EPJ Web of Conferences **307**, 04054 (2024) https://doi.org/10.1051/epjconf/202430704054
EUROPHOTON 2024

Output parameters optimization of Q-switched Nd:YAG/V:YAG microchip laser generating at 1.44 µm

Kryštof Kadlec[1], **Jan Šulc**[1], **Michal Němec**[1], **Helena Jelínková**[1], **Karel Nejezchleb**[2]
[1]*Czech Technical University in Prague, FNSPE, Brehova 7, Prague, Czech Republic*
[2]*Crytur, Ltd. Turnov, Na Lukách 2283, 511 01 Turnov, Czech Republic*

1 Introduction

A Nd:YAG active medium known primarily for the laser generation at a wavelength of 1.06 µm has also a strong emission at 1.34 µm and 1.44 µm. In the latter two cases, the V:YAG saturable absorber can be used as a passive Q-switcher. A diode-pumped Nd:YAG/V:YAG Q-switched microchip laser based on bonded active Nd:YAG and V:YAG saturable absorber represents a very compact and robust laser source of stable high-energy nanosecond pulses with dimensions in units of millimeters, which could be attractive in various fields of applications.

One of the benefits of 1.44 µm radiation compared to 1.06 µm and 1.34 µm is a higher absorption in liquid water, as shown in Fig. 1. As a result, 1.44 µm radiation falls into the eye-safe area, which can be useful when using such a laser system for free-space light manipulation applications such as LIDAR for autonomous vehicle control. Its absorption in the atmosphere is also higher, which lead to a significant reduction of background solar radiation intensity. However, the laser radiation itself at 1.44 µm is also absorbed in the atmosphere, and nanosecond pulses with sufficient energy are therefore necessary for long-range applications.

In this work we studied an output radiation parameters optimization of Q-switched Nd:YAG/V:YAG microchip laser generating at a wavelength of 1.44 µm. The optimization was based on varying the pumping beam size using four different pumping optics. Output parameters of generated laser radiation using individual selected pumping optics are presented here.

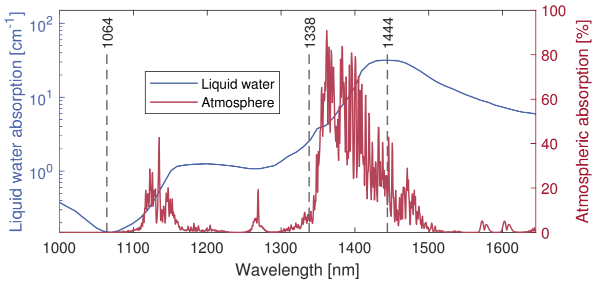

Fig. 1: Liquid water and atmospheric absorption spectra with main Nd:YAG laser emission lines marked.

2 Materials and methods

The designed Q-switched microchip laser consisted of bonded Nd:YAG active crystal and [111]-cut V:YAG saturable absorber. Flat resonator mirrors were deposited on faces of this composite crystal with a diameter of 5 mm. Nd:YAG gain part had a length of 4 mm and the Nd^{3+} active ions concentration in the YAG matrix was 1.2 % Nd/Y. The length of the V:YAG part was 1 mm and the V:YAG initial transmission at 1.44 µm at room temperature was 94 %. The laser resonator pumping mirror had a high transmission at a pumping wavelength of 0.8 µm and a high reflectivity at a generated wavelength of 1.44 µm. The reflectivity of the output coupler was 94 % @ 1.44 µm. Resonator mirrors were designed to prevent laser generation at 1.06 µm and 1.34 µm.

The laser was pumped longitudinally by a fiber-coupled laser diode (DILAS M1F4S22-808.3-50CSS2.9O3, fiber core diameter 400 µm and numerical aperture 0.22) operating in a pulse regime with a repetition frequency range of 10 – 715 Hz. The laser diode electric current and pulse duration were changed during measurement from 30 A to 50 A and from 300 µs to 420 µs, respectively, which corresponds to a power amplitude range of 18 – 37 W and a wavelength range of 805 – 807 nm.

To concentrate pumping radiation into the microchip laser and to optimize laser output radiation parameters, four different pumping optics were used. Each optics consisted of the same aspheric collimator with a focal length of 8 mm and appropriate aspheric focusing lens with a focal length of 8.0, 11.0, 13.8, or 15.3 mm. Based on the focal lengths of the focusing lenses, pumping optics are designated in this text as 8x8, 8x11, 8x13, and 8x15. Using different pumping optics it was possible to increase the pumping beam area and Rayleigh length more than three times up to 0.4 mm^2 and 4 mm, respectively, leading to output pulse energy and peak power optimization, as previously tested for the Nd:YAG/V:YAG microchip laser generating radiation at 1.34 µm [1].

3 Results and discussion

The laser radiation spectrum, mean and peak power, pulse energy and duration, and spatial beam profile were determined for Nd:YAG/V:YAG microchip laser radiation using each pumping optics in dependence on pumping pulse repetition frequency. In addition, the temperature of the aluminium microchip laser holder was analysed during experiments. Output laser radiation was linearly polarized even though a Nd:YAG crystal is an optically isotropic medium, as the V:YAG saturable absorber exhibits anisotropy of excited state absorption [2, 3]. The central laser wavelength was measured to be 1444 nm. Additionally, the laser generated radiation with a TEM_{00} single-mode profile in the case of each pumping optics used. The dependence of output radiation mean power, pulse energy, duration, and peak power on pumping pulse frequency is shown in Fig. 2. Increasing pumping frequency corresponds to the thermal load increase inside the composite crystal. This thermal load was more pronounced when a larger pumping beam was used. For this reason, the laser pulse at frequencies higher than 333 Hz was only generated using the 8x8 pumping optics as the pumping beam after passing through this optics has the smallest waist radius and the shortest Rayleigh length. On the other hand, increasing thermal load in the crystal caused an increase in pulse energy and peak power at low frequencies, which can be explained by the temperature dependence of the V:YAG absorption spectrum [4]. Similar effects were also responsible for the shortening of the generated pulse duration as it is determined by the laser resonator output coupler reflectivity and V:YAG saturable absorber initial transmission at 1444 nm. Using 8x8 pumping optics, the pulse duration decreased from 9.6 ns to 4.9 ns when the frequency was increasing. By using different pumping optics it was possible to increase the maximum pulse energy and peak power from 56 μJ and 10 kW to 91 μJ and 14 kW, respectively.

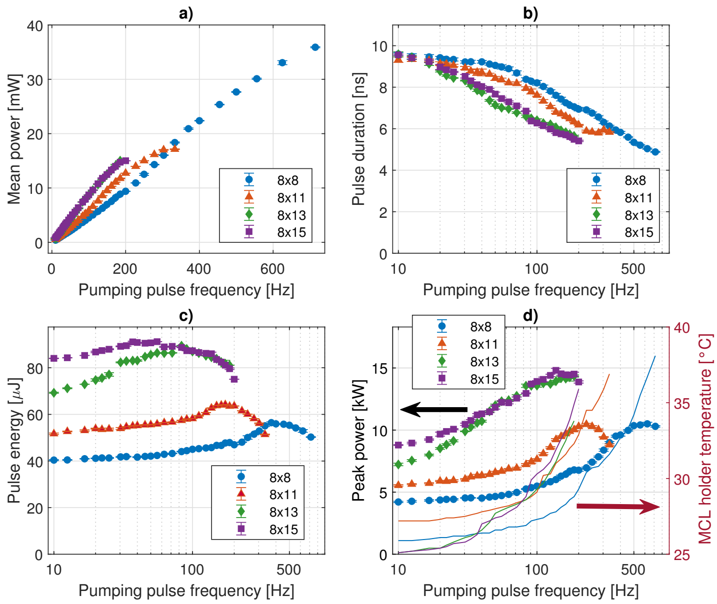

Fig. 2: Output parameters of the Nd:YAG/V:YAG microchip laser (MCL) generating at 1444 nm for each pumping optics in dependence on the pumping pulse frequency: a) mean power, b) pulse duration (FWHM), c) pulse energy, d) pulse peak power and MCL holder temerature.

4 Conclusion

Output radiation parameters of the Nd:YAG/V:YAG microchip laser generating nanosecond pulses at 1.44 µm were optimized based on the pumping beam size variation. By this method, it was possible to increase pulse energy and peak power from 56 μJ to 91 μJ and from 10 kW to 14 kW, respectively. Due to the thermal load inside the laser occurring at high pumping frequencies, the laser generation in frequency range of 333 – 715 Hz was only achieved using the 8x8 pumping optics. Similar effects also caused generated pulse shortening from 9.6 ns to 4.9 ns.

References

[1] K. Kadlec, J. Šulc, H. Jelínková, and K. Nejezchleb, "Output parameters optimization of Q-switched Nd:YAG/V:YAG microchip laser generating at 1.34 μm," in *Solid State Lasers XXXIII: Technology and Devices*, vol. 12864, pp. 106–114 (SPIE, 2024).

[2] N. N. Il'ichev, A. V. Kir'yanov, P. P. Pashinin, V. A. Sandulenko, A. V. Sandulenko1, and S. M. Shpuga, "Anisotropy of nonlinear absorption in a V^{3+}:YAG crystal," **25**(12), 1154–1157 (1995).

[3] J. Šulc, T. Koutný, H. Jelínková, K. Nejezchleb, and V. Škoda, "Influence of V:YAG saturable absorber orientation on linearly polarized laser Q-switching," in *Solid State Lasers XX: Technology and Devices*, vol. 7912, pp. 483–489 (SPIE, 2011).

[4] J. Šulc, J. Novák, H. Jelínková, K. Nejezchleb, and V. Škoda, "Influence of temperature on Nd:YAG/V:YAG compact laser generation at 1444 nm," in *Solid State Lasers XIX: Technology and Devices*, vol. 7578, pp. 585–593 (SPIE, 2010).