43. JUPITER KONFERENCIJA
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43rd JUPITER CONFERENCE
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ZBORNIK RADOVA
PROCEEDINGS

UNIVERZITET U BEOGRADU - MAŠINSKI FAKULTET

UNIVERSITY OF BELGRADE
FACULTY OF MECHANICAL ENGINEERING

Beograd, oktobar 2022.

43. JUPITER KONFERENCIJA

ZBORNIK RADOVA

PROCEEDINGS

36. simpozijum
CIM U STRATEGIJI TEHNOLOŠKOG RAZVOJA INDUSTRIJE PRERADE METALA

30. simpozijum
CAD/CAM

39. simpozijum
NU – ROBOTI –FTS

45. simpozijum
UPRAVLJANJE PROIZVODNJOM U INDUSTRIJI PRERADE METALA

23. simpozijum
MENADŽMENT KVALITETOM

Organizator:

UNIVERZITET U BEOGRADU - MAŠINSKI FAKULTET

Beograd, oktobar 2022. godine

43. JUPITER KONFERENCIJA

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Štampanje odobrila:
Komisija za izdavačku delatnost Mašinskog fakulteta i Dekan Mašinskog fakulteta

Odlukom br. 27/2022 od 19.09.2022.

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Beograd, oktobar 2022.

Tiraž: 100 primeraka
Štampa: **Planeta print**,
11000 Beograd, Igora Vasiljeva 33r, tel.: 011 650 6564

ISBN 978-86-6060-137-9

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JUPITER Konferencija prikazuje značajne rezultate istraživanja ostvarene u prethodne dve godine. Ovogodišnja XLIII JUPITER Konferencija je prilika da se sagledaju trendovi u domenu nauke, obrazovanja i industrije u Republici Srbiji u kontekstu koncepta Industrija 4.0. Industrija 4.0 označava promenu paradigme u proizvodnim kompanijama i njihovim lancima snabdevanja. Dok su procesi proizvodnje i logistike, koji su centralno upravljani sada već deo prošlosti, procesi budućnosti više su poput organizma koji se samostalno organizuje kroz umrežavanje svih uključenih strana.

Ubrzani tehnološki razvoj i digitalna transformacija industrije dovode do značajnih promena na tržištu rada. Industrija 4.0, u kojoj autonomni kibernetsko-fizički sistemi nadgledaju fizičke procese i donose odluke, nije potrebna radna, nego stručna snaga. To traži i potpuno nov pristup obrazovanju – posebno u oblasti inženjerskih nauka.

Ove godine obeležavamo i 50 godina od formiranja Katedre za proizvodno mašinstvo. Visokoškolska nastava iz oblasti proizvodnog mašinstva u Srbiji započela je na Tehničkom fakultetu Velike škole pre 128 godina. Velika škola je prerasla u Univerzitet u Beogradu u okviru kojeg je kasnije osnovan Mašinski fakultet. Katedre na Mašinskom fakultetu su formirane 1948. godine. Tada se nastava iz proizvodnog mašinstva odvijala pod okriljem Katedre za osnove mašinstva. 1956. godine osnovana je Katedra za industrijsku proizvodnju, a šef Katedre je bio prof. Pavle Stanković, jedan od utemeljivača proizvodnog mašinstva. Tokom sledeće reorganizacije na Mašinskom fakultetu 1960. godine formirana je Katedra za tehnologiju, a opet je kao šef Katedre imenovan prof. Pavle Stanković. Nakon donošenja određenih zakona 1972. godine i uspostavljanja nove organizacije Fakulteta osnovana je Katedra za proizvodno mašinstvo, a prvi šef Katedre bio je prof. Vladimir Šolaja.

Ministarstvo prosvete nauke i tehnološkog razvoja Republike Srbije, FMP Konzorcijum, Lola institut i Inmold Plast su pomogli organizovanje ove konferencije kao podršku naporima za unapređenje obrazovanja i nauke u oblasti proizvodnog mašinstva.

U ime organizacionog odbora posebno se zahvaljujem svim domaćim i stranim autorima, kao i članovima recenzentskog tima na izvršenim recenzijama.

Dobro došli na XLIII JUPITER Konferenciju.

U Beogradu, 4. oktobar 2022.

Prof. dr Bojan Babić

Izaberite simpozijum JUPITER Konferencije

UVODNI RADOVI

CIM U STRATEGIJI TEHNOLOŠKOG RAZVOJA INDUSTRIJE PRERADE METALA
CIM IN THE STRATEGY OF TEHNOLOGICAL DEVELOPMENT OF METALWORKING INDUSTRY

CAD/CAM

NU – ROBOTI –FTS
NC - ROBOTS – FMS

UPRAVLJANJE PROIZVODNJOM U INDUSTRIJI PRERADE METALA
PRODUCTION CONTROL IN METALWORKING INDUSTRY

MENADŽMENT KVALITETOM
QUALITY

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43. JUPITER konferencija
Beograd 2022

45. simpozijum

UPRAVLJANJE PROIZVODNJOM U INDUSTRIJI PRERADE METALA

Srećković, M., Janićijević, M., Jevtić, S., Ratković Kovačević, N., Malović, M. [1]

QUANTUM GENERATORS IN THEORY AND PRACTICE 2022

Abstract

The application of lasers/quantum generators for various purposes (toys/pacifiers, heavy/rocket industry/Space) has changed the millennium, and the trend is growing.In terms of education, doctorates (laser stations/design (SFRJ, Serbia)) have been arriving since the first days. Today there is no precision in the definition: new, started a long time ago; it is stated that lasers are in all areas of life (medicine, defense, mass media). It is basically the interaction of materials and lasing or facts/circumstancesthat lead/or don't to laser damage.Applications have gone far: theoretical, experimental; commercial "leads" no longer state that the process is based on a laser. The work will be limited to several areas (more exotic/potentially newer types of pumping, description of parameters). The interaction is looked at: through experiment, simulation through the case of scattering and temperature distribution and by choosing an area, where a deeper understanding is needed in this broad issue.

Key words: lasers, *characterization of materials, quantum generators, pumping, laser material*

1. MODELING OF INTERACTION AND DEPENDENCIES OF PROCESSING QUALITY

There are several types of laser-material interaction models. In the broadest sense of the topics, the processes of scattering, absorption and reflection are also considered, but most often it is about: thermal model, similarity model, models that take into account the recoil processes (which are important for aviation, but also corrosion). Regardless of these application directions, there are cases in which the material constants do not change much (such as thermodynamic, optical, but also mechanical and other important properties). Some models start from macroscopic approaches and some go to microstructural approaches, with atomic and molecular sizes appearing in the models [1] – [13].

The second group of approaches was based on the following equation type

$$A(selected\ \text{int}eraction\ output\ size) = B_1^{n_1}\ B_2^{n_2} \ldots B_m^{n_m} \tag{1}$$

where A is the final state of the material that has been processed, or some working pa rameter, and B_i^k are the selected key parameters related to the selected mode of operation of the quantum generator, i.e.: power, pulsed or CW operations, processing time, etc. Such approaches are related to the equation array with several terms of the productucts B_i with exponential dependencies and their support based on experimental data from certain processing: cutting, drilling, welding, soldering, glazing, surface structuring, lattice. One of the modern laser applications is related to Carbon Nanotubes - CNTs preparation and deposition, as well as nano materials and ablation processes, Fig. 1. One example of those equations is:

$$P = k\ \delta^x\ s^y\ V^z \tag{2}$$

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where: k - constant depending on the material (Table 1.), P – power, δ - thickness, V – cutting speed, and s – cut width.

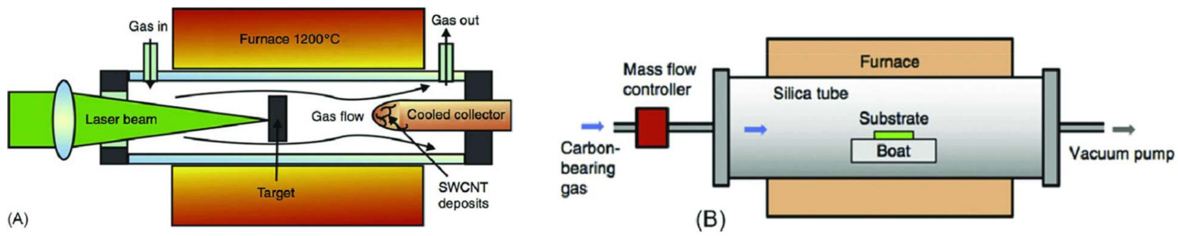

Figure 1. *(A) Laser ablation method of CNT perpetration. (B) Chemical vapor deposition technique for CNT preparation;* From: [12] https://www.researchgate.net/profile/Sayan-Dutta-5/publication/340273384/figure/fig2/AS:874732543041543@1585563898995/A-Laser-ablation-method-of-CNT-perpetration-B-Chemical-vapor-deposition-technique_W640.jpg

Table 1. The values of coefficient of processing-*k* for selected materials [2]

Materials	*Coefficient of processing - k*
Glass	442
Iron, mild and stainless steel	390
Rubber	340
Plastic (various kinds)	307
Wood	300
Plexiglas	297
PVC	294

Searching for relations with other properties, which are not in the foreground in case of destructive mechanisms, separation and joining of materials, various approaches that started with selected processing parameters: drilling depth and diameter, have been reduced to relatively simple dependencies, for practical applications that are related to approximations of different models. Formulas for diameter and depth of holes are related to the laser parameters and thermodynamic parameters of the material.

$$d(\tau) = 2\left[\frac{3P_S \cdot \tau \cdot tg\varphi}{\pi(L_b + 2L_m)}\right]^{\frac{1}{3}}, \qquad h(\tau) = \left[\frac{3P_S \cdot \tau}{\pi(L_b + 2L_m) \cdot tg^2\varphi}\right]^{\frac{1}{3}} \tag{3}$$

for $h(\tau) >> r_f$, where: L_b – specific volumetric heat of vaporization, as $L_b = c_b\rho$, L_m – specific volumetric heat of melting, as $L_m = c_m\rho$. Also, specific volumetric heat of disintegration, as:

$$L_d \approx \frac{(L_b + 2L_m)}{3} \tag{4}$$

Practical formulas are also related to the material parameters of destruction, which are related to the data from formulas and dependencies for Rayleigh scattering and anisotropy. Some models for biotissue are similar to thermal equation but with new terms and under the biothermal title. If treating induced optical breakdown in the tissue occures, some new modulations of theory should be included. The laser technique in various manner have significant biomedical applications and precise surgical procedures modelling include different/ or only modulation terms. Equations include aqua performances and in eyes plasma phenomena. When taste is related to transparent biological cells, nonlinear absorption occurs, as well as LIBS, changes in concentration of electrons. Rate equations describe the growth of concentration in biological tissue exposed to fs pulses. Accurate models before Keldysh and ADK theory existed. After the spark, the material becomes electrically conductive. The plasma in the eye cuts the intraocular tissue [6]. As a measure of destruction, there is the expression obtained from Rayleigh scattering and depolarisations monitoring, and description of scattering as a part of density, concentration and anisotropic material fluctuations, i.e. the term proportional to R_{an} defines destructuve processes [3].

For the purposes of analysis of possible processes through interactions in Table 2 will be presented some processes and corresponding time intervals.

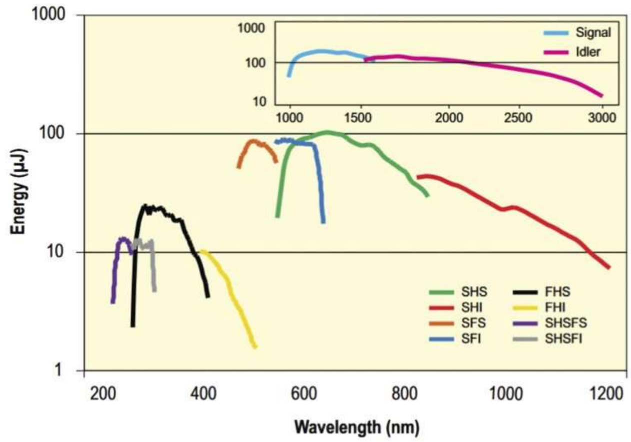

Figure 2. *Wavelength tuning afforded by nonlinear frequency conversion. A single pump λ = 800 nm is from an amplified fs laser. SHS, SHI – second harmonic signal and second harmonic idler, SFS, SFI – sums frequency signal and idler; FHS, FHI – fourth harmonic signal and idler, SHSFS, SHSFI – second harmonic of sum frequency signal and idler; From:* https://www.newport.com/n/laser-wavelength-tuning

Table 2. Phenomena and time in interaction laser material

Phenomena in interaction	Time
Photoionisation in laser-material int.	After 1 fs
Photoionisation (tunneling/ multiphot.)	After 50 fs
Quascade ionisation	After 100 fs
Electron thermalisation	After 1 ps
Termal difusion	After 1 ns
Photochemical processes (Chem. react., phase transitions)	After 1 ns

2. CRITICAL PHENOMENA AND PREDICTION OF MATERIAL BEHAVIOR

For the determination of critical parameters, there are various criteria with different degree of reliability, (with adopted theoretical definitions of critical phenomena in the narrow sense) such as: critical temperature, pressure, volume, etc. The problems are reaching experimental conditions for materials in which these parameters are very difficult to achieve (low or high temperatures and pressures). In this regard, the role of laser is to accept established connections from the theory of critical phenomena, where liquids are measured, and conclusions analog to the ones used for solid bodies and for magnetic materials as well [5]. In a broader sense, we strive for other extended approaches, where the application of lasers in measurement transfers many mechanical measurements into the optical world. The other side of these approaches includes the connection between acoustic phenomena and lasers as: generation of acoustic processes and applications, determination with the dispersion of materials through the possibility of measurement. Classic speed of sound is related to the limit values of mechanical measurements (low frequencies). High frequency measurements of acoustical values (covered by the theory) i.e. hypersound are messured by Brillouin (Mandelstamm Brillouin scattering methods).

2.1 Determination of stresses / residual stresses

Fracture theory has been greatly developed for years and many pages of literature have been devoted to it, not counting the introduction, catastrophes and theories related to large catastrophic fractures. Part of experimental science was taken over by holographic and tomographic techniques, in addition to basic approaches related to photoelasticity, interference and diffraction processes in general. It is also present in medical applications, for implant modeling and organization of test chambers with clamps or other, to achieve appropriate situations in real processes, in cases of human and veterinary medicines. A special task is laser beam produced stresses in material. For certain positions of implants in organism in vivo (or solid tissue - teeth), it is relatively easy, but for tomography and access to the oral cavity, "acrobatics" are often needed for both the patient and the doctor. Another large area has entered into constructions (Vukotić), transmission lines, tunnels and many others. In particular, the field of seismology had and still has significant successes from soil testing and monitoring earthquakes with classical methods as well as their interpretation by transferring them to holographic data, calculations and theory. Here too, the use of CW lasers differs from the use of ultrashort pulses, such as occurred after the first Q switch pulses.

More recent applications are related to Raman scattering and laser linewidth comparisons under various loads; thus the case of semiconductors with carbon and other materials already have solid experimental confirmation. Attempts to tie ourselves to the Mendeleev system and give formulas for depth or diameter and the protruding place in the periodic system of elements failed partially because in each of the 7 elements there was some that *jumped* out of the established quasi regularity. Connections with parameters of viscosity, moduls of elasticity, etc., exist including surface tension phenomena.

The inclusion of non-linear behavior of materials with high intensities is particularly important, so with that in mind, the initial database of materials was used, and their inclusion in models of the selected type is forthcoming. In all of this, the question polarization remains unanswered and it requires special analyses with different models. In the area of high beam intensity, the specific material will not be recognized. Models that seek to state that the semiconductor will behave as metallic or dielectric, depending on the parameters of the stimulated system (action time, associated electric field and its relationship with internal fields in the solid material) are also of interest. There would be a separate discussion and analysis about the materials in the fiber state, but the experiments and development of final models (or ones built into the part of construction), already were based long time ago on the optical fibers. Fiber optical sensors provide data ranging from the state of tension in the material, to counting the daily difference in the number of vehicles that pass on the defined road section etc. In the second part of the paper, some of the cases of interaction with the selected type, the cases of scattering as well as some of the cases will be shown.

2.2 Some chosen unconventional laser types or other uncommon types

We do not answer the question which laser *today* has the highest power, because answers on the Internet will always be inconclusive, and even if we select one, it will be only the one most powerful in a particular category. The issue of the possibility of tuned wavelengths has long been resolved for many types, Tab. 3. The issue of basic beam and harmonics means of transformations from IR to visible and UV ranges, have long been developed. It has a wide area of applications, starting from cultural heritage, to medical and other metrological needs, i.e. obtaining frequency chains in metrological comparisons.

Some of the rare types of lasers are: quantum well, spin flip, fiber laser, polymer laser, white laser, hollow cathode laser, lasers with solar pump, lasers with exotic particle pump, as well as nuclear radiation pump. Fiber lasers are compared with CO_2 lasers and vanadate laser, etc. New kind of laser uses tiny particle clumps to generate light. [15]

3. SOME SIMULATIONS AND RESULTS OF LASER-MATERIAL INTERACTION

In Figs 3. some damages are presented. In Figs. 4. some predictions of laser damage, in general, in various materials as in [4] are considered: damage probability vs. energy density, provoked real damages. Figs. 5. have shown some simulation of the time and temperature distribution for various materials and operating conditions [9] – [11].

4. CONCLUSION

In recalling today's possibilities of lasers, we wanted to present the complexity, or great simplification, of methods used in laser technology, in the multitude of developed, everyday or rare laser applications.

Approaches change over time and when we talk about the advantage of one or another method from energy, metrological, philosophical or mass media application changes, but in all areas, laser technology has its place. Whether in a given case, after an evaluation, the type which will be chosen the first or not at all depends on many real situations (price, speed, reaction speed, robustness), but in a large swarm of laser types and over the years of work and new proposals, one can always find something that can certainly play a positive role in everyday life, in exploring the depth of the Earth, for going to the Cosmos, and looking for a way out for the Earth if (we will not mention it now) one thinks how far in advance one should think only about the Earth (willingly or not).

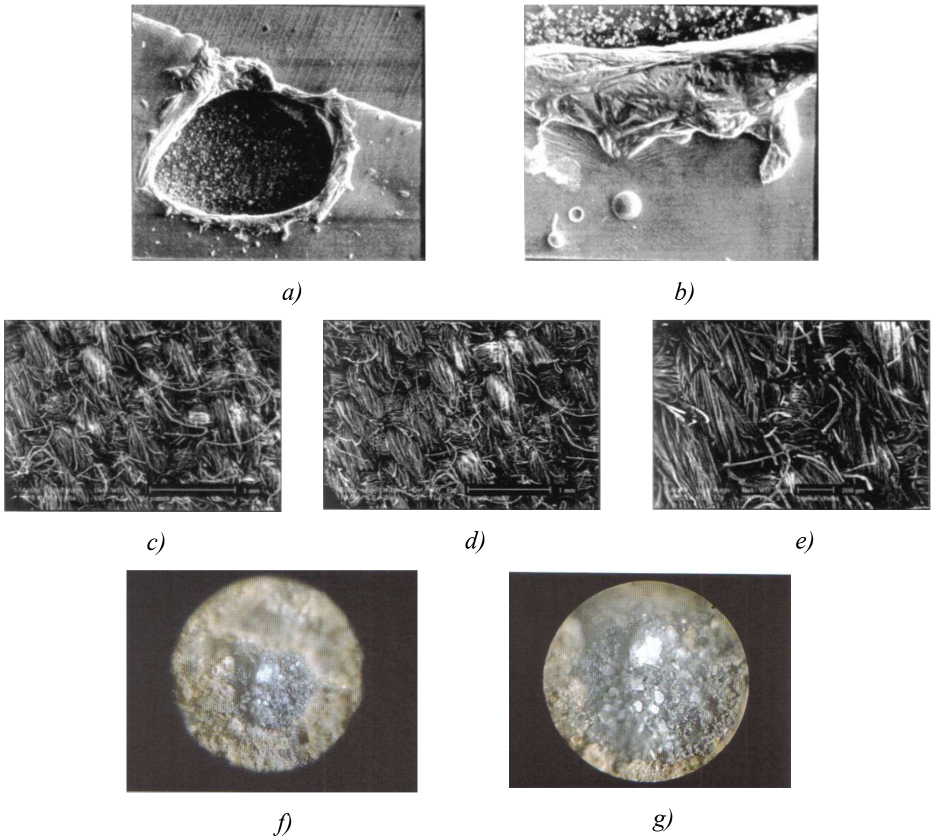

Figure 3. *Chosen laser damages: a), b) amorh materials: 52%Ti-48%Cu Ruby Laser, E = 0.3 J; c), d), e) Red cotton textile treated by* Nd^{3+}*:YAG laser, E = 35 mJ,* τ *= 20 ns, 10 pulses; f), g) Some ceramics from Pločnik treated with laser (Sample 1 Crater 3);* From: [9] – [11]

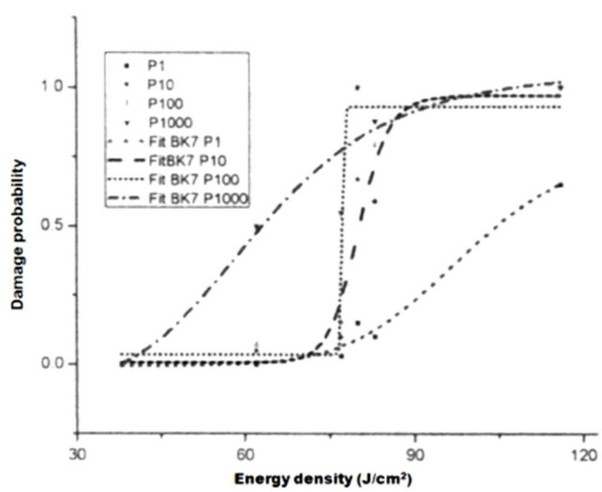

Figure 4. *Prediction of laser damage considered as damage probability vs. energy density*

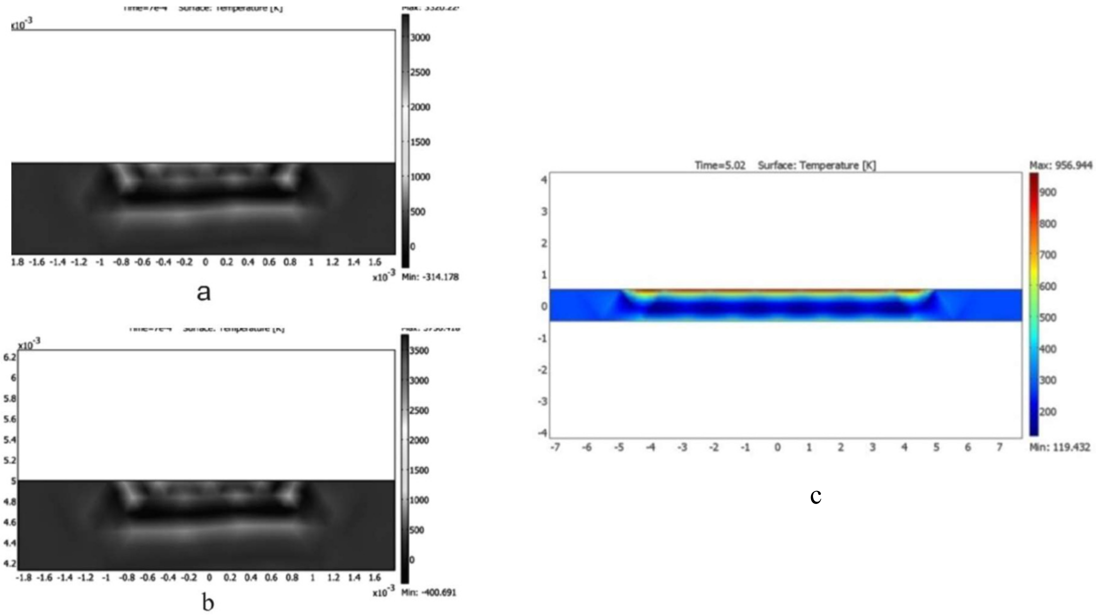

Figure 5. *a), b) Wavelength 1.064 µm, power 0.35 kW, or 0.4 kW, Energy density 112 J/cm^2 or 128 J/cm^2, Pulse duration 0.7 ms; c) The influence of 5 pulses of the alexandrite laser to P7295-2; simulation obtained by COMSOL Multiphysics 3.5 program;* From: [7], [8]

The authors acknowledge the support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, contract no 451-03068/2022-14/200287, as well as Eng. Srđan Milanović for professional assistance

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KVANTNI GENERATORI U TEORIJI I PRAKSI 2022[3)]

Rezime

Primena lasera/kvantnih generatora u najrazličitije svrhe, promenila je milenijum, a trend raste (igračke/cucle, teška/raketna industrija/Kosmos). Edukaciono, od prvih dana stižu doktorati (laserske stanice/dizajn (SFRJ, Srbija)). Danas nema preciznosti u definiciji: novo, početo odavno; konstatuje se da su laseri u svim porama života (medicine, odbrane, mass media). U osnovi je interakcija materijala i lasinga ili činjenica koje dovode/ili ne, do laser damage.Primene su otišle daleko: teorijski, eksperimentalno; komercijalne ,,vode" više i ne konstatuju da se proces bazira na laseru. Rad će se zadržati na nekoliko oblasti (egzotičniji/potencijalno noviji tipovi pumpanja, deskripcija parametara). Interakcija se sagledava: kroz eksperiment, simulacija kroz slučaj rasejanja i raspodele temperature i izborom oblasti, gde treba dublje shvatanje u ovoj širokoj problematici.

Ključne reči:laseri, karakterizacija materijala, kvantni generatori, obrada,pumpanje.

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