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TECHNICAL NOTE

Nd:YAG LASER SYSTEM FOR OPHTALMOLOGY: BIOLASER-1

D. Savastru, S. Miclos, C. Cotîrlan, E. Ristici*, M. Mustata, M. Mogîldea, G. Mogîldea, T. Dragu, R. Morarescu

National Institute for Optoelectronics, P. O. Box MG-5, Bucharest-Magurele, Romania

A specific ophthalmic system, *Biolaser-1,* containing a Q-switch Nd:YAG laser, an optical stereomicroscope and two red output laser diodes is presented. As Q-switch, a Cr^{4+}:YAG crystal is used. It works in monopulse or double pulse regime. The laser beam is focused at 150 micrometers behind the optical plane to reduce the risk of pitting the lens when performing posterior capsulotomies. In order to obtain eleven different energy levels in the domain (0.8÷9) mJ domain, eleven attenuators are used. The laser ophthalmic system must fulfill many conditions. The energy level, the pulse length and the used attenuators must have such values to eliminate every undesired effect in the medical applications. This instrument has an important application in posterior capsulotomies and pupilar membranectomies.

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1. Introduction

Nd: YAG laser is good for an ophthalmic surgical instrument. The instrument has important applications in posterior capsulotomies and pupilar membranectomies [1, 2, 3].

Biolaser –1 system [4] is an instrument containing a specific Nd:YAG laser, an optical microscope and two red light laser diodes. This system was made in association with Romanian Optical Industry - IOR Corporation, and it provides sufficient energy density to create a small ionization site (plasma) which causes an acoustic wave which disrupts adjacent tissue. This is known as the "photo-disruptive effect".

A Q-switch Nd:YAG laser has been designed. As active medium a 4 mm diameter and 65 mm length laser rod was used. One of the rod ends is a partially reflecting mirror having 30 % reflectivity coefficient 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 coefficient > 99.9 % at 1064 nm).

The laser beam was spatially filtered in order to obtain the TEM_{00} mode operation. We used an aperture to obtain spatial filtering of the laser beam and also the desired energy [5].

This paper presents some results obtained in the optimization laser parameters required in medical application of Biolaser-1. The optical scheme is presented in Fig. 1.

One of the important parameter is the specific energy for a specific application. So, for the capsulotomy operation an energy about 3 mJ is enough. The transmission is determined for each optical filter from the known optical formula. But, because the laser has a range of variation of the energy values, we must determine the thickness of the filter taking into account this variation. Because there are eleven filters we calculate every thickness corresponding to a chosen transmission for every filter so that, the obtained energy values cannot superpose each other in the domain of normal variation of Nd:YAG laser. These filters are inserted into a device which can rotate so that

* Corresponding author: esofina@inoe.inoe.ro

each filter be in the front of laser beam. This device is placed between the laser head and the collimating system.

Before using filters in *Biolaser-1* we have verified them by using a ratiometric method.

Fig. 1 present the optical scheme of the laser system used in *Biolaser-1*. A_i represents the optical filters.

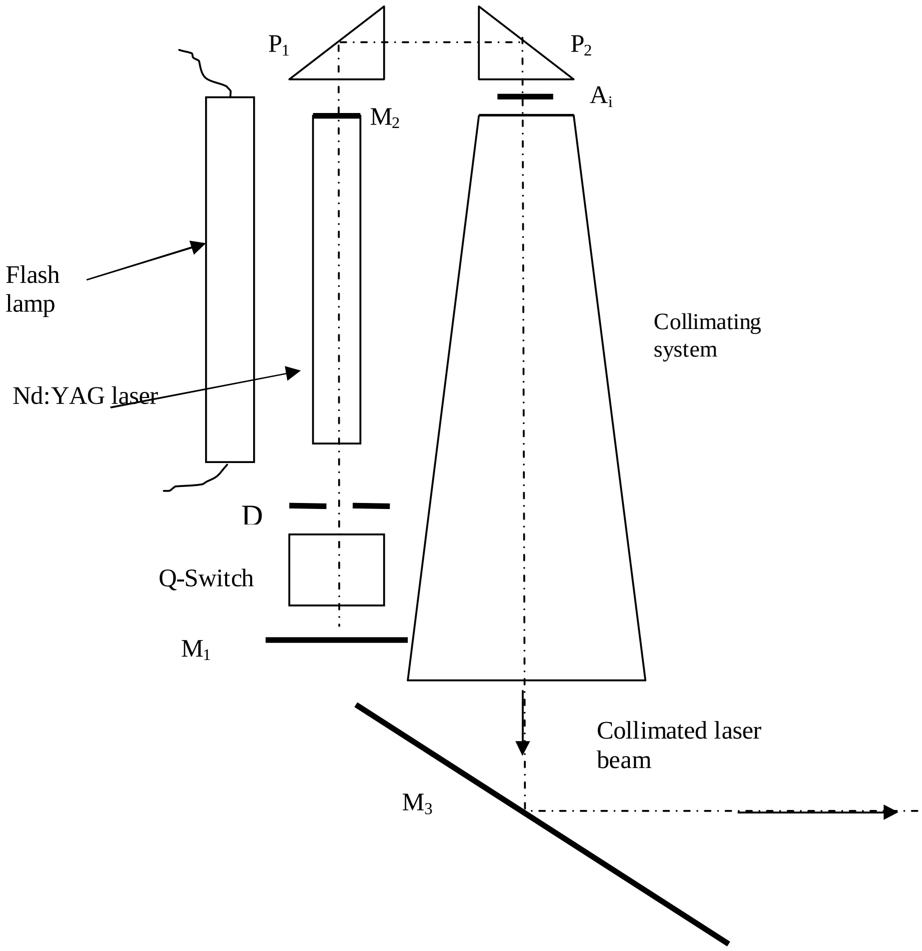

Fig. 1. Optical scheme of the collimated Q-switched Nd:YAG laser. M_1 – total reflecting mirror, M_2 – partial reflecting mirror, D - aperture, P_1 – optical prism (right angle), P_2 – optical prism (right angle), A_i – attenuator, M_3 – total reflecting mirror (45°).

The laser beam is deflected at 180° by two optical prisms P_1 and P_2. Attenuated laser beam by filter A_i is passed through a collimated system with a 10 × magnification 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 Intra Ocular Lens (IOL). Diameter of the laser beam in focal point is less than 20 microns. To mark the object plane there was used an original system formed by two red light laser diodes. Fig. 2 shows the optical images of the markers. Each marker gives a clear optical image of two wings. The two couple of wings are superposed in the object visible plane (as in Fig. 2a) so that the laser beam strikes in the central part of them. The circle represents the place where the laser beam hits.

If we move the two upper wings to the right with a distance equal to a distance between wings and a quarter, we obtain the laser focal plane (Fig. 2b). This movement is obtained by moving the microscope table.

But, the surgeon arranges the position of the wings as in the Fig. 3. In this position he knows that the laser beam focus is placed between the two wings and it is placed at 150 µm behind of this plane, to reduce the risk of pitting of IOLs.

Fig. 2. a) shows the position of the wings in the object plane, (the wings are superposed); b) shows the position of the wings in the laser focal plane situated at 150 µm (the wings are displaced one from another with a distance between wings and a quarter of wing).

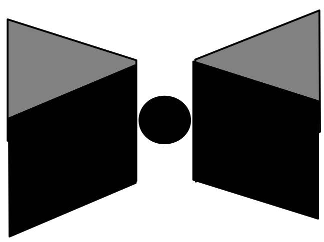

Fig. 3. The image of the markers (wings) in the object plane and the position of the 1064 nm laser beam.

After some experiments one concluded that this optical system for optical alignment of the laser focus is better than using two simple laser diode beams. The intensity of the laser diodes was chosen to obtain a good brightness of the wings. For this purpose one can use an optical system to change the intensity of the laser diodes.

Experimental setup to inspect the optical filters consists in two energymeters, a Nd:YAG laser and a beamsplitter. The optical scheme is presented in Fig. 4.

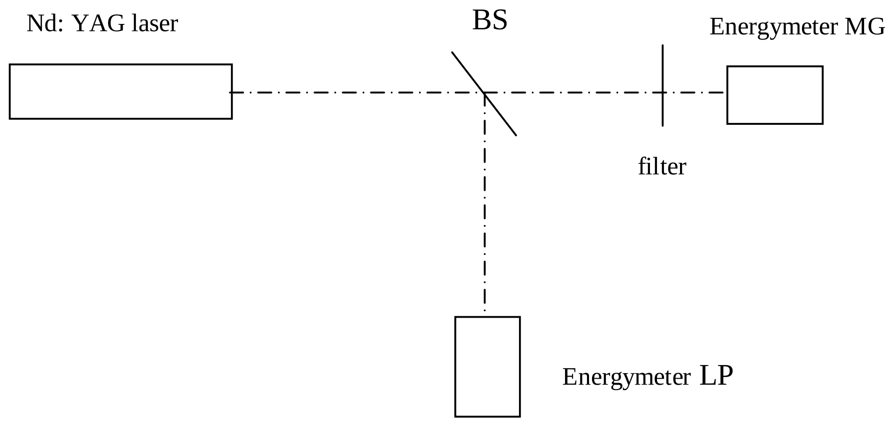

Fig. 4. Optical scheme of the ratiometer method. BS – beamsplitter, MG- Melles Griot 13PEM001/J energymeter, LP – Laser Precision RJ-7610 energymeter.

First, a calibration is necessary for the ratiometer method, without filter.

Filter is inserted in a laser beam just in front of an energymeter LP, type RJ-7610. Its transmission is determined by the ratio between the two laser beams energies.

The transmissions of the filters are measured by placing the filter in the front of LP energymeter.

Table 1 presents the results for the filter no. 9. Transmission of the filter number 9 is obtained from ratio R'/R. R' represents the ratio of the two energy values measured with the two energymeters when one filter is inserted in a laser beam, and R represents the ratio of the two energy values from the calibration method. The measured average value for the R ratio is 2.719.

Table 1. Experimental energy values for the filter number 9.

No.	LP	MG	R'	T= R'/R
1	1.72	1.5	1.146667	0.421724
2	1.75	1.5	1.166667	0.429079
3	1.72	1.5	1.146667	0.421724
4	1.67	1.5	1.113333	0.409464
5	1.67	1.6	1.04375	0.383873
6	1.72	1.6	1.075	0.395366
7	1.73	1.5	1.153333	0.424176
8	1.74	1.5	1.16	0.426627
9	1.72	1.6	1.075	0.395366
10	1.73	1.6	1.08125	0.397665
Average	1.717	1.54	1.116167	0.410506

Experimental measured transmission is 41%. This value corresponds to a 5.5 mW energy value of the Biolaser-1 for the filter no. 9. For a better precision we used a number of 10 laser pulses. So, we can see the variation of the transmitted laser energy. This method was applied for all eleven filters.

Filters are placed in their revolver of the *Biolaser-1*. The energy values were measured in object focal plane.

From Fig. 5 we can determine the average of the energy values for each filter.

The average energies measured for the eleven filters are: 0.8 mJ, 1 mJ, 1.5 mJ, 2 mJ, 2.5 mJ, 3.1 mJ, 3.8 mJ, 4.5 mJ, 5.5 mJ, 6.5 mJ and 8.2 mJ.

Standard deviation of the energy values is less than ±7% (Table 2) of the average. These measurements were obtained using the Melles-Griot 13PEM 001/J energymeter, placed in the object plane of the microscope from Biolaser-1 system.

Table 2. Measured energy values of the eleven filters in the focal plane of Biolaser-1.
Av- average, SD – standard deviation as % of average, T% - transmission.

No	F1 E(mJ)	F2 E(mJ)	F3 E(mJ)	F4 E(mJ)	F5 E(mJ)	F6 E(mJ)	F7 E(mJ)	F8 E(mJ)	F9 E(mJ)	F10 E(mJ)	F11 E(mJ)
1	0.8	1	1.5	2	2.43	3.11	3.8	4.5	5.49	6.1	8.1
2	0.8	0.97	1.52	2.05	2.5	3.12	3.85	4.6	5.5	6.5	8.3
3	0.83	1.03	1.48	2	2.56	3	3.74	4.4	5.5	6.8	7.9
4	0.8	0.99	1.46	2	2.57	3	3.7	4.5	5.51	6.9	8.5
5	0.77	0.99	1.5	1.95	2.44	3	3.81	4.55	5.38	6.2	8.6
6	0.8	1.01	1.5	2	2.50	3	3.78	4.45	5.56	6.45	7.7
7	0.79	0.98	1.53	2	2.49	3.08	3.86	4.35	5.62	6.55	8.4
8	0.8	1.01	1.54	1.95	2.51	3.09	3.7	4.5	5.44	6.2	7.5
9	0.8	1.02	1.48	2	2.52	3.07	3.89	4.65	5.29	6.8	8.5
10	0.81	1	1.5	2.05	2.48	3.13	3.89	4.5	5.72	6.5	8.5
Av	**0.8**	**1**	**1.50**	**2**	**2.5**	**3.06**	**3.80**	**4.5**	**5.50**	**6.5**	**8.2**
SD	3.75%	3.00%	2.66%	2.50%	2.8%	2.12%	2.50%	3.33%	3.91%	6.15%	6.71%
T%	5.9	7.4	11	14.8	18.5	23	28	33	41	48	60.7

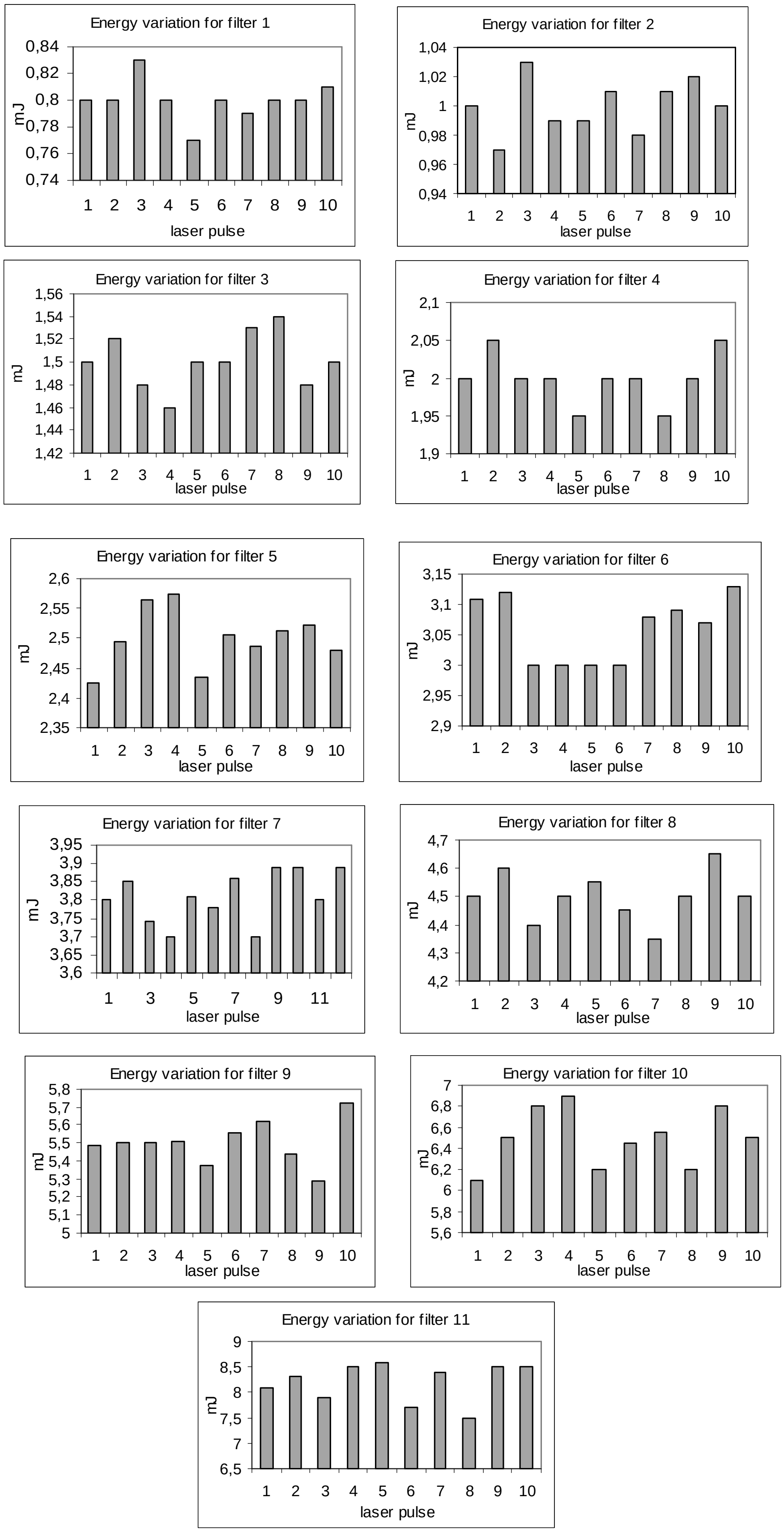

Fig. 5. Variations of the energy values for the all eleven filters.

In Table 2 Av means the average energy corresponding to each filter. SD means the standard deviation of laser energy as percentage of the average value for each filter.

From Table 2 it can see that the standard deviation of the energy values for the filters with higher transmission (F10 and F11) is larger than for the rest of the filters which have small transmission coefficients.

2. Conclusions

The object plane is accurately positioned with the aid of a slit lamp microscope and a “four wings” aiming system.

The laser pulses may be accurately focused on a plane placed at 150 µm behind of the object plane. The energy contained within a single pulse is concentrated by focusing to a small spot (approximately twenty microns) so that plasma formation occurs at the focal point. This creates an acoustic wave that disrupts the near tissue. Once formed, the plasma absorbs and scatters further incident light. Also, the beam divergence is large enough after the focus to protect the retina from damage which can appears due to the absorption of the concentrated laser energy.

The microscope is fitted with the protective infrared absorption filters so that the user is protected in the normal operating position. Any other personnel in the area should have protective glasses to eliminate the risk of eye damage from accidental emissions.

The “four wings” aiming system is composed from two laser diodes emitting at 635 nm, Class 2 laser, with power less than 1 mW. For such a laser the blink reflex is considered to give sufficient protection.

The intensities of the diode beams are controlled by the command unit.

The energy level is chosen by changing the position of the filter. These filters are placed in a support in front of the collimating optical system. Their transmission and their thickness are theoretically calculated so that, the obtained laser energies do not superpose each other in the normal variation range (± 7%).

Using the ratiometric method we have determined the experimental transmission coefficient for all eleven filters.

For filters with large transmission coefficient (F10, F11), the variations of the laser energy are larger than for the filters with a small transmission coefficient.

The unit command is achieved on a microprocessor that permits to select the parameters for the Nd:YAG laser system and for the “four wings” aiming system.

Prior the firing of the laser in Ready mode, the display indicates the expected energy of the shot that will be fired.

The Biolaser-1 is used now in hospital and the obtained results are good. In the near future, we want to obtain the changing of the energy value in a continuous mode, using a new type of optical system.

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