High power, pulsed flash-lamp pumped erbium laser designed for medical applications

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Abstract: A record 2,4MW peak power, actively Q-switched Er:YAG laser is presented. For 10Hz repetition rate 21mJ, 86ns pulses at the wavelength of 2940nm were achieved. The beam divergence was 2,3mrad.
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1. Introduction

Lasers generating in the range of 3 μm are especially desired in medicine (e.g. cataract surgery), mainly due to very high water absorption (above 104 cm^{-1}) at 3 μm wavelength [1,2]. The main effect occurring when high-peak power ns-pulses interact with a biological tissue is ablation. However, too high energy delivered to the tissue in ns-pulse can cause undesirable effects (shock wave for instance) and therefore it seams to be reasonable to use lasers with middle output energy (range of 10 mJ) working at higher repetition rate (at least 10 Hz). However, increasing the repetition rate leads to the higher thermal load of the laser rod and very strong thermal lensing which is, according to our measurements, almost an order of magnitude stronger in lamp pumped Er:YAG rod than in Nd:YAG one.

2. Laser set-up and experimental results

In this paper we report on a 20 mJ of output energy, 10 Hz repetition rate, TEM_{00} mode, actively Q-switched Er:YAG laser. The general layout of the laser is shown in Fig. 1. The system operated at 2,94 μm.

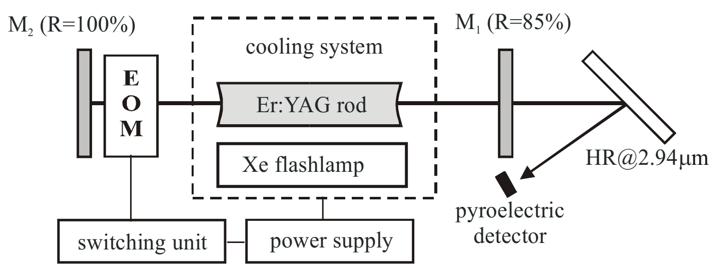

Fig. 1. Actively Q-switched Er:YAG laser set-up.

A Pockels cell consisting of a $LiNbO_3$ with dimensions of 35x10x5 mm and crystal faces cut at Brewster's angle was used as an active Q-switch. The crystal was mounted in a hermetically sealed housing filled with dry nitrogen and equipped with the sapphire Brewster orientated windows what increased the Q-switch contrast and allowed applying the voltage lower than the half-wave voltage. A ϕ4x100 mm Er:YAG rod was used as an active medium. In order to compensate thermal lensing the laser resonator contained one convex mirror. The output coupler was 85% reflectivity. The Er:YAG crystal was pumped by a xenon flash lamp. Both elements were located in a single close coupled, diffusion (ceramics) cavity.

The only drawback of using the $LiNbO_3$ crystal as a Q-switch is its damage threshold as low as 200 $MWcm^{-2}$. Therefore a special laser resonator had to be designed to ensure long term laser operation without any damage of the Q-switch. The beam diameter in the area of the Pockels cell was around 2 mm and the beam shape was close to Gaussian distribution. The project of the resonator took into account the results of the thermal focal length measurements which were performed either using 1μm wavelength fibre laser beam directly or by means of finding the laser stability limit. Both results were comparable. The focal length of the thermal lens was inversely depended on the pump power and additionally we noticed that there is an optimal value of the pump pulse equaled 300 μs when the thermal lensing effect is minimal (Fig .2). The output energies in a Q-switching mode as well as in a free running are presented in Fig. 3.

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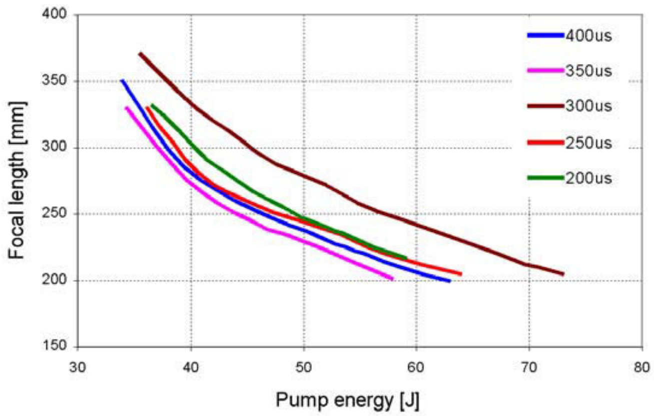

Fig. 2. Focal length of the Er:YAG rod thermal lens vs. pump energy for 10 Hz repetition rate.

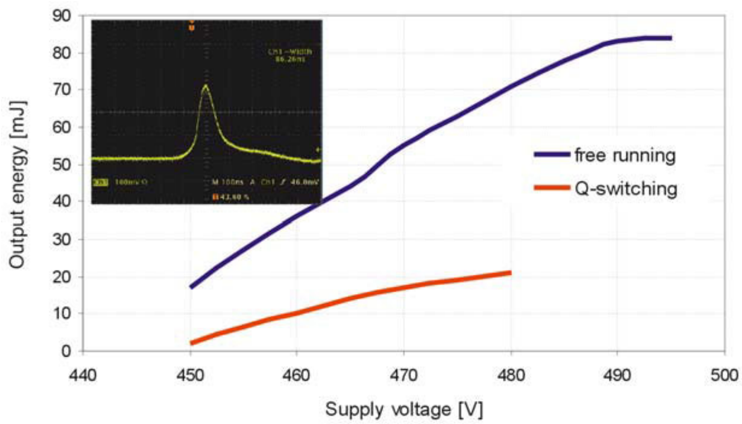

Fig. 3. Output pulse energy vs. voltage supply. The oscilloscope trace of the shortest pulse of 86 ns is shown in the frame.

The shortest pulse width was 86 ns at the output energy level of 21 mJ. The beam divergence was measured to be 2,3 mrad and estimated on this basis M^2 factor was only $M^2 \sim 1{,}2$. The laser worked with a stability of several percent for many hours without any fractures. The beam was launched into a 425 μm thick, 30 cm long sapphire fiber and the output energy reached the level of 15 mJ in that case.

The laser presented in this paper may be successively used in ophthalmology. Currently the clinical investigations are being in progress.

3. Conclusions

In conclusion, we have produced Q-switch pulses in Er:YAG laser. The results obtained, according to our knowledge, are the best world-wide achievement. Pulses as short as 86 ns with the energy of 21 mJ (at 10 Hz repetition rate) have been generated. The level of pulse energy obtained is sufficient to ablate most of biological tissues. The laser developed can be successfully applied in microsurgery, laryngology or ophthalmology.

4. References

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