MICROSURGICAL Nd:YAG LASER USED IN OPHTHALMOLOGY*

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A microsurgical ophthalmological laser for posterior capsulotomy and pupil membranectomy, allowing stereoscopic examination of eye’s transparent medium and microsurgical procedures in the anterior and posterior chambers using the photodisruptive effect is presented. A circular variable filter and two LED-phototransistor pairs are used to get a precise energy dosing.

Key words: photodisruptor, Nd:YAG laser, ophthalmology, capsulotomy, membranectomy.

1. INTRODUCTION

The system produces a beam of infrared light at 1064 nm (a Q-switch Nd:YAG laser) 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 photo disruptive effect (Fig. 1).


The laser beam was spatially filtered in order to obtain the TEM\(_{\infty}\) and it was focused at 150 microns behind the visible image plane to reduce the risk of pitting of the intraocular lens when performing posterior capsulotomy. The laser system is adapted to an ophthalmic stereomicroscope used in ophthalmology.

2. EXPERIMENTAL SET-UP

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 antireflex 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 the transmitted laser light energy are obtained by a variable neutral density filter. The used energy range is 0.5\(\div\)10 mJ. Also we have obtained 4\(\div\)10 ns pulse length. The collimated laser radiation is reflected by a mirror with 100% reflectivity for 1064 nm at 90 degrees to enter in the objective. This objective has 100 mm focal length.

Laser beam is deflected at 180\(^\circ\) by two optical prisms \(P_1\) and \(P_2\). Laser beam is passed through a collimated system with a 12\times 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-phototransistor pairs are used to position the filter. The calibration curves for the LED-phototransistor pairs and for the laser beam versus the neutral variable filter transmission were obtained. They are used to obtain the desired energy values of the laser beam for different surgical procedures.

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 measurement of the pulse length was done using a Tektronix 3032A oscilloscope.

3. RESULTS AND DISCUSSION

In order to obtain a short laser pulse, about 8 ns length, a Cr\(^{3+}\):YAG crystal as optical passive Q-switch was used. Using an oscilloscope as Tektronix TDS
the pulse length of laser radiation was registered (Fig. 3). For a BDN Q-switch with the transmission 40%, the pulse length is about 14 ns. So, in this case the Cr\textsuperscript{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 photo disruptive effect.

As represented in Fig. 4, a variable neutral filter is used to obtain an exact value for the laser beam energy. The laser beam (the magenta spot) is filtered by rotating a circular variable density filter (OD 0 to OD 2). The rotation is accomplished by a stepper controlled by a microcontroller. The exact rotation of
the disk needed by a chosen energy is found using two IR LEDs (named the Left LED – the green spot and the Right LED – the dark blue spot) and two phototransistors to determine the actual rotation angle of the disk and consequently to determine the actual transmission of the filter. The microcontroller rotates the filter using the stepper till the measured signals of the two LEDs reach the values prescribed for the corresponding chosen energy value.

Fig. 5 shows the calibration curves of the laser energy and the corresponding signal level of the two LEDs.

Fig. 5 – Calibration curves for the transmitted laser beam versus the rotation of the neutral filter.

The laser beam (1064 nm) is passed through a beam expander with a 12× magnification coefficient, than 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. We obtained energies up to 10.0 mJ for capsulotomy and iridotomy in less than ±10% energy variations.

4. CONCLUSIONS

An important parameter is the specific energy for a specific application. So, for the capsulotomy operation an energy of about 3 mJ is enough, while for iridotomy operation an energy of about 7–9 mJ is needed. We obtained energies in the range 0–10 mJ with less than ±10% energy variations. The values of the
transmitted laser light are obtained using a variable neutral density filter. Two infrared LED-phototransistor pairs are used to position the filter. Also we have obtained a laser pulse length of 8 ns. The aiming system uses a laser diode with 635 nm wavelength, less than 1 mW output power, spit into two beams and then directed through the objective marking the object plane. The adjustment is made by superposing the two red laser diode beams in the visible image plane and the Nd:YAG laser beam strikes in the central part of them. In conclusion, BIOLASER is a very precise instrument allowing a very good applicability in ophthalmology. One of the advantages of this laser system is that the energies can continuous varies on a long field (0.5–10 mJ), making possible a great numbers of application in clinical ophthalmology.

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.

REFERENCES

Fig. 2 – Optical scheme of laser stereo-bi microscope.