High-power $LiNbO_3$ Pockels cell Q-switched flash lamp-pumped Er:YAG laser as a microsurgery instrument for ophthalmologic applications

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Lasers generating in the range of 3 μm are especially desired in medicine (e.g. microsurgery), mainly due to very high water absorption (above 10^4 cm^{-1}) at 3 μm wavelength range [1]. The main effect occurring when high-peak power μs pulses interact with a biological tissue is an ablation. Additionally, thermal effects should also be considered in terms of free running mode of a laser. One way of eliminating these undesirable thermal effects is the use of Q-switched lasers.

In this paper we report on a record 1.4 MW peak power, actively Q-switched Er:YAG laser operating at 2.94 μm. A Pockels cell consisting of a $LiNbO_3$ with dimensions of 35x9x5 mm and crystal faces cut at Brewster's angle was used as an active Q-switch. The control voltage applied to the $LiNbO_3$ crystal equaled 1.35 kV and was much lower than the half wave voltage. A ϕ4x100 mm Er:YAG rod was used as an active medium. In order to decrease thermal lensing, the laser rod was characterized by two side 5 m concave surface. The laser resonator was plan-parallel and it consisted of an output mirror with 85% reflectivity. The Er:YAG crystal was pumped by a xenon flash lamp. Both elements were located in a single diffusion (ceramics) cavity.

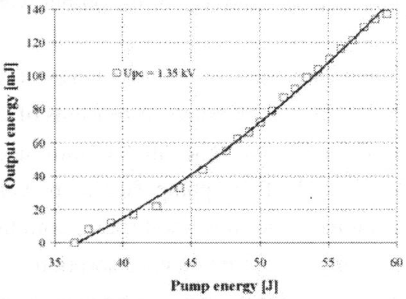

Fig. 1. Pulse output energy vs. pump energy.

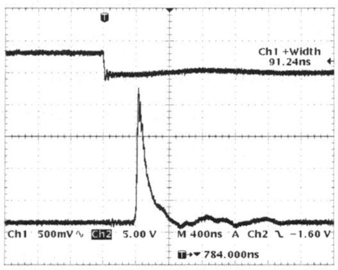

Fig. 2. Oscilloscope picture of the shortest Q-switch pulse.

As a result of our experiment, at 3 Hz repetition rate, we achieved 91 ns pulses with 137 mJ energy. The characteristic of output pulse energy measured is depicted in Fig. 1. At higher repetition rate (10 Hz) the laser generated 100 ns pulses with 35 mJ energy. The oscilloscope traces of the output pulses measured are presented in Fig. 2. To our knowledge, it is the best achievement in the world as far as Q-switched Er:YAG lasers applied in medicine are concerned.

A few preliminary experiments connected with interaction between the laser pulses and biological tissue were carried out. We used gelatine as a substitute of a biological tissue – because of its similar optical properties and in order to visualize the effects of the interaction in a relatively simple way. The laser power was delivered to the gelatine through 90 cm long and 350 μm thick sapphire optical fiber. The fiber output end was 1 mm away from the gelatine surface or a few mm inside the gelatine. Depending on these two arrangements and also on pulse energy, pulse width, repetition rate, the results of the interaction were extremely different. A top view of the gelatine surface after irradiation with the free-running (right) and Q-switched (left spot) pulses is shown in Fig. 3, whereas the side view of the craters created in case of different fiber end locations is presented in Fig. 4.

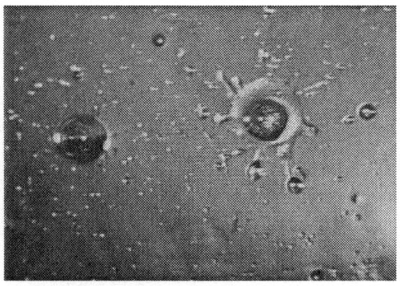

Fig. 3. Er:YAG laser interaction with gelatine –top view.

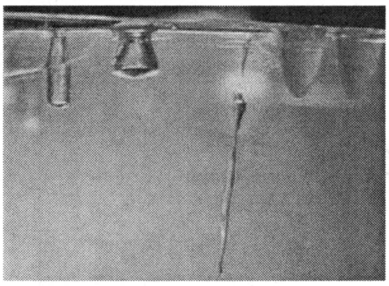

Fig. 4. Er:YAG laser interaction with gelatine –side view.

The effects of the Q-switched Er:YAG laser pulses interaction with biological tissues are currently under detailed investigations.

[1] A.D. Zweig, M. Frenz, V. Romano, H.P. Weber, "A comparative study of laser tissue interaction at 2.94 μm and 10.6 μm," Appl. Phys. B **47**, 259-265 (1988).