Technical University of Denmark

Passively synchronized dual-wavelength Q-switched lasers

Janousek, Jirí; Tidemand-Lichtenberg, Peter; Mortensen, Jesper Liltorp; Buchhave, Preben

Link to article, DOI:
10.1109/QELS.2005.1548964

Publication date:
2005

Document Version
Publisher's PDF, also known as Version of record

Passively synchronized dual-wavelength Q-switched lasers

Jirí Janousek, Peter Tidemand-Lichtenberg, Jesper L. Mortensen, Preben Buchhave

Department of Physics, Technical University of Denmark, DK-2800 Lyngby, Denmark
Corresponding author: tidemand@fysik.dtu.dk

Abstract: We present a simple and efficient way of generating synchronized Q-switched pulses at wavelengths hundreds of nanometers apart. This principle can result in new pulsed all-solid-state light sources at new wavelengths based on SFG.

OCIS codes: (140.3580) Lasers solid-state, (140.3540) Lasers, Q-switched

1. Introduction

Recent interest in efficient diode-pumped solid-state pulsed lasers in the yellow spectral region has led to a number of interesting configurations, typically based on sum-frequency mixing of two pulsed infrared lasers. To obtain efficient conversion in the nonlinear process the two laser pulses have to be synchronized very carefully. A convenient way of doing this is by generating the two pulses in a common cavity using an active Q-switch acting at both wavelengths simultaneously [1].

In this paper it will be shown that it is possible to obtain nicely synchronized dual-wavelength pulses using a passive Q-switching material in a common optical cavity. Previously, V:YAG has been shown to work as a saturable absorber at both 1064 nm and 1342 nm [2, 3]. The material works at both wavelengths simultaneously, saturating the same energy state. The material can therefore be used as a passive Q-switch in a common path of two lasers operating at 1064 nm and 1342 nm, respectively, leading to synchronized Q-switching of the two lasers [4]. The synchronized state of operation is described both theoretically and experimentally.

2. Setup for passively synchronized operation of two infrared lasers

The setup is shown in Fig. 1. We used two $Nd:YVO_4$-based folded cavity lasers operating at 1064 nm and 1342 nm, respectively. The two laser resonators are designed to share a common beam path, in which the V:YAG saturable absorber is positioned. Each laser has a beam waist radius of approximately 80 μm at the position of the absorbing V:YAG material. The 0.5 mm long V:YAG crystal supplied by Crytur Ltd. has a small-signal transmission of 4 % and 10 % at 1064 nm and 1342 nm, respectively.

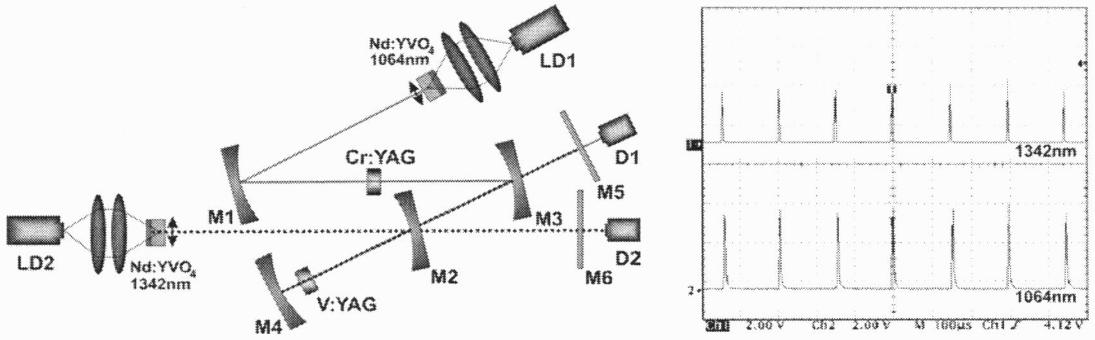

Fig. 1. Setup for passively synchronized Q-switched $Nd:YVO_4$ lasers oscillating at 1064 and 1342 nm respectively. To the right the generated pulses are shown; upper trace is the 1343 nm laser, lower trace is the 1064 nm laser.

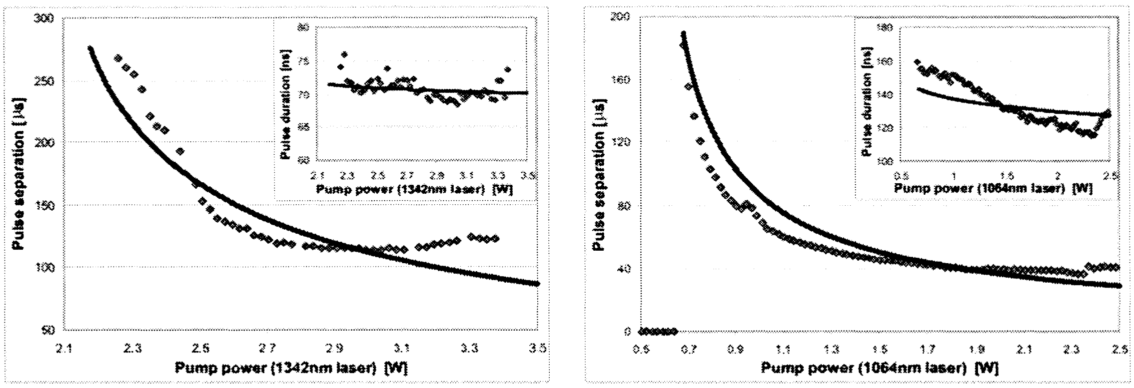

Fig. 2. Measurements and simulations of pulse separation and pulse duration. Left figure shows the results for the 1342 nm laser using V:YAG as the saturable absorbing material. The right figure shows the results for the 1064 nm laser, using Cr:YAG in combination with V:YAG. The insert on both figures shows the measured and simulated results for pulse separation.

An additional 10 % saturable absorbing Cr.YAG material is inserted into the 1064 nm laser. This is used in order to obtain approximately the same repetition rate of the two lasers free running. The right part of the figure shows a measurement of the pulses generated using this setup.

The left graph in fig. 2 shows measured (diamonds) and simulated (solid line) pulse separation as a function of the pump power for the 1342 nm laser. The insert in the figure shows the corresponding measured and simulated pulse durations. Clearly there is some difference between the measured and the simulated curve. However, this is mainly caused by thermal lensing in the V:YAG saturable absorber. The V:YAG material is modeled by a set of coupled differential equations describing the populating of the various energy levels, including excited state absorption. The right part of fig. 2 shows a corresponding measurement on the 1064 nm laser using the combination of the two saturable absorbing materials. Again both measurements and modeled data for the pulse separation and pulse duration are shown. There is a quantitative agreement between the measured and modeled results, however, thermal lensing influences the measurements. Clearly the pulse separation ought not be increasing at increasing pump power as is seen at higher pump powers.

3. Measured states of synchronization

Figure 3 shows measured pulse separation of the 1342 nm laser as a function of diode pump power, when the 1064 nm laser is pumped by 1.0 W. The pulse separation of the 1064 nm laser is approximately 120 µs. It is clearly seen, that the pulses from the two lasers lock together as the pump power is varied. If the pulse separations of the two lasers have nearly an integer ratio, they synchronize due to the coupling in the V:YAG saturable absorber. The insert in the figure shows the corresponding model results.

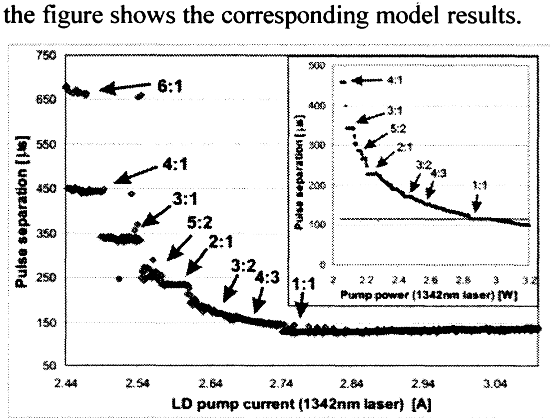

Fig. 3. Measurement of pulse separation of the two lasers. The 1064 nm laser is pumped at constant power. The 1342 nm laser pump power is increased along the x-axis. The insert shows the corresponding simulation.

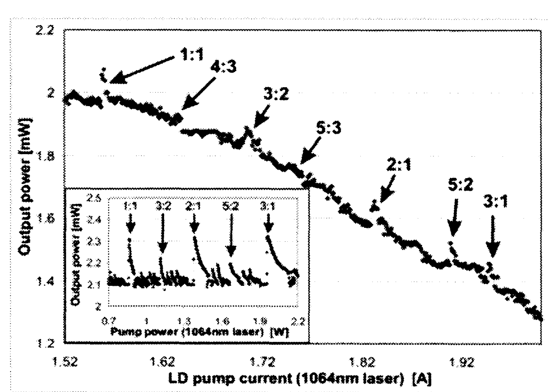

Fig. 4. Measurement of average power of the 1342 nm laser varying the pump power of the 1064 nm laser. The insert shows the corresponding simulated results. The pump power of the 1342 nm laser is fixed at 2.6 W.

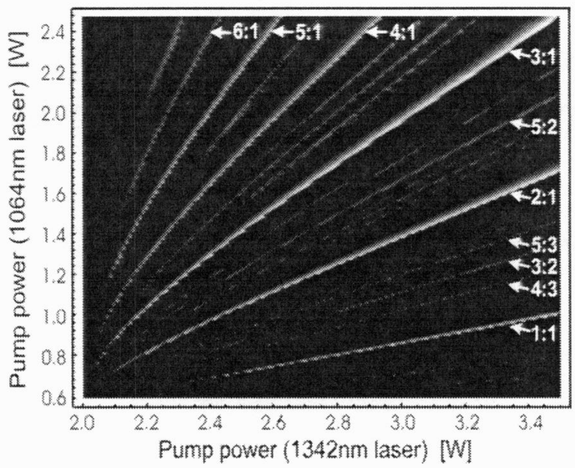

Fig. 5. Calculated pulse overlap as a function of pump power in the two lasers.

When the first of the two lasers reach threshold, it starts to build up a circulating field in the resonator saturating the V:YAG material. This results in reduced losses for the second laser, which thereby reaches threshold. The laser that reaches the threshold first thereby sets the repetition rate of the system. The pulse duration of the first laser is increased due to bleaching of the absorber by the second laser.

Figure 4 shows the average power of the 1064 nm laser as the pump power of the 1342 nm laser is varied. The overall decrease in power is probably due to thermal effects in the V:YAG material, as the circulating power at 1342 nm is increased. However, the interesting feature of this graph is the small spikes corresponding to states of synchronization of the two lasers. When the two lasers are synchronized they work together bleaching the saturable absorber, and therefore the losses for both lasers are decreased corresponding to an increase in average power for both wavelengths. The insert shows the modeled results.

Figure 5 shows modeled data for the pulse overlap between the two lasers, as a function of the diode laser pump power for the two lasers. This graph is calculated as the product of the power of the two lasers, divided by the number of synchronized pulses per second. This therefore corresponds to the pulse energy of generated yellow light in a subsequent sum-frequency generation process.

4. Future improvements on the system

The next step using this setup is to increase output coupling from the system, maintaining the strong coupling between the two generated wavelengths. Also we need to decrease the thermal lensing in the V:YAG material by using a longer crystal with a reduced doping level. Finally we need to make SFG between the generated pulses.

References:

[1] Y. F. Chen and S. W. Tsai, "Diode-pumped Q-switched Nd:YVO4 yellow laser with intracavity sum-frequency mixing", Optics Lett. **27**, 397-399 (2002).

[2] A. M. Malyarevich, I. A. Denisov, K. V. Yumashev, V. P. Mikhailov, R. S. Conroy, and B. D. Sinclair, "V:YAG – a new passive Q-switch for diode pumped solid-state lasers", Appl. Phys. B **67**, 555-558 (1998).

[3] A. Agnesi, A. Guandalini, G. Reali, J. K. Jabczynski, K. Kopczynski, and Z. Mierczyk, "Diode pumped Nd:YVO4 laser at 1.34 μm Q-switched and mode locked by V^{3+}:YAG saturable absorber", Optics comm. **194**, 429-433 (2001).

[4] P. Tidemand-Lichtenberg, J. Janousek, Radek Melich, Jesper L. Mortensen and P. Buchhave, "Synchronization of 1064 and 1342 nm pulses using passiv saturable absorbers", Optics Comm. **241**, 487-492 (2004).