http://www.laserapplicationslab.com

VACUUM DEPOSITION TECHNOLOGIES FOR FILMS & COATINGS
SEVILLA, 20 FEBRUARY, 2014

LASER ASSISTED SURFACE FUNCTIONALIZATION

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http://www.laserfiring.eu

http://www.ceramglass.eu

Outline:

1.- LASER TECHNOLOGY: FUNDAMENTALS FOR PEDESTRIANS.

2.- LASER-MATERIAL INTERACTION.

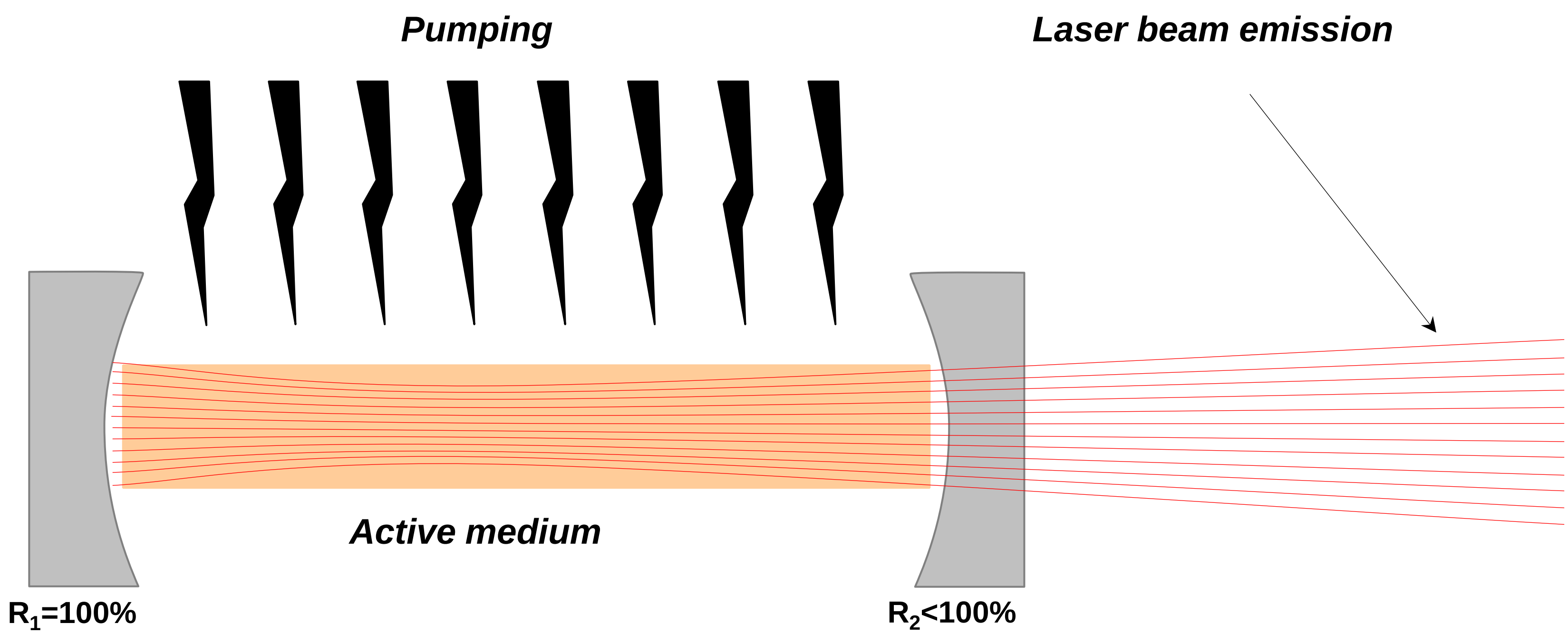
3.- EXAMPLES IN MATERIALS SCIENCE & TECHNOLOGY.

- 3.1. SURFACE HEATING
- 3.2. MELTING AND DIRECTIONAL SOLIDIFICATION
- 3.3. ABLATION

1.- LASER TECHNOLOGY: FUNDAMENTALS FOR PEDESTRIANS

¿What is a LASER?

"Light Amplification by the Stimulated Emission of Radiation"



Elements within a Laser Cavity:

1.- Active Medium

2.- Excitation mechanism

3.- Optical resonator

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LASER SYSTEMS FOR INDUSTRIAL APPLICATIONS

LASER TYPE	⌊	SPECTRAL RANGE	ACTIVE MEDIUM
EXCIMER	157-390 nm	UV	Excimer gas mixture (XeCl, …)
DIODE	800-940 nm	n-IR	P-N junction (semiconductor)
Nd:YAG	1064 nm	n-IR	YAG single crystal doped with Nd^{3+}
CO_2	10.6 µm	mid-IR	Gas mixture: CO_2, N_2, He
Fibre	1070 ±10 nm	n-IR	Doped fibre (Yb^{3+})
Disc	1030 nm	n-IR	Single crystal thin disc of Yb:YAG, …

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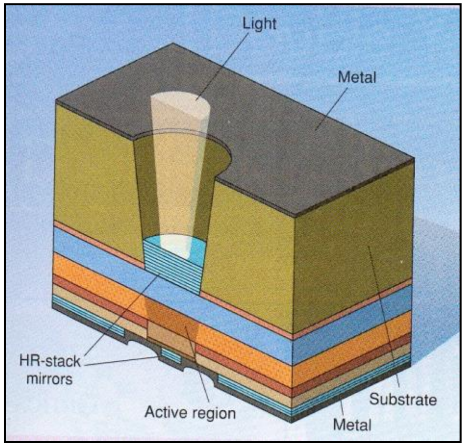
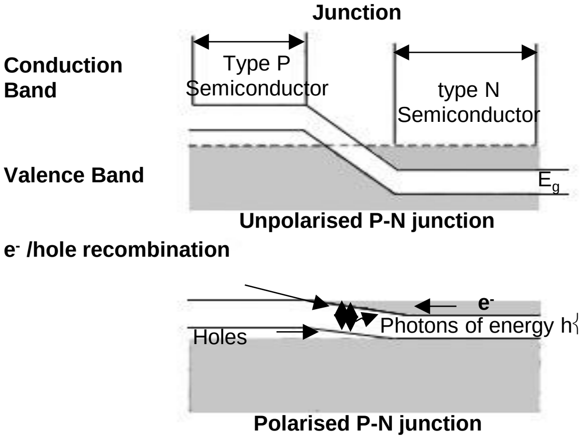
LASER SYSTEMS FOR INDUSTRIAL APPLICATIONS

Laser diode system





APLICACIONES:

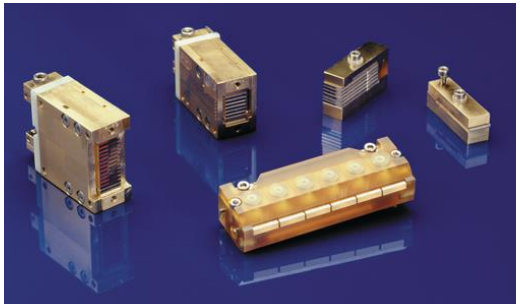
mW: **fibre optics communications, medicine, noncontact measurements (metrology), ...**

kW: **materials processing, ...**

Power range:

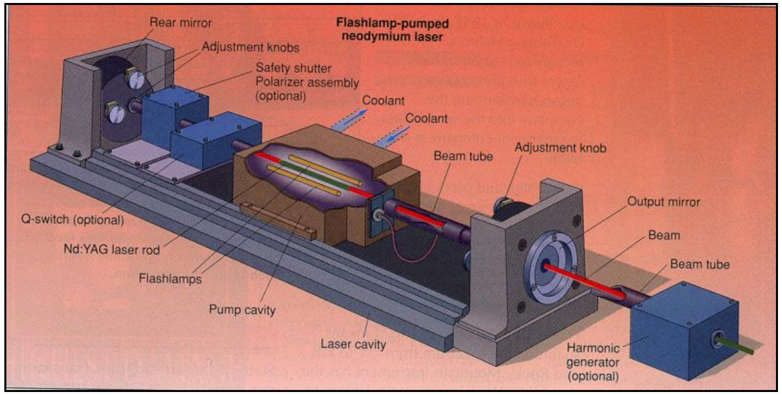
0-2 W (low)

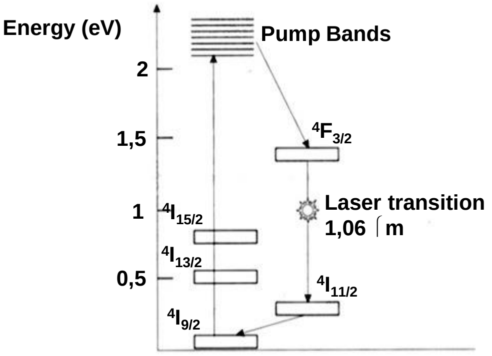
0-6 kW (high)



LASER SYSTEMS FOR INDUSTRIAL APPLICATIONS

Nd:YAG Laser system



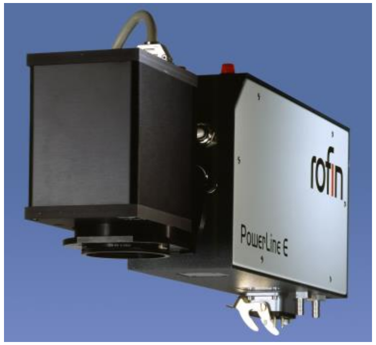


APLICATIONS:

Materials processing (cutting, welding, marking, ...)
Scientific & Measurements (nuclear fusion, environment, ...)
Applications in medicine

Power range:

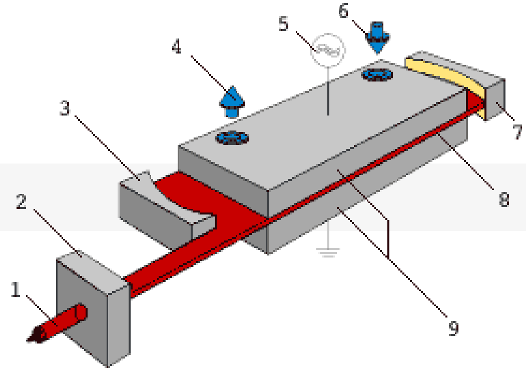
5 W-5 kW



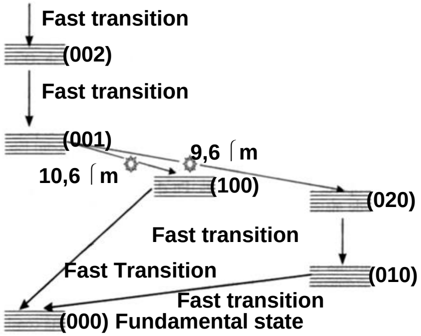
LASER SYSTEMS FOR INDUSTRIAL APPLICATIONS

CO_2 Laser

1. Laser beam
2. Beam modifying unit
3. Exit mirror
4. Cooling water
5. RF excitation
6. Cooling water
7. Back reflecting mirror
8. RF excitation discharge
9. Electrodes



De-excitation from higher energy levels



APLICATIONS:

Materials Processing (cutting, welding, thermal treatment, ...)
Others

Power range:

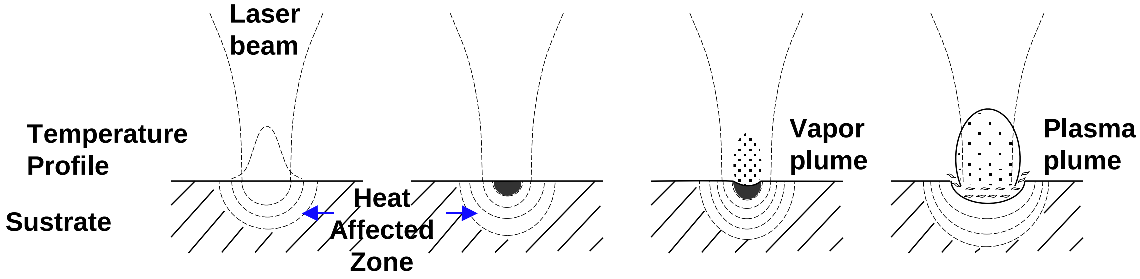
0.1-5 kW SLAB

20 W-20 kW Others

2.- Laser-Material Interaction

LÁSER PARAMETERS → Wavelength, IRRADIANCE → *Photon-electron interaction*

Physico-Chemical mechanisms



Heating **Melting** **Evaporation** **Plasma formation**

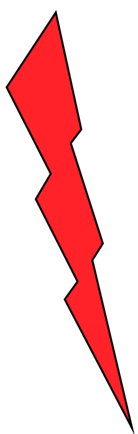
LASER ⟵ LIGHT ⟶ LAMP

8 W, 20 Hz, 5 *n*s, ⌊ =1064 *n*m, 80 MW pulses,

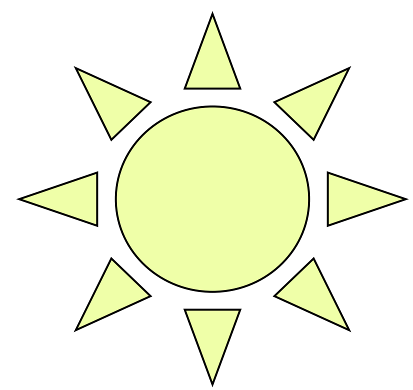
focus 300 μm^2

≈ **2.6x10^{13}** W/cm^2

QTH lamp, 1 kW, cw, ⌊ range <400 to >2500 *n*m, focus 3 cm^2 ≈ **330** W/cm^2



Collimated beam



Noncollimated

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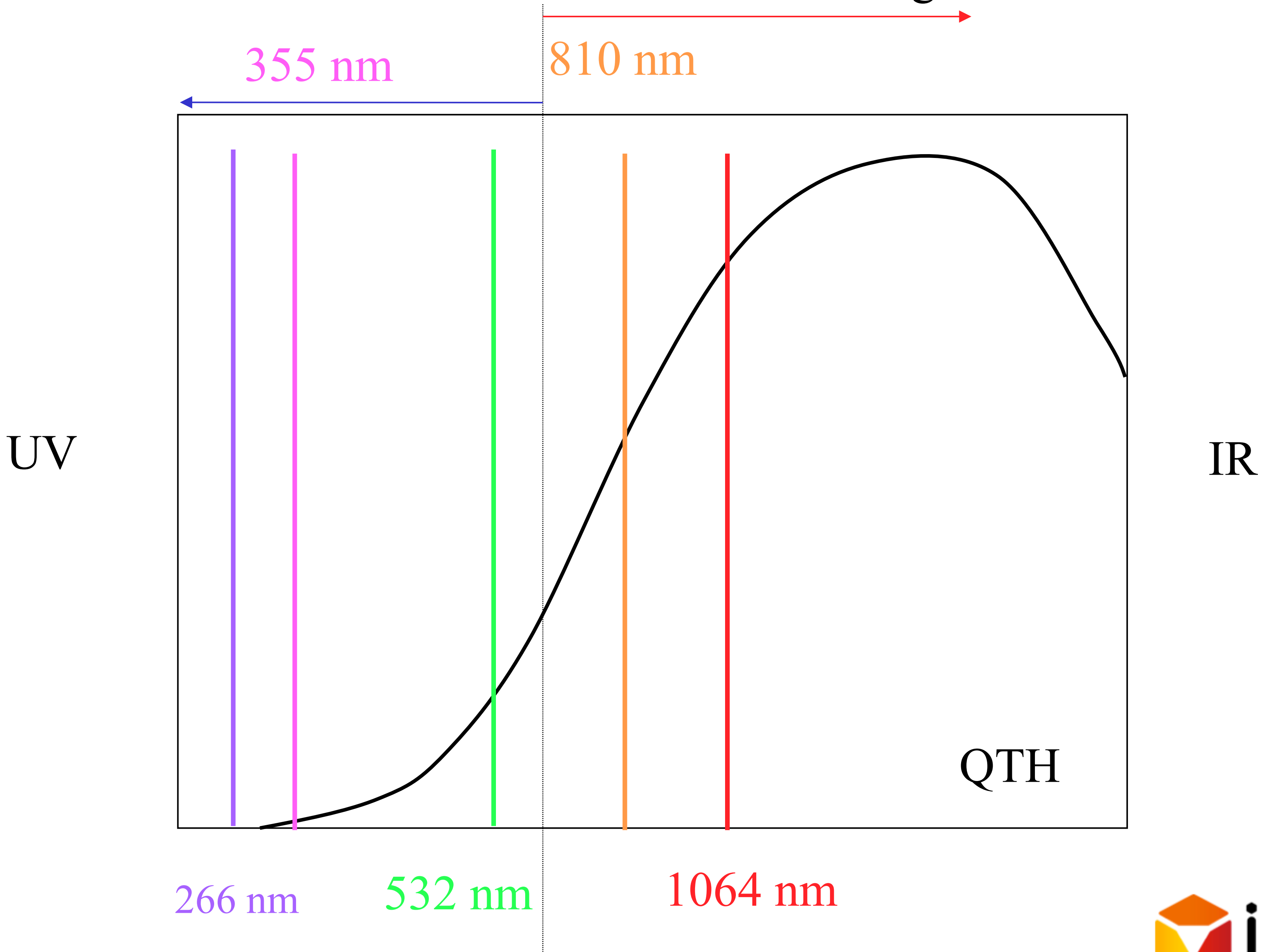
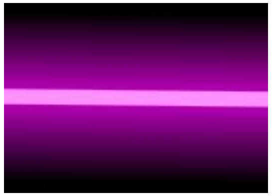
Characteristic Emission of different light sources

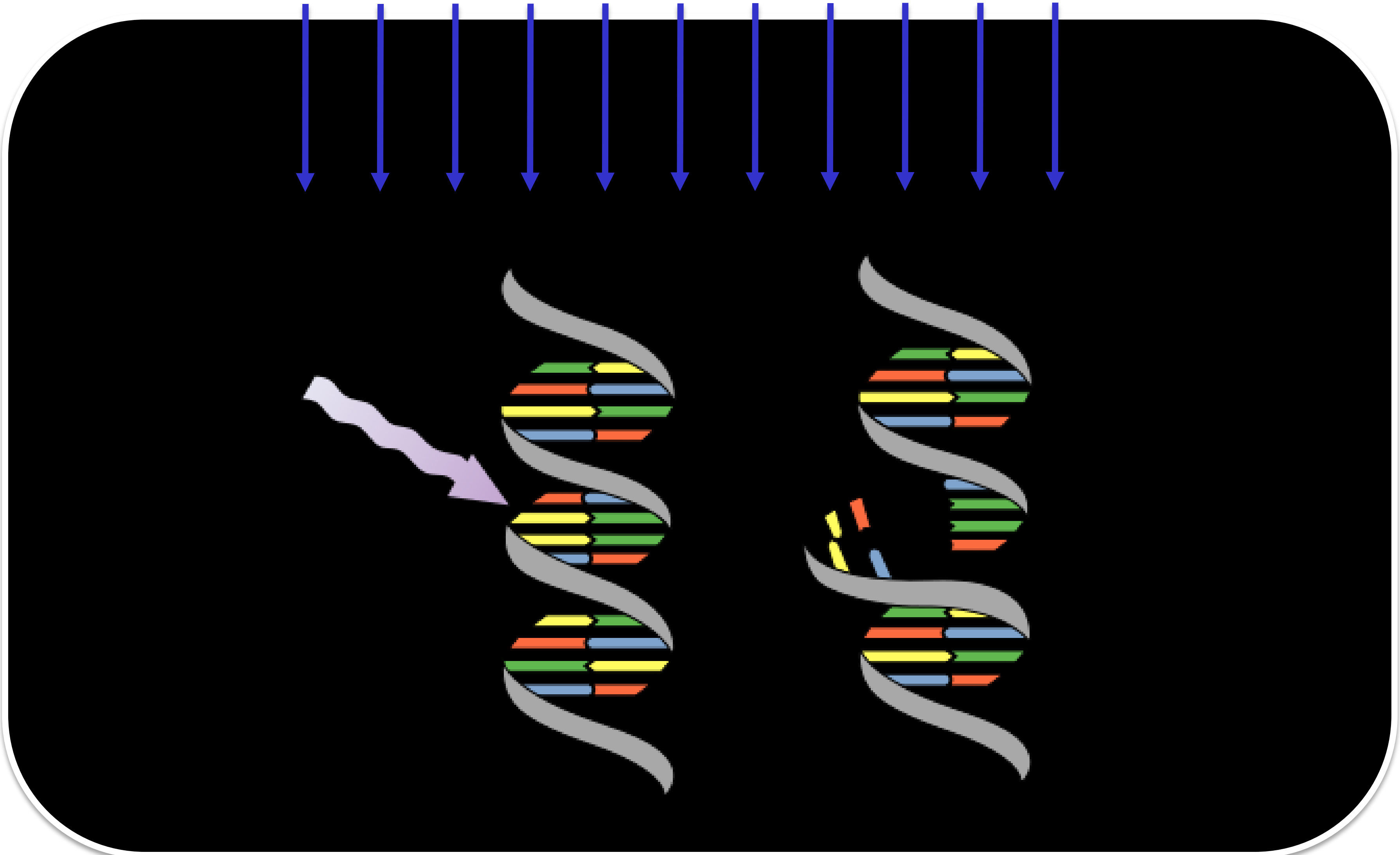


2.- LASER-MATER INTERACTION

ULTRAVIOLET

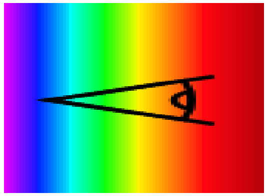


WHAT WE CAN SEE



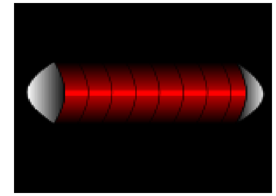
2.- LASER-MATER INTERACTION

VISIBLE

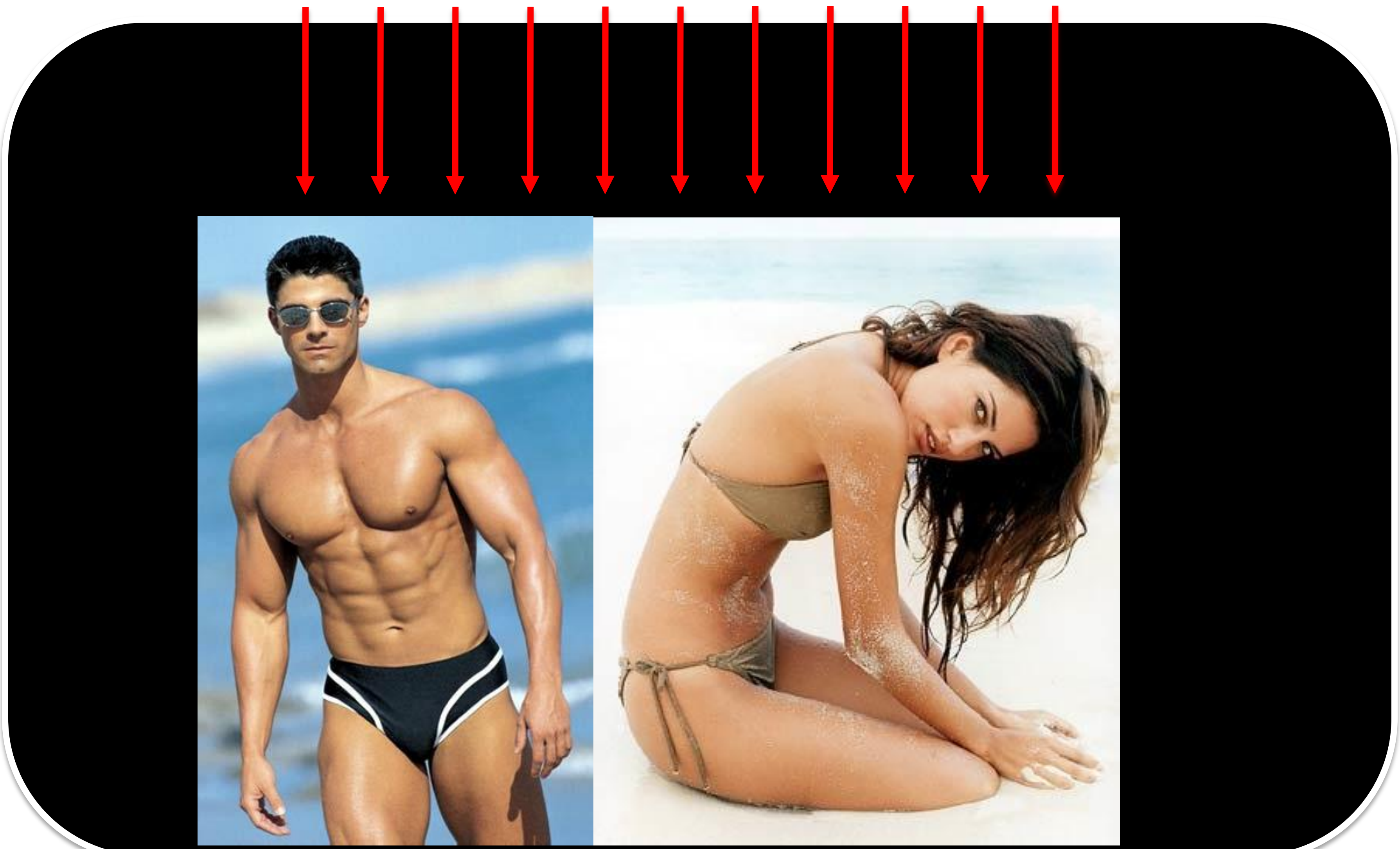


2.- LASER-MATER INTERACTION

INFRARED



WHAT WE CAN SEE



HUMAN SUBJECTS AFTER A PROLONGED *IR* EXPOSURE

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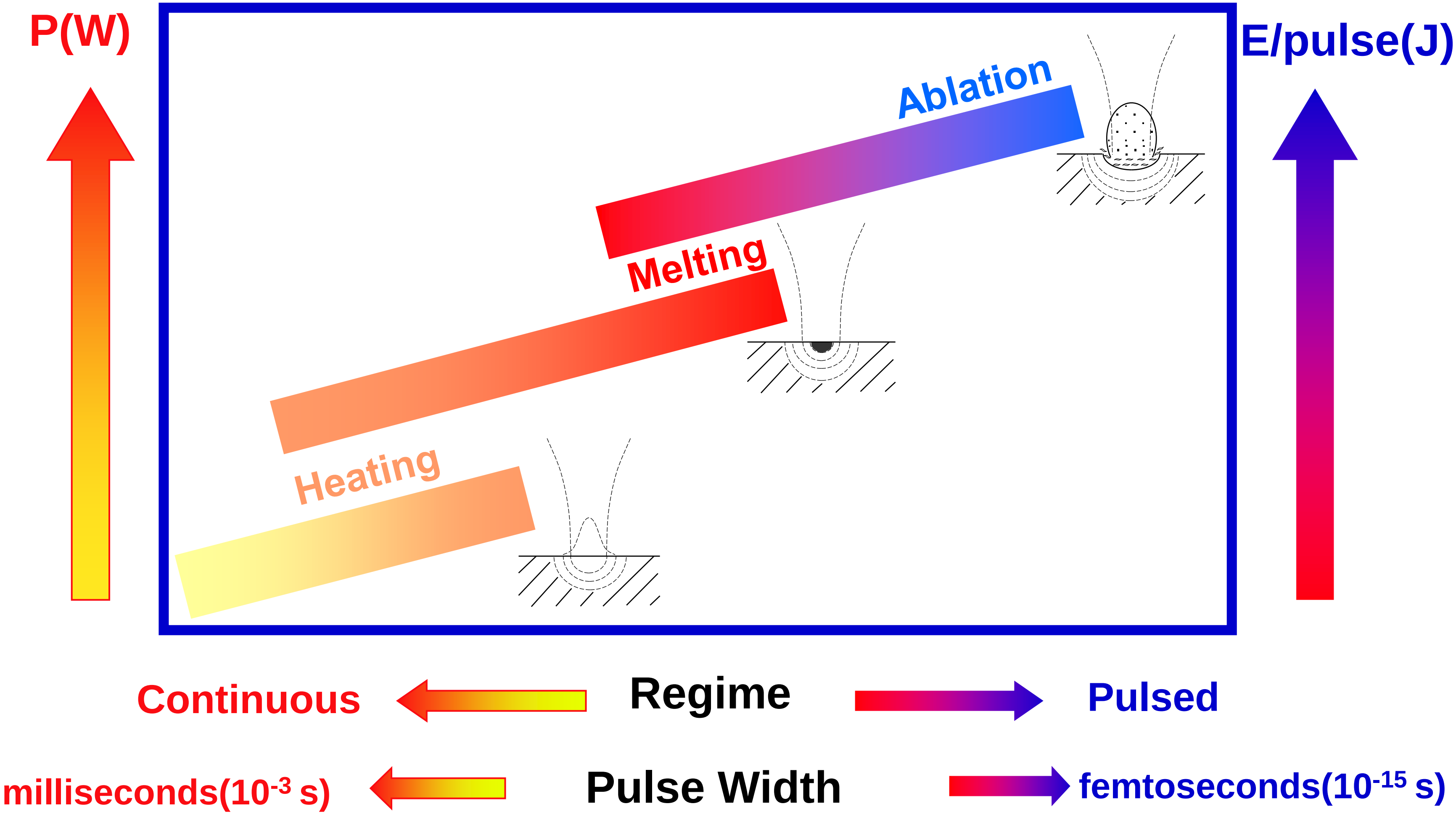
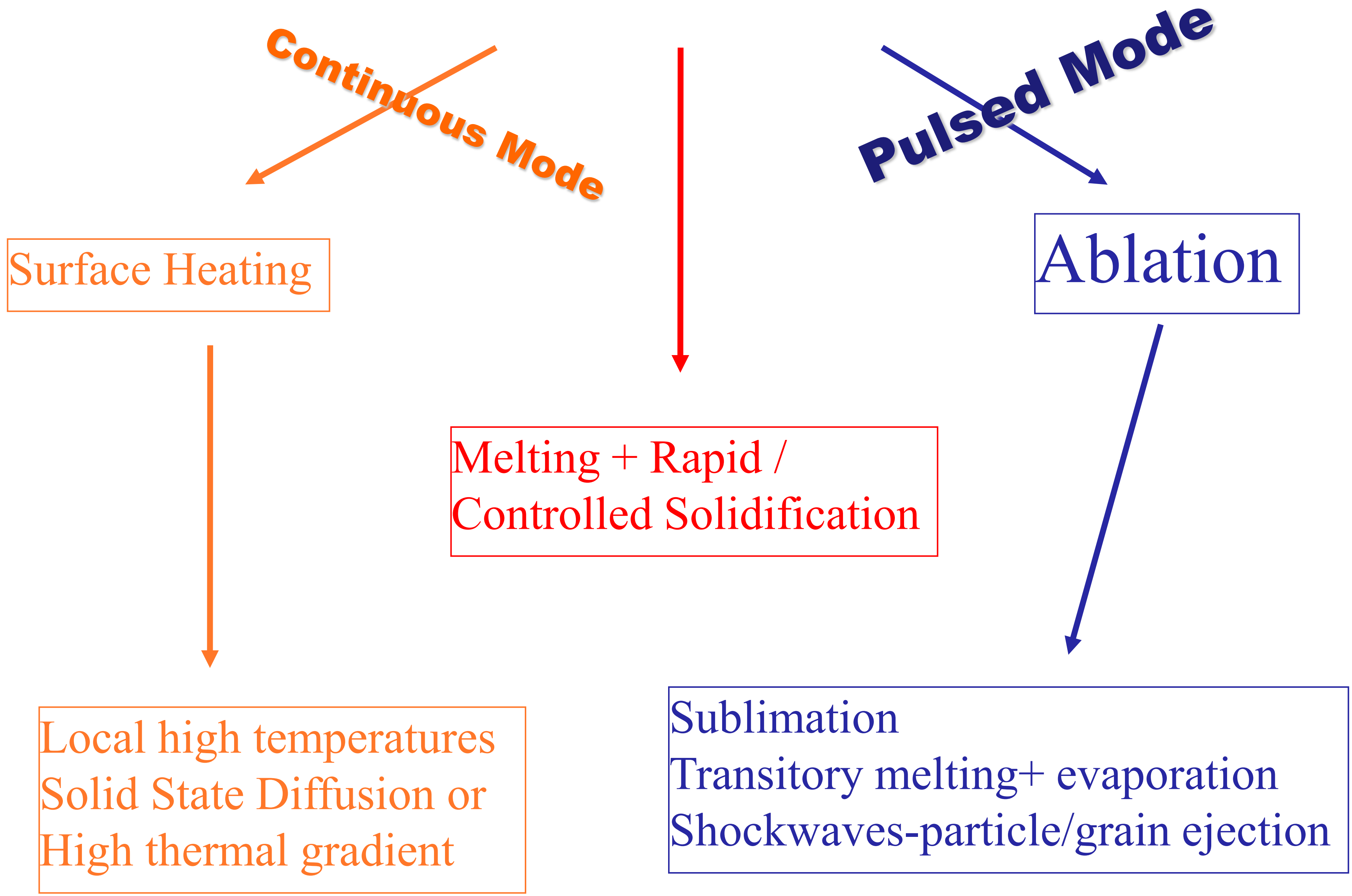
HUMAN SUBJECTS AFTER A PROLONGED *UV* EXPOSURE

2.- LASER-MATER INTERACTION

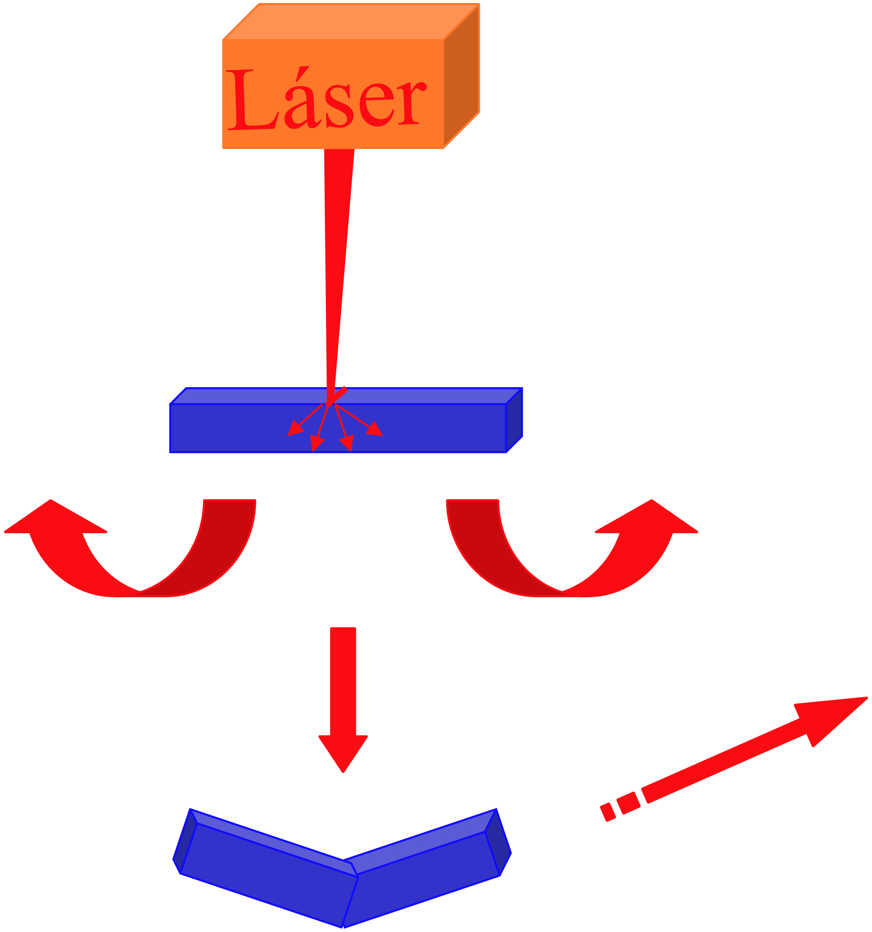
Irradiance

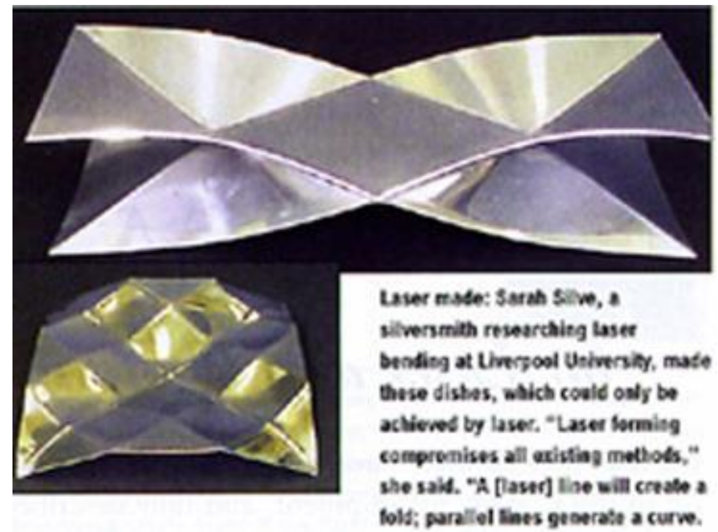


Laser Irradiation



HEATING

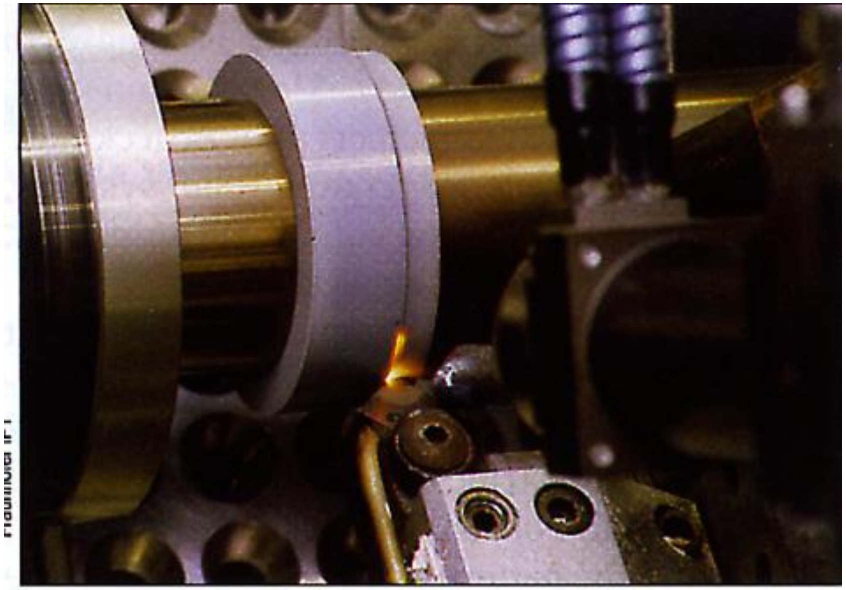




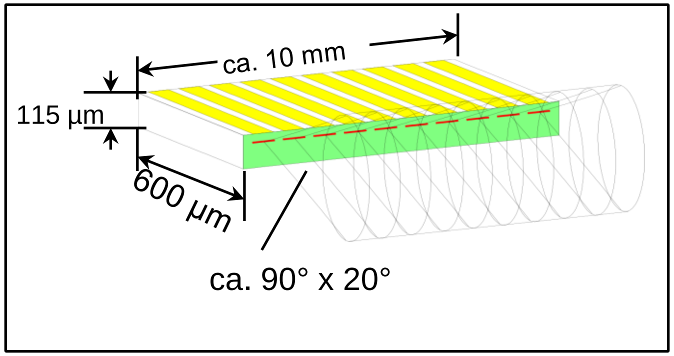
¿IS THERE ATOMIC DIFFUSION?

CERAMIC MACHINING IN PLASTIC REGIME

SiN Ring- no microcracks observed



Laser-assisted turning of a silicon nitride ring.

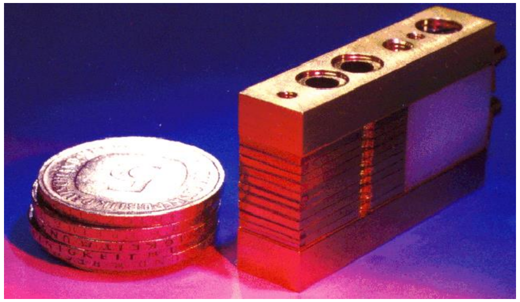


Diode Laser

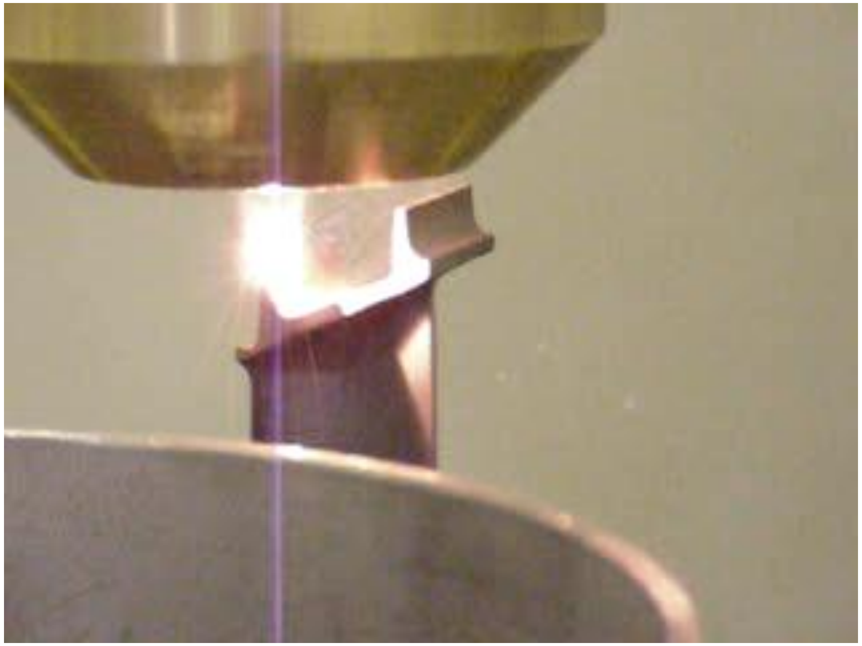
1.2 kW, l=940 nm

1.5 x 5 mm beam

≥ 1000 °C



LASER CLADDING
Material is supplied simultaneously to laser irradiation



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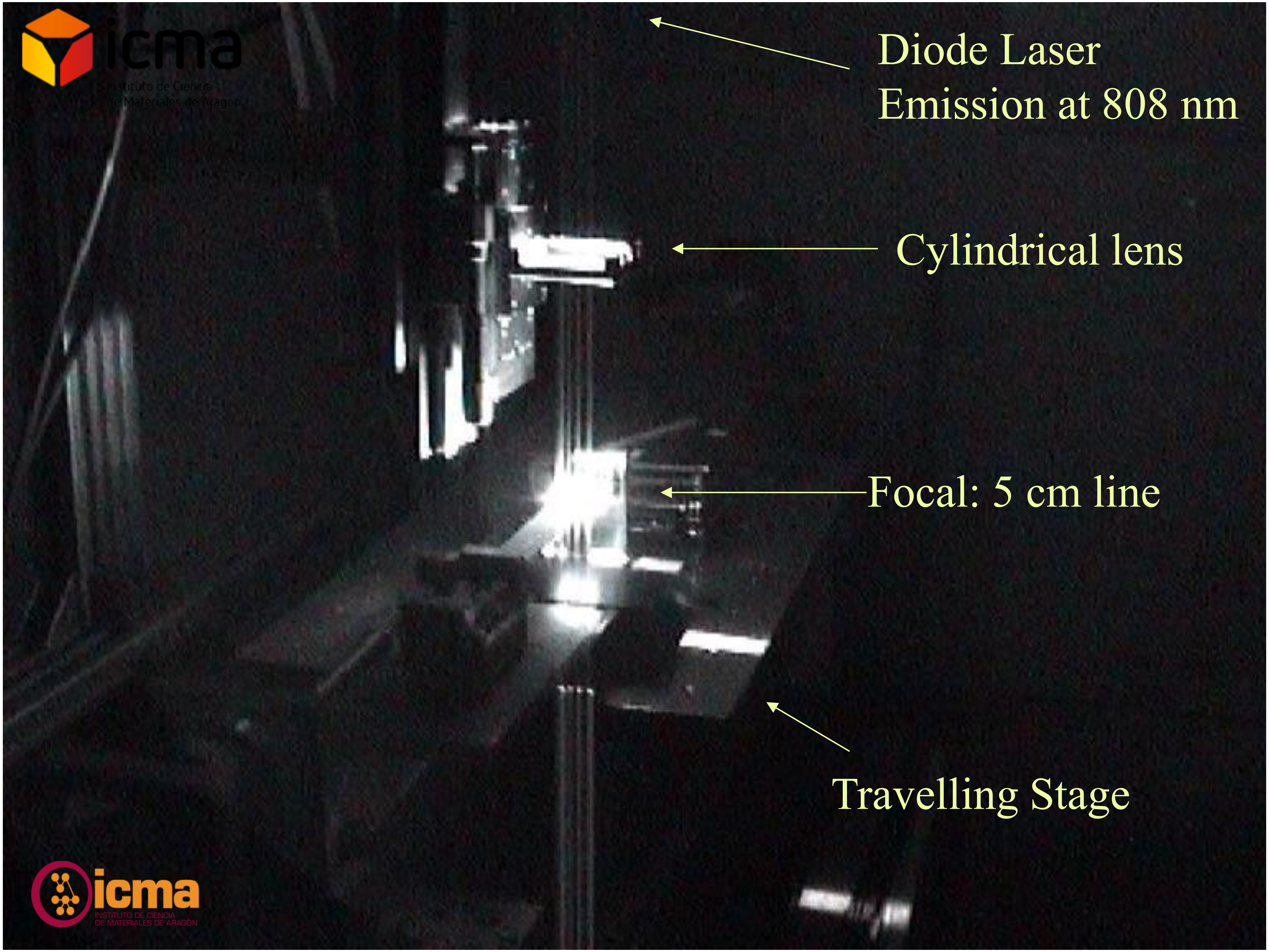
Stainless Steel cutting
Melting + GAS pressure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Diode Laser
Emission at 808 nm
Cylindrical lens
Focal: 5 cm line
Travelling Stage
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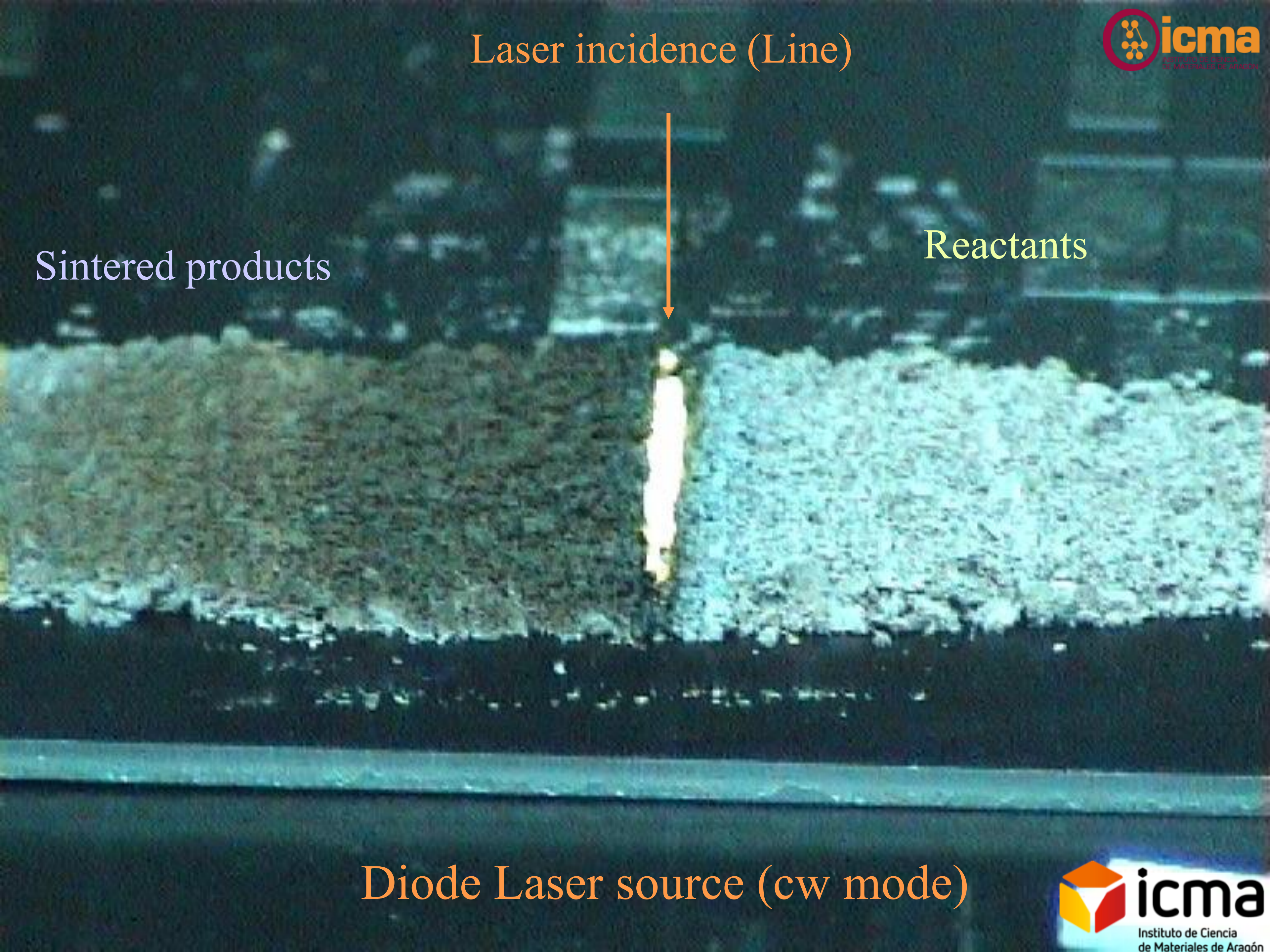
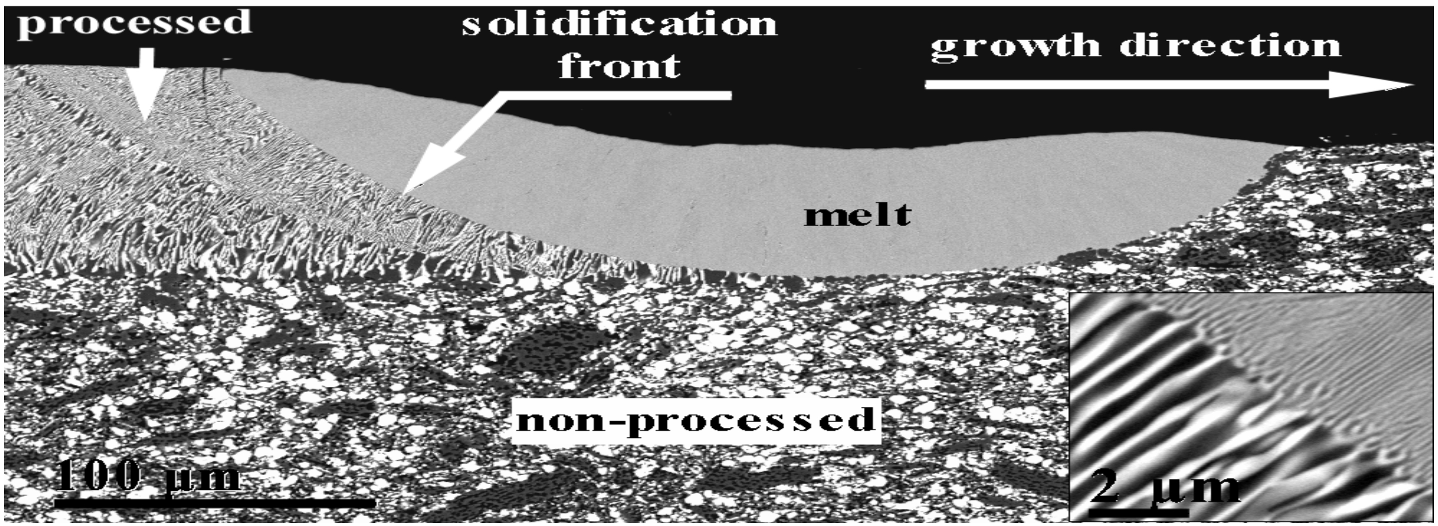
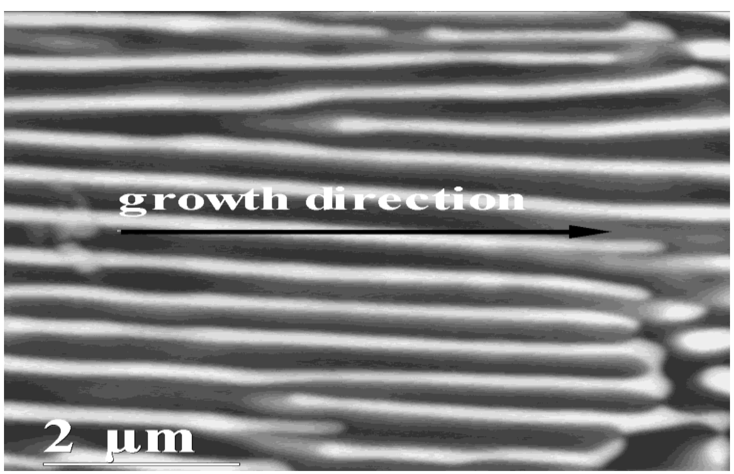

Laser incidence (Line)
Sintered products
Reactants
Diode Laser source (cw mode)

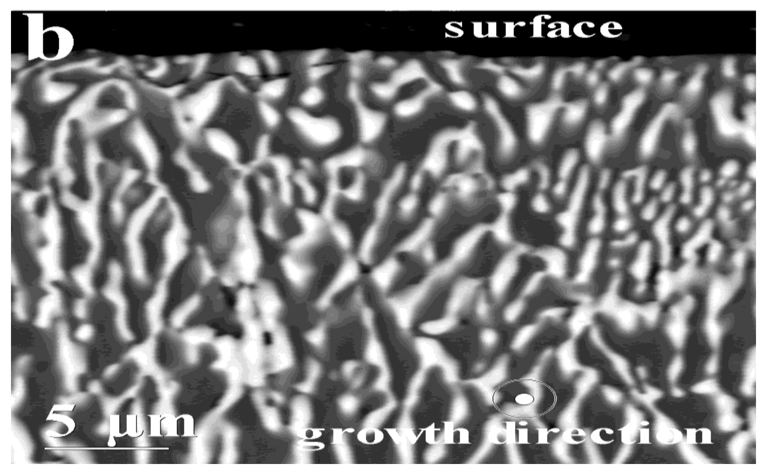
Laser Zone Melting of Al_2O_3-ZrO_2 Eutectics

V=72 mm/h, Al support ⌊ $^{2}R = 0.9 \times 10^{-17}$ m^3/s

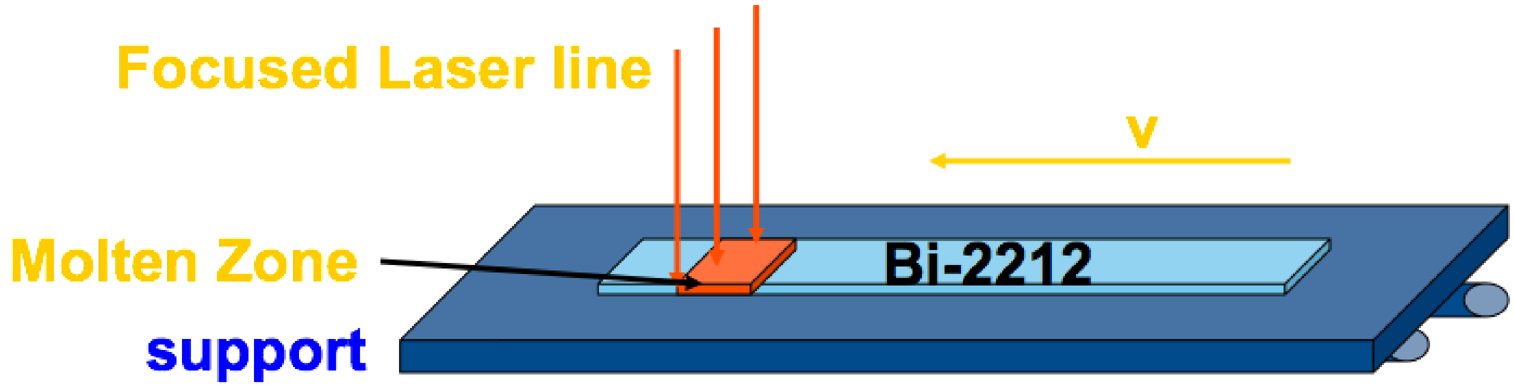
A. Larrea et al, J. Eur. Ceram. Soc. **22** (2002) 191-198.



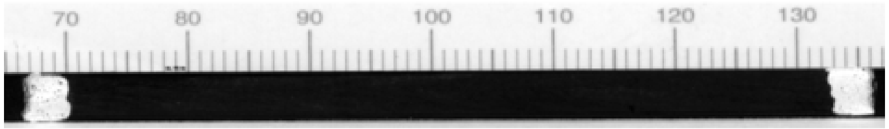




- LASER INDUCED TEXTURE



v ≈ 30-50 mm/h (tipical I_c ≈ 60 A)



Approx. size 100 x 10 x 1 mm^3

- [2] M. Mora, J. C. Diez, C. I. López-Gascón, E. Martínez and G. F. de la Fuente, IEEE Trans. Appl. Supercon. **13** (2003) 3188-3191.

- LASER ZONE MELTING (IN-PLANE)

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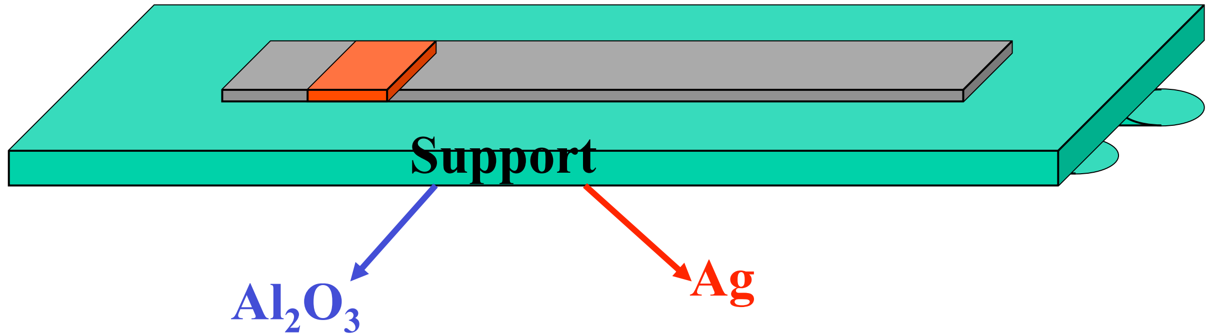

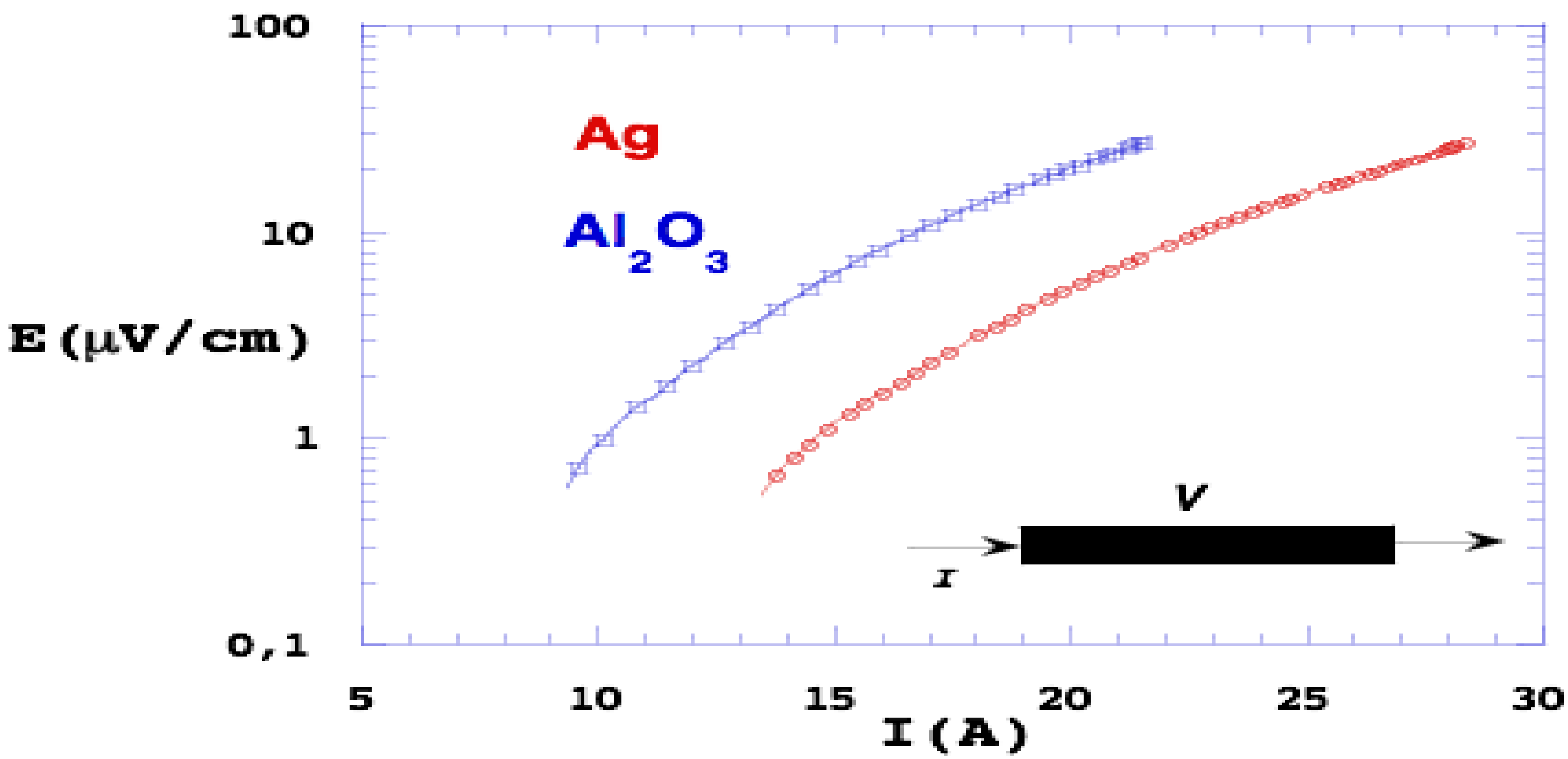

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*Metallic support reduces thermal gradients on the sample

Externally heated support vs. Ic (Critical Current in A)

T (ºC)	Ic (A)	Observations
25ºC	9.6	cracks
145ºC	13.2	cracks
150ºC	14.0	cracks
330ºC	16.0	no cracks
430ºC	27.5	no cracks

⌊ (CO_2) = 10.6 µm; v=36 mm/h

$T_{support}$ ↑ ⟹ Ic ↑

M. Mora, C.I. López Gascón, L.C. Estepa, J.A. Gómez, L.A. Angurel,J.C. Diez, G.F. de la Fuente **Supercond. Sci. Technol. 17 (2004) 1133-1138**

Cutting blown glass with a CO_2 Laser

ADVANTAGE OF LOCALIZED THERMAL STRESS

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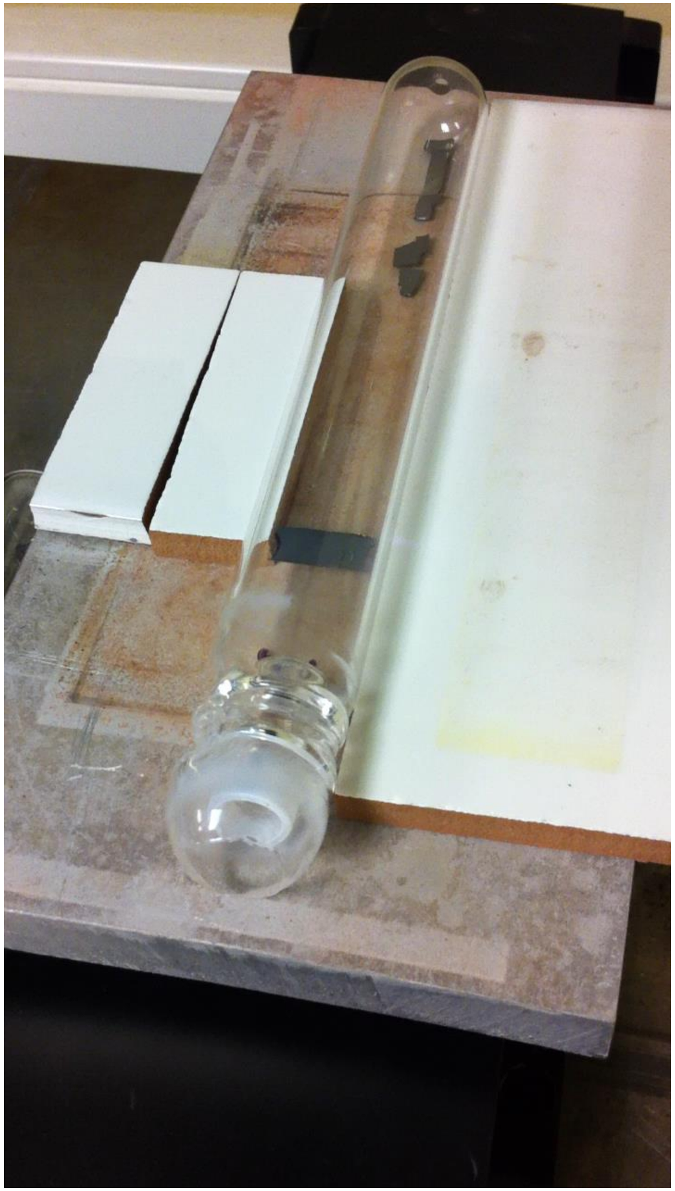
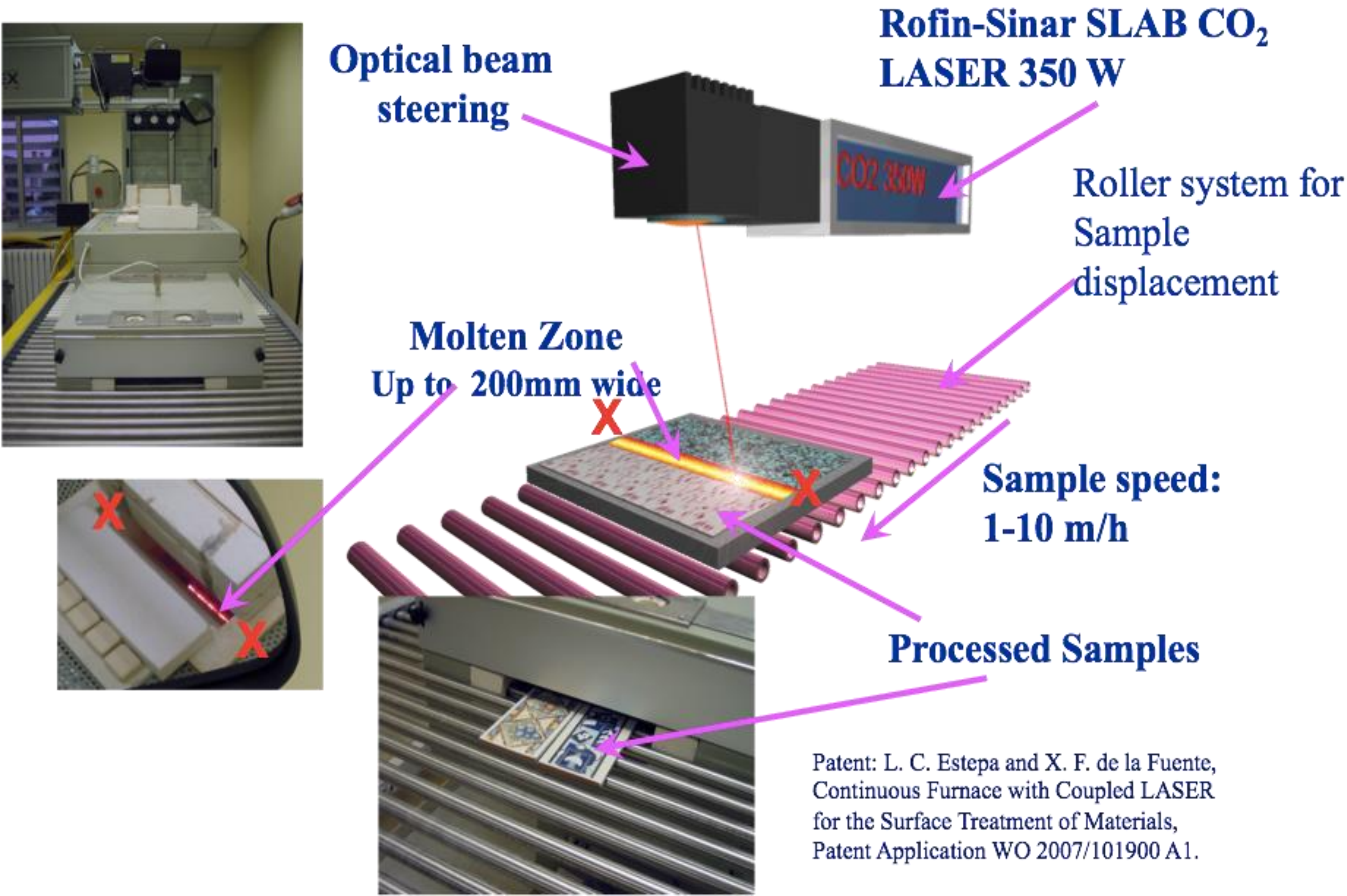
THERMAL STRESS/SHOCK



LASER FURNACE

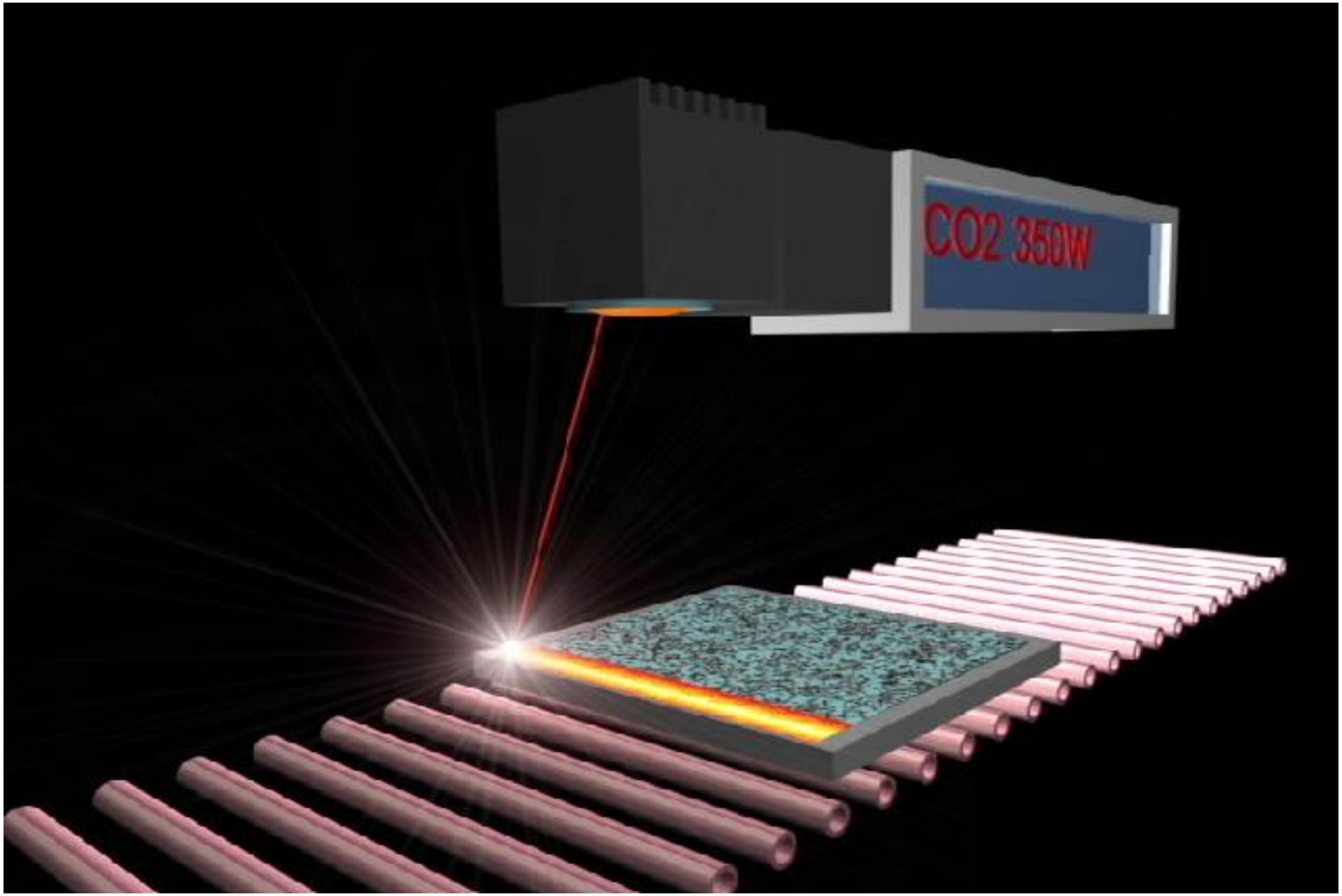


Patent: L. C. Estepa and X. F. de la Fuente, Continuous Furnace with Coupled LASER for the Surface Treatment of Materials, Patent Application WO 2007/101900 A1.

CONTINUOUS LASER FURNACE: THE CONCEPT

SURFACE AT EXTREME TEMPERATURE

SUBSTRATE AT MUCH LOWER TEMPERATURE



LIFE09 ENV/ES/000435

LASER FIRING

LIFE11 ENV/ES/560

CERAMGLASS

I. de Francisco, V. Lennikov, L. A. Angurel, L. C. Estepa, R. Lahoz, G. F. de la Fuente

ICMA (Materials Science Institute of Aragón) CSIC-University of Zaragoza, Zaragoza.

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CSIC

Universidad Zaragoza

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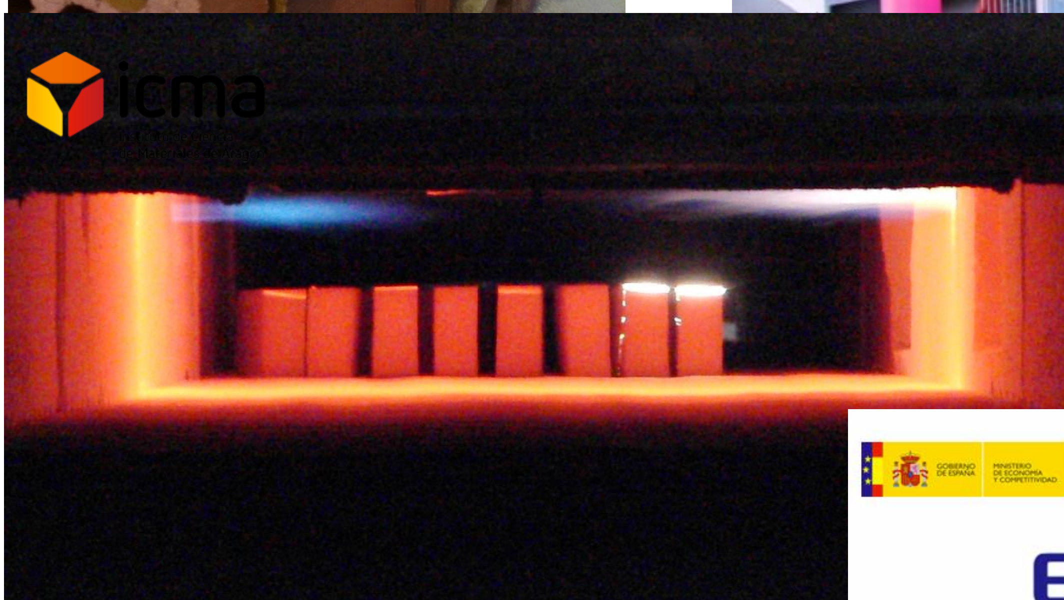
LASER APPLICATIONS LABORATORY



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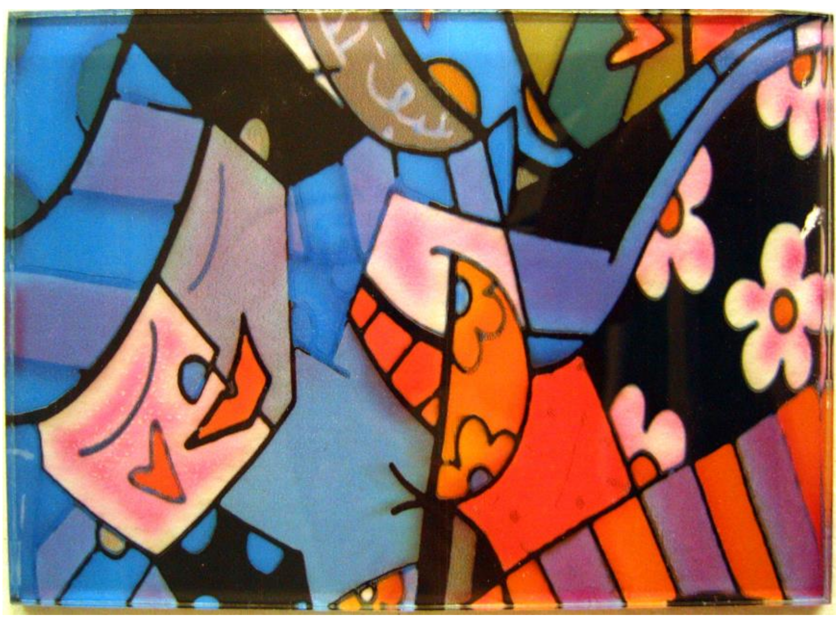
Aitemin
Centro Tecnológico

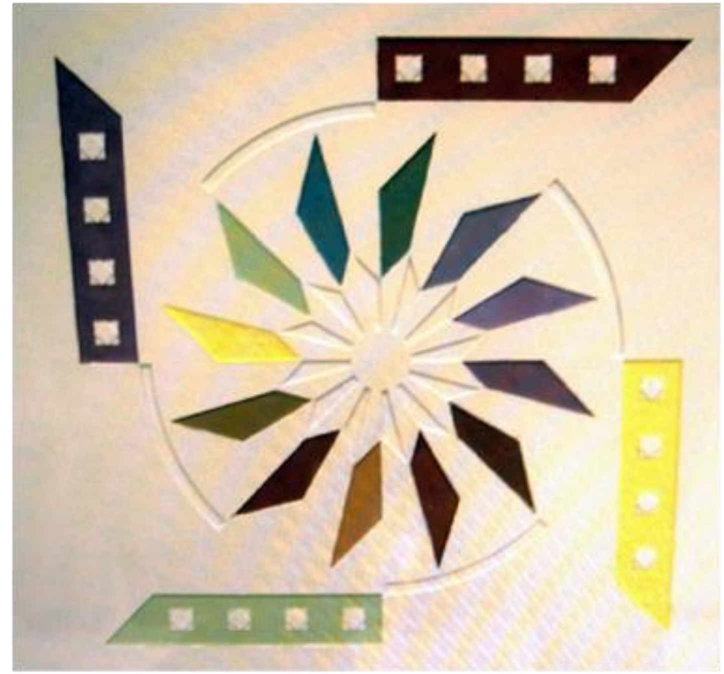
easy LASER

physicgm

Novelty: Laser processed glass/TORRECID



SURFACE ABLATION STRUCTURING AND IN-SITU PIGMENT DEVELOPMENT



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THE LASER FURNACE

- LONG PULSE & CW MODE LASERS + HEAT (Laser Furnace)...MAY ALLOW TO...
- SURPASS THE INTRINSIC PROCESSING LIMITS OF KNOWN MATERIALS:
  - GLASS > 1500 ºC
  - CERAMICS > 2950 ºC
- DEVELOP NOVEL INDUSTRIAL MATERIALS TRANSFORMATION & FABRICATION PROCESSES

ABLATION

Laser Ablation Process

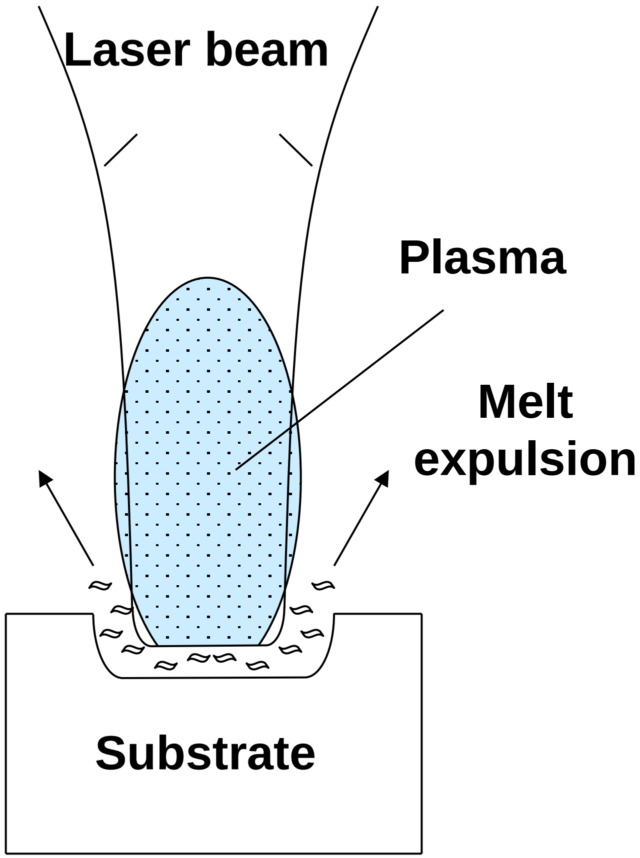
Combination of phenomena:

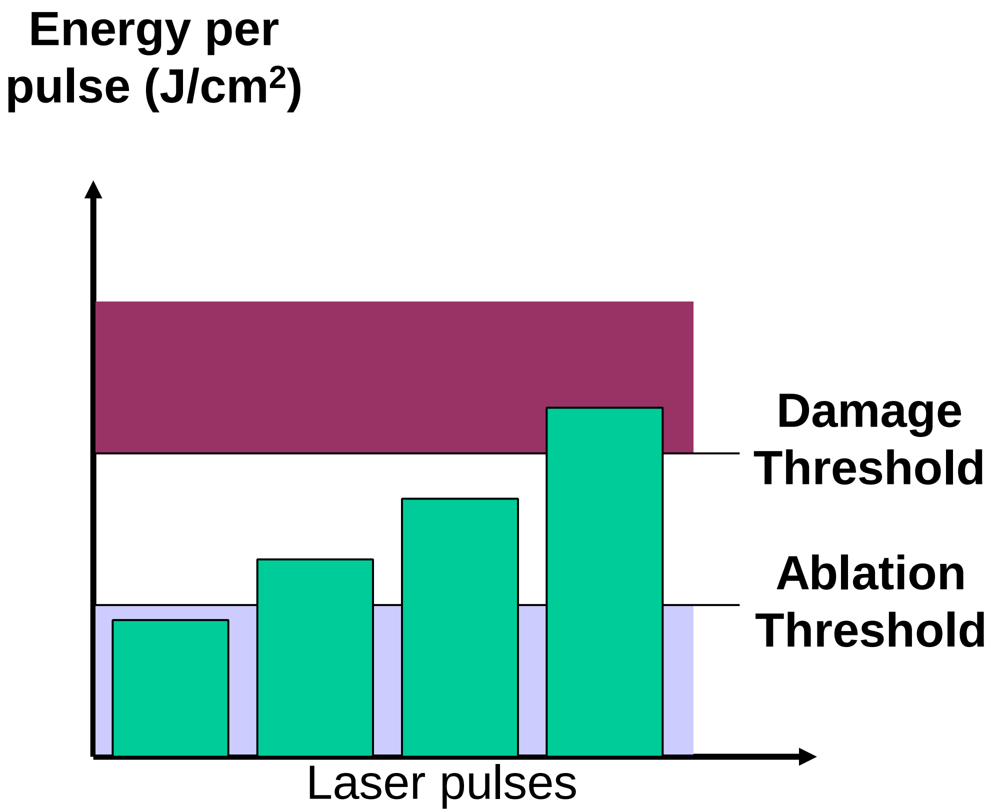
Melting + Evaporation

Direct Sublimation

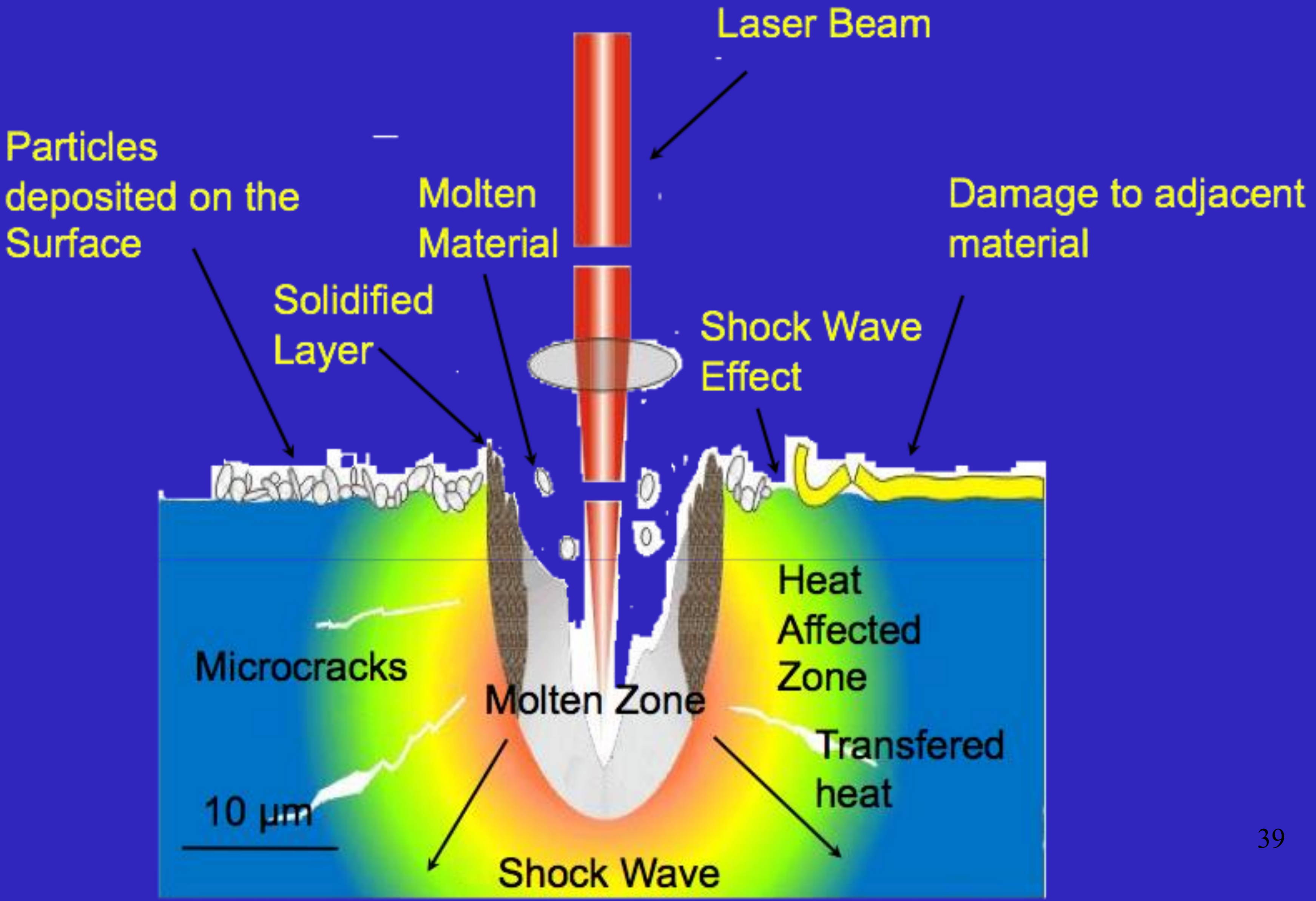
Shock Waves

Particle & melt drop ejection

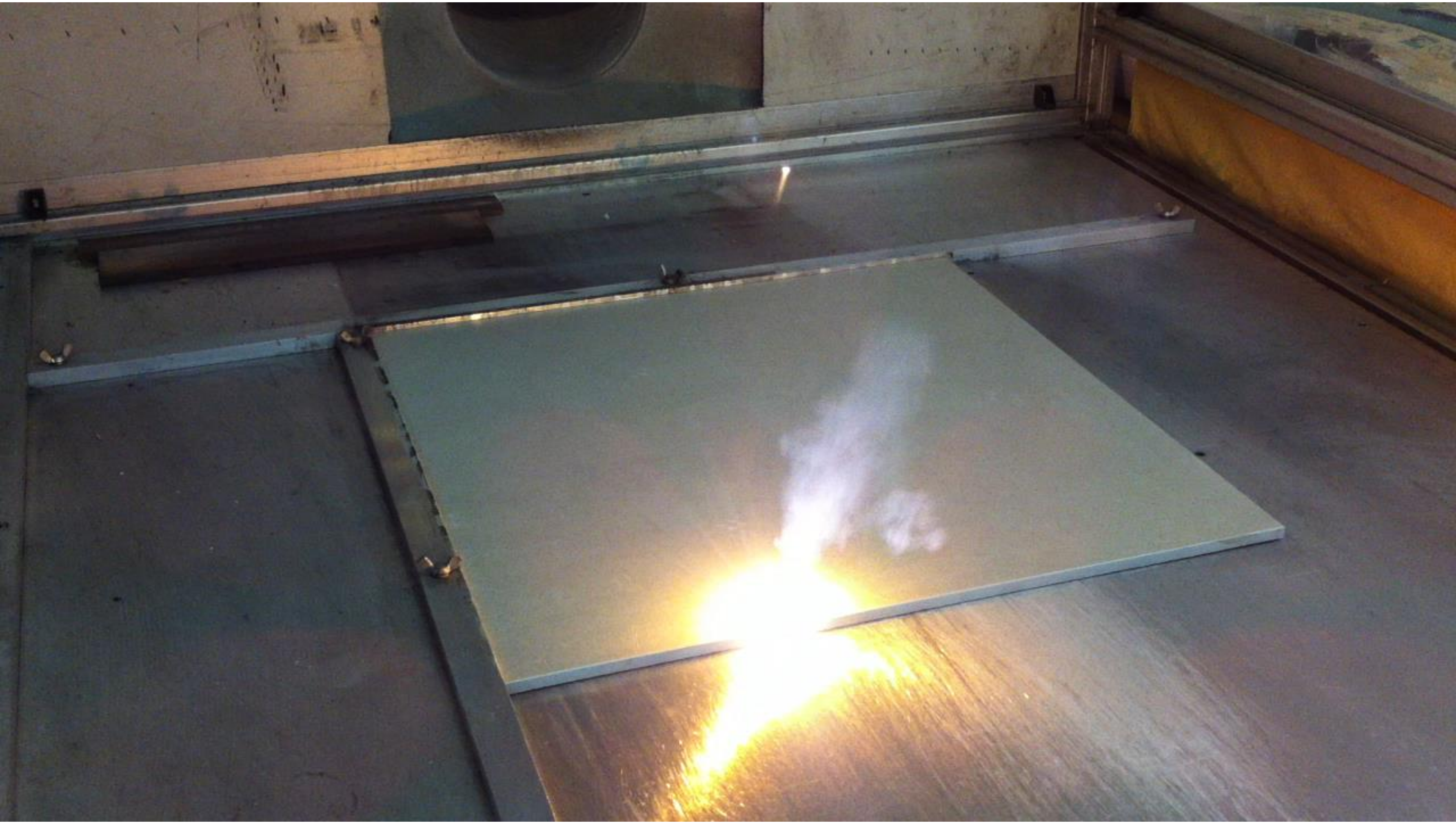




LASER ABLATION



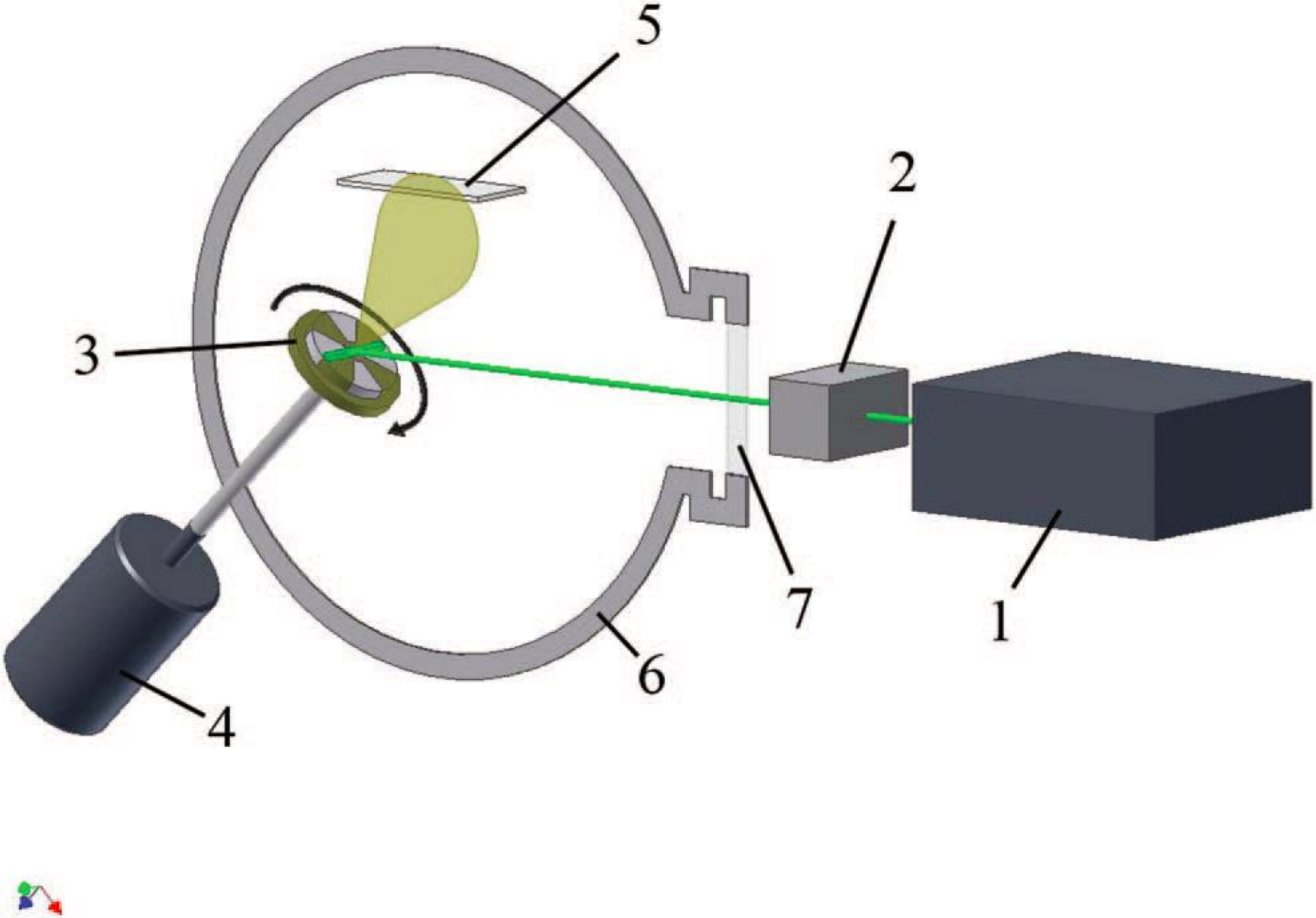
SURFACE ABLATION STRUCTURING COMBINED WITH PVD



SURFACE ABLATION STRUCTURING COMBINED WITH PVD

SURFACE ABLATION STRUCTURING COMBINED WITH PVD

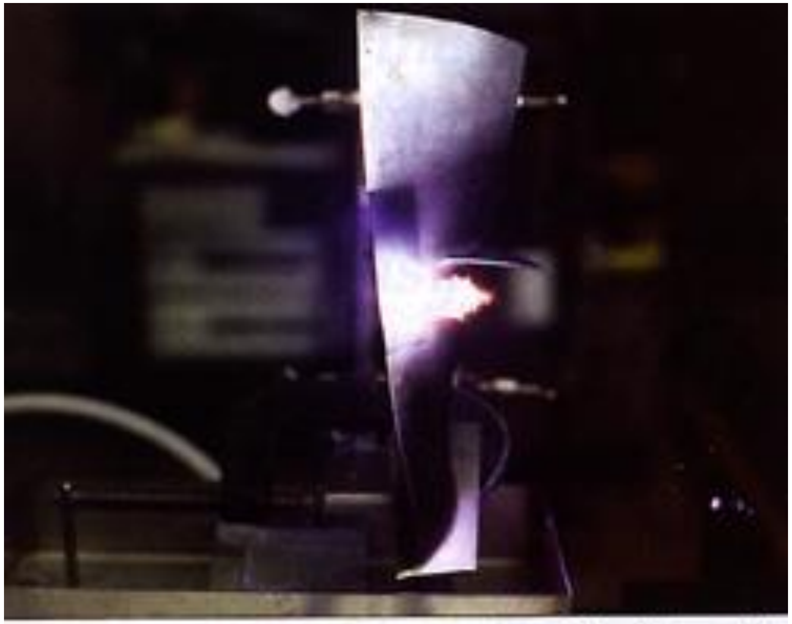
PLD-CLD



3D image inside a thick glass block
532 nm Laser, ns or ps pulses
Ablation at the focal spot

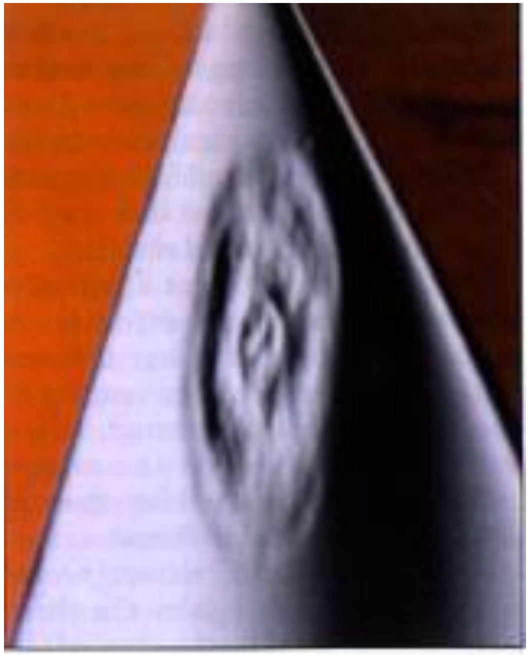
Laser Surface treatment of a fan blade (Laser Pinning)

Nd:Glass Laser, 100 J pulses at 6 Hz



Lawrence Livermore's 100 J pulse laser treating a GE fan blade at 6 Hz.

Effect of a single pulse on Al



A single laser impact on an aluminium sample.

STENT FABRICATION

rofin

FOCUS ON FINE SOLUTIONS

BAASEL LASERTECH

Mixed Processes

MELTING + EVAPORATION
in cw mode

Ablation in pulsed mode

ALSO

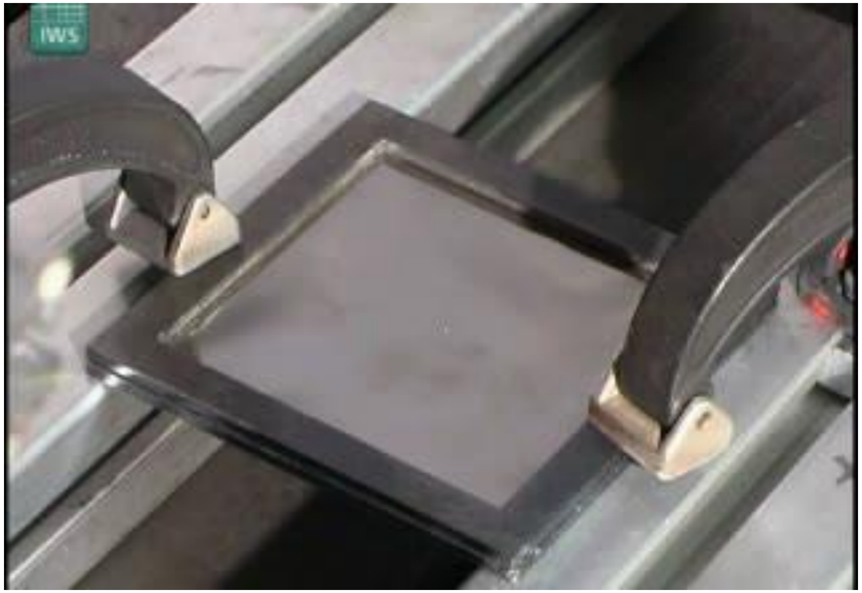
Photochemical or Photothermal Processes

POLYMER BOX MARKING

ON-LINE COMPUTER KEYBOARD MARKING

POLYMER + PHOTOSENSITIVE ADDITIVE

Stainless Steel Perforation



PAINT DESORPTION OVER ALUMINIUM ALLOY

EVEN ON THE RUN…

SURFACE DESORPTION OF OXIDE LAYER ON STEEL

L. C. ESTEPA, V. LENNIKOV, R. LAHOZ, I. DE FRANCISCO, L. A. ANGUREL, C. LÓPEZ-GASCÓN, J. C. DIEZ (ICMA)
J. CARDA, J. M. PEDRA (UJI)
C. GÓMEZ-REINO, C. BAO, M. T. FLORES, F. REY-GARCÍA (USC)
A. R. GONZÁLEZ-ELIPE, J. P. ESPINÓS, V. RICO (ICMSE)

THANK YOU!