

Workshop-uri Exploratorii

"EXTREME LIGHT INFRASTRUCTURE"

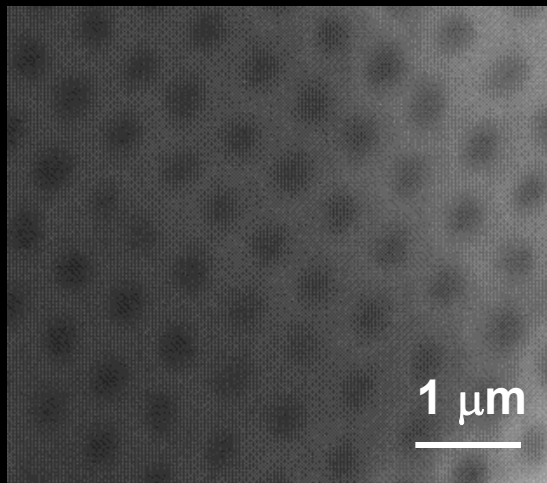
un nou impuls pentru cercetarea stiintifica interdisciplinara

7-18 Septembrie 2008, Magurele



Sisteme laser pulsate cu durate de picosecunde si femtosecunde pentru aplicatii in nanotehnologii

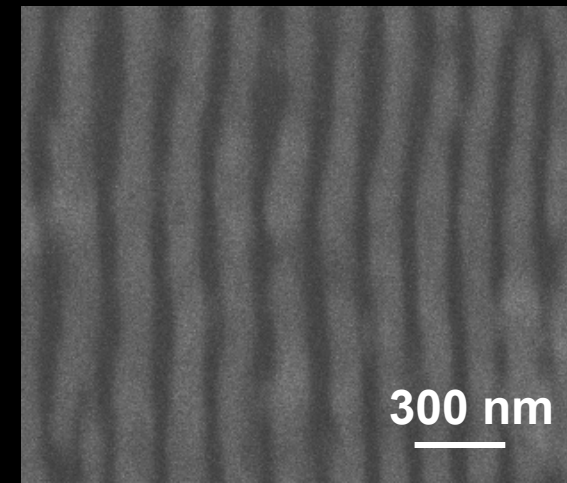
*Institutul National pentru Fizica Laserilor Plasmei si Radiatiilor
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Sisteme laser pulsate

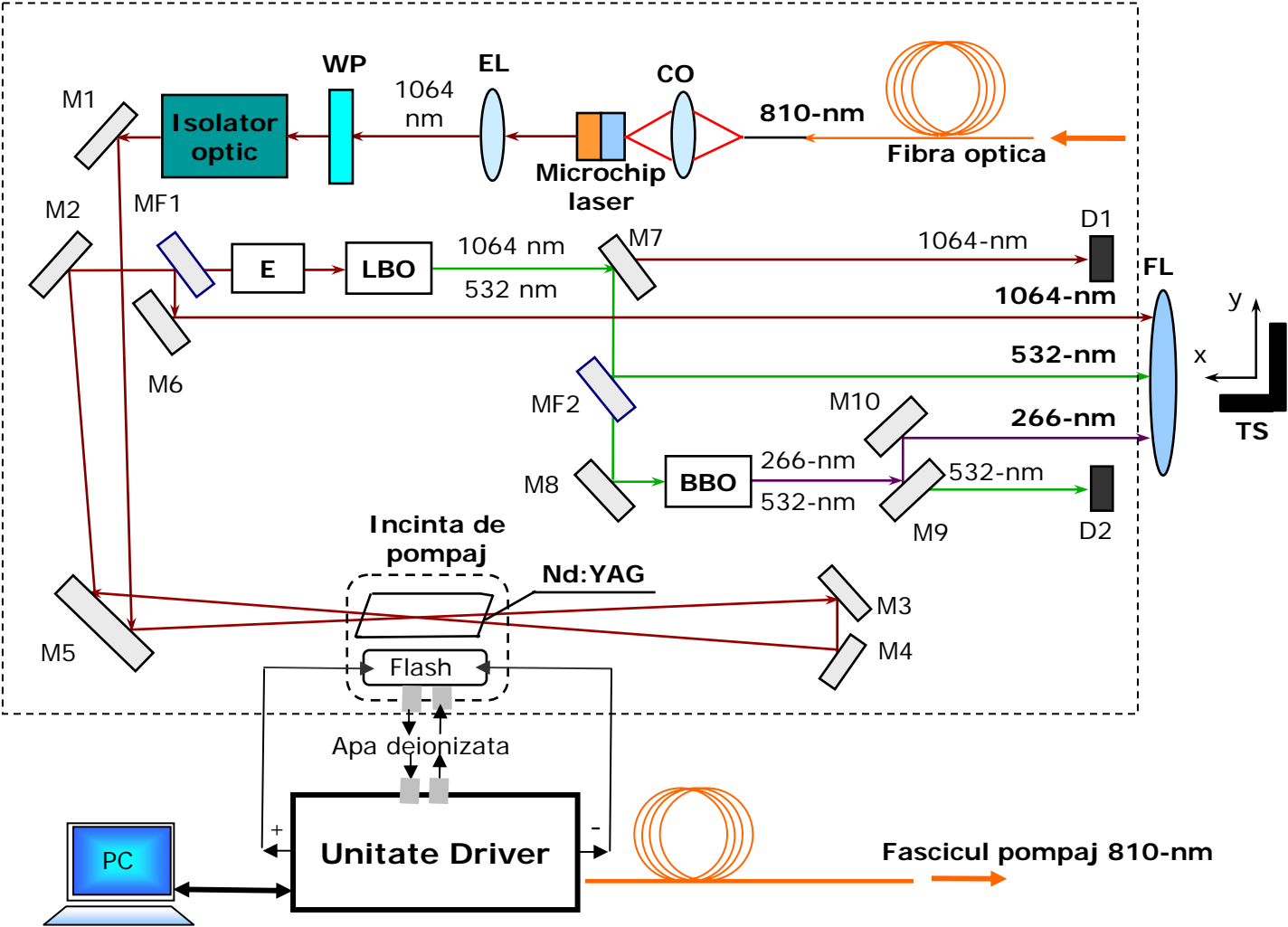
- Laserul in picosecunde
- Laserul in femtosecunde

Aplicatii in nanotehnologii

- Ablatie laser la limita de difractie si in camp apropiat
- Nanostructurarea suprafetelor (LIPSS)
- Transfer de material indus cu laserul (LIFT)
- Fotopolimerizare prin absorbtie de doi fotoni (TPP)

Concluzii

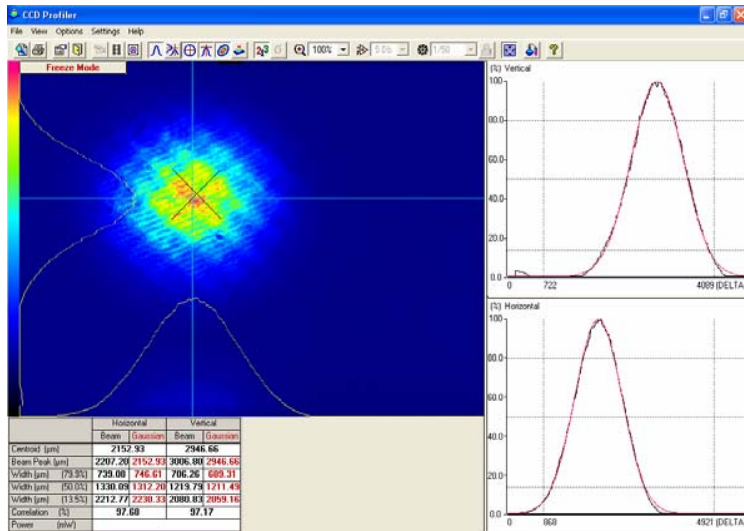
Sistemul Laser in Picosecunde



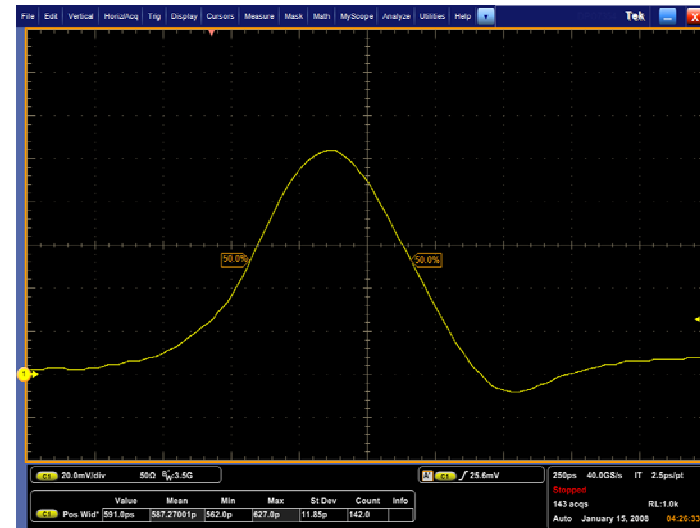
Caracteristicile tehnice ale laserului in picosecunde



Emisie laser:	1064 nm	532 nm	266 nm
Energie maxima pe puls	15 mJ	7 mJ	3 mJ
Abaterea standard a puterii medii de fascicul	< 1 %	< 2%	< 4%
Durata pulsului	< 450 ps		
Frecventa de repetitie	1, 2, 5, and 10 Hz		
Factor de merit M^2	1.3	1.5	2.2
Diametru fascicul	2.8 mm		
Dimensiuni Cap Laser : Unitate de control :	500 x 300 x 120 mm 525 x 395 x 480 mm		

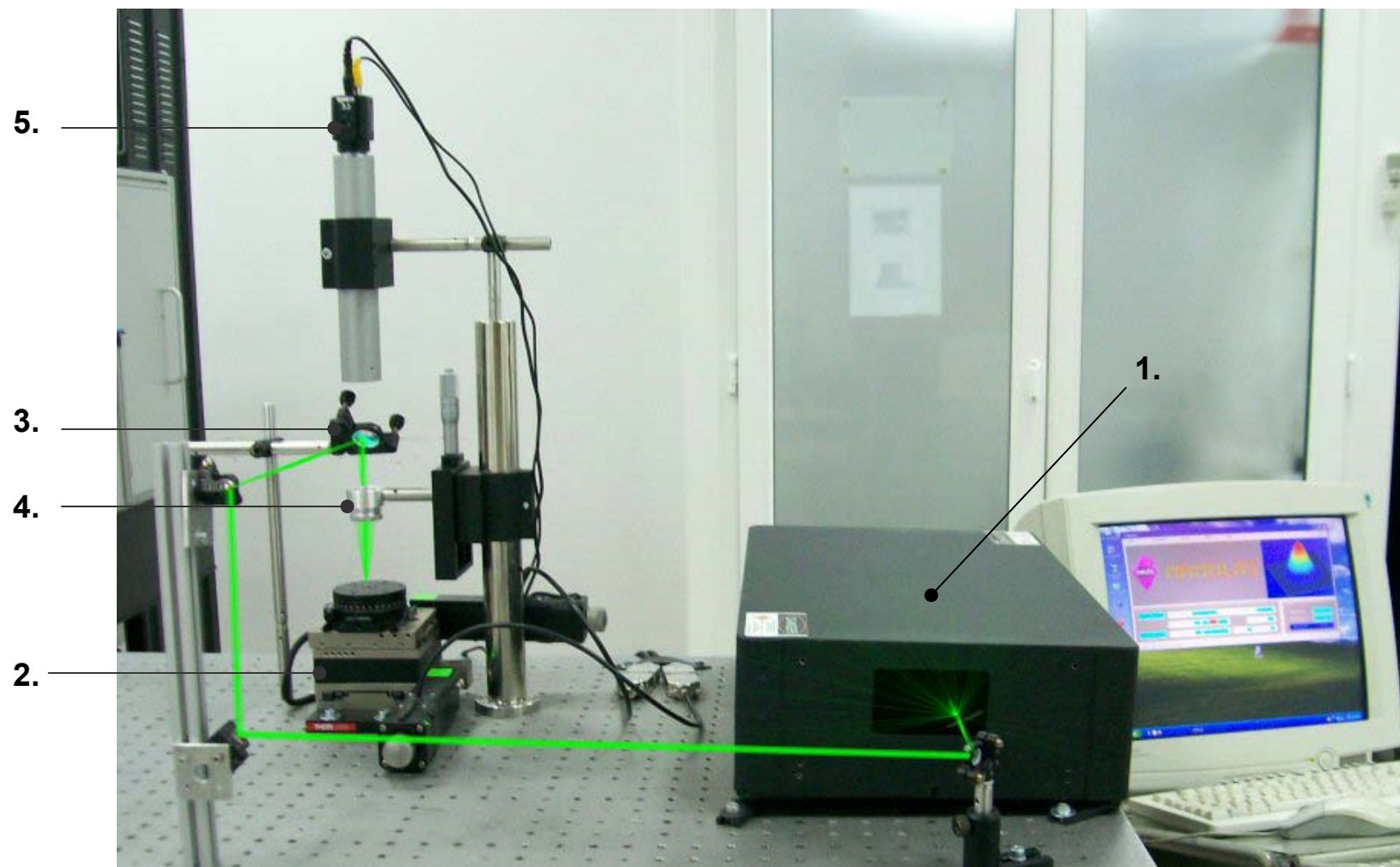


Profilul transversal de intensitate al fascicului laser la 1064-nm, 15-mJ energie pe puls , 2-Hz.



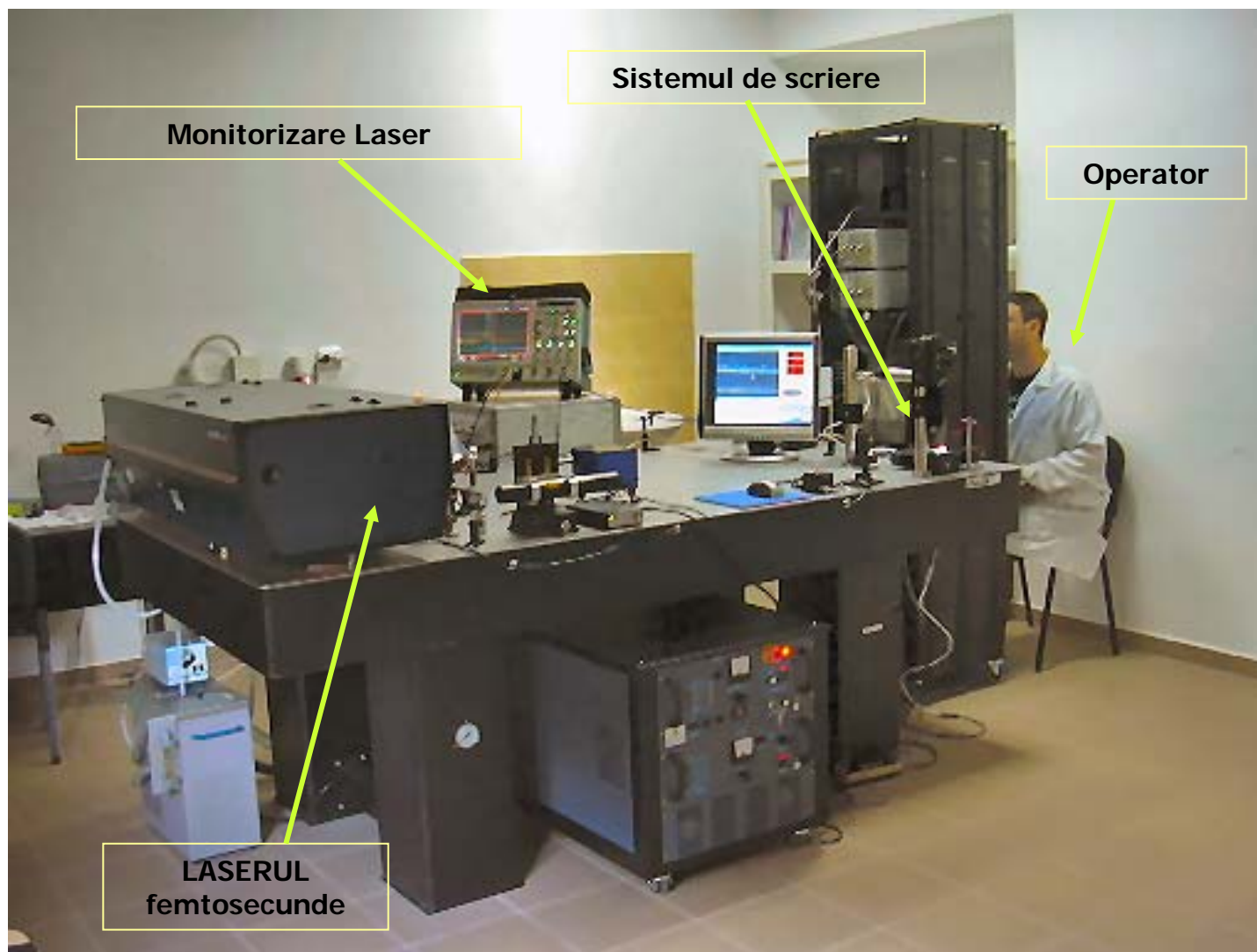
Profilul temporal
FWHM ~ 450-ps la 1064-nm

Sistemul opto-mecanic pentru micro/nanoprosesari cu laserul in picosecunde



1 – Laser 450 ps; 2 – Translatii XY - gama de deplasare (50 x 50 mm); 3 – Oglinda dicroica; 4 – Lentila de focalizare; 5 – Camera CCD.

Sistemul experimental de scriere directa cu laserul in femtosecunde (DLW)



Parametrii laserului in femtosecunde

Laser CLARK CPA2101

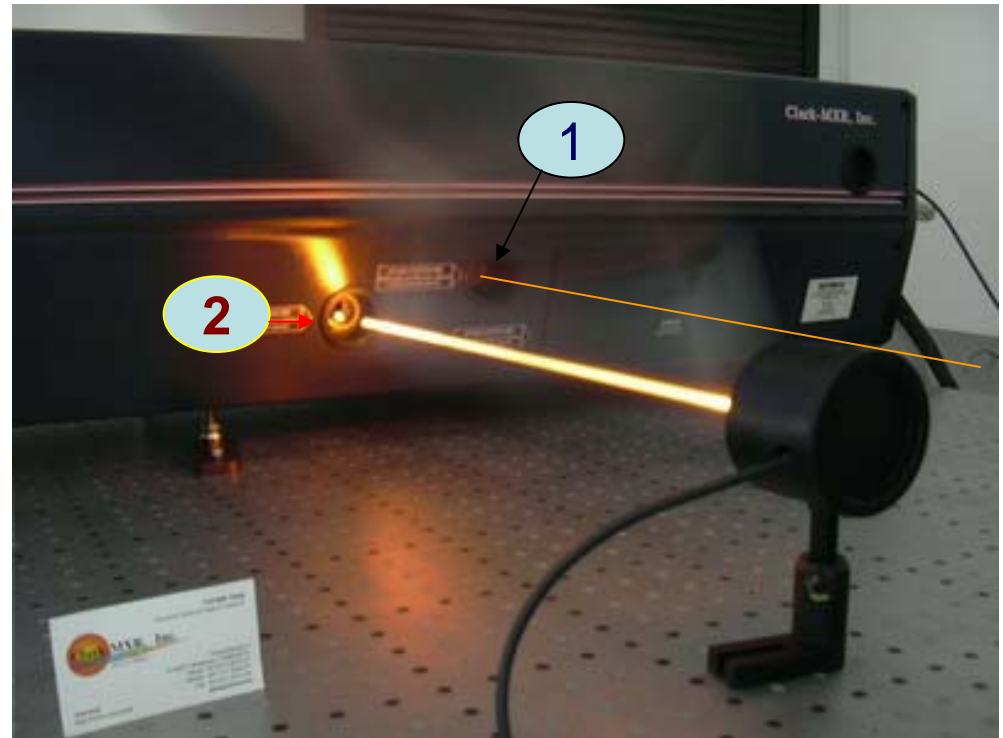
- Oscilator cu Fibra SErF
- Amplificator Regenerativ (CPA)

Output 1:

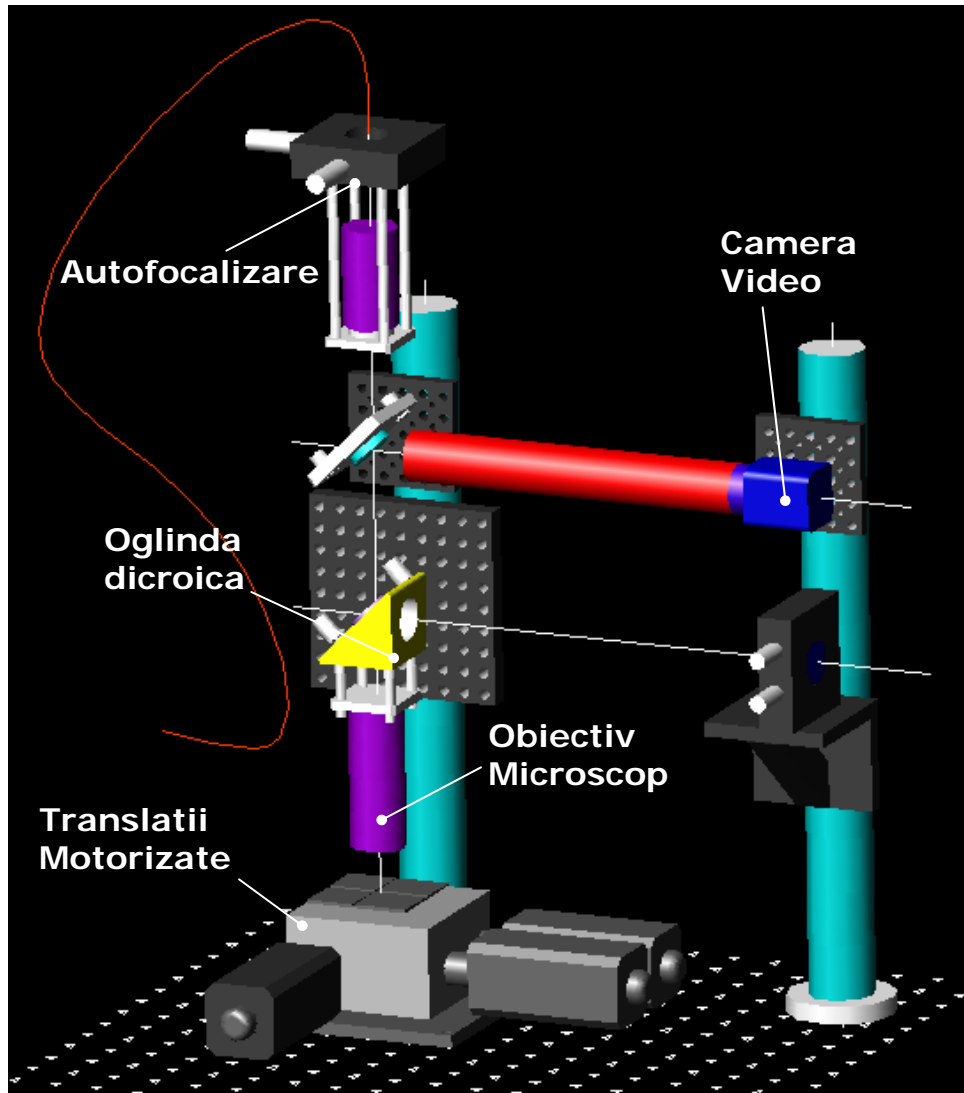
- Radiatie laser la 775 nm
- Durata de puls 150 fsec
- Frecventa de repetitie 35 MHz
- Energie ~50 pJ (Putere ~1.5 mW)

Output 2:

- Radiatie laser la 775 nm
- Durata de puls 200 fsec
- Frecventa de repetitie 2 kHz
- Energie ~700 μ J (Putere ~1.5 W)



Sistemul opto-mecanic pentru procesari laser in femtosecunde



LASER

- durata de puls 200 fs
- lungimea de unda 775 nm
- frecventa 2 KHz

Obiectiv de microscop

- apertura numerica 0.5NA
- marire 100X
- distanta focala 2 mm

Translatii motorizate XYZ

- gama de deplasare $(4 \text{ mm})^3$
- pas 100 nm
- precizie 400 nm

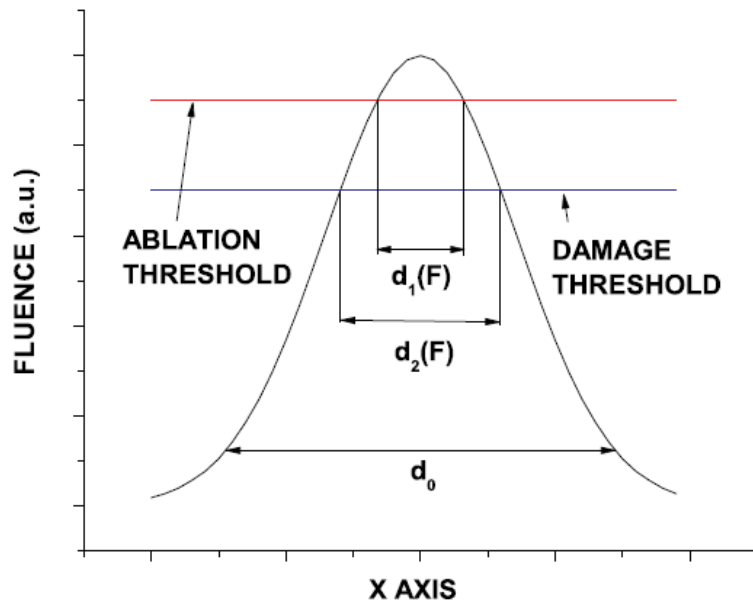
Translatii Piezo XYZ

- gama de deplasare $(20 \mu\text{m})^3$
- precizie 5 nm (senzor)

Vizualizare

- camera 768 x 494 pixeli
- lentila 200 mm

Procesari cu fascicule laser Gaussiene



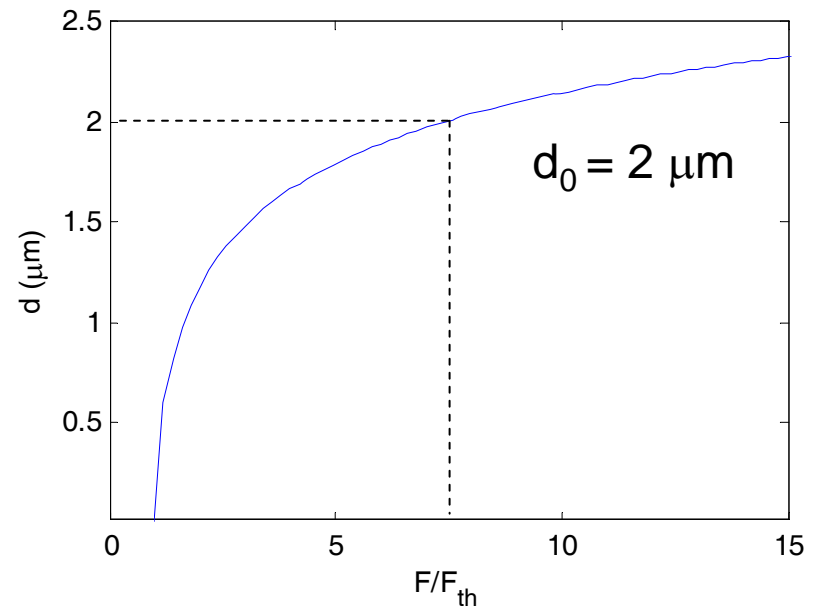
$$d_0 = \frac{2M^2 \lambda}{\pi AN} \approx \frac{\lambda}{AN}$$

d_0 – diametrul minim al spotului laser focalizat

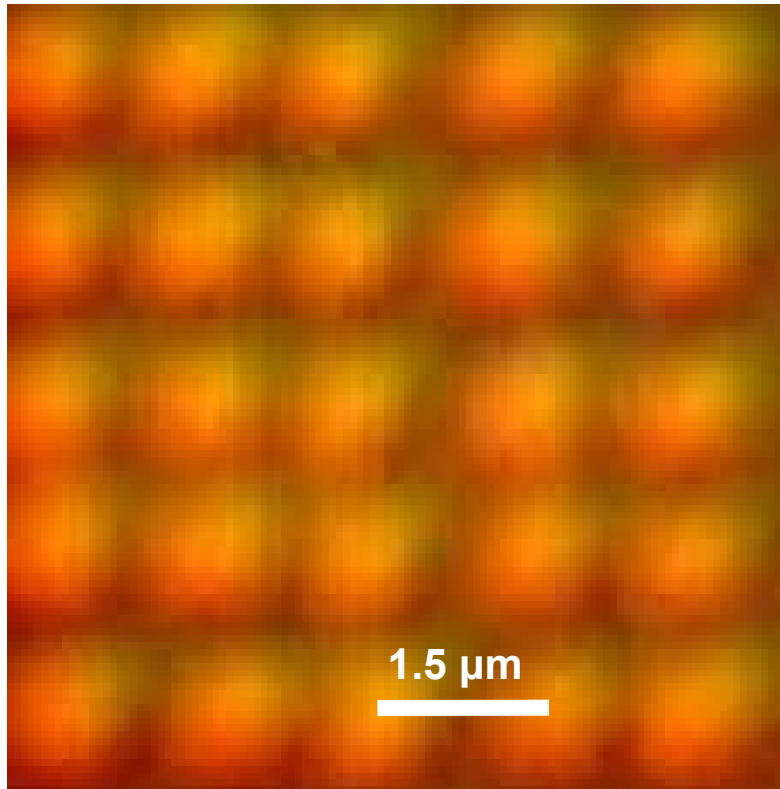
AN – apertura numerica

$$d(F) = \frac{d_0}{\sqrt{2}} \sqrt{\ln(F / F_{th})}$$

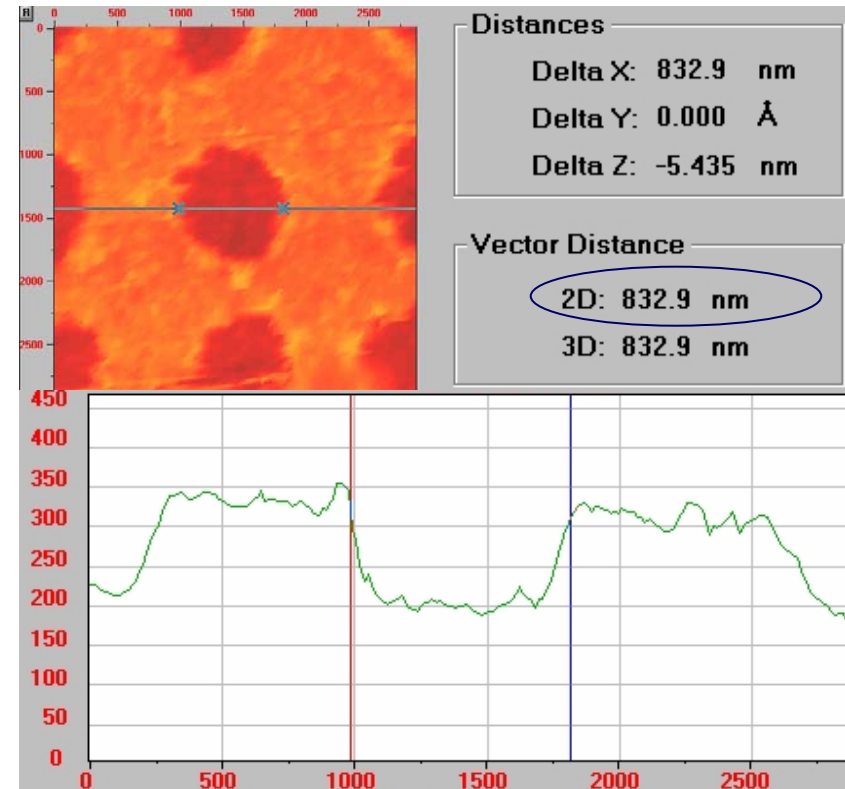
Procesarea materialelor prin ablatie laser se poate face cu precizie sub limita de difractie prin ajustarea corespunzatoare a fluentei laser.



Ablatie laser la limita de difractie



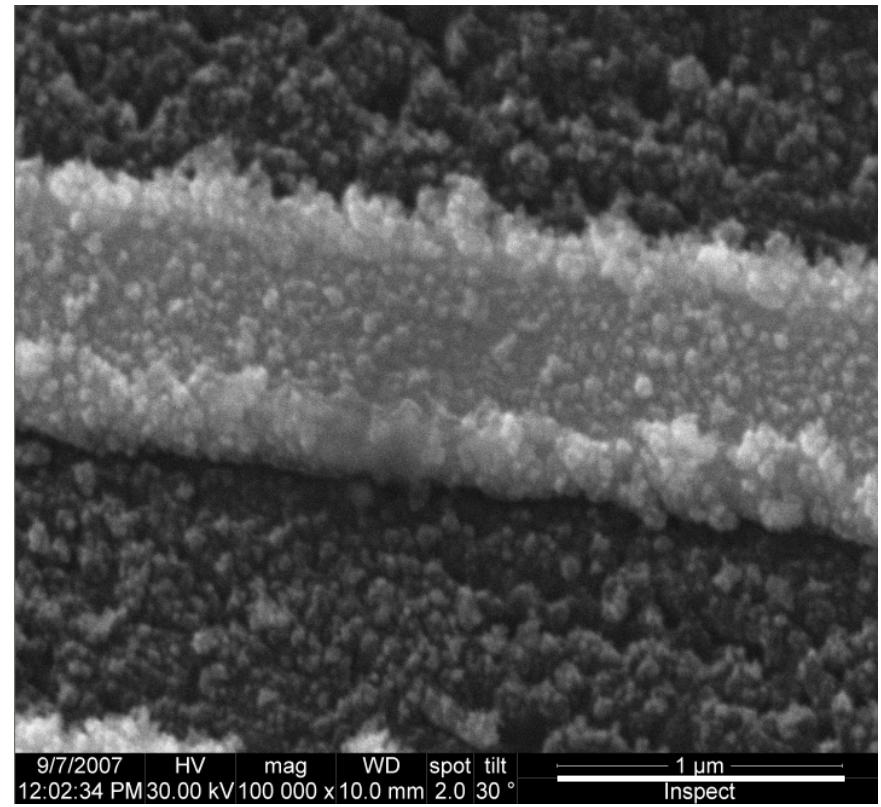
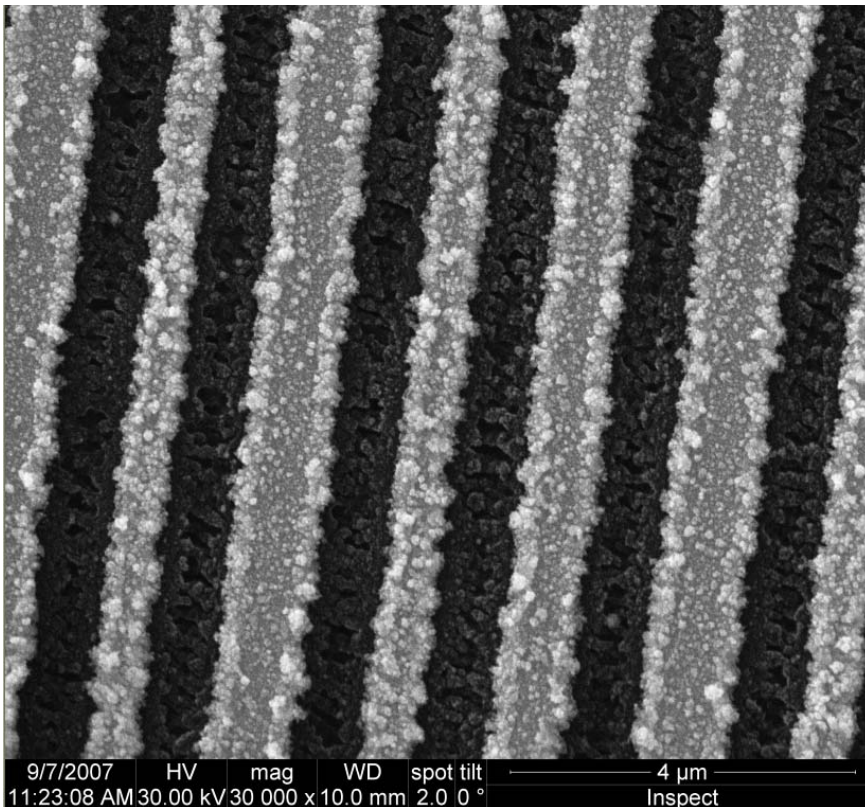
Imagine de microscopie optica prin transmisie a rețelei de gauri pe film de aur 50 nm grosime. Laser 775 nm, 200 fs.



Caracterizare AFM

- diametrul gaurilor 850 nm
- pana la 650 nm pe alte probe de aur
- pana la 300 nm pe alte materiale

Ablatie laser la limita de difractie



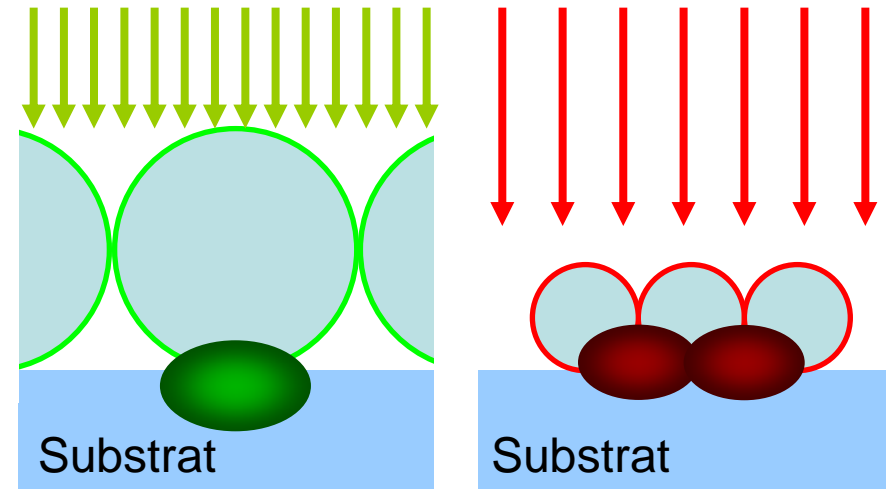
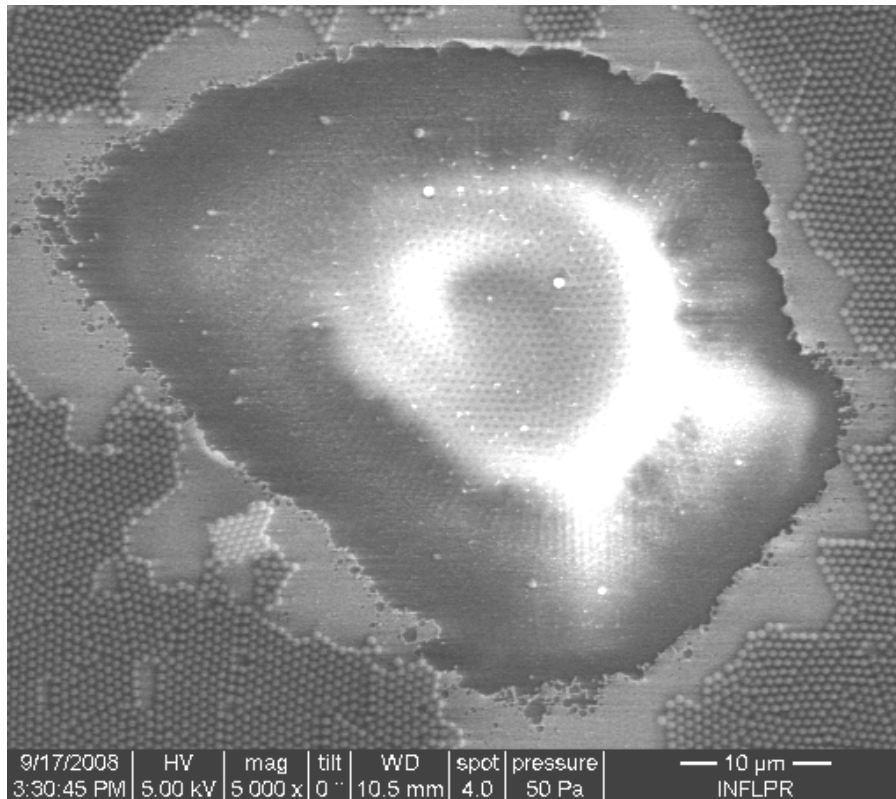
Imagini SEM.

Film de Au depus pe sticla. Perioada structurilor 2 μm

Laser 775 nm, 200 fs.

Ablatie laser in camp apropiat

Prin intensificarea campului electromagnetic al luminii in vecinatatea unui monostrat de particule coloidale se pot obtine structuri cu dimensiuni mult sub limita de difractie.



$$\lambda < d$$

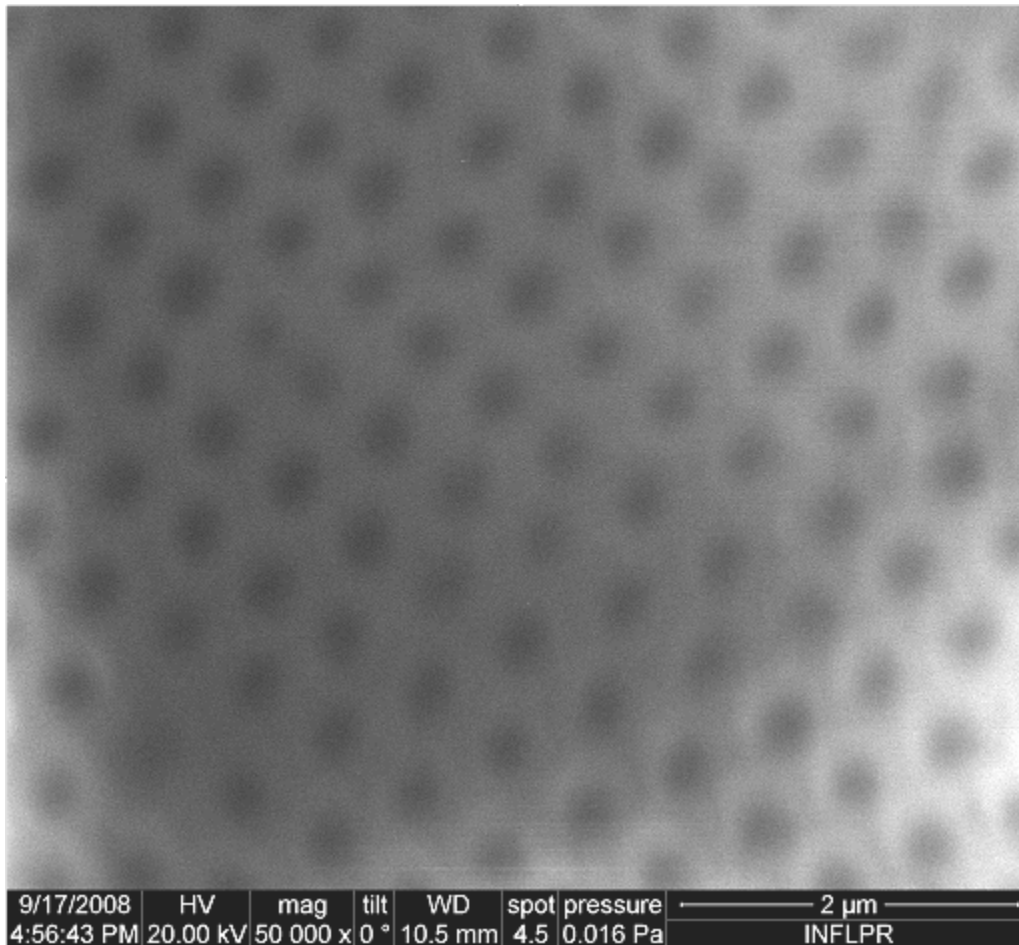
$$\lambda > d$$

$d = \text{diametrul sferelor}$

Sfere de silica de 700 nm depuse pe substrat de sticla cu un strat intermediar de Ag de 50 nm grosime.

Laser 532-nm, 450-ps
Lentila de focalizare 75 mm.
Fluenta laser 6 J/cm²

Caracterizarea SEM a structurilor obtinute prin ablatie laser in camp apropiat



Fluenta laser 6 J/cm^2

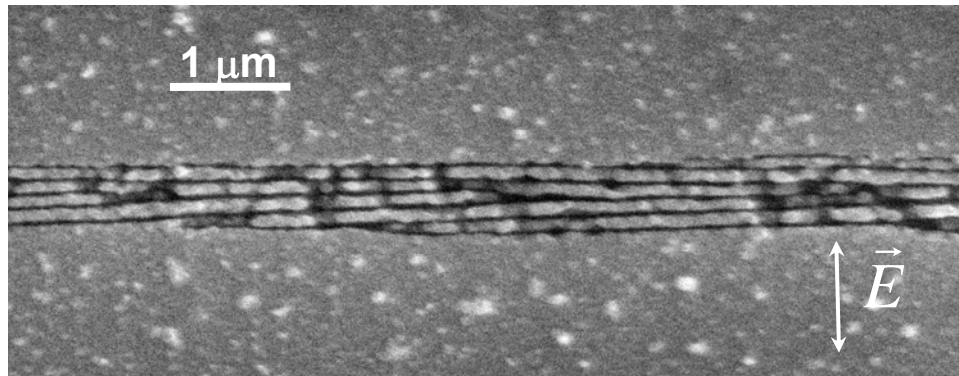
Laser **532-nm**, 450-ps

Dimensiune sfere: **700-nm**

Dimensiune structura: **~250 nm**

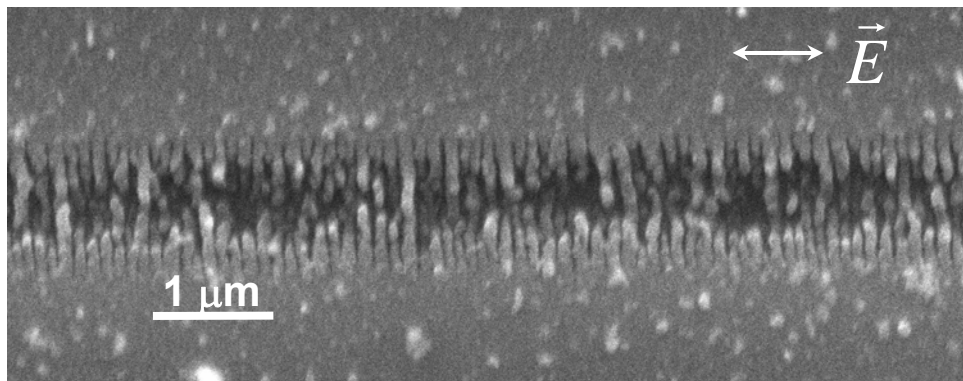
Structurare periodica a suprafetelor indusa cu laserul (LIPSS)

Scanare in directie X



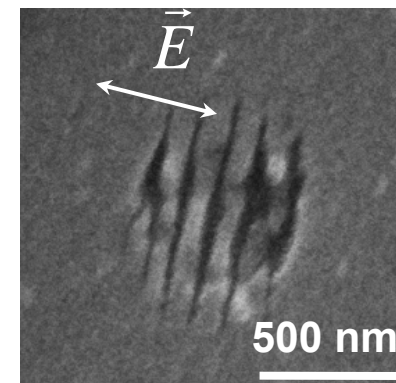
Atunci cand fluenta laserului este mentinuta in vecinatatea pragul de ablatie, prin scanarea probei de ZnO se formeaza structuri periodice pe suprafata, orientate perpendicular pe directia de polarizare a laserului. Imaginile SEM pun in evidenta structuri cu perioada de 150nm, mult sub lungimea de unda a laserului.

Scanare in directie Y



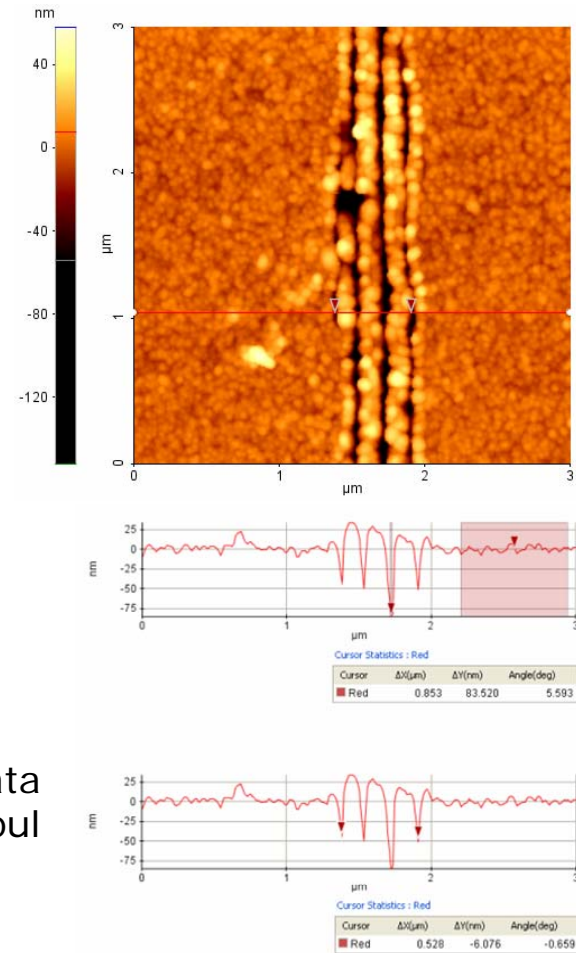
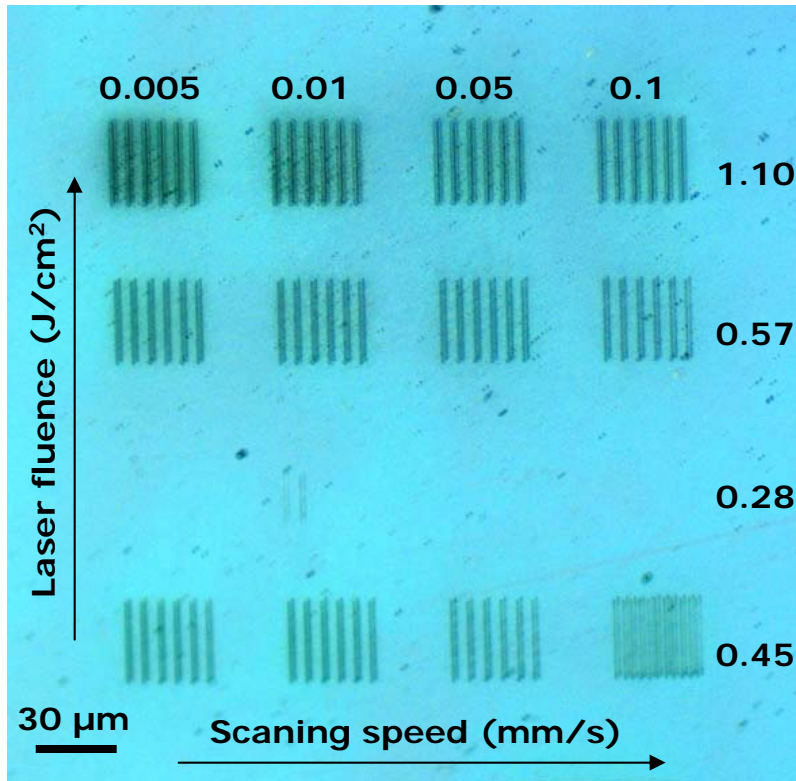
Perioada rețelei < 150 nm

Scanare in directie Z



Viteza de scanare 0.01 mm/s
Laser 775 nm, 200 fs
Fluenta laser 0.45 J/cm²

Studiul formarii nanostructurilor LIPSS



TEORIA 1. Formarea structurilor periodice este datorata interferentei dintre unda luminoasa incidenta si campul electric al plasmei de electroni din material.

N_e – densitatea plasmei de electroni
 T_e – temperatura plasmei.

$$\Lambda = \frac{2\pi}{\sqrt{\frac{1}{T_e} \left(\frac{m_e \omega^2}{3k_B} - \frac{e^2 N_e}{3\epsilon_0 k_B} \right) - k_{ph}^2}}$$

TEORIA 2. Efect de reorganizarea a atomilor pe suprafata in urma difuziei in prezenta campului electromagnetic al luminii.

Aplicatiile nanostructurilor LIPSS

Suprafata structurata de ZnO
0.4 x 0.1 mm

Viteza de scanare 0.1 mm/s

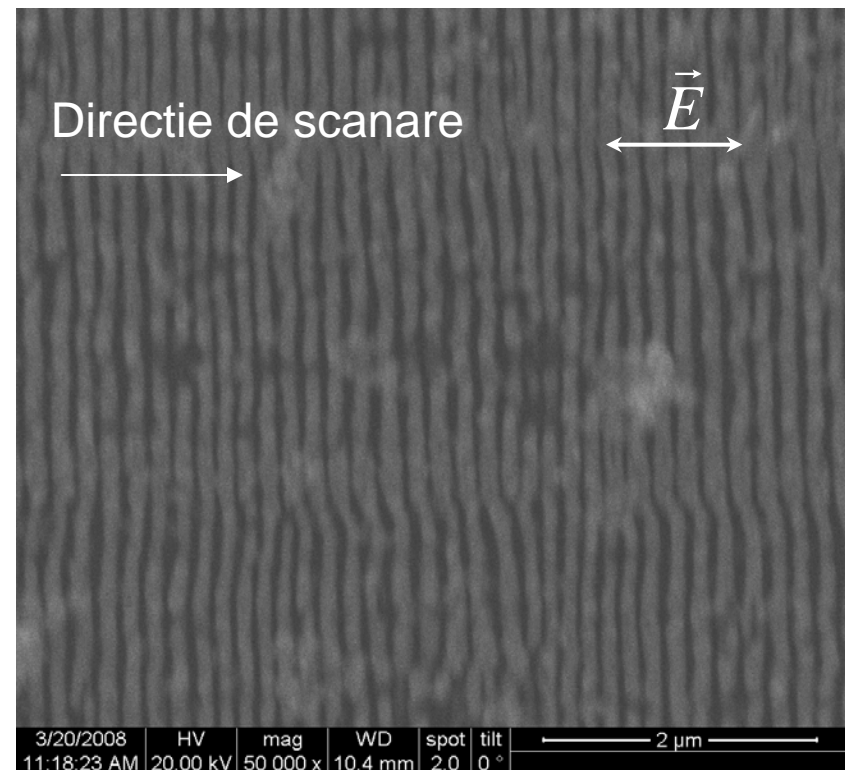
Offset 0.5 μm

Suprafata scanata 200 x 500 μm^2
Fluenta laser 0.34 J/cm²

Dimensiune spot 2 μm .

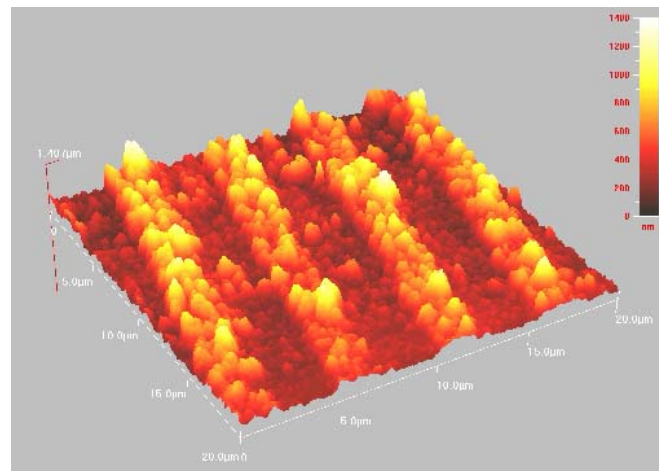
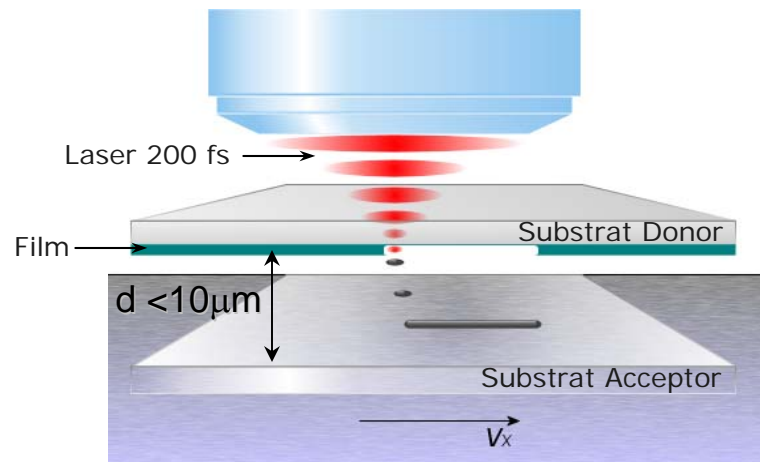
Polarizarea laser paralela cu
directia de scanare

- Nano-retele de difractie fabricate prin LIPSS
- Micropolarizori
- Marirea suprafetei efective pentru cresterea sensibilitatii micro-senzorilor.

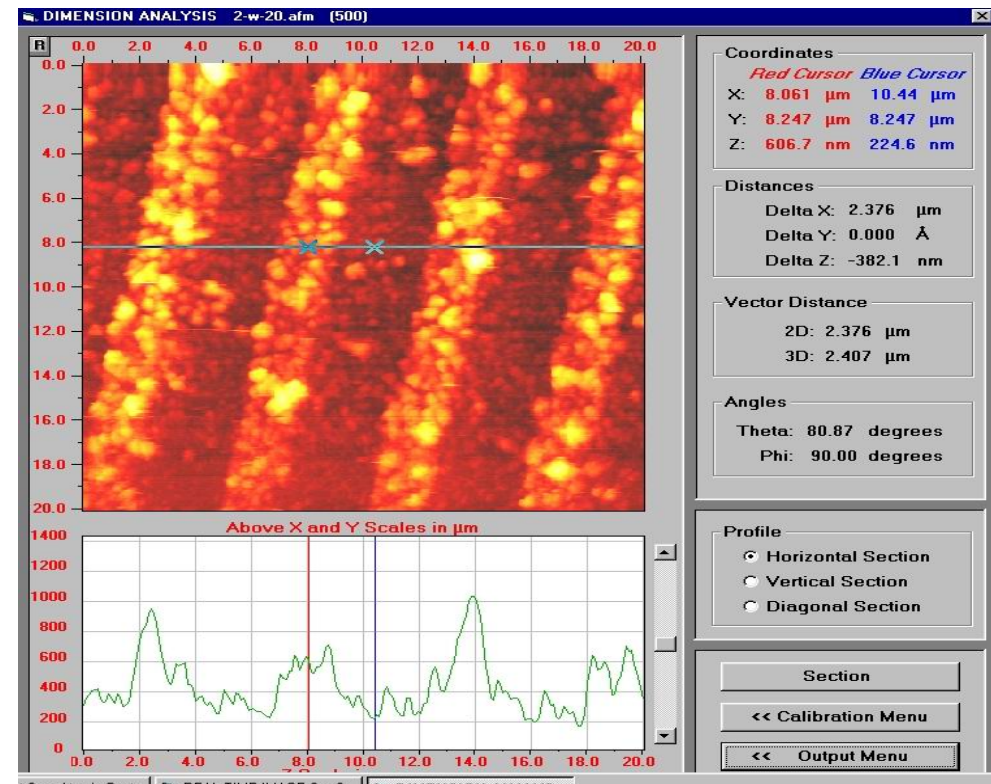


Depunere de material prin de transfer indus cu laserul (LIFT – Laser Induced Forward Transfer)

- semiconductori, polimeri, tesuturi biologice -



Structura de scuterudit obtinuta prin LIFT



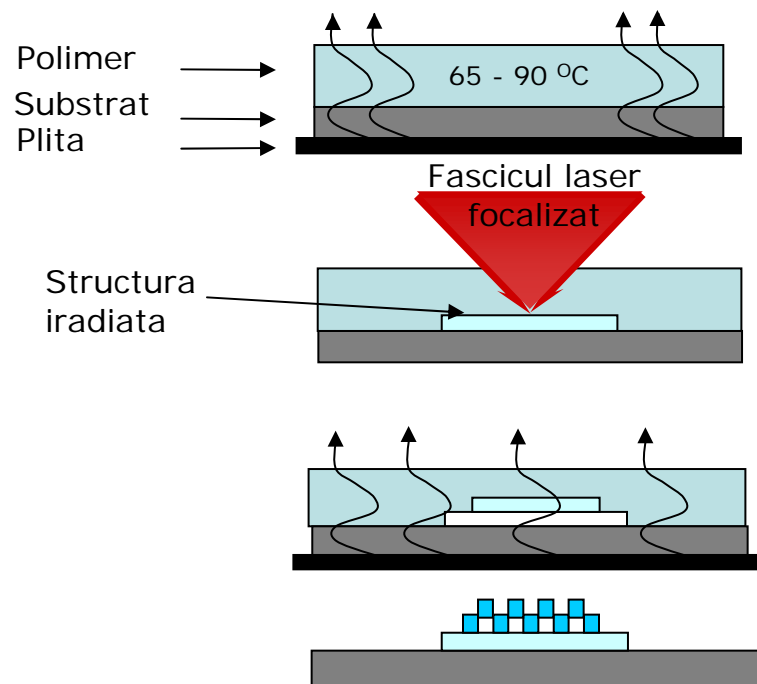
Fotopolimerizari in rasini fotosensibile: SU8

SU-8 :

- Rasina de tip epoxy
- Absorbție în domeniul spectral 240-400 nm
- Prin iradiere UV se generează acizi care ajută la îmbinarea grupurilor epoxy
- Polimerizarea (Cross-linking) apare doar după încălzire la 95 °C
- Rezistă până la o temperatură de 600 °C



Protocolul de procesare a probelor din SU8



ETAPA 1: Depunerea pe substrat a rasinei fotosensibile (nepolimerizată) și încălzirea probei. Rasina fotosensibilă devine solidă.

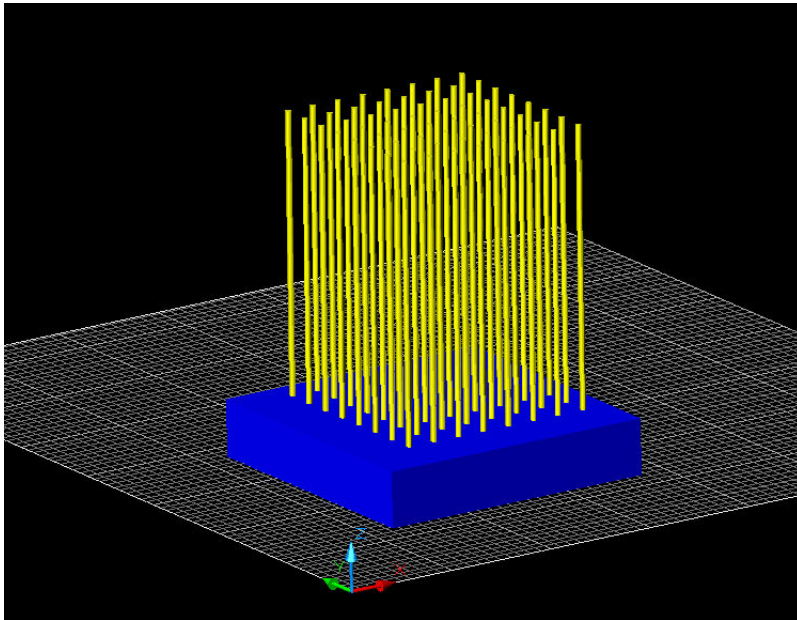
ETAPA 2: Iradierea materialului cu laser femtosecunde focalizat. Generarea de acizi Lewis.

ETAPA 3: Accelerarea procesului de cuplare a moleculelor (cross-linking) prin încălzire la 90°C

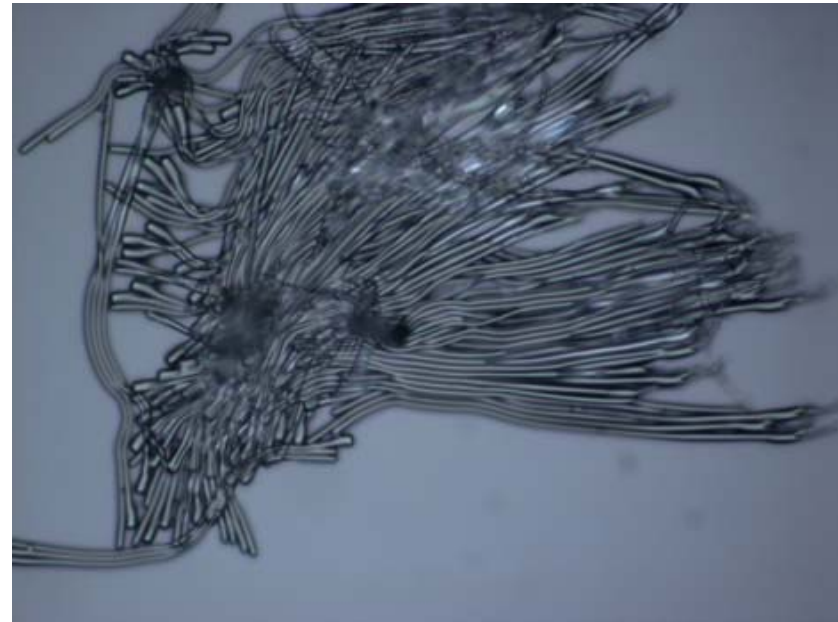
ETAPA 4: Developarea probei în solvent PGMEA

Structuri 3D in scriere transversala

Modelul 3D



Structura dupa dezvoltare



Au fost create fire din SU 8 cu inaltimea de $100\ \mu\text{m}$ si diametrul de $2\ \mu\text{m}$ (raport 50:1)

Atunci cand raportul dintre inaltimea structurilor 3D si dimensiunea lor laterala este mai mare de 20:1, structurile se prabusesc pe substrat.

Structuri 3D in scriere transversala

Parametri laser folositi pentru realizarea de coloane in polimer :

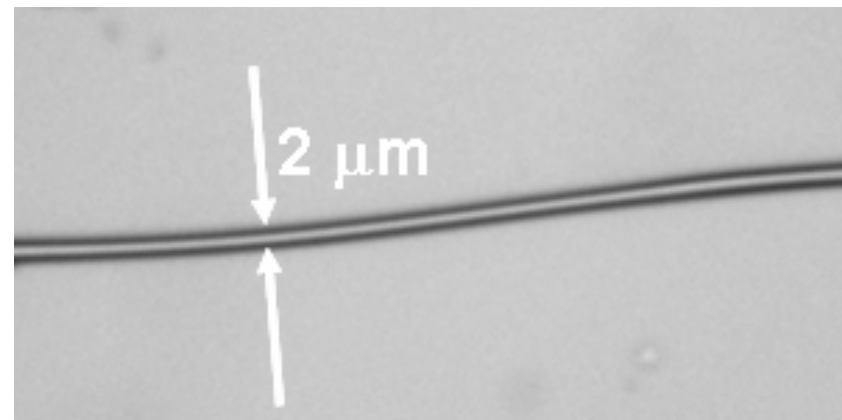
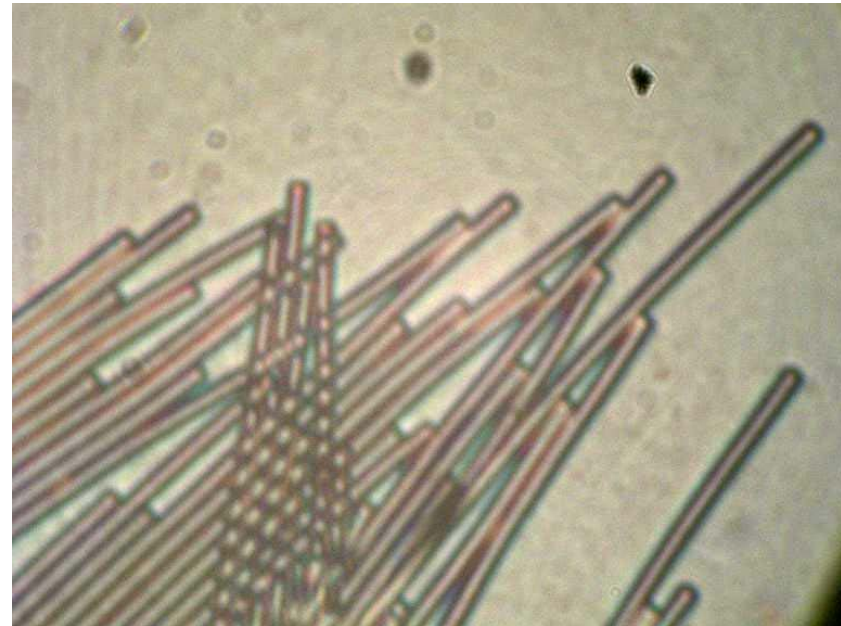
LASER 800-nm, 60-fs

Energie: 0.25 nJ

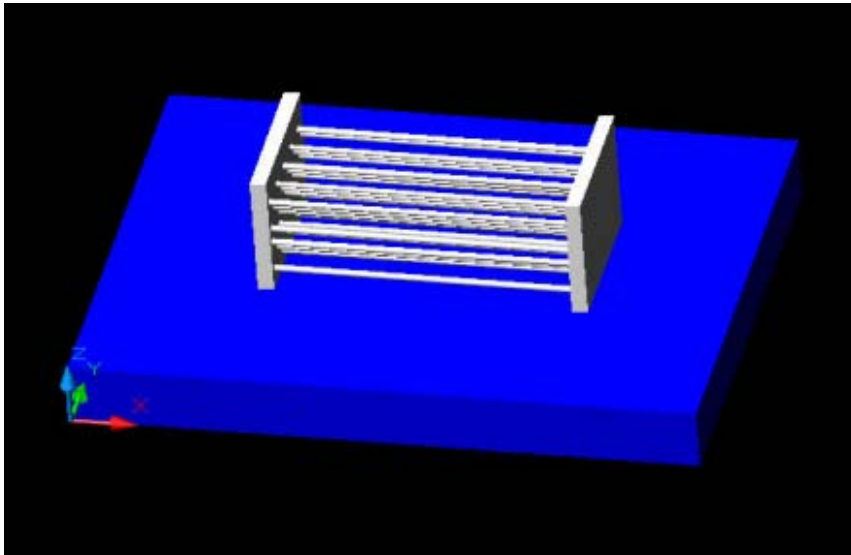
Viteza deplasare: 0.1 mm/s

Frecventa: 80 MHz

Suprafata structurilor realizate este extrem de neteda, cu rugozitate foarte redusa.



Structuri 3D in scriere longitudinalala



Modelul grafic 3D simulat:

***Retea de fire orizontale
consolidate de blocuri de sustinere***

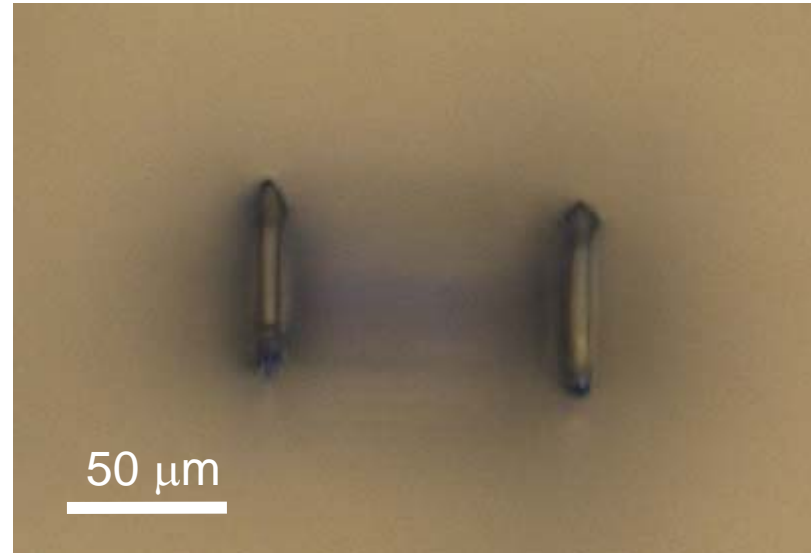
Baza bloc: 5 x 50 μm

Inaltime bloc: 30 μm

Distanta intre 2 blocuri: 100 μm

Diametru fire: 2 μm

Pas intre fire: 5 μm



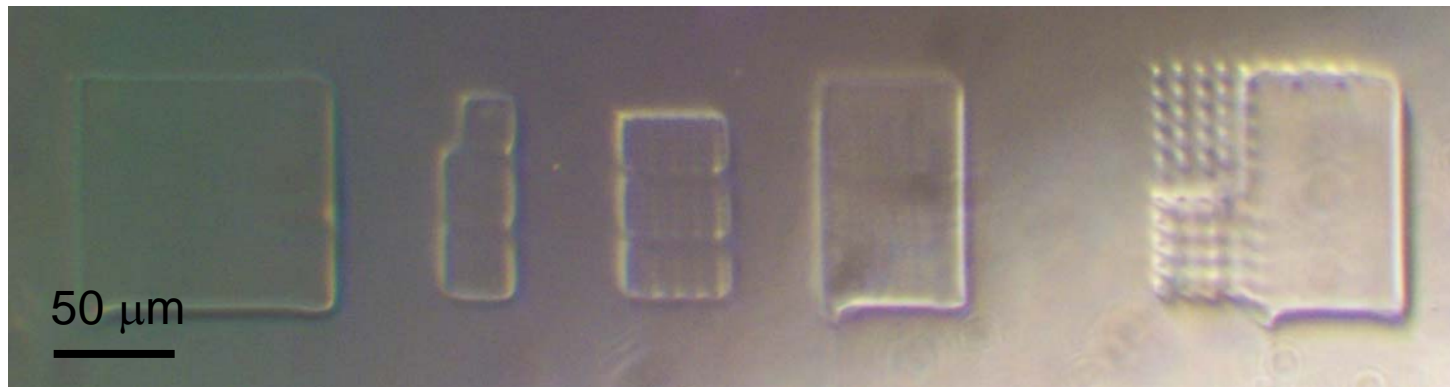
Structura geometrica obtinuta:

Energie laser: 0.25 nJ

Viteza de scriere: 0.1 mm/s

Aplicatiile fotopolimerizarii prin absorbtie bifotonica

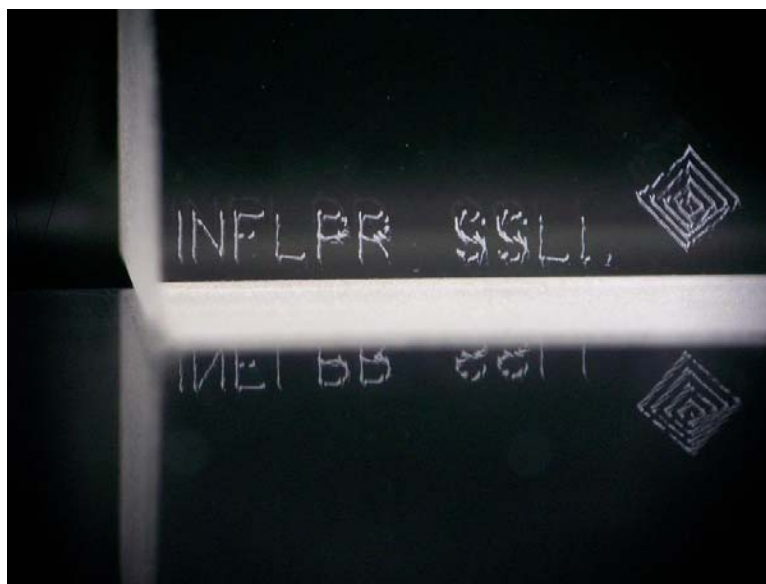
- **Componente micro-optice:**
microlentile, cristale fotonice, ghiduri de unda, cuploare optice ;
- "fantome" pentru OCT ;
- **Medicina: obtinerea de microstructuri biocompatibile.**



Concluzii

- ✓ Au fost configurate doua sisteme de scriere directa cu laserul cu durata de puls de femtosecunde si picosecunde.
- ✓ Cele doua sisteme permit producerea de micro si nano-structuri 2D si 3D cu precizie submicronica.
- ✓ Microstructurarea materialelor se face utilizand efecte precum ablatia suprafetelor, ablatie in camp apropiat, polimerizarea materialelor fotosensibile.
- ✓ Instalatiile laser sunt compatibile cu tehnicile de tip Gravare Laser, litografie in camp apropiat, LIPSS, LIFT, TPP.
- ✓ Structurile obtinute prin scriere directa cu laserul au aplicatii in fabricarea de structuri de tip MEMS, metamateriale, micro-optica, etc.

Va multumesc!



- | | |
|--|---|
| Magda Ulmeanu | - Depuneri de particule coloidale, ablatie in camp apropiat |
| Aurel Stratan, Constantin Blanaru, Laurentiu Rusen | - Laser picosecunde |
| Florin Jipa | - Fotopolimerizari prin absorbtie bifotonica |
| Iulia Anghel | - Microprocesari cu laserul femtosecunde |
| Catalin Luculescu | - Caracterizari SEM |
| Marius Dumitru | - LIFT, Caracterizari AFM |
| Antoni Moldovan | - Caracterizari AFM |