd:YAG laser has been designed and built. As active medium a 3 mm diameter and 50 mm length laser rod was used. One of the rod ends is a partially reflecting mirror having 27% reflectivity at 1064 nm. The other rod end was antireflection dielectrically coated at 1064 nm. In order to obtain an optical active resonator a high reflecting mirror was used (reflectivity > 99.8% at 1064 nm). The values of transmitted laser light are obtained by a variable neutral density filter. The used energy range is 0.5÷10 mJ. Also we have obtained 8÷14 ns pulse lengths. The collimated laser radiation is reflected by a mirror with 100% reflectivity for 1064 nm at 90 degree to enter in the objective. This objective has 100 mm focal length. Laser beam is deflected at 180° by two optical prisms P_1 and P_2. Laser beam is passed through a collimated system with a 12× magnification, is attenuated by a variable neutral filter and, finally, it will be focused by the objective of the microscope at 150 microns behind the object plane to avoid the damage of the Intraocular Lens. Diameter of the laser beam in focal point is less than 10 microns. Two infrared LED phototransistors are used for the filter positioning. The aiming system uses a laser diode with 635 nm wavelength, less than 1 mW output power, split into two beams and then directed through the objective marking the object plane. This aiming system presents the evolution of the diameter and the position of the Nd:YAG laser pulse and also of the depth where the focal point of the laser pulse is located. The measuring of the pulse length was done with a Tektronix 3032A oscilloscope.

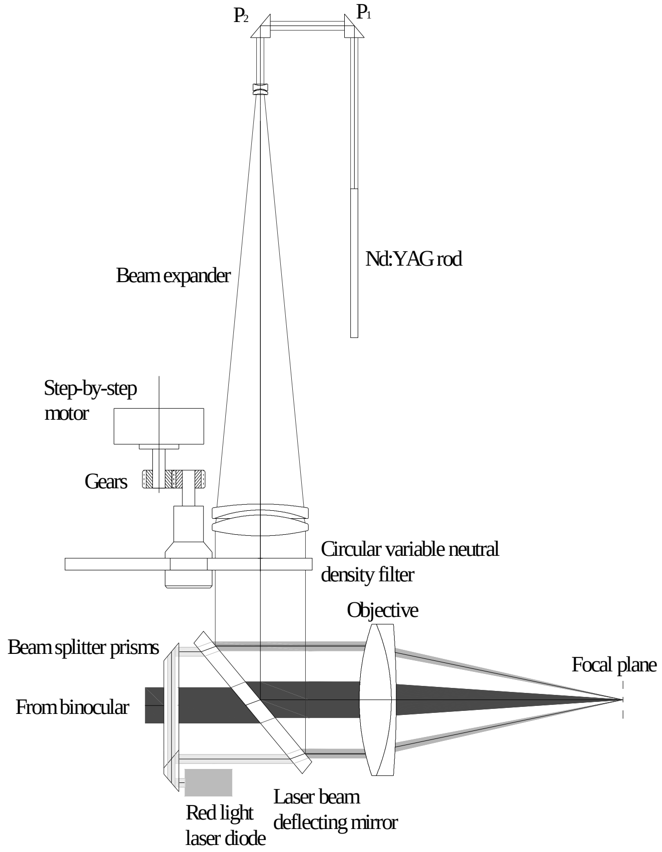

Fig. 2. Optical scheme of laser stereo-biomicroscope.

RESULTS AND DISCUSSION

Using a Cr^{+4}:YAG as Q-switch, we have obtained 8 ns pulse length for the laser radiation (Fig. 3). For BDN Q-switches with the initial transmission about 30% and 40%, the pulse lengths are about 10 ns, respectively 14 ns. So, in this case the Cr^{4+}:YAG is better to use as Q-switch. The small pulse length is necessary to obtain a very short time to develop the plasma in the focus and such the acoustic wave in order to obtain the photodisruptive effect. Fig. 4 shows the transmitted laser beam energy and the transmitted LEDs light function of the rotating angle of the variable neutral filter. We can see three curves that represent: the red one is the transmitted laser beam energy function of rotating angle of the variable neutral filter, the green one is the transmitted energy of the left LED light and the blue one is the transmitted energy of the right LED light. The filter transmits the laser beam between 0° – 60° range and between 60° and 360° the transmission of the filter decreases progressively from 100% to 1%. The rotation counts start at 0°.

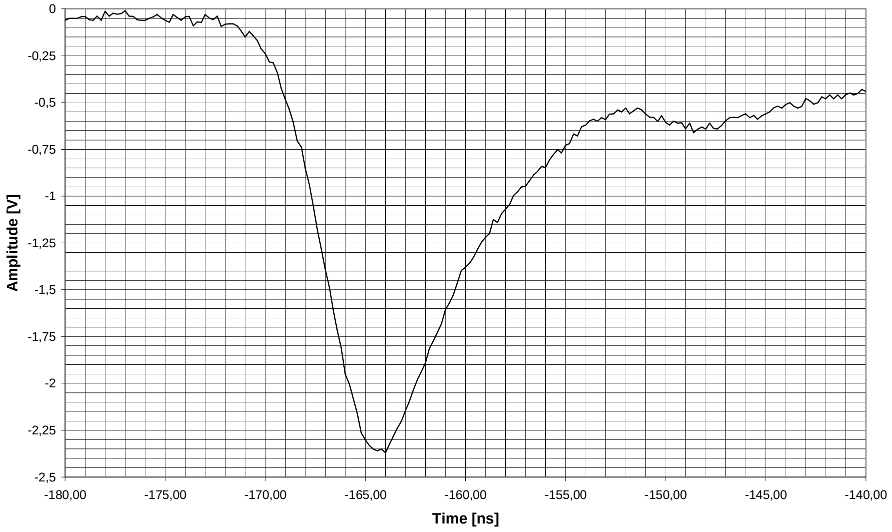

Fig. 3. The pulse length oscilloscope image.

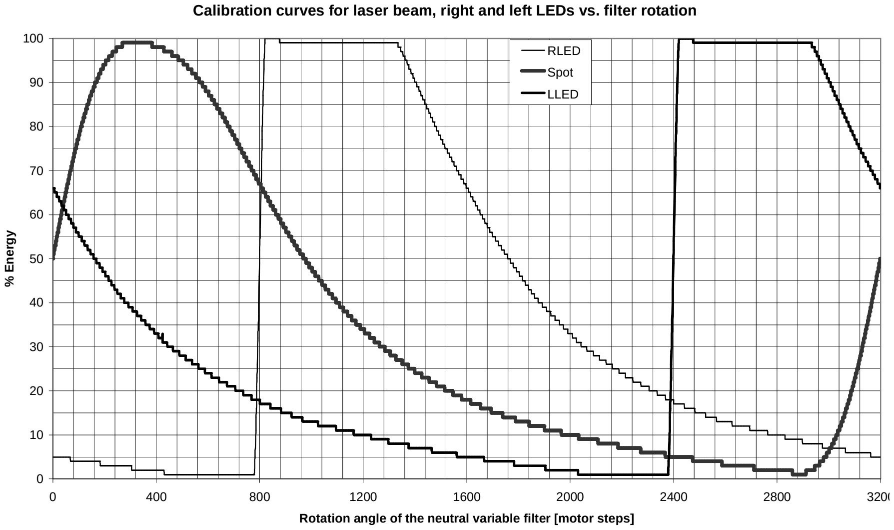

Fig. 4. Calibration curves for the transmitted laser beam (1064nm) versus the rotating angle of the neutral filter.

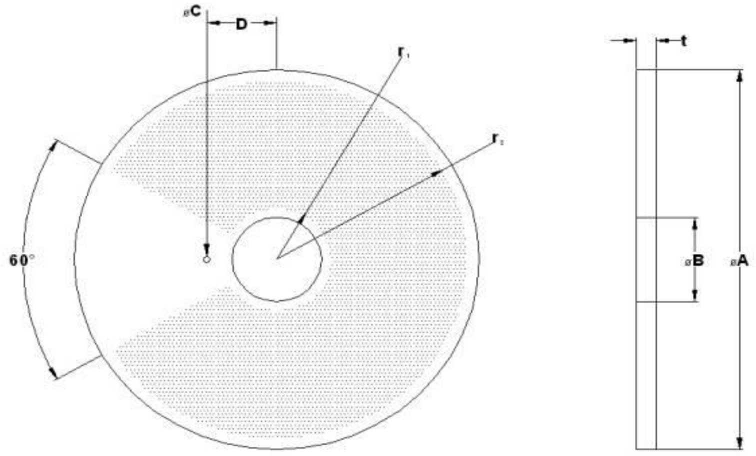

Fig. 5. Circular variable neutral density filter with 300° active area.

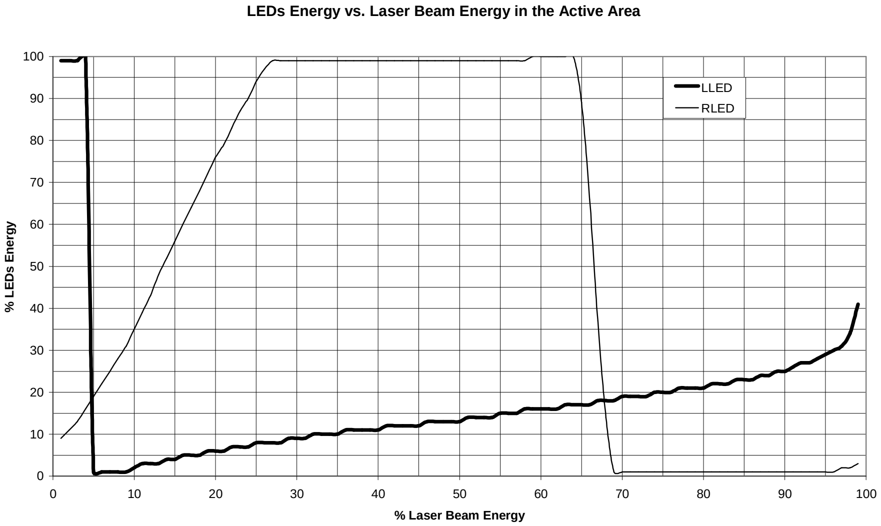

Fig. 6. LEDs energies vs. transmitted laser beam energy in the active area.

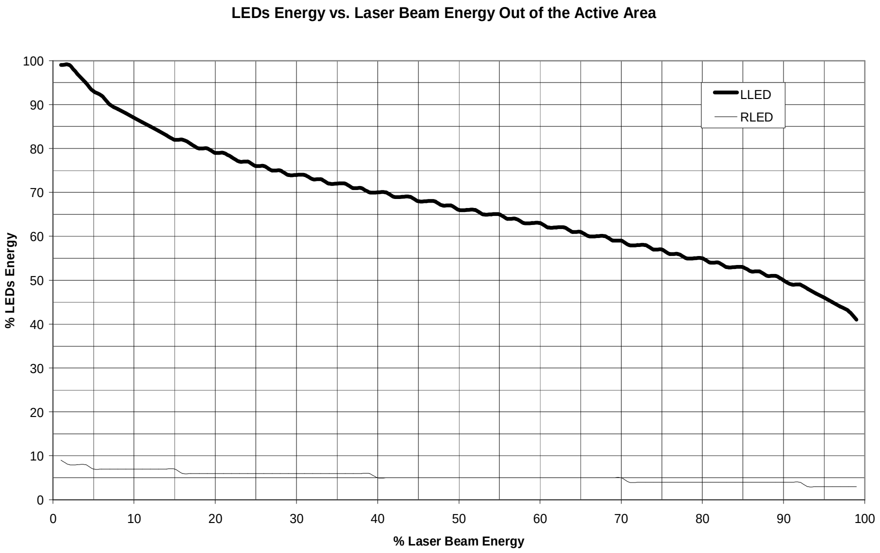

Fig. 7. LEDs energies vs. transmitted laser beam out of the active area.

Fig. 6 shows the energies of the left and right LEDs function of the laser energy in the active area of the variable neutral density filter. Fig. 7 shows the energies of the left and right LEDs function of laser beam energy out of the active area. The adjustment is made by superposing the two red laser diode beams in the object visible plane and the Nd:YAG laser beam strikes in the central part of them. The laser beam (1064 nm) is passed through a beam expander with a 12× magnification coefficient, then attenuated by a circular variable neutral filter and, finally, it is focused by the objective of the microscope in about 10 microns focal area diameter. The focal dimensions were determined with an electronic microscope on a hole done with the laser beam focused on a Sn sheet. The energies of the laser beam were determined using a Melles-Griot energy-meter. For the energy arrived at the focus a filter was used with the known transmission for 1064 nm, and also some measurements were done for a known distance without filter, where the energy density of the laser beam does not produce damages on the receptor of the measuring device.

We obtained energies up to 10.0 mJ for capsulotomy and iridotomy in less than ±10 % energy variations.

CONCLUSIONS

The stereomicroscope will be exploited in the Eye Clinical Hospital in Bucharest and, after some months, it will be introduced in the Romanian Optical Enterprise' (IOR) production. The preliminary clinical results show that this instrument is good enough to compete with other such instruments on the market.

Acknowledgments: This paper was partial supported by RELANSIN program.

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