Regular Issue Papers

OPTO-ELECTRONICS REVIEW **13**(4), 317–323

Q-switched mode locking in diode pumped lasers

J.K. JABCZYŃSKI*, W. ŻENDZIAN, and J. KWIATKOWSKI

Institute of Optoelectronics, Military University of Technology,
2 Kaliskiego Str., 00-908 Warsaw, Poland

The Q-switched mode locking (QML) regime provides the generation of relatively high peak power picosecond pulses train with energies of a few µJ each in a simple resonator. The critical review of QML methods and results including our investigations is given in the first part of presentation. The application of several types of saturable crystalline absorbers (Cr^{4+}:YAG, V^{3+}:YAG, LiF, GaAs) leads to chaotic, partial QML effect, with less than 100% modulation depth in principle. The fully modulated efficient QML laser was demonstrated in the next part. The acousto-optic cell playing a double role of Q-switch and mode locker was located near a flat output coupler. The two folding mirrors were mounted on the translation stages for matching the resonance frequency of the cavity to the radio frequency of acousto-optic modulator. The QML pulses with envelope durations of 100–150 ns and 100% modulation depth were observed for wide range of pump powers and repetition rates. In the preliminary experiments up to 3 W of output average power, 100 µJ of the envelope energy, having approximately 5–8 mode locked pulses were achieved.

Keywords: diode pumped lasers, mode locking, Q-switching, acousto-optic, saturable absorbers.

1. Introduction

The ps pulses of µJ energies with dozens kHz pulse repetition frequency (PRF) are demanded in several areas, e.g., micro machining, ophthalmology, dental surgery etc. Its high intensities together with relatively low heat deposition ensure precise removal of material during the short interaction time. The three methods can give pulses satisfying the above requirements:

- amplification of mode locked pulses in high power fiber amplifiers,
- regenerative amplification of mode locked pulses in bulk diode pumped systems,
- Q-switching and mode locking in bulk diode pumped systems.

The first one method requires the development of high power fiber lasers with relatively high damage thresholds [1–3], moreover nonlinear pulse distortions have to be overcome. The level of 2 µJ with 0.2 MW peak power was achieved in last year [3] applying specially designed photonic fiber. The second method gives much wider opportunities. Applying pulse picker technique and thin disk concept [4–6], high peak powers, even a few mJ pulse energies with kHz PRF were achieved in Nd:YAG laser. Applying Yb doped gain media (Yb:YAG, Yb:KGW, Yb:KYW) and the intracavity GVD compensation technique, a few hundred femtosecond pulses with above 0.2 GW peak power were demonstrated lately [6]. The much simpler designs [7,8] based on well developed end pumped side cooled $Nd:YVO_4$ lasers offer a few hundreds µJ-pulse energies with 10-ps pulse duration and 10-W average power. The main disadvantage of these systems is complicated HV electronics needed for electro-optic cells of pulse picker and regenerative amplifier.

The last method, well known since the 70'ies of last century [9], consists in generation of simultaneous mode locking and Q-switching in the same cavity. The simple transfer of QML techniques (e.g., liquid dye cells, LiF, colour centre foils etc.) developed for low rep. rate lamp pumped lasers is not possible for the laser system operating at several dozens kHz rep. rates. Thus, the numerous works had been devoted to research on efficient bulk saturable absorbers satisfying such requirements [10–15]. In Sec. 2 of this paper, the results of our investigations of Cr:YAG, GaAs, LiF, V:YAG crystals as QML elements in diode pumped lasers are presented. Despite numerous works devoted to application of bulk passive Q-switches for such a purpose, the efficient reliable QML regime (with 100% modulation depth) has never been, to our knowledge, demonstrated. The main reason consists in lack of sufficiently stable, reliable mechanism causing fast (with recovery time less than 1 ns) loss modulation and inherent chaotic, very noisy operation of such type modulators. Combination of different mode locking techniques (e.g. nonlinear mirrors [16–17], specially designed semiconductor saturable absorber elements [18–20], acousto-optic modulators [21]) with active Q-switches can lead to 100% modulation depth and stabilization of temporal and energetic parameters of QML regime. We have demonstrated in this paper the efficient QML regime enforced by acousto-optic cell. In Sec. 3, the system description and ex-

*e-mail: jjabczynski@wat.edu.pl

periments on acousto-optic QML (AO-QML) laser are given. In the last section, conclusions were drawn and prospects for future work are given.

2. Investigation of passively Q-switched mode locking

2.1. Investigations of QML effects at 1064-nm wavelength

The 20-W fiber coupled diode laser (NA = 0.22, d_{core} = 0.4 mm) was used for pumping of 0.5% Nd doped YVO_4 crystal of the size 3×3×12 mm^3 with AR coated both facets. The basic outline of the laser set up is shown in Fig. 1. The laser crystal was wrapped with indium foil and mounted in a water-cooled copper block. We designed the cavity to easily reach mode matching with the pump beam and provide the proper size in the saturable absorber placed next to the output coupler OC. The resonator consisted of two spherical highly reflective (at 1064-nm wavelength) mirrors, R_1 and R_2, with the radii of curvature of 1000 and 500 mm respectively. In this configuration, over 4 W of the output power in a fundamental mode in free running regime was obtained. In the same cavity with Pockels cell Q-switch (without any nonlinear elements) smooth pulses of 260-ns duration were observed. Several Cr^{4+}:YAG, GaAs, and LiF crystals with different initial transmissions and various output couplers with different reflectivity were used to optimize the output performance.

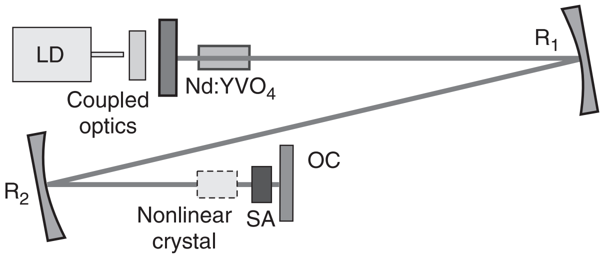
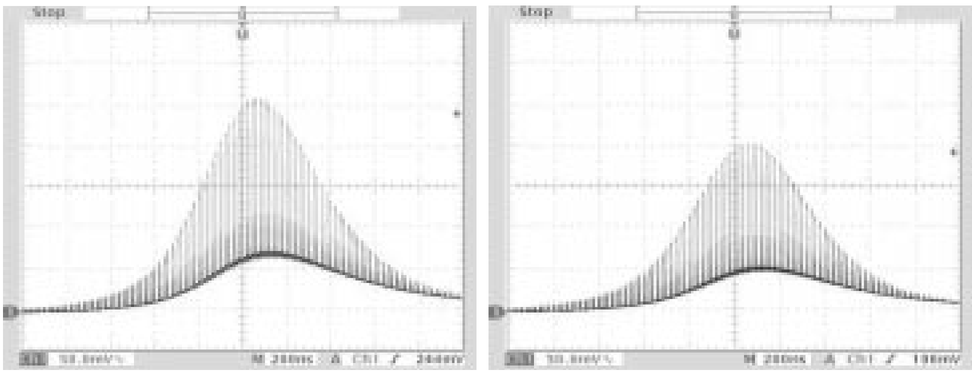


Fig. 1. Scheme of laser cavity, SA denotes saturable absorber, LD-20 W – fiber coupled diode, and OC-output coupler.

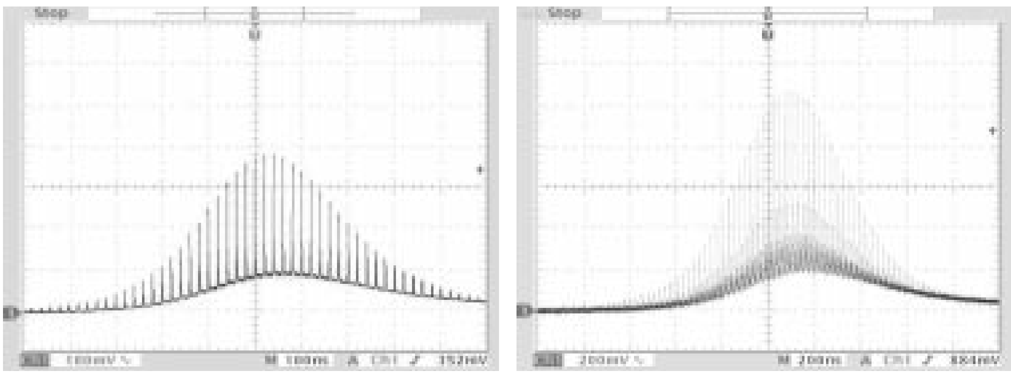
The pulse's temporal behaviour was recorded by a Tektronix TDS 3052 digital oscilloscope (500-MHz bandwidth). Some of the oscilloscope traces of Q-switched and mode-locked laser pulses are presented in Figs. 2(a), 2(b), and Figs. 3(a) and 3(b).The envelope pulse length with Cr^{4+}:YAG crystals changed from 300 to 900 ns over the range of the absorbed pump power.

The highest energy of QML envelope up to 100 µJ but with a modulation depth of about 50% was obtained for Cr^{4+}:YAG crystal. For LiF modulators we observed much longer envelopes with the modulations depths much better than 50%. However, strong thermal effects and photorefractive bleaching characteristic for LiF crystals delim-



(a) (b)

Fig. 2. QML pulse train for Cr^{4+}:YAG, T_0 = 85.7%, envelope duration t_{env} = 620 ns (a). QML pulse train for Cr^{4+}:YAG, T_0 = 81.6%, envelope duration t_{env} = 600 ns (b).



(a) (b)

Fig. 3. QML pulse train for combination of Cr^{4+}:YAG (T_0 = 81.6%) and LiF (T_0 = 89%), envelope duration t_{env} = 342 ns (a). QML pulse train for LiF, T_0 = 72%, envelope duration t_{env} = 570 ns (b).

ited averaged pump power to relatively low values of a few Watts. Examination of GaAs crystals gave much worse output energies but much longer QML envelopes with durations of a few µs. The true cw mode locking regime for GaAs crystals [4] was not evidenced despite numerous experimental efforts. For each case, strong thermal lensing inside gain medium and Q-switch was observed, thus the regime of a stable QML operation with relatively low energetic and temporal jitter should be found for a given geometry of a bare cavity by appropriate balancing of a rate and duty factor of a pump.

2.2. Investigations of QML effects at 1340-nm wavelength

The similar cavity scheme was applied for experiments at 1340-nm wavelength. We have used here 0.3% Nd doped YVO_4 crystal of the size 3×3×10 mm^3 and the same pump unit. The output power of 3.5 W in short cavity case, and about 2-W power for Z-type cavity were achieved in a free running mode. The V^{3+}:YAG crystals of several initial transmissions were investigated as passive Q-switches. We have observed over 80% modulation depth QML pulse of envelopes with durations in the range of 1–2 µs. The problems of jitter and chaotic pulsations, similar to relaxation spiking, were much more stringent comparing to experiments at 1064-nm wavelength. To stabilize mode locking and mitigate jitter, the frequency converter of II type, made of l0-mm length LBO crystal was inserted in the vicinity of V^{3+}:YAG Q-switch. We achieved elongation of envelope duration and enhancement of stability and depth of modulation for the pulses at fundamental 1340-nm wavelength. Moreover, fully modulated pulses at II harmonic at 670 nm were demonstrated in Figs. 4(a) and 4(b).

3. Investigations of acousto-optic QML effects in Nd:YVO_4 laser

3.1. Operation principle of AO-QML laser

The principle of operation of AO-QML laser consists in enforcing in the laser resonator the mode locking on the frequency equal to radio-frequency (RF) of acousto-optic cell. We have applied the travelling wave acousto-optic modulator NEOSN33041-10-15 (AOM) operating at 40.67 MHz RF. It was evidenced, that this AOM introduces, in a "switch on" state, 60% single pass losses with 15% modulation depth at 40.7 MHz, Fig. 6(a).

Assuming total resonator length of 3690 mm and not higher than 4-mrad divergence angle in the output arm of Z cavity (Fig. 5), the dynamically stable layout was found analytically. Approximately 0.4-mm fundamental mode diameter at gain medium was estimated for wide range of

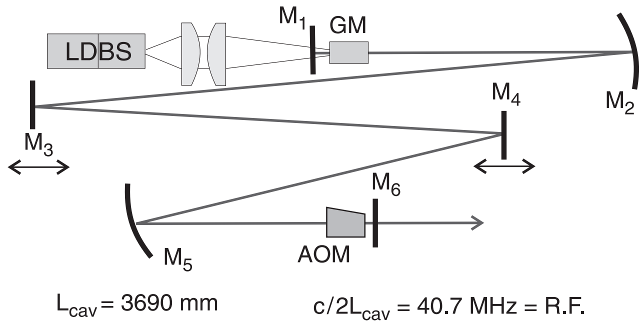


Fig. 5. Schematic of AO-QML laser: LDBS – 20 W laser diode bar with beam shaper, AOM – acousto-optic modulator, M_2, M_5 – folding mirrors of 1-m radii of curvature, GM – 0.3% Nd:YVO_4 crystal of 3×3×10 mm^3, M_3,M_4 – flat folding mirrors at translation stages, M_6 – flat output coupler (OC), M_1 – rear mirror highly reflective at 1064 nm and antireflective at 810 nm.

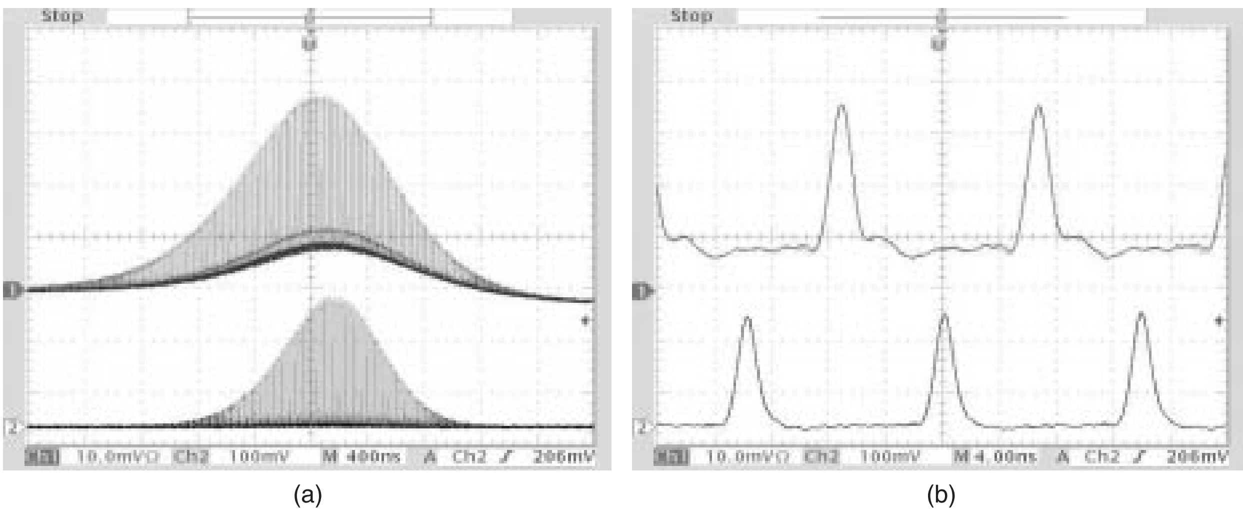
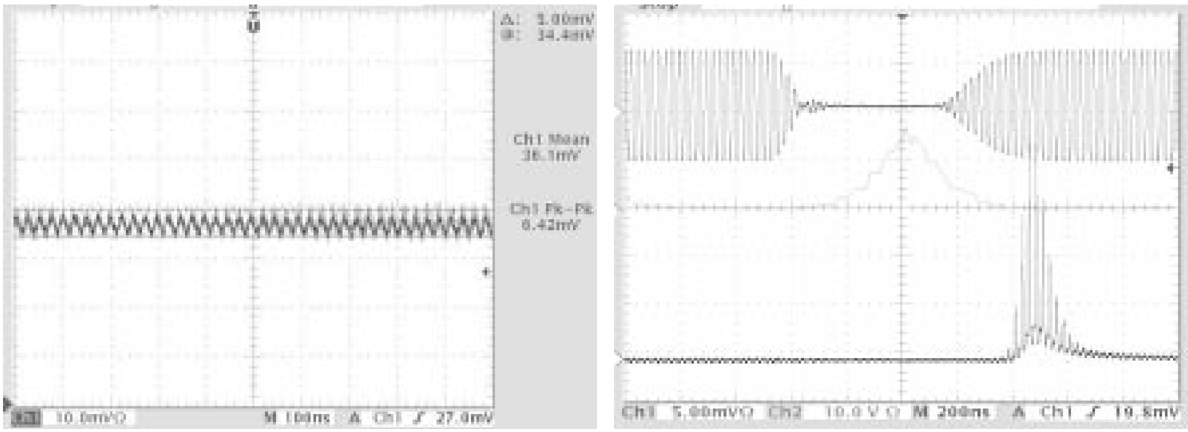


Fig. 4. Oscilloscope traces of QML trains at 1340-nm wavelength (upper trace), and intracavity II harmonic at 670-nm (lower trace); V^{3+}:YAG, $T_{0(1340)}$ = 86.2%, envelope duration t_{env} = 1200 ns (a). Oscilloscope traces of ML pulses at 1340-nm wavelength (upper trace), and intracavity II harmonic at 670-nm (lower trace); V^{3+}:YAG, $T_{0(1340)}$ = 86.2% (b).



(a) (b)

Fig. 6. Oscilloscope trace of optical signal after passing through AOM, detected in far field of "zero order" diffraction mode for non interrupted cw RF driving signal – "switch on" mode of AOM (a). Oscilloscope traces of RF electric signal at AOM (upper Ch2 trace), optical QML output signal (lower Ch1 trace), Fast Fourier transform of RF signal (middle trace) (b).

1–20 D of optical power of thermal lens induced in gain medium. The AOM was located close to the output mirror of a double Z cavity (Fig. 5) with total length L_{cav} = 3690 mm. The resonator frequency ($c/2L_{cav}$) was matched to the RF of AOM by means of precise movement of folding mirrors (M_3, M_4) mounted on translation stages. Thus, after "switch off " gate signal [Ch2 trace in Fig. 6(b)] the QML pulse [Ch1 trace in Fig. 6(b)] builds up from weak prelasing of mode locked 40.7 MHz radiation.

3.2. Investigations of Nd:YVO_4 laser operating in free running mode

The maximum pump power corresponding to near stability edge of cavity was approximately 15 W. The measurements of energetic characteristics for a wide set of OC transmissions were carried out (Fig. 7). The optimal OC transmission for free running mode was found to be 30%, giving for 15-W pump power of 3.3 W and roundtrip small signal gain of 3.5.

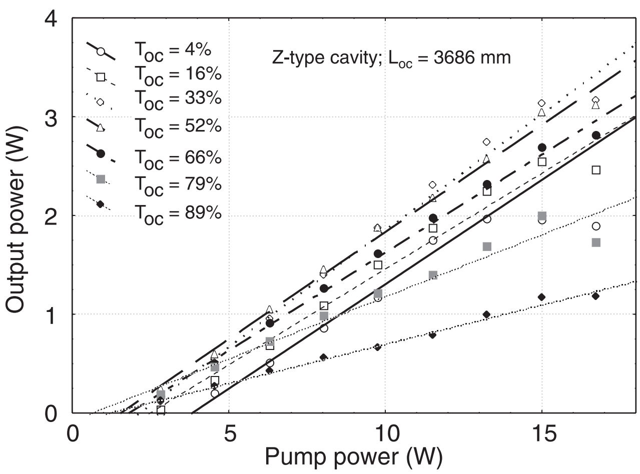


Fig. 7. Output power vs. pump power for double Z cavity laser operating in cw mode.

3.3. Investigations of QML regime

The investigation of QML effects were carried out in AO-QML laser (Fig. 5). The fully modulated QML trains were observed for the numerous set of OC transmission. However, for transmission lower than 60%, not neglected laser action occurred between QML pulses for high excitation level. It was accompanied by a chaotic background between mode locked pulses inside QML envelope. Thus, to obtain clean fully modulated QML pulses with high contrast, OC transmission has to be higher than 60%. The typical energetic characteristic was shown in Fig. 8, with QML train oscilloscope trace demonstrated in Fig. 9. Even for uncoated plane parallel plate applied as a OC mirror, quite reasonable averaged output power of 1.3 W with 50 µJ energies of QML pulses was obtained. With decrease in PRF, the leakage between QML pulses increased. The compromise between QML energy and average power was found

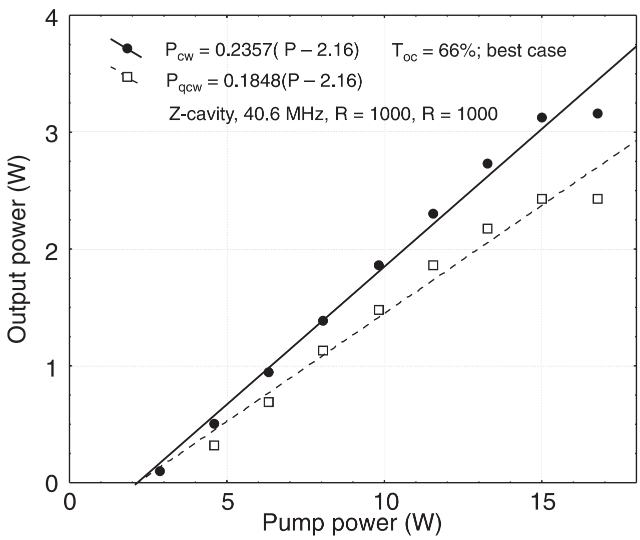


Fig. 8. Output power vs pump power; diamonds blue – cw, squares QML regime.

for 20–30 kHz of PRF. The additional problem was connected with low (6 mrad) diffraction angles of AOM. The location of AOM at, opposite to the gain medium, end of a cavity, necessary for effective mode locking of single round trip pulse, is not a good solution from the point of laser optics. The M_6 and M_1 mirrors are near to geometrical optic conjugate planes despite high thermal optical power induced in gain medium. In effect, the higher orders beam diffracted by AOM could return to gain medium and it will be again amplified. The higher order mode structure in output beam can be observed for high gain and high thermal lensing (pump power > 15 W). Thus, to improve the energetic parameters of QML laser, the additional requirements of low divergence at output arm and possibility of spatial filtering have to be satisfied in the cavity design. In the best case we obtained up to 3 W of average power for a pump power of 15 W and 66%-transmission of OC coupler. The maximal QML energy of 100–120 μJ was with envelope duration of 100–120 μs. For a roundtrip time of 25 ns, the estimated energy of the highest pulse inside envelope was about 30 μJ. The measurements of mode locked pulse duration gave ambiguity results. Applying electronic technique (1 GHz DSA-601 scope and New Focus 1601 photo receiver of 0.2-ns rise time) we have observed that the pulse is shorter than 1 ns. For comparison we have arranged collinear autocorrelator of Michelson scheme with the II type KTP crystal as a II harmonic conversion element. The pulse duration, averaged over the several QML envelopes, was determined to be not shorter than 0.5 ns. The reason of such wide mode locked pulse (or multi pulsing behaviour) seems to be the inherent low stability of AOM signal. Between signal triggering gates, only about 1000 periods of acoustic wave occur, thus the relative width of AOM spectrum is about 0.001 or wider. We suppose that it is a main source of imperfect mode locking observed in the autocorrelation experiments.

3.4. Investigation of cavity dumped AO-QML laser

We have tried to select a single pulse from the QML train applying the cavity dumping technique. Investigations of cavity dumping were carried out with the laboratory set up shown in Fig. 10. The KDP* Pockels cell (EOM) of 3.2 kV quarter wave voltage was inserted between M_5 mirror and AOM. The first weak pulses of QML envelope after passing through M_5 mirror detected and amplified to level of 3–5 V by the optical trigger OT and further was sent to high voltage driver PDP to switch on quarter wave voltage jump of 7 ns rise time. The delay of trigger signal was accomplished by the change of magnitude of optical signal and the distance to OT. The quarter wave voltage jump at EOM changes the polarization of travelling pulse. The rotated polarization, after double pass through EOM pulse, is rejected out of cavity by the thin film polarizer (TFP). As was shown at Figs. 11 and 12 the cavity dumping technique

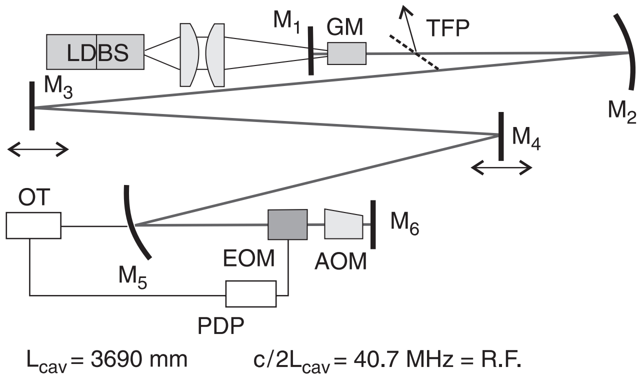


Fig. 10. Scheme of cavity dumped AO-QML laser, GM – gain medium Nd:YVO_4, M_2, M_5 – 1 m radius curved mirrors, EOM – KDP* Pockels cell, AOM – acousto-optic modulator, TFP- thin film polarizer, OT – optical trigger of 0.2 ns rise time, PDP – high voltage driver for EOM, LDBS – 20 W laser diode with beam shaper.

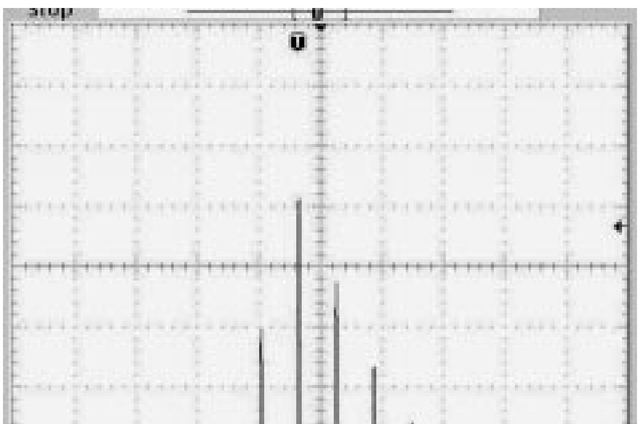


Fig. 9. Oscilloscope trace of fully modulated QML pulse train.

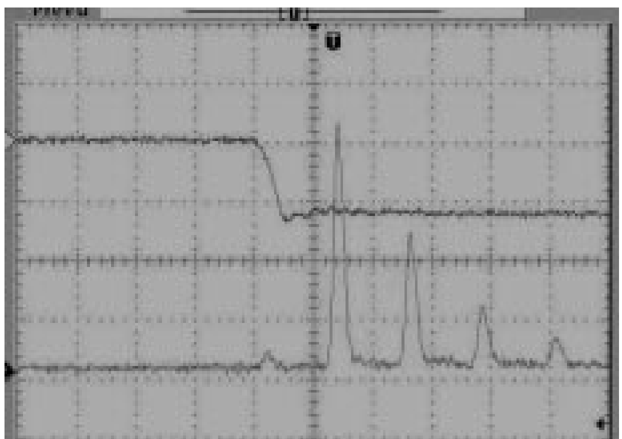


Fig. 11. Oscilloscope trace of HV signal – Ch1 and cavity dumped train – Ch2.

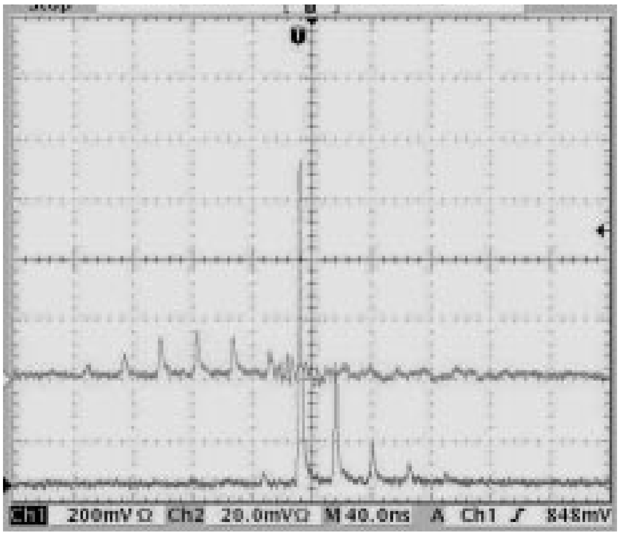


Fig. 12. Oscilloscope trace of cavity dumped pulses of vertical polarization Ch1 and residual pulses at horizontal polarization Ch2.

enabled rather "to clip" the pulse train from the one side only. The reason is probably too low contrast of TFP and not perfect operation of EOM. The residual pulse of vertical polarization after passing through the TFP was again amplified in the gain medium ($Nd:YVO_4$ crystal has also significant gain cross section for transverse s-polarization) and travelled once again through the cavity. To eliminate this effect, the higher contrast Glan polarizer should be used and the better alignment of EOM is required.

4. Conclusions

The experiments on two types (passive and acousto-optic) QML lasers were carried out. The application of several types of saturable crystalline absorbers (Cr^{4+}:YAG, V^{3+}:YAG, LiF, GaAs) leads to chaotic, partial QML effect, with less than 100% modulation depth in principle. The main reason consists in lack of sufficiently stable, reliable mechanism causing fast (with recovery time much less than round trip time) loss modulation and inherent chaotic, very noisy operation of such type modulators. The fully modulated efficient QML regime was demonstrated in AO-QML laser. The acousto-optic modulator playing here a double role of Q-switch and mode locker, was located near flat output coupler of double Z-type resonator. The resonance frequency of the cavity was matched to the radio frequency of acousto-optic modulator by the precise movement of two folding mirrors located at translation stages. The QML pulses with envelope durations of 100–150 ns and 100% modulation depth were observed for wide range of pump powers and repetition rates. We have shown that the contrast of QML pulses increases with increase in OC transmission. The best energetic parameters were achieved for 66% of OC transmission. Up to 3 W of output average power, 100 µJ of the envelope energy, having approximately 5–8 mode locked pulses were achieved. The maximal pulse energy inside the QML train was about 30 µJ. To improve the energetic parameters of QML laser, new cavity design satisfying requirement of the low divergence angle at output arm and possibility of spatial filtering has to be worked out. The estimated pulse duration of 0.5–1 ns was caused mainly by relative wide width of frequency spectrum of AOM driver. The application of cavity dumping technique to select single pulse was not successful. We obtained, in the best case, the single high energy pulse followed by two or three pulses of much lower amplitude. The highly effective selection of single pulse can be made out of cavity with pulse picker technique.

Acknowledgments

This work was supported by the Polish Committee for Scientific Research under the projects 4T11B02724, PBZ-MIN-009/T11/2003. We would like to thank Prof. Z. Jankiewicz, Dr M. Skórczakowski for fruitful discussion on the results.

References

1. J. Limpert, A. Liem, T. Gabler, H. Zellmer, A. Tunermann, S. Unger, S. Jetschke, and H.R. Muller, "High average-power picosecond Yb doped fiber amplifier", *Opt. Lett.* **26**, 1849–1851 (2001).
2. J. Limpert, S. Hofer, A. Liem, H. Zellmer, A. Tünnermann, S. Knoke, and H. Volckel, "100-W average-power high-energy nanosecond amplifier", *Appl. Phys.* **B75**, 477–479 (2002).
3. J. Limpert, N. Deguil-Robin, I. Manek-Honninger, and F. Salin, "High-power picosecond fiber amplifier based on nonlinear spectral compression", *Opt. Lett.* **30**, 714–716 (2005).
4. D. Muller, S. Erhard, and A. Giesen, "High power thin disk Yb:YAG regenerative amplifier", in *Trends in Optics and Photonics, Conference on Lasers and Electro-Optics OSA Technical Digest of CLEO*, Vol. 50, pp. 319–324, Optical Society of America, Washington, 2000.
5. E. Innerhofer, T. Südmeyer, F. Brunner, R. Häring, A. Aschwanden, R. Paschotta, U. Keller, C. Hönninger, and M. Kumkar, "60-W average power in picosecond pulses from a passively mode-locked Yb:YAG thin-disk laser", in *Trends in Optics and Photonics, Conference on Lasers and Electro-Optics OSA Technical Digest of CLEO*, Vol. 73, pp. 152–153, Optical Society of America, Washington, 2002.
6. A. Byertt, D. Nickel, and A. Giesen, "Femtosecond thin-disk Yb:KYW regenerative amplifier", *Appl. Phys.* **B80**, 655–660 (2005).
7. M. Siebold, M. Hornung, J. Hein, G. Paunescu, R. Sauerbrey, T. Bergmann, and G. Hollemann, "A high-average-power diode-pumped $Nd:YVO_4$ regenerative laser amplifier for picosecond-pulses", *Appl. Phys.* **B78**, 287–290 (2004).
8. J. Kleinbauer, R. Knappe, R. Wallenstein, "A powerful diode-pumped laser source for micromachining with ps pulses in the infrared, the visible and the ultraviolet", *Appl. Phys.* **B80**, 315–320 (2005).
9. A.J. de Maria, W.H. Glenn, M.J. Brienza, and M.E. Mack, "Picosecond laser pulses" in *Selected Papers on Fundamen-*

tals of Lasers, Vol. MS70, pp. 452–475, edited by W.T. Silfvast, SPIE Milestone Series, Bellingham, 1990.
10. T.M. Jeong, C.M. Chung, H.S. Chung, H.S. Kim, C.H. Nam, and C.J. Kim, "Generation of passively Q-switched mode-locked pulse from a laser diode pumped Nd:YAG laser", *J. Korean Physical Society* **35**, 290–293 (1999).
11. Y.F. Chen, S.W. Tsai, S.C. Wang, and J. Chen, "A diode-pumped high power Q-switched and self-mode-locked Nd:YVO_4 laser with LiF:F^{2-} saturable absorber", *Appl. Phys.* **B73**, 115–118 (2001).
12. Y.F. Chen, J.L. Lee, H.D. Hsieh, and S.W. Tsai, "Analysis of passively Q-switched lasers with simultaneous mode locking", *IEEE J. Quantum Electron.* **38**, 312–316 (2002).
13. D.Y. Shen, D.Y. Tang, and C. Lu, "CW and Q-switched mode-locking of a Nd:YVO_4 laser with GaAs wafer", in *Trends in Optics and Photonics, Conference on Lasers and Electro-Optics OSA Technical Digest of CLEO*, Vol. 73, pp. 151–152, Optical Society of America, Washington, 2002.
14. A. Agnesi, A. Guandalini, G.C. Reali, J.K. Jabczyński, K. Kopczyński, and Z. Mierczyk, "Diode-pumped Nd:YVO_4 laser at 1.34 μm Q-switched and mode-locked by a V^{3+}:YAG saturable absorber", *Opt. Commun.* **194**, 429–433 (2001).
15. J. Kong, D.Y. Tang, S.P. Ng, B. Zhao, L.J. Qin, and X.L. Meng, "Diode-pumped passively mode-locked Nd:$GdVO_4$ laser with saturable absorbers", *Appl. Phys.* **B79**, 203–2006 (2004).
16. A. Agnesi, G.C. Reali, and V. Kubecek, "Nonlinear mirror operation of a diode-pumped quasi-cw picosecond Nd:YAG laser", *Appl. Phys.* **B66**, 283–285 (1998).
17. P.K. Datta, S. Mukhopadhyay, S.K. Das, L. Tartara, A. Agnesi, and V. Degiorgio, "Enhancement of stability and efficiency of a nonlinear mirror mode-locked Nd:YVO_4 oscillator by an active Q-switch", *Opt. Express* **12**, 4041–4046 (2004).
18. V. Kubecek, J. Biegert, J.C. Diels, and M.R. Kokta, "Practical source of 50 ps pulses using flashlamp pumped Nd:YAG laser and passive all-solid state pulse control", *Opt. Comm.* **174**, 317–321 (2000).
19. H. Jelinkova, M. Cech, V. Kubecek, A. Dombrovsky, J.C. Diels, and A. Stintz, "All solid state picosecond flashlamp pumped oscillator-amplifier Nd:YAG laser system", *Proc. SPIE* **5777**, 373–377 (2005).
20. G.J. Valentine, D. Burns, and A.I. Ferguson, "High power, passively mode locked quasi-cw Nd:YLF laser with feedback for Q-switch and spike suppression", in *Trends in Optics and Photonics, Conference on Lasers and Electro-Optics OSA Technical Digest of CLEO*, Vol. 73, pp. 150–151, Optical Society of America, Washington, 2002.
21. P. Kappe, M. Ostermeyer, and R. Menzel, "Active mode locking of a phase-conjugating SBS-laser oscillator", *Appl. Phys.* **B80**, 49–54 (2005).

ANNOUNCEMENT & CALL FOR ABSTRACTS

QWIP2006

(International Workshop on Quantum Well Infrared Photodetectors)
June 18-24, 2006
Kandy, Sri Lanka
Webpage: http://www.phy-astr.gsu.edu/qwip2006/index.htm

On behalf of the organizing committee, I am happy to announce that the 4th QWIP workshop will be held in Kandy, Sri Lanka as planned during the QWIP-2004 workshop in Canada. The topics to be covered include (but not limited to) QWIP & QDOT Physics, technology, applications, Innovative directions, engineering issues. Other competing quantum technologies, such as HgCdTe, InSb, supperlattices, and other heterojunction/ homojunction will also be considered. Please mark your calendar and plan to submit your abstracts to the workshop before January 15th 2006. Travel support for (about 10) US students and post-docs who will be presenting authors will be available. Several Tutorials on QWIP physics, technology, novel directions and Photon detection using dye-sensitized nanostructures are also planned.

A. G. Unil Perera
uperera@gsu.edu (404-651-2709)

Organizing Committee:

A. G. U. Perera chair	Georgia State University USA
H. C. Liu, co-chair	National Research Council Canada
S. D. Gunapala, co-chair	Jet Propulsion Laboratory USA
K. Tennakone, chair (local arrangements)	IFS Sri Lanka
P. M. Sirimanne	IFS Sri Lanka
H. W. M. A. A. Wijesinghe	IFS Sri Lanka

Advisory Committee:

Sumith Bandara	Jet Propulsion Laboratory USA
Pallab Bhattacharya	University of Michigan USA
Gail Brown	Air Force Research Laboratory USA
Anna Carbone	Polito Italy
Dave Cardimona	Air Force Research Laboratory USA
K. K. Choi	Army Research Laboratory USA
Eric Costard	Thales France
Paul Harrison	University of Leeds UK
Bernhard Hirschauer	Acreo Sweden
R. P. G. Karunasiri	Naval Postgraduate School USA
Barbara Mc Quiston	QWIP Technologies USA
Gabby Sarusi	Elop Israel
Harald Schneider	Forschungszentrum Rossendorf Germany
Kirthi Tennakone	Institute of Fundamental Studies Sri Lanka
Meimei Tidrow	Missile Defense Agency USA
Nikzad Toomarian	Jet Propulsion Laboratory USA

Workshop Coordinators:

Viraj Jayaweera, Steven Matsik