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J. Neumann

R. Huss

C. Kolleck

Dietmar Kracht

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ENERGY SCALING OF PASSIVELY Q-SWITCHED LASERS IN THE mJ-RANGE

J. Neumann[1,2], R. Huss[1], C. Kolleck[1,2], D. Kracht[1,2]
E-Mail: j.neumann@lzh.de
[1]Laser Zentrum Hannover e.V., Germany. [2]Centre for Quantum Engineering and Space-Time Research, Germany

I. INTRODUCTION

Q-switched lasers systems with ns pulse duration and energies ranging from 1 to more than 100mJ are utilized for many spaceborne applications such as altimetry of planets and moons. Furthermore, Q-switched lasers can be used for distance measurements during docking and landing manoeuvres. To keep the diameter of the beam small over a large distance and to consequently achieve a good lateral resolution, a good beam propagation factor M^2 is required. Moreover, Q-switched lasers can be used directly on the planetary surface for exploration by laser-induced breakdown spectroscopy [1] or laser desorption mass spectrometry [2].

II. PASSIVELY Q-SWITCHED LASERS

Passive Q-switching enables a very compact laser design, because the Q-switch is introduced by a saturable absorber instead by an electro-optical or acousto-optical modulator into the laser cavity. This approach decreases complexity of the system and saves mass as well as space. Passively Q-switched diode pumped solid-state lasers have been demonstrated to withstand harsh space environments while being realized within a low mass budget [3, 4]. However, in most cases passive Q-switching is implemented in microchip lasers usually emitting several tens of µJ at a repetition rate of several kHz. For passively Q-switched lasers at low repetition rates of several tens of Hz and good beam quality usually 1-3mJ are achieved [1-4]. At higher repetition rates the heat dissipation in the laser rods can lead to thermal effects resulting in a bad beam quality or even to stress-induced fracture of the laser crystals. Further optimization work towards high energy passively Q-switched lasers with higher repetition rates has been initiated by using multi-segmented Nd:YAG laser crystals and pumping at a wavelength of 885nm instead of 808nm [5]. In order to enable a longer energy storage time and therefore to save pump diode peak power Nd:YLF instead of Nd:YAG crystals have been used, which exhibit a fluorescence lifetime of 470µs compared to 230µs for Nd:YAG [1]. For further energy scaling often a master oscillator power amplifier (MOPA) configuration is used [3, 6, 7]. However, this study focusses on the energy scalability of passively Q-switched low repetition rate oscillators at good beam quality.

III. ENERGY SCALING PASSIVELY Q-SWITCHED OSCILLATORS

For the experimental setup, which is shown in Fig. 1, a fiber-coupled q-cw diode laser (DILAS GmbH, N7F-806.7-1000Q-H207) with a peak output power of 1 kW, a pump pulse duration of 200 µs and a repetition rate of 10 Hz was used as a pump source. The q-cw diode module with a spectral width of 2.5 nm (FWHM) was temperature stabilized by a thermo-electric cooler. To maximize pump light absorption in the laser rod, the pump wavelength was matched by temperature tuning of the pump diode module to 806 nm. The fiber tip with 800 µm core diameter was imaged by two lenses into the laser rod, which was mounted in a temperature-controlled holder.

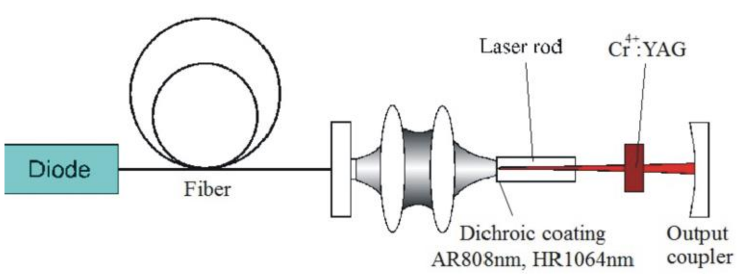

Fig. 1. Experimental setup of the passively Q-switched oscillator.

By end-pumping with a fiber coupled pump diode and the corresponding good overlap between the pump light and the laser mode, a good beam quality is usually achieved at efficient operation. The dichroic mirror of the laser oscillator was directly coated on the 1at. % doped 25mm long Nd:YAG crystal rod. The other endface of the rod had an antireflection coating for 1064 nm. The barrel surface of the rod was roughened to avoid transversal self lasing at high pump energies [8]. The oscillator had a length of 80mm. A Cr:YAG saturable absorber with a linear transmission of 10% had been chosen. The pump spot diameter ($Ø_{pump}$) was increased from 800µm to 1600µm by changing the imaging lenses of the pump optics. Due to the larger pumped volume, the working point of the passively Q-switched laser changed towards higher pulse energies (E_{pulse}, Tab. 1), whereas the optical-to-optical efficiency ($\nu_{opt.-opt}$) stayed at approximately constant value. The beam propagation factor M²-value slightly increases with the pumped volume.

Tab. 1. Energy scaling by increasing the pump spot in the laser crystal.

$Ø_{pump/}$µm	**800**	**1000**	**1200**	**1600**
E_{pulse}/mJ	**3.3**	**4.8**	**7.0**	**11.6**
E_{pump}/mJ	32.6	47.6	62.3	104.7
$\nu_{opt.-opt}$/%	10.2	10.1	11.3	11.1
M²	1.1	1.3	1.6	1.9
τ_{FWHM}/ns	2.6	2.6	2.6	2.6

IV. DISCUSSION

Using solely an oscillator for pulse energy scaling can lead to a less complex laser design compared to MOPA configurations, at the cost of a lower optical-to-optical efficiency and a slightly worse beam quality. End pumped MOPA configurations, where a passively Q-switched oscillator is amplified by two subsequent amplifier stages, have been realized, e.g. a 50mJ MOPA with a beam propagation factor of M²<1.3 [6]. Here, more than 50mJ were achieved at a total pump power of E_{pump} ~240mJ ($\nu_{opt.-opt}$=20%). A MOPA design which contains less complexity can be implemented by pumping the oscillator and one amplifier with the same pump diode [7]. In this case, a pulse energy of 8.4mJ at a duration of τ_{FWHM}=2ns and a beam propagation factor of M²=1.5 was achieved at a pump energy of 160mJ. The efficiency of this system might be increased by optimizing the pump diode pulse duration and the oscillator pulse energy for better amplifier saturation.

V. SUMMARY

Scaling the pulse energy of a passively Q-switched oscillator is an easy technique for achieving higher pulse energies at good beam quality. However, an oscillator contains less complexity, but usually operates less efficient than a MOPA configuration.

REFERENCES

[1] J. Neumann, T. Lang, R. Huss, M. Ernst, A. Moalem, C. Kolleck, D. Kracht, "Development of a Pulsed Laser System for Laser-induced Breakdown Spectroscopy (LIBS)," International Conference on Space Optics (ICSO), Ajaccio, Corse (F), October 9th-12th 2012

[2] C. Kolleck, A. Büttner, M. Ernst, M. Hunnekuhl, T. Hülsenbusch, A. Moalem, M. Priehs, D. Kracht, J. Neumann, "Enhancement of the design of a pulsed UV Laser System for a Laser-Desorption Mass Spectrometer on Mars," International Conference on Space Optics (ICSO), Ajaccio, Corse (F), October 9th-12th 2012

[3] D. J. Krebs, A.-M. Novo-Gradac, S. X. Li, S. J. Lindauer, R. S. Afzal, A. W. Yu, "Compact, passively Q-switched Nd:YAG laser for the MESSENGER mission to Mercury," Appl. Opt. 44(9), 1715-8 (2005).

[4] H. Riris, J. F. Cavanaugh, X. Sun., L. Ramos-Izquierdo, P. Liiva, M. Rodriguez, S. Schmidt, J. McGarry, C. Peters, G. B. Jackson, D. E. Smith, "The Lunar Orbiter Laser Altimeter (LOLA) on NASA's Lunar Reconnaissance Orbiter (LRO) Mission," CLEO/IQEC 2009, Baltimore, USA, May 31 – June 5, 2009, Paper CFJ1

[5] C. Evangelatos, P. Bakopoulos, G. Tsaknakis, D. Papadopoulos, G. Avdikos, A. Papayannis, G. Tzeremes, "Continuous wave and passively Q-switched Nd:YAG laser with a multisegmented crystal diode-pumped at 885 nm," Appl. Opt. 52(36), 8795-8801 (2013).

[6] D. Kracht, S. Hahn, R. Huß, J. Neumann, R. Wilhelm, M. Frede, P. Peuser, "High Efficiency, Passively Q-Switched Nd:YAG MOPA for Spaceborne Laser-Altimetry" in Hoffman H. J., R. K. Shori (eds.): Solid State Lasers XV: Technology and Devices. Proc. SPIE **6100**, pp. 548-555 (2006).

[7] P. Peuser, W. Platz, G. Holl, "Miniaturized, high-power diode-pumped, Q-switched Nd:YAG laser oscillator–amplifier," Appl. Opt., **50**(4), 399-404 (2011).

[8] R. Huß, R. Wilhelm, C. Kolleck, J. Neumann, D. Kracht, "Suppression of parasitic oscillations in a core-doped ceramic Nd:YAG laser by Sm:YAG cladding," Optics Express, 18(12), 13094-101 (2010).