# Tunable, gain switched $Ti^{3+}:Al_2O_3$ laser pumped by intracavity frequency doubled, $Nd^{3+}$:YLF laser

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**Abstract** — A room-temperature, coherently pumped, tunable titanium-sapphire laser was constructed and examined. For excitation diode pumped, a neodymium laser with intracavity frequency doubling was deployed. The Nd:YLF laser was emitting 1.3 mJ-pulses with the pulse duration of 50 ns. After conversion in LBO crystal, the 1.2 mJ of output energy was obtained at the 523 nm of the output wavelength. A tunable titanium-sapphire laser has been running in the gain switching regime. The 0.12 mJ output energy was obtained in a FWHM pulse length of 40 ns for the best case, which corresponded to 3 kW peak power. Tunability range was found between 753 nm and 820 nm. The pulse repetition rate was set to 200 Hz.

Tunable lasers based on titanium doped sapphire crystals ($Ti^{3+}:Al_2O_3$) find many applications in contemporary sciences and technology branches, such as: spectroscopy [1-4], interferometry, medical sciences [4,5] and many others [6-8]. One of their most important advantages is a very broad tuning range that is far above 300 nm [9].

The aim of this work was the construction of a pulsed, tunable laser source with a tuning range 780 – 850 nm which is characterized by considerable high peak powers of output radiation. It will be applied in the research of new lasing materials, especially Nd:YAG ceramics. As a pump source for the presented laser generator a neodymium laser with intracavity frequency doubling was built.

The pump laser was working at a wavelength of 523 nm, which corresponds to Nd:YLF generation line for π-polarization (1047 nm). The layout of a resonator is shown in Fig. 1. The back mirror was transparent for pumping radiation and had a 500 mm curvature radius. Output mirror was flat and transparent for second harmonic of neodymium laser radiation. The fundamental wave was reflected back to the resonator with nearly 100% efficiency.

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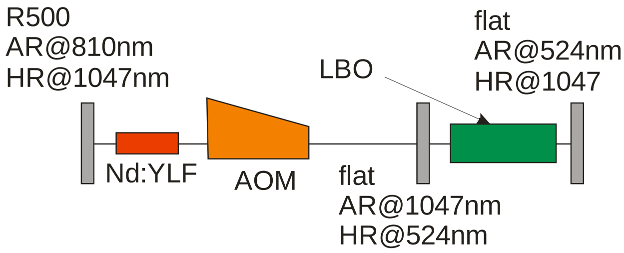


Fig. 1. Scheme of the pump laser

The length between the mirrors was about 450 mm. A nonlinear crystal (LBO type I) was placed inside the cavity near the beam waist, to provide high intensity of radiation, which is needed for efficient conversion.

The acousto-optical modulator has been placed inside the cavity to obtain pulsed operation. There was also a separator mirror to avoid the influence of the second harmonic of the laser on gain material and the laser diode. The modulator was driven by a 25 W RF source. Frequency of the modulation signal was 40.7 MHz. The signal was synchronized with the pumping diode current. Diffraction efficiency of the modulator was above 80%.

As a source of pumping radiation for neodymium oscillator, a laser diode was used. The maximum output power of the diode in continuous work regime was 32 W for current 44.5 A. The output wavelength of the laser diode was tuned by thermoelectric cooler’s temperature to achieve optimum absorption in the gain medium. The diode was driven by a SDL 830 power supply (200 Hz repetition rate, 0.5 ms pump duration).

In the best case we were able to get pulses of second harmonic radiation of energy close to 1.2 mJ and duration of about 50 ns. It corresponds to more than 24 kW of peak power.

The generation characteristics of a “green” laser was shown in Fig. 2.

 

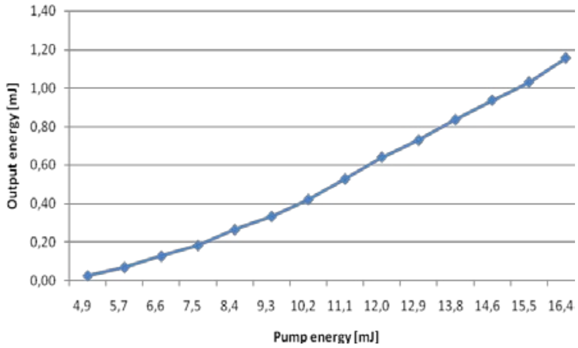


Fig. 2. Output energy of “green” laser vs. laser diode energy (repetition rate 200Hz, 0.5 ms pump duration).

The head of the titanium sapphire laser (Ti:S) was built according to a V-type resonator layout. Such a configuration let us to match the area of laser mode to that of pump mode, which is essential to obtain effective energy extraction from gain medium.

The layout of Ti:S laser resonator is presented in Fig. 3.

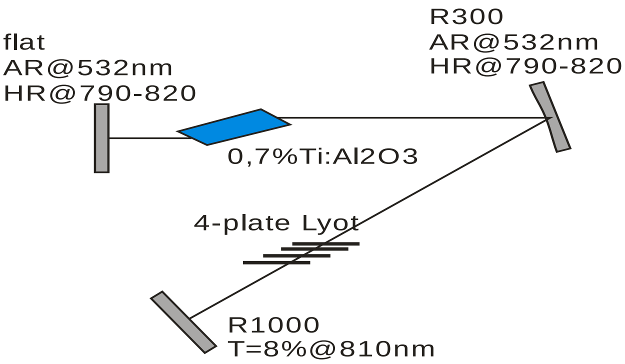


Fig. 3. Scheme of titanium sapphire laser.

In the shorter arm of the resonator, which length was equal to 160 mm, a sapphire crystal was placed. Titanium doping was about 0.7%. Active medium was cut plane parallel at an angle that enabled placing the crystal at the Brewster angle towards the direction of radiation propagation. Pumping radiation from Nd:YLF “green” laser was focused inside the sapphire rod by one lens with a 125 mm focal length. Due to the Brewster angle the incidence of Fresnel losses at faces of the crystal is diminished.

To obtain tunable wavelength output, a four-plate Lyot filter was placed in the longer arm of the resonator. The arm length was 240 mm. The transmittance of output coupler was 8%, which is the optimal value confirmed by the experiment.

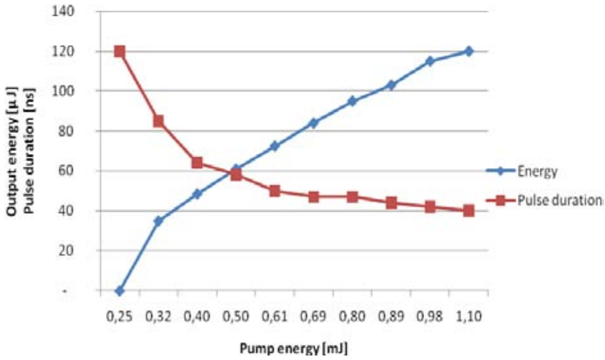


Fig. 4. Output energy of Ti:S laser and its pulse duration vs. energy of “green” pump laser (repetition 200Hz)

The Ti:S laser was working in the gain-switching regime. We were able to obtain pulses up to 0.12 mJ of energy and slope efficiency of about 11%. Pulse duration decreased 3 times with a 4-times increase in pump energy. After the insertion of a Lyot filter, output energy dropped to 90 μJ. Pulse duration was not affected. Output energy and pulse duration of the Ti:S laser vs. pump energy are presented in Fig. 4. There was also noticed nearly 5-times shortening of the pulse duration according to pumping pulse duration. It is qualitative confirmation of the thesis presented by E. Sali [10]. The temporal characteristics of laser generation is shown in Fig. 5.

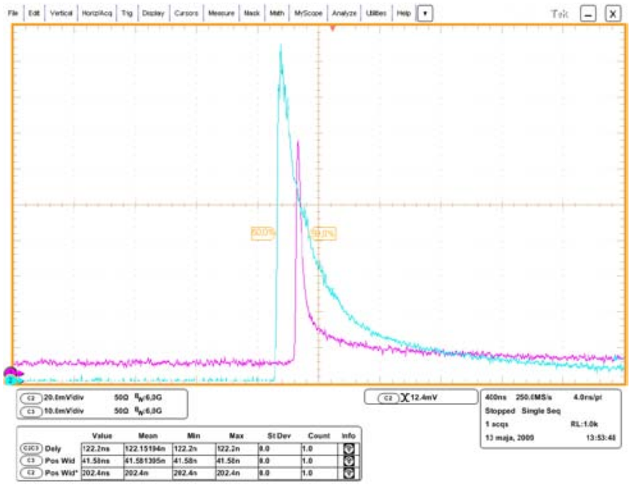

Fig. 5. Titanium: Sapphire laser pulse with peak power ~3kW (narrow one) and green pump pulse (broader one).

We have achieved continously tunable output wavelength generation in the range between 753 nm and 820 nm with the linewidth less than 1-nm. The factor limiting the tunability of the costructed source was free spectral range (FSR) of deployed Lyot’s filter. It is expected that using of filter with larger FSR will result in extention of tuning range.

 

In Fig. 6 the tuning spectrum of the laser for maximum pump energy 1.1 mJ is depicted. Spectral measurements were performed with monochromator and photodiode system. Spectral resolution of the system was about 1 nm.

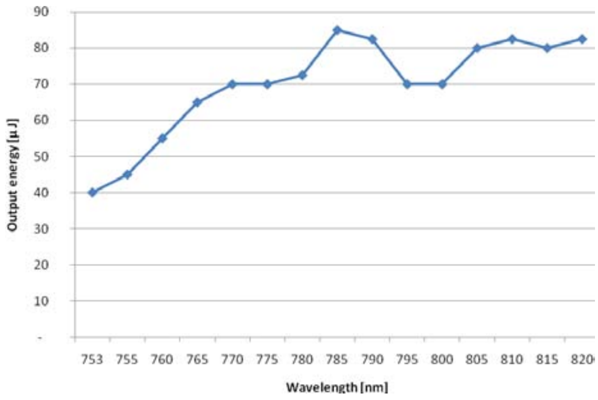


Fig. 6. Tuning spectrum of Titanium: Sapphire laser.

In this work actively q-switched neodymium laser with intracavity second harmonic generation was costructed and used as a pumping source for tunable titanium-sapphire laser. LBO type I crystal was used for the conversion of radiation to second harmonic. In the case of Nd:YLF laser 1.2-mJ pulses were generated at the wavelength of 523 nm. The pulse duration was about 50 ns and peak power was above 24 kW.

The main aim of this work has been achieved by a $Ti:Al_2O_3$ laser working in the gain switching regime. The output energy of the laser was about 0.12 mJ, with pulse duration about 40 ns. It corresponds to nearly 3 kW peak power at the wavelength of the 790 nm.

To provide the tunability of output wavelength a four-plate Lyot filter was placed inside the cavity. The maximum tuning range achieved in the experiment was about 67 nm (from 753 nm to 820 nm). A further extension of the tuning range is possible by increase the filter's free spectral range parameter. The output energy obtained from the laser while tuning was between 40 – 90 μJ, dependanding on the wavelength.

The main aim of further work is to extend the tunability range by designing a Lyot filter with better parameters. It is also planned to increase laser diode power (about 80 W output power) to obtain more energy at the wavelength of 523 nm.

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