PARTENERIATE IN DOMENII PRIORITARE

RAPORT STIINTIFIC

Contractul de Finantare nr. 58/02.07.2012

Sistem Laser pentru Aprinderea Motoarelor de Automobile (LASSPARK)

Etapa II / 2012: **Dinamica procesului de aprindere folosind bujia laser. Influenta concentratiei de aer-combustibil asupra aprinderii. Metode pentru curatirea ferestrei optice.**

Principalele rezultate obtinute in cadrul acestei etape sunt prezentate in continuare.

1. Fereastra optica

Pentru introducerea radiatiei laser in cilindrul motorului s-a ales solutia utilizarii unei ferestre de safir. Grosimea acesteia a fost determinata, in prima faza, in experimente statice, proiectand un montaj mecanic (Fig. 1) in care prinderea ferestrei s-a facut intr-un mod similar (din punct de evedere mecanic si de fixare prin lipire) cu cel care se intentiona a fi utilizat si la dispozitivul laser de tip bujie.

Testele au aratat ca sistemul respectiv suporta presiuni statice de 200 atm., aceasta fiind presiune maxima care s-a putut aplica pe ferestre. In consecinta, in urma acestor teste a fost stabilit modul de fixare a ferestrei optice si au fost selectate grosimile ferestrelor pentru dispozitivul laser de tip bujie, care sa fie testate si pe un motor real.

[redacted]

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[redacted]

2. Componentele optice (lentile si mediul activ)

Deoarece componentele optice trebuie sa reziste la temperaturi inalte, de pana la 150^{o}C, au fost facute teste de temperatura, in incinta statica. Temperatura in incinta a fost crescuta pana la 200^{o}C, iar pe durata unei zile nu au fost observate deteriorari ale straturilor antireflex depuse pe lentile, sau alte tipuri de modificari. Astfel, au fost selectate componentele optice pentru dispozitivul laser de tip bujie.

3. Dispozitivul laser de tip 'bujie'

A fost realizat un nou prototip de 'bujie' laser, asa cum este prezentat in Fig. 2. [redacted]

Acest dispozitiv emite un puls laser corespunzator unui puls de pompaj [redacted] In plus, prin cresterea duratei pulsului de pompaj la un pompaj constant, sau prin cresterea nivelului de pompaj pentru aceeasi durata a pulsului de pompaj, laserul emite pulsuri multiple (2, 3 sau 4 pulsuri). In acest mod, primele pulsuri pot fi utilizate pentru curatirea ferestrei de safir de eventualele depuneri care se dezvolta in timpul aprinderii combustibilului, in timp ce pulsul/sau pulsurile urmatoare aprind amestecul de combustibil.

Fig. 2 Dispozitivul laser de tip bujie (stanga), cu dimensiuni comparabile cu cele ale unei bujii clasice (dreapta).

In acest dispozitiv laser, modificarea punctului de aprindere in camera de ardere se poate face static, prin schimbarea lentilei de focalizare. Experimentele arata ca [redacted]

4. Testare pe un motor real

<u>Prelucrare chiulasa</u>. A fost necesara prelucrarea unei chiulase pentru a permite montarea inca a unei bujii la cilindrul [redacted]

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<u>Testare pe motor a fereastrei optice.</u> In urma testelor cu rezultate promitatoare facute la presiune statica 200 atm realizate la INFLPR, s-a dorit testarea ferestrei cat si a adezivului folosit in conditiile de solicitari mecanice, termice si de vibratii din cilindrul motorului. Primele teste au fost facute pe un motor cu aprindere prin scanteie care a avut montata chiulasa modificata. S-a dorit doar testarea ferestrei de safir fara ca bujia laser sa fie activa (fara a realiza scanteia). Au fost facute teste cu motorul functionand [redacted]

[redacted]

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Fig. 4 Traductor de presiune (stanga) montat pe motor (dreapta).

Aceste teste au fost facute pe acelasi motor cu aprindere prin scanteie. Pentru masurarea diagramei de presiune in cilindrul 4 in care are loc aprinderea cu bujie laser, a fost montat un traductor de presiune piezoelectric direct in camera de ardere fara a fi nevoie de o teaca de protectie (Fig. 4). Presiunea din cilindrii 1, 2 si 3 au fost realizata si inregistrata cu 3 bujii clasice instrumentate (Fig. 5).

[redacted]

<u>Realizarea controlului electronic intre ECU si bujia laser.</u> Semnalul de tensiune pentru bujia laser a fost luat din ECU. Bujia laser a funcționat in mod similar cu bujia clasica, [redacted]

Inainte de inceperea testelor, a fost realizata o etalonare, [redacted] (Fig. 6).

Fig. 6 Comparatie intre scanteia produsa de laser (prin ’spargerea’ aerului) si ce produsa de o bujie clasica

Vizualizarea procesului de aprindere a amestecului aer-combustibil. Testele au fost facute pe un motor cu aprindere prin scanteie (Fig. 7a), cu admisie normala (atmosferic - nesupraalimentat) avand calibrarile de serie. Aceste teste si-au propus sa evidentieze capacitatea bujiei laser de a aprinde amestecul aer-combustibil la diferite turatii de mers in gol cat si la diferite sarcini. Procesul de ardere din cilindrul motorului a fost evidentiat [redacted]

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Fig. 7 a) Dispozitivul laser de tip bujie montat pe cilindrul unui motor si **b)** imagini ale presiunilor inregistrate in cilindrii motorului, cilindrul nr. 4 fiind aprins cu laser de tip bujie.

5. Laser de tip Nd:YAG pompat lateral printr-o prisma

In etapa anterioara a acestui contract (Etapa I) a fost propus un nou tip de laser, numit 'laser Nd:YAG pompat lateral printr-o prisma', ce se doreste a fi o alternativa la configuratia utilizata in prezent pentru dispozitivul laser de tip bujie. Schema generala a unui astfel de laser este prezentata in Fig. 8, iar caracteristicile principale (proiectare, avantaje etc.) precum si date preliminare au fost publicate in articolul: T. Dascalu, G. Salamu, O. Sandu, F. Voicu, and N. Pavel, "Novel laterally pumped by prism laser configuration for compact solid-state lasers," Laser Physics Letters **10** (5), 055804 (2013).

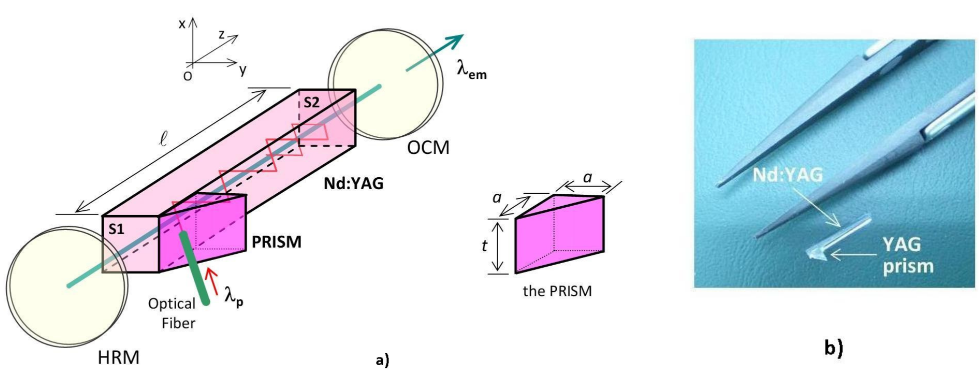

Fig. 8 a) Schema de principiu a unui laser Nd:YAG pompat lateral cu dioda laser printr-o prisma; **b)** O fotografie a laserului Nd:YAG/prisma YAG.

Au fost facute noi experimente, in care performantele unui astfel de laser (Fig. 9a) au fost imbunatatite. Astfel, in regim relaxat laser a emis pulsuri cu energia maxima de 10.3 mJ pentru pompaj cu pulsuri avand energia de 49.5 mJ, panta eficientei find η_s= 0.23 (Fig. 9b). Fasciculul laser a fost caracterizat de factorul M^2~ 4.1. Au fost facute modelari ale eficientei de absorbtie a radiatiei de pompaj si ale castigului laser, prin care au fost stabilite reguli generale de proiectare ale unui astfel de laser. Au fost obtinute noi date cu privire la caracteristicile emisiei laser in regim de operare comutata Nd:YAG/Cr^{4+}:YAG.

In final, au fost propuse cateva noi configuratii pentru un laser Nd:YAG/prisma YAG comutat pasiv cu cristal Cr^{4+}:YAG, care pot sa furnizeze unul (Fig. 10a, b) sau doua fascicule laser (Fig. 10c), cu posibile aplicatii in obtinerea unui dispozitiv laser de tip bujie. Rezultatele au fost trimise spre publicare intr-o revista ISI (T. Dascalu, O. Grigore, G. Salamu, and N. Pavel, "A compact solid-state Nd:YAG laser pumped laterally trough a prism," trimis la Opt. Express, noiembrie 2013), iar noile configuratii constituie subiectul unui brevet depus la OSIM, Romania (T. Dascalu, N. Pavel, G. Salamu, O. Grigore, F. Voicu, M. Dinca, "Sistem laser monolitic, compozit si compact cu livrare simultana a doua fascicule laser," Aplicatie patent OSIM, numar A-100417 / 03.05.2013).

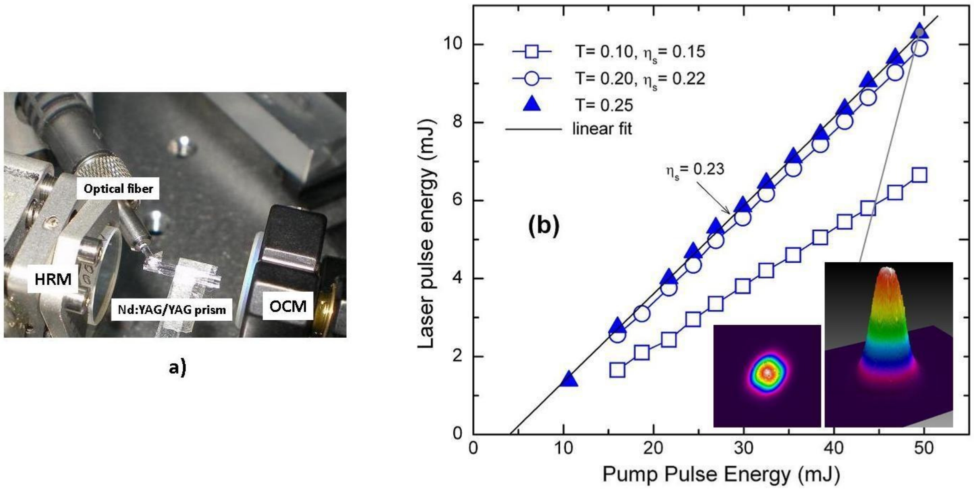

Fig. 9 **a)** Montaj experimental cu laser Nd:YAG/prisma YAG; **b)** Performantele unui astfel de laser in regim de operare libera.

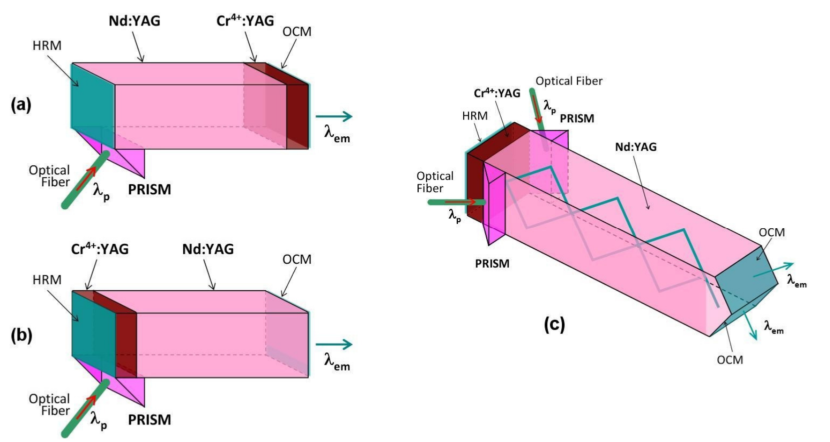

Fig. 10 Configuratii de laser Nd:YAG/prisma YAG/Cr^{4+}:YAG in care cristalul cu absorbtie saturabila este plasat **a)** dupa mediul activ sau **b)** inainte de mediul activ. **c)** Laser compact cu livrare simultana a doua fascicule laser.

In **concluzie**, in cadrul acestei etape:

- A fost realizata fereastra din safir si au fost facute teste de rezistenta la presiune statica. Configuratia mecanica de prindere si modul de lipire au permis rezistenta ferestrelor la presiuni statice de 200 atm. (aceasta fiind presiunea maxima disponibila);
- A fost realizat un nou model de dispozitiv laser de tip bujie, acesta putand emite pulsuri laser simple, sau multiple (3 la 4 pulsuri), scopul primelor pulsuri fiind de a curata fereastra optica, in timp ce ultimele pulsuri aprind combustibilul din cilindrul motorului;
- In acest moment, pozitia de focalizare a fasciculului laser in camera de ardere se poate modifica prin utilizarea de lentile de focalizare cu diferite distante focale;
- Lungimea de unda a diodelor laser este stabilizata prin controlul activ al temperaturii diodelor;
- A fost modificat un motor de automobil, prin constructia unui orificiu suplimentar intr-un cilindru. In acest orificiu a fost introdus dispozitivul laser, testele urmarind rezistenta ferestrei de safir la conditii dinamice de presiune;
- A fost montat dispozitivul laser pe cilindrul unui motor si au fost facut teste de operare. Motorul a fost operat cu succes la diferite turatii (ralanti, 1500 si 2500 rpm), in regim fara sarcina. A fost monitorizata presiunea din cilindru, testele confirmand faptul ca motorul a functionat cu un cilindru aprins cu dispozitivul laser. aceste teste au fost considerate un succes. Testele viitoare (Etapa III, anul 2014) vor considera operarea motorului aprins cu laser (un cilindru) in diferite regimuri de turatii si sarcina;
- Rezultatele au fost diseminate prin prezentari orale la 4 conferinte internationale, o cerere de brevet depusa la OSIM si un manuscris trimis la o revista ISI. In acest an a fost publicat un articol intr-o revista ISI cu factor de impact de 7.714. Aceste rezultate sunt mentionate in continuarea acestui raport.

Indicatori de proces si de rezultat

Indicatori de proces	Numarul de proiecte realizate în parteneriat international	-
	Mobilitati interne (luna $\times$ om)	0.0065
	Mobilitati internationale (luna $\times$ om)	0.0109
	Valoarea investitiilor în echipamente pentru proiecte	261.62 Mii lei
	Numarul de întreprinderi participante	1
	Numarul de IMM participante	-
Indicatori de rezultat	Numarul de articole publicate sau acceptate spre publicare în fluxul stiintific principal international	1 articol publicat, 1 articol trimis spre publicare; 1 articol in proceeding SPIE; 4 prezentari orale la conferinte internationale
	Number of articles published in journals indexed AHCI or ERIH Category A or B (applies to the Humanities only)	-
	Number of chapters published in collective editions, in major foreign languages, at prestigious foreign publishing houses (applies only to Social Sciences and Humanities)	-
	Number of books authored in major foreign languages at prestigious foreign publishing houses (applies only to Social Sciences and Humanities)	-
	Number of books edited in major foreign languages at prestigious foreign publishing houses (applies only to Social Sciences and Humanities)	-
	Factorul de impact relativ cumulat al publicatiilor publicate sau acceptate spre publicare	4.564
	Numarul de citari normalizat la domeniul publicatiilor	-
	Numarul de cereri de brevete de invenție inregistrate (registered patent application), în urma proiectelor, din care: - naționale (în România sau în altă țară); - la nivelul unei organizații internaționale (EPO/ PCT/ EAPO/ ARIPO etc.)*	- 1 -
	Numarul de brevete de invenție acordate (granted patent), în urma proiectelor, din care: - naționale (în România sau în altă țară); - la nivelul unei organizații internaționale (EPO/ PCT/ EAPO/ ARIPO etc.)*	- - -
	Veniturile rezultate din exploatarea brevetelor si a altor titluri de proprietate intelectuala	-
	Veniturile rezultate în urma exploatarii produselor, serviciilor si tehnologiilor dezvoltate	-
	Ponderea contributiei financiare private la proiecte	20% - Etapa II 15%- Proiect
	Valoarea contributiei financiare private la proiecte	178.000 - Etapa II 530.000 - Proiect

DISEMINARE REZULTATE

ARTICOLE ISI

- T. Dascalu, O. Grigore, G. Salamu, and N. Pavel, “A compact solid-state Nd:YAG laser pumped laterally trough a prism,” trimis la Opt. Express (November 2013). (paginile 12-18)

1. T. Dascalu, G. Salamu, O. Sandu, F. Voicu, and N. Pavel, “Novel laterally pumped by prism laser configuration for compact solid-state lasers,” Laser Physics Letters 10 (5), 055804 (2013); [2012 Impact Factor: 7.71] Pagina web a articolului: http://iopscience.iop.org/1612-202X/10/5/055804. (pagina 8)

PROCEEDINGS

1. G. Salamu, A. Ionescu, C. Brandus, O. Grigore, N. Pavel and T. Dascalu, "Generation of high-peak power 532-nm green pulses from composite, all-ceramics, passively Q-switched Nd:YAG/Cr^{4+}:YAG laser," Proc. SPIE **8882**, ROMOPTO 2012: Tenth Conference on Optics: Micro- to Nanophotonics III, 888206 (June 10, 2013); doi:10.1117/12.2032267; http://dx.doi.org/10.1117/12.2032267. (pagina 9)

   NOTA: Lucrarea este publicata in Proc. SPIE **8882**, ROMOPTO 2012: Tenth Conference on Optics: Micro- to Nanophotonics III, 888206 (June 10, 2013), cu mentiunea ”**Best Poster SPIE Award**”. Prezentarea poster a primit diploma ”**Certificate of Excellence for First Place Student Presentation**”.


SPIE Student Services hereby awards this

Certificate of Excellence

to

Gabriela Salamu

For First Place Student Presentation

Generation of high-peak power 532-nm green pulses from passively Q-switched, all-poly-crystalline Nd:YAG/Cr4+:YAG ceramics laser

Intl. Conference "Micro- to Nano-Photonics III- ROMOPTO 2012"

Bucharest, Romania

September 6, 2012

SPIE

Eustace L. Dereniak

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2012 SPIE President

PATENTE

- T. Dascalu, N. Pavel, G. Salamu, O. Grigore, F. Voicu, M. Dinca, "Sistem laser monolitic, compozit si compact cu livrare simultana a doua fascicule laser," Aplicatie patent OSIM, nr. A-100417 / 03.05.2013.

CONFERINTE

1. N. Pavel, T. Dascalu, G. Salamu, and O. Grigore, “Novel geometry for compact, diode-pumped solid-state lasers,” The 1st Laser Ignition Conference ’13, 23-25 April 2013, Yokohama, Japan; oral presentation LIC4-2. (pagina 10)
2. T. Dascalu, G. Salamu, N. Pavel, O. Grigore, and F. Voicu, “Compact ‘prism-by side-pumped’ solid-state laser,” CLEO Europe - EQEC 2013 Conference, 12-16 May 2013, Münich, Germany, oral presentation CA-9.5. (pagina 11)
3. N. Pavel, G. Salamu, and T. Dascalu, “Passively Q-switched Nd:YAG/Cr^{4+}:YAG lasers for ignition of an automobile engine,” The 13th International Balkan Workshop on Applied Physics, 4-6 July 2013, Constanta, Romania, presentation S5-L01, Book of Abstracts p. 116 (invited presentation).
4. N. Pavel, G. Salamu, and O. Grigore, “Passively Q-switched Nd:YAG/Cr^{4+}:YAG lasers with high peak power,” LPHYS’13: 22nd International Laser Physics Workshop, Prague, 15-19 July, 2013, presentation 4.1.2 (oral presentation).

IOP PUBLISHING LASER PHYSICS LETTERS
Laser Phys. Lett. 10 (2013) 055804 (5pp) doi:10.1088/1612-2011/10/5/055804

LETTER

Novel laterally pumped by prism laser configuration for compact solid-state lasers

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Received 13 August 2012, in final form 28 December 2012
Accepted for publication 19 December 2012
Published 7 March 2013
Online at stacks.iop.org/LPL/10/055804

Abstract

We propose a new laser configuration in which the pump radiation is coupled into the laser crystal through a prism. The laser medium is square shaped and the prism is attached on one of its lateral sides, near one of the crystal extremities. The diode-laser fiber end is placed close to the prism hypotenuse, the pump radiation is coupled into the laser crystal through the opposite surface of the prism and propagates into the crystal through total internal reflections. This laser geometry is simple to align and permits the realization of compact diode-pumped laser systems, as well as power scaling. A diode-pumped Nd:YAG laser yielding pulses of 2.1 mJ energy under a pump with pulses of 9.9 mJ is demonstrated. The laser slope efficiency is 0.22. Furthermore, this geometry enables one to obtain passively *Q*-switched lasers with the saturable absorber crystal placed between the resonator high-reflectivity mirror and the laser crystal. A Nd:YAG laser, passively *Q*-switched by a Cr^{4+}:YAG crystal with initial transmission $T_0 = 0.90$, delivering laser output with a pulsed energy of 93 μJ, a duration of 26 ns and a pump threshold of 1.9 mJ, is realized in order to prove the concept.

(Some figures may appear in colour only in the online journal)

1. Introduction

Diode-pumped solid-state lasers are nowadays used widely in various industrial and medical applications such as

in a small volume and short length parts, which yields a very good overlap of the laser beam with the pumped volume of the crystal. However, the pump beam can be coupled into the laser crystal from at most two directions (i.e. the end faces

prism) is necessary. Furthermore, the Cr^{4+}:YAG SA crystal can be placed between the HRM of the resonator and Nd:YAG, where the laser beam is more intense. This kind of laser can also be a solution for a spark plug with applications in the automotive industry [27].

We perform preliminary experiments in order to prove the functionality of this new design. Thus, when a Cr^{4+}:YAG SA with initial transmission $T_0 = 0.90$ was placed as in figure 1(b), between uncoated Nd:YAG-1 and an OCM with transmission $T = 0.25$, the laser emitted pulses with energy of 109 μJ and 32 ns duration. The pump pulse energy was 3.9 mJ. On the other hand, when the Cr^{4+}:YAG crystal was moved between HRM and Nd:YAG-1 (the dashed position of figure 1(b)) the characteristics of the *Q*-switch laser pulse were the same, but the energy of the pump pulse decreased at 3.0 mJ. Similar behavior was observed for the coated Nd:YAG-1 laser crystal and an OCM with $T = 0.20$: the laser pulse energy and duration was 93 μJ and 26 ns, respectively; the pump pulse energy decreased from 4.1 mJ when Cr^{4+}:YAG was near to OCM to only 1.9 mJ when Cr^{4+}:YAG was between HRM and the laser

and the output mirror to a position between the resonator high-reflectivity mirror and the laser crystal. We believe that such a laser could find applications in the automotive industry.

Acknowledgments

This work was financed by the Romanian National Authority for Scientific Research, CNDI-UEFISCDI, project number 58/2012 (PN-II-PT-PCCA-2011-3.2-1040) and partially supported by projects IDEI 36/2011 (PN-II-ID-PCE-2011-3-0363) and IDEI 37/2011 (PN-II-ID-PCE-2011-3-0801).

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Best Poster SPIE Award

Generation of High-Peak Power 532-nm Green Pulses from Composite, All-Ceramics, Passively Q-switched Nd:YAG/Cr^{4+}:YAG Laser

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ABSTRACT

Laser pulses at 1.06 μm with 2.5-mJ energy and 3.1-MW peak power have been obtained from a composite, all-poly-crystalline ceramics, passively Q-switched 1.1-at.% Nd:YAG/Cr^{4+}:YAG laser that was quasi-continuous-wave pumped with diode lasers. Single-pass frequency doubling with LiB_3O_5 nonlinear crystal at room temperature yielded green laser pulses at 532 nm with energy of 0.36-mJ and 0.45-MW peak power; the infrared-to-green conversion efficiency was 0.27.

Keywords: Lasers, neodymium; Diode-pumped lasers; Q-switching; Harmonic generation.

1. INTRODUCTION

The passive Q-switching technique yields lower output performances compared to electro-optic or acousto-optic Q-switched lasers, but presents various others advantages, such as simple design, good efficiency and reliability, compactness, or low cost. This method yields laser pulses that are of interest for scientific, medical and industrial applications that do not require very high (better than microseconds range) temporal accuracy. The first continuous-wave (cw) diode end-pumped Nd:YAG laser, passively Q-switched by Cr^{4+}:YAG saturable absorber (SA) crystal, was made of a short piece of Nd:YAG crystal bonded to a thin Cr^{4+}:YAG SA crystal, and delivered laser pulses with 11-μJ energy (E_p) and 337-ps duration (t_p), at 6-kHz repetition rate [1]. A passively Q-switched Nd:YAG-Cr^{4+}:YAG laser that was

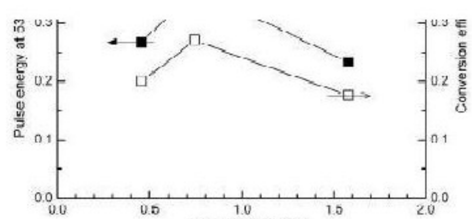

Fig. 4 Energy of the green laser pulse and conversion efficiency versus radius of the 1.06-μm laser beam.

4. CONCLUSIONS

In conclusion, laser pulses at 1.06 μm with 2.5-mJ energy and 3.1-MW peak power were obtained from a composite, all-ceramics 1.1-at.% Nd:YAG/Cr^{4+}:YAG medium. Green laser pulses at 532 nm with 0.36-mJ energy and 0.45-MW peak power were achieved by single-pass frequency doubling of the fundamental wavelength with an LBO nonlinear crystal at room temperature. This is believed to be the first demonstration of such a compact laser system and offers a solution for realizing high-peak power laser pulses into visible and ultraviolet regions by single-pass nonlinear conversion.

ACKNOWLEDGEMENTS

This work was supported by the Romanian National Authority for Scientific Research, CNDI-UEFISCDI, project number 58/2012 (PN-II-PT-PCCA-2011-3.2-1040) and project IDEI 36/2011 (PN-II-ID-PCE-2011-3-0363).

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ROMOPTO 2012: Tenth Conference on Optics: Micro- to Nanophotonics III,
edited by Valentin I. Vlad, Proc. of SPIE Vol. 8882, 888206 · © 2013 SPIE
CCC code: 0277-786X/13/$18 · doi: 10.1117/12.2032267

Novel geometry for compact, diode-pumped solid-state lasers

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Abstract: We propose a new geometry for diode-pumped solid-state lasers in which a prism is used to couple the pump beam into the active crystal. A Nd:YAG laser that in free-generation regime yields pulses with 1.8-mJ energy at optical efficiency of 18% and that generates pulses with 109-μJ energy and duration of 32 ns when is passively Q-switched by Cr^{4+}:YAG crystal is realized. Such configuration could allow building of compact devices useful for automotive industry.

Diode-pumped solid-state lasers are employed in various industrial and medical applications, like materials processing, generation of visible light, ultra-violet or mid-infrared radiation and surgery, or in communications. Among the geometries used for realizing the laser, commonly used is end-pumping scheme [1], side pumping [2], thin-disc active medium pumped with parabolic mirror [3], or edge-pumping technique [4]. The choice of the laser configuration for a specific application depends on different requirements, like the output power level, the beam quality or temporal characteristics of the laser pulse. For laser-induced spark ignition in internal combustion engines the best scheme was proved to be the end pumping [5-7], although side pumping was also considered [8].

In this work we introduce a new pumping technique for diode-pumped solid-state lasers, called 'prism-by side-pumped' geometry. The laser medium is rectangular and the pump beam is coupled directly from the fiber into the

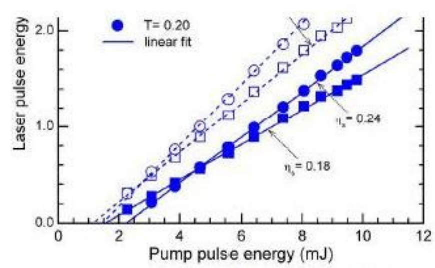

Fig. 2. Laser pulse energy versus pump pulse energy for the Nd:YAG medium that was pumped using the two schemes.

The laser pulse energy obtained in free-operation regime from the laser is shown in Fig. 2. The best results were obtained with OCM of transmission T= 0.20. The end-pumped Nd:YAG laser delivers pulses with energy E_p= 2.7 mJ for the pump with pulses of energy E_{pump}= 9.8 mJ, which corresponds to an overall optical-to-optical efficiency, η_o of ~0.28. The slope efficiency was η_s= 0.32. The pump beam absorption efficiency was measured as η_a= 0.85.

The 'prism-by side-pumped' Nd:YAG laser outputted pulses with energy E_p= 1.8 mJ (E_{pump}= 9.8 mJ; η_o~ 0.18) for the OCM with T= 0.20. The slope efficiency was η_s= 0.24. Ray-tracing concluded that ~0.91 of the pump beam was absorbed in Nd:YAG. The decrease of η_s for the new laser configuration in comparison with the end-pumped scheme was explained by lower overlap efficiency between the laser beam and the pump beam, η_m that was evaluated to be in the range of 0.65 to 0.70. Parameter η_m can be improved by a new design of the laser crystal or by using a different laser resonator. However the advantage of power scaling for this laser configuration can compensate its lower overall efficiency in comparison with that of an end-pumped laser.

The 'prism-by lateral-pumped' geometry allows positioning of the Cr^{4+}:YAG SA crystal between the resonator HRM and the Nd:YAG crystal, where the laser beam is more intense. Preliminary experiments were made in order to prove functionality of this design. Thus, when a Cr^{4+}:YAG SA with initial transmission T_0= 0.90 was placed between Nd:YAG and the OCM (transmission T= 0.25), the laser emitted pulses with energy of 109 μJ and 32-ns duration. The pump pulse energy at threshold of emission was 3.9 mJ. On the other hand, when the Cr^{4+}:YAG crystal was moved between HRM and Nd:YAG (dashed position of Fig. 1b) the characteristics of the Q-switch laser pulse were the same, but the required energy of the pump pulse decreased at 3.0 mJ. These first experiments indicate that the 'prism-by lateral-pumped' laser can improve the efficiency of a passively Q-switched laser by positioning the SA crystal between the HRM of the resonator and the laser crystal. We think that such laser geometry can provide high-peak power pulses in a compact and reliable device useful for automotive industry.

This work was financed by project 58/2012 (PN-II-PT-PCCA-2011-3.2-1040) of UEFISCDI, Bucharest, Romania.

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Compact 'prism-by side-pumped' solid-state laser

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Diode-pumped solid-state laser application in automotive industry requires high peak power, compact and reliable lasers. To date such devices were demonstrated using end pumping [1-3] and side-pumping scheme [4]. In this work we introduce a new pumping technique for diode-pumped solid-state lasers, named 'prism-by side-pumped' laser. The laser medium is rectangular and a prism is used to couple the pump beam directly from the fiber into the crystal. This geometry is simply to align and presents more compactness in comparison with an end-pumped laser, while power scaling can be realized easily. The design is interesting for passively Q-switched lasers because it allows positioning of the saturable absorber (SA) crystal between the resonator high-reflectivity mirror (HRM) and the laser medium.

Figure 1a shows the 'prism-by side-pumped' laser. The key optical element is a prism whose section is a 90°, isosceles triangle. The Nd:YAG crystal has square transversal section and the prism is positioned near one of the laser crystal extremity. The fiber end is placed close of the prism hypotenuses and the prism is in contact with the Nd:YAG crystal through the opposite surface. In order to couple without losses the pump radiation into the laser crystal, the prism is attached to Nd:YAG with a glue of suitable index of refraction. The pump beam propagates in Nd:YAG by total internal reflections In comparison with an end-pumped laser this geometry is simpler; it contains less optical elements and therefore is easier to align, while the laser device is even more compact. Figure 1b presents a Nd:YAG laser crystal and the prism before gluing it to Nd:YAG.

In order to prove the functionality of the new geometry we performed experiments using Nd:YAG crystal. The optical pumping was made at 807 nm (λ_p) with a pulsed diode laser (JOLD 540 QAFN-6A, JENOPTIK, Germany) having optical fiber with 600-μm diameter and numerical aperture NA= 0.22. The repetition rate and the pump pulse duration were 5 Hz and 250 μs, respectively. The 1.0-at.% Nd:YAG crystal has length of 10 mm, section of 1.0×1.0 mm^2 and uncoated end faces. The 90° prism was made of undoped Nd:YAG and only the larger surface of the prism was coated for high transmission at λ_p.

Comparison with performances of an end-pumped scheme of the same Nd:YAG medium is made.

This new geometry is interesting for Q-switching because it allows positioning of a Cr^{4+}:YAG SA crystal between mirror HRM and Nd:YAG (as in Fig. 1a). Preliminary experiments performed with a Cr^{4+}:YAG SA of initial transmission T_i= 0.90 shows no changes of the laser pulse energy (90 μJ), but a decrease of the pump pulse energy at threshold of emission from 4.1 mJ to 1.9 mJ when Cr^{4+}:YAG was moved from OCM near HRM of the resonator was mesured. We believe that such a laser can provide high-peak power pulses in a compact and reliable device useful for automotive industry.

This work was financed by project 58/2012 (PN-II-PT-PCCA-2011-3.2-1040) of UEFISCDI, Bucharest, Romania.

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978-1-4799-0594-2/13/$31.00 ©2013 IEEE