



# Introduction au Microusinage par laser

Optec S.A.

A.Biernaux

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## CONTENU

- Introduction Optec
- Objectif de la présentation
- Généralités sur le laser
- Traitement des matériaux par laser
- Tendances du marché
- Point de vue d'un intégrateur
- Quelques ex de machines

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**Micro Usinage par laser Excimer et laser Ultra Rapide pour les domaines du semiconducteur, électronique, optronique, médical et marquage de sécurité :-**

- Excimer & lasers Ultra Rapides
- Centre d'usinage laser standard
- Solutions spécifiques
- Sous ensembles opto-mécaniques
- Expertise Process
- SAV

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Quelques exemples de systèmes

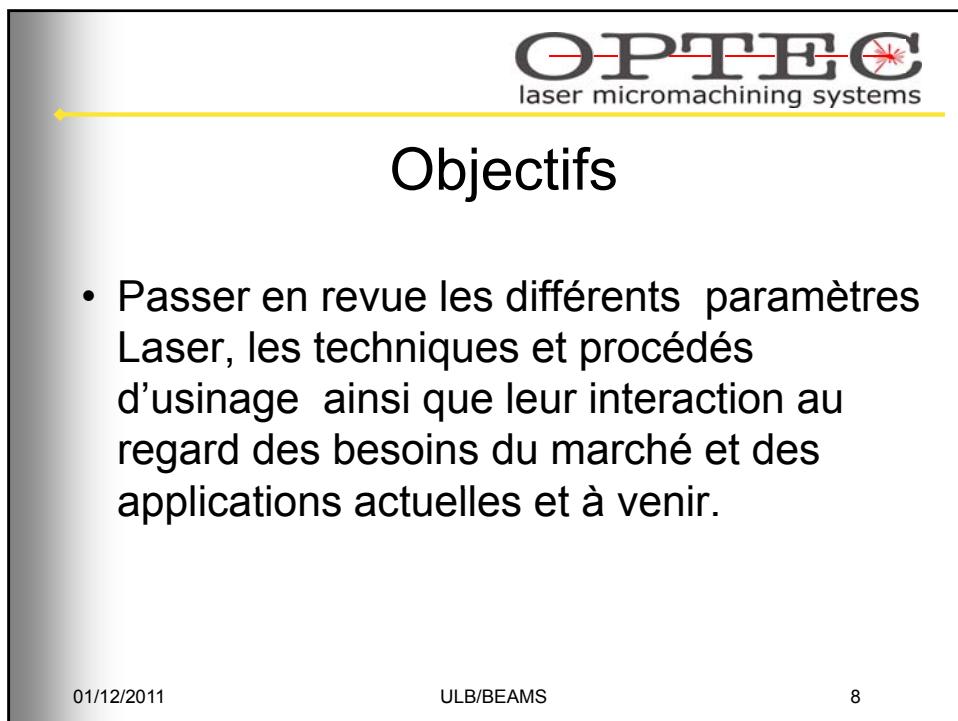
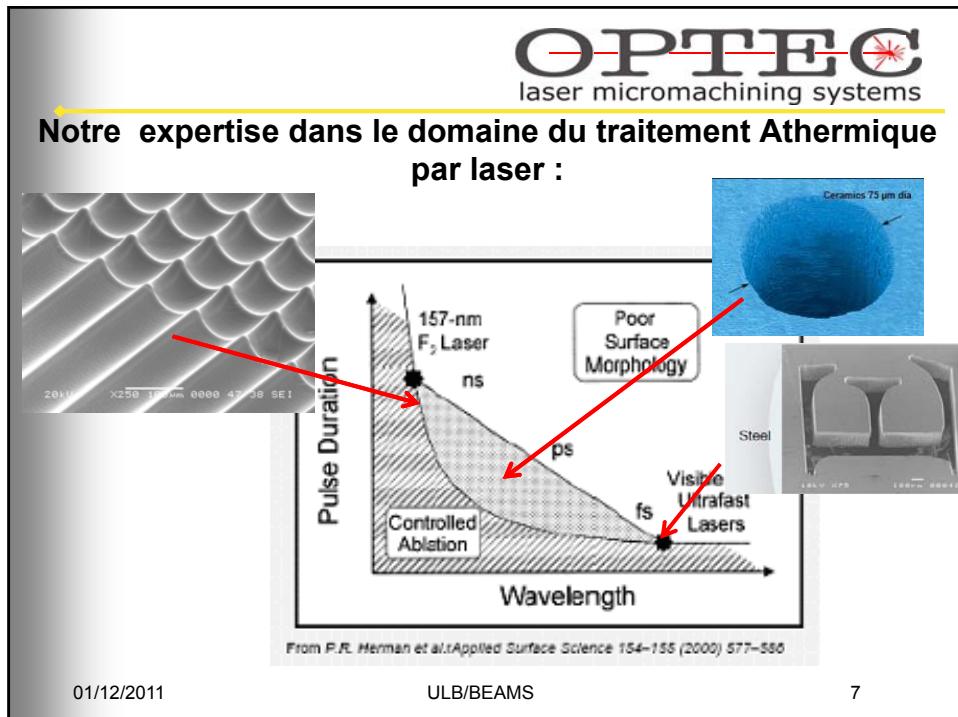
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**Notre expertise dans le domaine du traitement  
Athermique par laser :**

Nous intégrons des sources lasers avec des durées d'impulsions comprises entre fs-ns, des longueurs d'ondes situées dans le spectre UV-IR, en combinaison avec des techniques de projection ou d'usinage au point focal.

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## Un peu d'histoire...

The diagram illustrates the historical timeline of laser development across four eras:

- Classical Physics Era:** Key figures include Maxwell, Planck, Einstein, and Bohr.
- Quantum Physics Pre-Laser Era:** Key figures include Laue, Compton, and Davisson.
- Maser Era:** Key figures include Bloch, Purcell, and Townes.
- Laser Era:** Key figures include Schawlow, Prokhorov, and Townes.

Annotations provide context for the historical context of each era:

- Classical Physics Era:** "The theoretical foundation for the laser can be traced back over 100 years."
- Quantum Physics Pre-Laser Era:** "Europe was the epicenter of this extraordinary scientific revolution until the events surrounding World War II disrupted this remarkably productive period in physics. Many leading Western European scientists involved in quantum mechanics fled to the US during the war, and were welcomed by the US government to continue their research. After the war the US offered unparalleled resources supporting scientific research and innovation: intact and well-funded university, government and industry enterprises, as well as a free-market economy which rewarded entrepreneurship."
- Maser Era:** "This dynamic research environment in the US created the perfect setting for the invention of the laser."
- Laser Era:** "Paul Ballesteros and Thomas Baer"

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## Le laser ce n'est pas...

**FROM OUT OF SPACE....  
A WARNING AND AN ULLIMATUM!**

**THE DAY THE EARTH STOOD STILL**

**MICHAEL RENNIE · PATRICIA NEAL · HUGH MARLOWE**

**STAR WARS - EPISODE V: THE EMPIRE STRIKES BACK**

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Mais c'est aussi...

Un rayon lumineux

Pointeur laser



Spectacle

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Le laser c'est...

Dans l'industrie

Découpe de plaques, tubes, pièces métalliques ...

Laser à CO<sub>2</sub>



... et aussi de bois, de tissu,  
de plastique



Le laser est un outil universel

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## Le laser c'est...

### Dans l'industrie (suite)

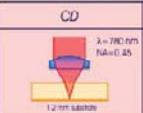
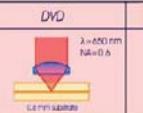
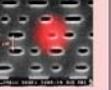
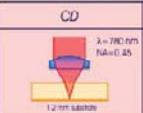
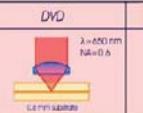
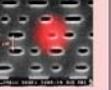
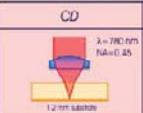
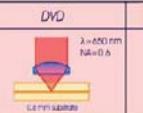
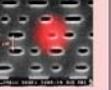
<b>Perçage</b> Laser YAG ou CO <sub>2</sub>  Trous de 10 µm dans un film en polymères	 <b>Usinage</b> Supports en céramique pour microélectronique
 <b>Soudage</b> Petites pièces mécaniques	 <b>Soudage</b> Réservoir de carburant pour fusée

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## Le laser c'est...

### Pour stocker l'information et la lire

 <b>Lecture de code-barres</b> Lasers à semiconducteurs	<b>CD et DVD</b> 	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 2px;">CD</th> <th style="text-align: center; padding: 2px;">DVD</th> <th style="text-align: center; padding: 2px;">Blu-ray Disc</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 2px;">   <math>\lambda = 780 \text{ nm}</math>  <math>N.A. = 0.45</math>            1.2 mm substrate         </td> <td style="text-align: center; padding: 2px;">   <math>\lambda = 650 \text{ nm}</math>  <math>N.A. = 0.6</math>            0.6 mm substrate         </td> <td style="text-align: center; padding: 2px;">   <math>\lambda = 405 \text{ nm}</math>  <math>N.A. = 0.85</math>            0.1 mm substrate         </td> </tr> <tr> <td style="text-align: center; padding: 2px;">  </td> <td style="text-align: center; padding: 2px;">  </td> <td style="text-align: center; padding: 2px;">  </td> </tr> </tbody> </table>	CD	DVD	Blu-ray Disc	 $\lambda = 780 \text{ nm}$ $N.A. = 0.45$ 1.2 mm substrate	 $\lambda = 650 \text{ nm}$ $N.A. = 0.6$ 0.6 mm substrate	 $\lambda = 405 \text{ nm}$ $N.A. = 0.85$ 0.1 mm substrate			
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## Le laser c'est...

### Pour transporter l'information



Le réseau mondial sous-marin de câbles de fibres optiques



On peut coupler les lasers avec des fibres optiques qui guident la lumière pendant des milliers de km

Les pertes à grande distance sont plus faibles que celles qu'on a pour un signal électrique dans un conducteur métallique



80% des communications à longue distance dans le monde le sont grâce au réseau de fibres optiques

Le multiplexage (superposition de signaux de différentes fréquences) permet d'avoir jusqu'à 256 canaux par fibre et d'augmenter le débit

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## Le laser c'est...

### Au bureau ou à la maison

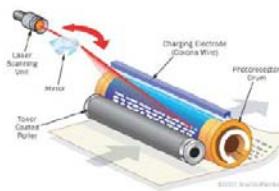
#### Imprimante laser



Le toner se colle au tambour au niveau du spot laser

Il est ensuite déposé sur la feuille de papier

Grâce au laser, vitesse et la résolution sont meilleures qu'avec un jet d'encre



Particule de toner

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## Le laser c'est...

### Dans le bâtiment (suite)

Nettoyage de la pierre des monuments et des sculptures : sans eau, sans produit chimique, sans abrasif, sans pression

Laser YAG pulsé

Restauration du Musée national du Moyen Age

Centre de recherche et de restauration des musées de France

Façade de la cathédrale Notre Dame de Paris

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## Le laser c'est...

### Le laser Mégajoule

En construction par le CEA au CESTA près de Bordeaux, il sera avec le NIF à Livermore le laser le plus énergétique au monde

La cible : une microbille au centre d'une chambre d'expérience de 10 m de diamètre

Un hall de 320 m de long (40 000 m<sup>2</sup>) maquette

240 faisceaux synchronisés entre eux, durée de l'impulsion 20 ns, YAG 1053 nm amplifiés puis triplés en fréquence → UV  
L'énergie produite à chaque impulsion sera de 1,8 MJ focalisée sur moins de 1mm<sup>2</sup>

Puissance crête 550 TW

Fonctionnement prévu en 2014

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## Mais le Laser c'est aussi...

### Mesurer des distances ou des vitesses

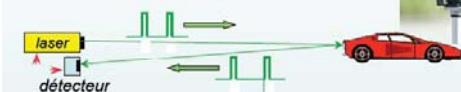


Télémètre laser

Laser en impulsions

Mesure de distance : temps mis par la lumière pour faire un aller-retour

en plus des radars, les "jumelles laser"



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## Et aussi...



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## Et Malheureusement aussi...

Rue89  
La guerre au laser, c'est pour bientôt  
Par Fabrice Verdier | Journaliste scientifique, Rue89 Paris | 11 MAI 2009 | 11:18  
Partager: [Twitter](#) [Facebook](#) [Digg](#) [Email](#)

Depuis lors après son inventeur, le laser semble bien prêt à faire son entrée dans les armées. Un progrès ?

Illustration fausse par Boeing de

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## Une grande variété de lasers...

**Une grande variété de réalisations et de propriétés**

- **Géométries et dimensions**

100 microlasers à semiconducteur

- **Puissances**

du microwatt au pétawatt ( $1\text{PW} = 10^{15}$  watts)

- **Continus ou pulsés**

Des impulsions de plus en plus courtes :
 

- fonctionnement relaxé (le premier laser)
- fonctionnement déclenché (Q-switch, 1961)
- blocage de modes

Impulsions femtosecondes ( $1\text{fs} = 10^{-15}$  s)

$\lambda = 600 \text{ nm}$   
 $v = 500 \text{ THz}$   
 $T = 2 \text{ fs}$

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Le laser, quelques données commerciales...

**Worldwide commercial laser revenues**

Year	Total Revenue	Diode (%)	Non-diode (%)
2007	\$6.84B	49%	51%
2008	\$6.54B	50%	50%
2009	\$5.00B	51%	49%
2010	\$6.37B	51%	49%
2011 (forecast)	\$7.05B	51%	49%

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Le laser, quelques données commerciales...

**Laser revenues by application**

**2010**

Application	Percentage
Materials processing	35.2%
Communications	30.6%
Data storage	12.6%
Medical and aesthetic	6.8%
Scientific and military	6.3%
Instrumentation and sensors	4.3%
Pumps	3.3%
Entertainment and displays	0.4%
Image recording	0.6%

Total: \$6.37 Billion

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## Le laser est un composant dans la chaîne ...

The laser has moved in fifty years from "a solution looking for a problem" to a key technology which enables major sectors of the US economy.

**Timeline:**

- May 16, 1960: Ted Maiman demonstrates the first ruby laser at Hughes Research Laboratory.
- 1970: Early Laser-compatible disk.
- 1980: Laser printer HP vintage 1980's.
- 1990: Vintage laser and fiber-optic cable.
- 2000: Laser disc player.
- Vintage Laser tape cassette machine.
- Vintage Cutting and engraving and laser security.

**Laser devices are the core technology in instruments performing vital functions in many industries including transportation, healthcare, and telecom.**

**Transportation Sector \$1 Trillion**

- Airplane Automobile Manufacturing: \$50 Billion
- Automotive: \$50 Billion
- CO<sub>2</sub> & Fiber Lasers: \$1.3 Billion
- Industrial: \$10 Billion
- CO<sub>2</sub> & Fiber Lasers: \$0.2 Billion

**BioTech Healthcare Sector \$2.5 Trillion**

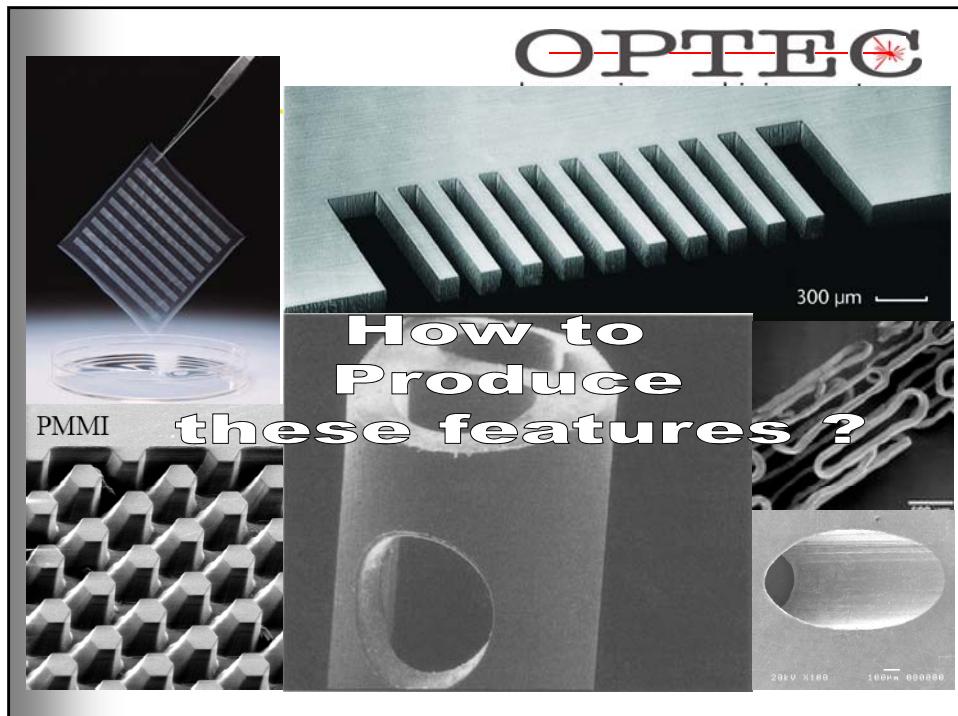
- Blood Testing: \$0.5 Billion
- Diagnostics & Surgery: \$1.5 Billion
- Endo & Other Lasers: \$0.4 Billion
- Information Routing & Storage: \$2.5 Billion
- Internet Computers Music Movies: \$200 Billion

**Telecom e-Commerce & IT Sectors \$4 Trillion**

- Information Routing & Storage: \$2.5 Billion
- Internet Computers Music Movies: \$200 Billion

Fred Schleicher and Thomas Bier

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## Why use lasers at all?

- Conventional

- EDM
- Mechanical
- Chemical milling
- Water jet
- Ion milling
- EB
- Plasma
- Punching
- Others...

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- Laser

- Non Contact
- No Chemicals
- Selectivity
- Processing Speed
- High Resolution
- Flexibility
- Compactness
- Cost effectiveness

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## Laser Materials Processing

- Laser
- Type
- Wavelength
- Output Power
- Pulse Energy
- Rep.Rate
- Pulse Length
- Beam Diameter
- Beam Polarisation
- Beam Divergence
- Beam Intensity Profile
- Spatial  
Temporal

### Material

- OPTICAL
- Absorptivity
- Reflectivity
- Refractive Index
- Surface Roughness

### THERMOPHYSICAL

- Thermal Conductivity
- Specific Heat
- Melting Point
- Boiling Point
- Evaporation Enthalpy
- Surface Tension
- Vapour Pressure

### MECHANICAL

- Density
- Hardness
- Poisson Ratio
- Young's Modulus

### Processing

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique

**IMPORTANT:**

Most parameters are interrelated and/or depend on temperature, pressure, etc.

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**Laser**

- Type
- Wavelength
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- Temporal

**Light Amplification by Stimulated Emission of Radiations**

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## Lamp / Laser

**Spontaneous emission:**

Glow lamp

Energy

Excited levels

Base level

Energy transition

Electrical power

Energy level diagram of Tungsten

Photons have various frequencies

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**Lamp / Laser**

**The laser media:**

- E<sub>2</sub> = upper laser level, („long“ life time)
- E<sub>1</sub> = lower laser level, (fast relaxing)
- Very narrow band width ( $E=h \times v$ )
- ⇒ Enables stimulated emission

**LASER LIGHT = COHERENT LIGHT:**

- Very small bandwidth (temporal coherence)
- almost parallel beam propagation (spatial coherence)

Glow discharge → Power transfer by electron collision

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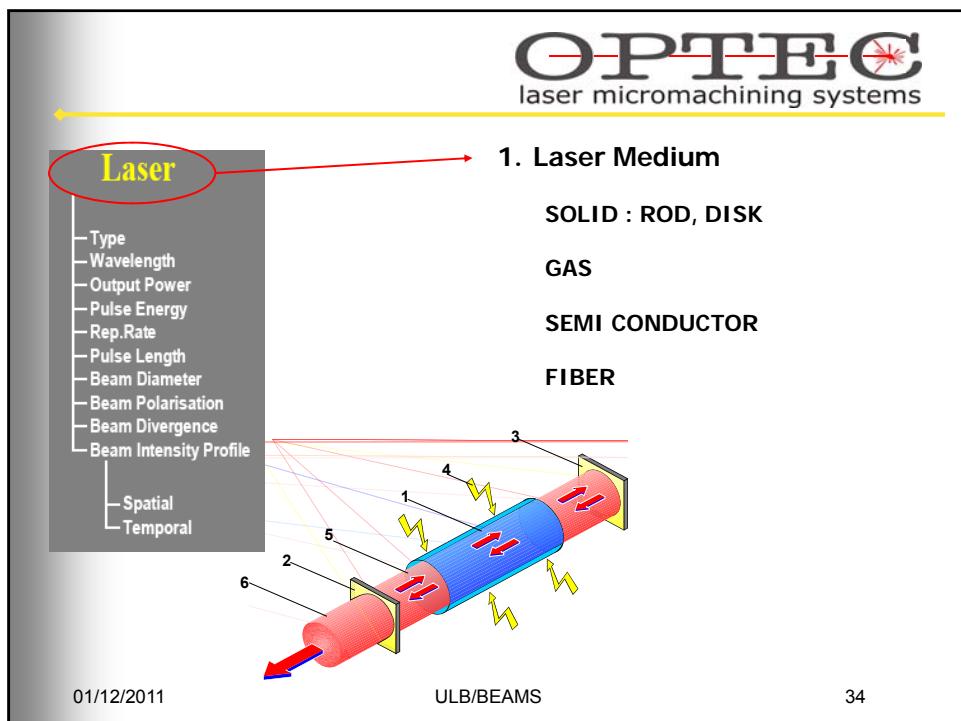
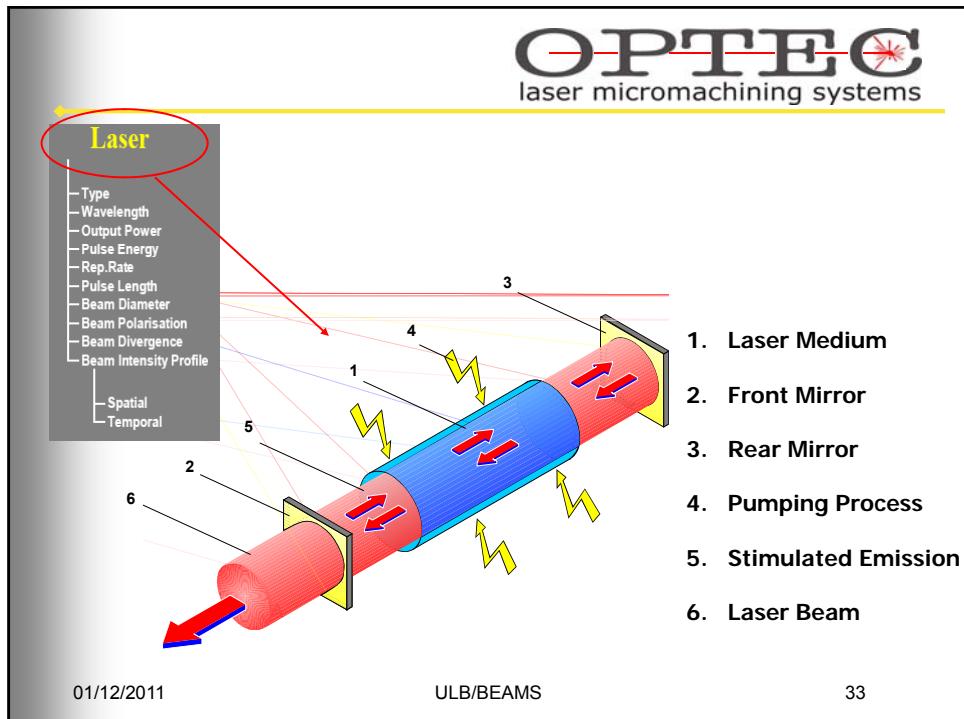
**What is a LASER ?**

- A LASER is a device which generates or amplifies light.
- Properties of laser beams:
  - Monochromatic
  - Directional
  - Coherent
  - Intense

**Laser**

- Type
- Wavelength
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Temporal

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Laser

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4. Pumping Process

Electrical Discharge

Flash Lamp

Diode Laser

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Laser Parameters

Laser

- Type
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# Laser Parameters

**Tripled Nd:YAG**

Wavelength (nm)	Source
1.06 μm	Nd:YAG
337 nm	Cu Vapor
428 nm	Cu Vapor
364 nm	Nd:YAG
222 nm	F
193 nm	ArF
157 nm	XeCl
199 nm	KrF
248 nm	XeF
351 nm	XeCl
300-1000 nm (tunable)	Dye

**Cu Vapor**

**Diodes**

**Fiber laser**

**CO<sub>2</sub>**

**Excimers**

**Doubled Nd:YAG**

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**Wavelength Range**

- X-Ray:** 0.1 nm - 10 nm
- Ultraviolet:** 100 nm - 300 nm
- Visible:** 300 nm - 700 nm
- Near Infrared:** 800 nm - 1000 nm
- Mid Infrared:** 3 μm - 10 μm
- Far Infrared:** 100 μm - 1 mm

**Cr + Forsterite**  
1150-1350 nm  
(beamlets)

**DF**  
3.6-4 μm

**Color Center**  
2.2-3.3 μm  
(beamlets)  
(1.4-1.58 μm)

**Cr LISAF**  
780-1000 nm  
(beamlets)

**Lead Salt**  
3-30 μm  
(beamlets)

**HF**  
2.8-3.0 μm

**He-YLF**  
2.08 μm

**He-YAG**  
2.1 μm

**Ti-SAPG**  
2.02 μm

**O**  
10 μm (9-11 μm)

**CO**  
5.7 μm

**1000 μm / 1 mm**  
**MILLIMETER WAVES**

**Excimer Fluoride:**  
496-1222 μm

**Methanol:**  
17-1217 μm

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**Laser**

- Type
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↓

- Spatial**
- Temporal**

# Laser Parameters

The figure consists of two side-by-side graphs. Both graphs have 'Laser Power Density' on the vertical axis and 'Time' on the horizontal axis.

(a) Continuous-Wave: This graph shows a single, constant, horizontal line representing a continuous power level over time. A red arrow points from the label 'Output Power' in the legend to this graph.

(b) Pulsed-Beam: This graph shows two distinct pulses of power. Each pulse has a sharp peak followed by a decay. A double-headed arrow between the peaks indicates the 'Pulse Length'. A red arrow points from the label 'Pulse Length' in the legend to this graph.

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## Laser Parameters

„metallurgical“ adaption of the laser pulse

seam welding of steel-bronze

thermal

„metallurgical“

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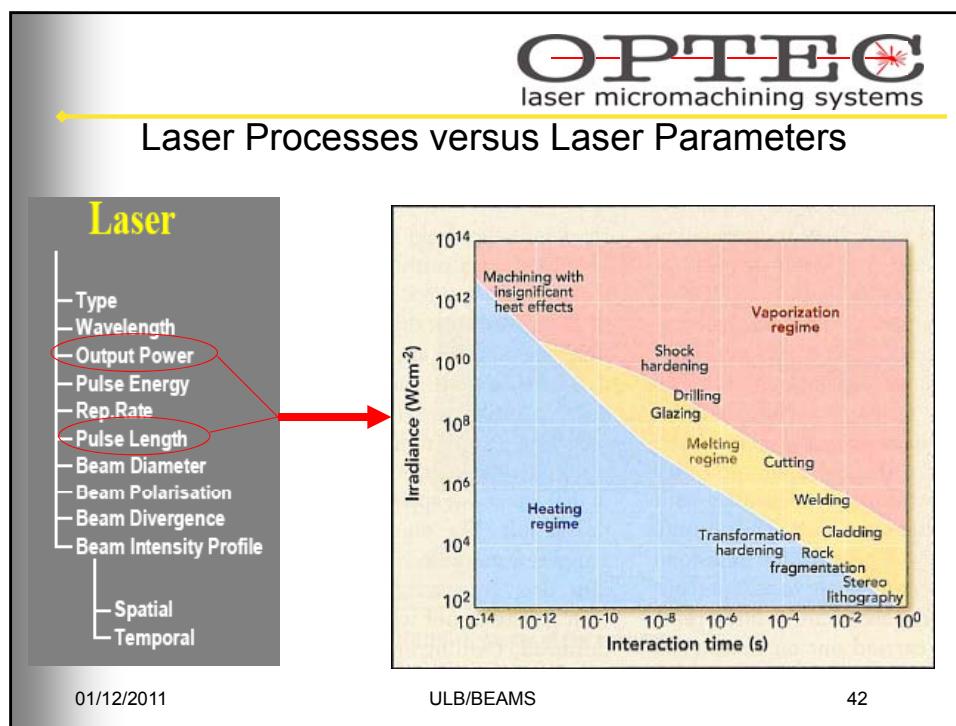
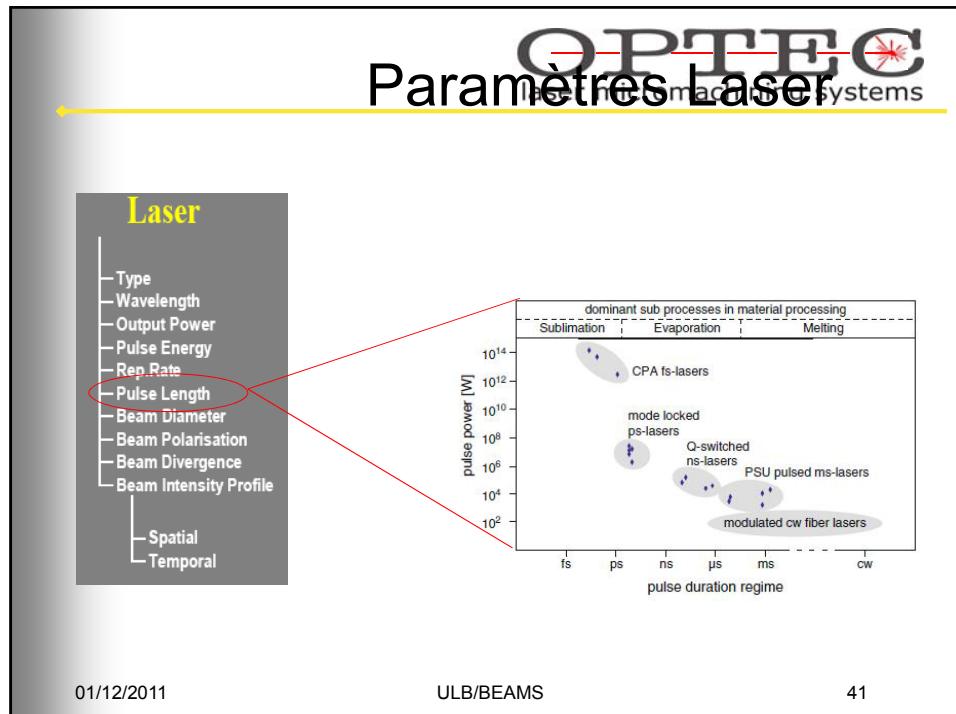
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## Laser Parameters

<b>Laser</b>	<ul style="list-style-type: none"> <li>Pulse length (*):</li> <li>– Millisecond (ms)</li> <li>– Microsecond (<math>\mu</math>s)</li> <li>– Nanosecond (ns)</li> <li>– Picosecond (ps)</li> <li>– Femtosecond (fs)</li> </ul>
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(\*): time scale considered for  $\mu$ machining

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## Laser Parameters

The diagram illustrates the effects of pulse duration on laser processing. On the left, a vertical list of laser parameters is shown, with 'Pulse Energy' and 'Pulse Length' circled in red. Red arrows point from these circles to the corresponding sections of the diagram. The top section, titled 'By speed of light:', shows a horizontal timeline from 1 ms to 100 fs ( $10^{-13}$  s). It includes a distance of 30 μm and the text 'FROM STRASBOURG TO MUNICH as far as 1/2 a diameter of a hair'. The bottom section, titled 'Pulse power @ 1 mJ:', shows a power spectrum from 1 W to 10 GW. It includes intensity values at 100 μm<sup>2</sup>:  $10^6$  W/cm<sup>2</sup> and  $10^{16}$  W/cm<sup>2</sup>. A red circle highlights 'Peak Power' on the 10 GW curve.

**Laser**

- Type
- Wavelength
- Output Power
- Pulse Energy**
- Rep. Rate**
- Pulse Length**
- Beam Diameter
- Beam Polarisation
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- Beam Intensity Profile

Spatial  
Temporal

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## Laser Parameters

The diagram compares material processing for long and short pulses. The left panel, labeled 'Long Pulse', shows a cross-section of a workpiece being processed by a single, broad red beam. Labels include: LONG PULSE LASER BEAM, ELECTED MOLTEN MATERIAL, SURFACE DEBRIS, RECAST LAYER, SURFACE RIPPLES DUE TO SHOCK WAVE, DAMAGE GLUED TO ADJACENT STRUCTURES, MICRO CRACKS, MELT ZONE, SHOCK WAVE, and HEAT TRANSFER TO SURROUNDING MATERIAL. The right panel, labeled 'Short Pulse', shows a cross-section of a workpiece being processed by multiple narrow, rapid red beams. Labels include: ULTRAFAST LASER PULSES, NO RECAST LAYER, NO SURFACE DEBRIS, PLASMA PLUME, NO SURFACE RIPPLES DUE TO SHOCK WAVE, NO DAMAGE CAUSED TO ADJACENT STRUCTURES, NO MELT ZONE, NO SHOCK WAVE, NO MICROCRACKS, NO HEAT TRANSFER TO SURROUNDING MATERIAL, and HOT, DENSE ION/ELECTRON SOUP (I.E. PLASMA).

Long Pulse

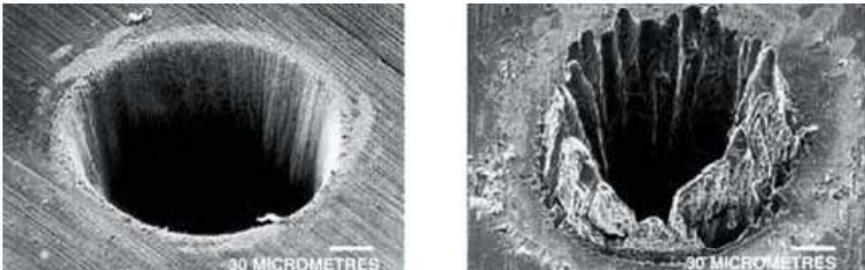
Short Pulse

©1999 Clark-MPR, Inc.      ©1999 Clark-MPR, Inc.

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laser micromachining systems

## Laser Parameters



**t = 200 femtoseconds**

**t = 3.2 nanoseconds**

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laser micromachining systems

## LASERS...

LASER	MEDIUM	Wavelength (nm)	Pulse width	PRF
<b>DPSS</b>	Solid	213 - 1064	ns - $\mu$ s	1 Hz – 200 kHz
<b>CVL</b>	Gas	255, 511	ns	kHz
<b>Excimer</b>	Gas	157 - 351	ns	1 Hz – 1 kHz
<b>Ultrafast</b>	Solid	390 – 1048	fs – ps	1Hz – 10 MHz
<b>Fiber</b>	Fiber	1057	ps – ns	1Hz – 100 kHz
<b>CO<sub>2</sub></b>	Gas	9000 - 11000	ns - $\mu$ s	1 Hz – 100 kHz

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## Laser Parameters

**Laser**

- Type
- Wavelength
- Output Power
- Pulse Energy
- Rep.Rate
- Pulse Length
- Beam Diameter
- Beam Polarisation
- Beam Divergence
- Beam Intensity Profile

Spatial      Temporal

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## Laser Parameters

Gaussian

Multimode

01 \* "Donut"

Donut

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## Laser Parameters

- Type
- Wavelength
- Output Power
- Pulse Energy
- Rep.Rate
- Pulse Length
- Beam Diameter
- Beam Polarisation
- Beam Divergence
- Beam Intensity Profile
- Spatial
- Temporal

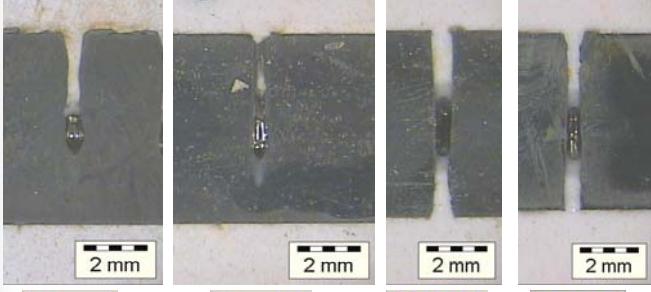
**Tailored PulsesTrains**  
**A new Process?**

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laser micromachining systems

### Special laser solutions for super alloy hole drilling

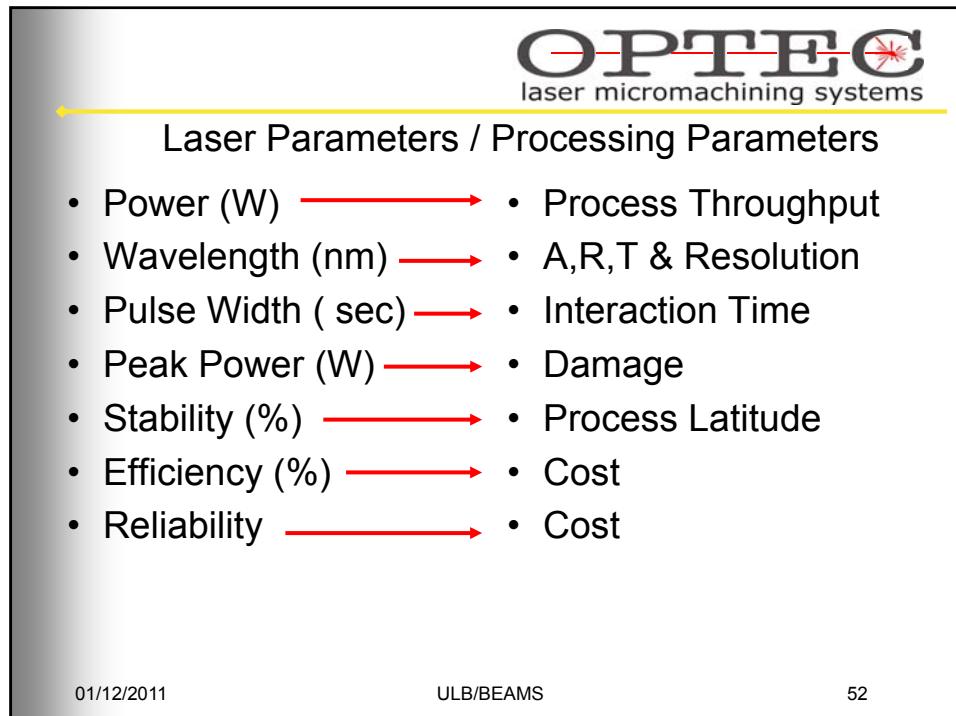
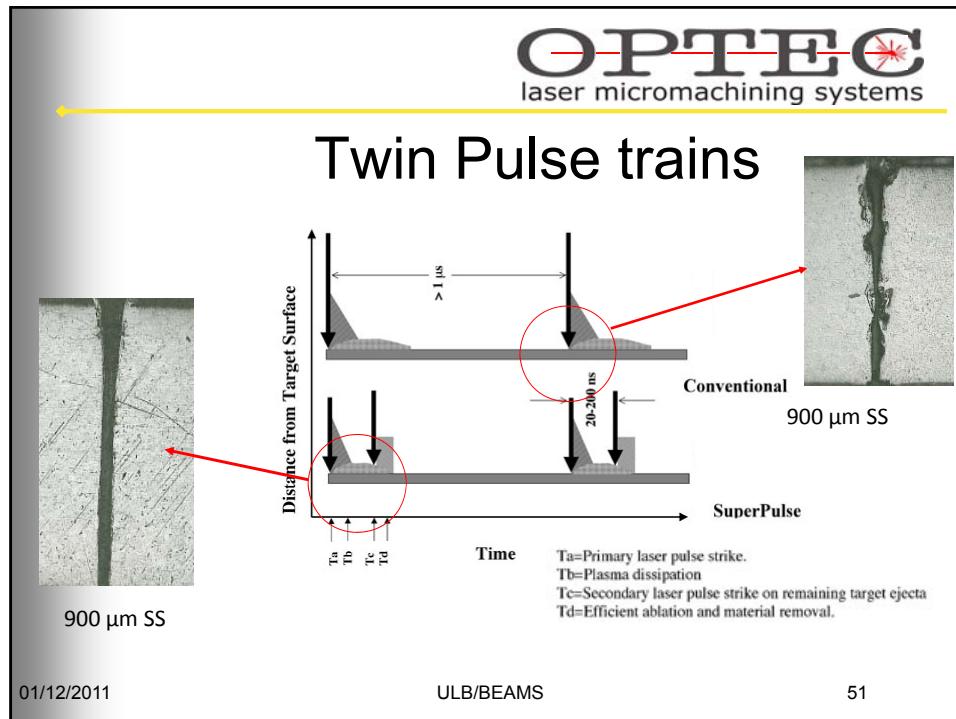
R&D: Drilling with pulse shaping technique

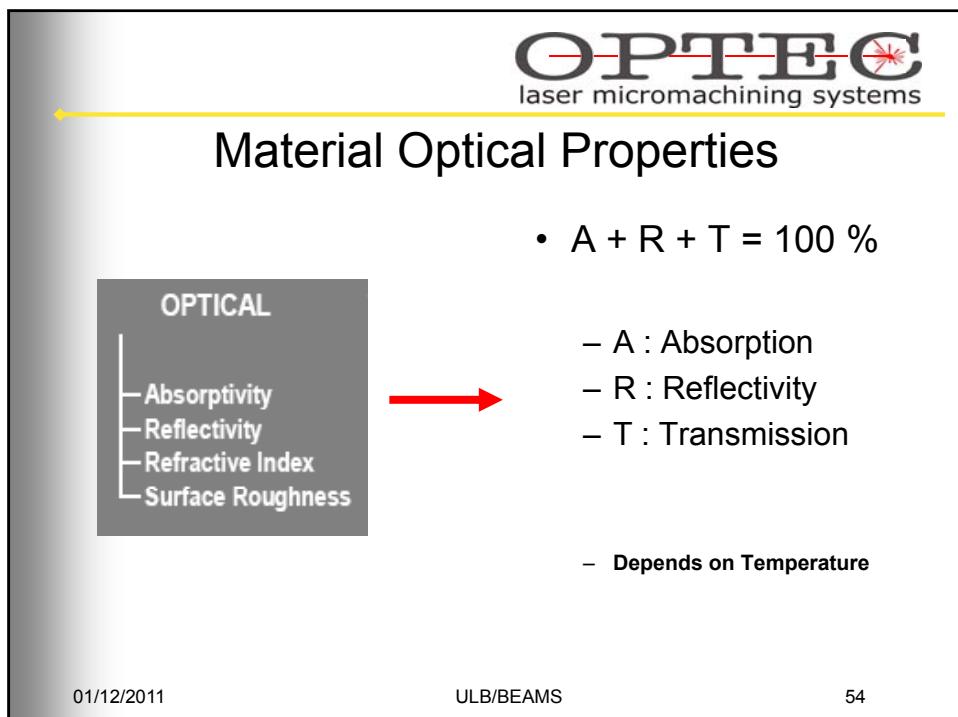
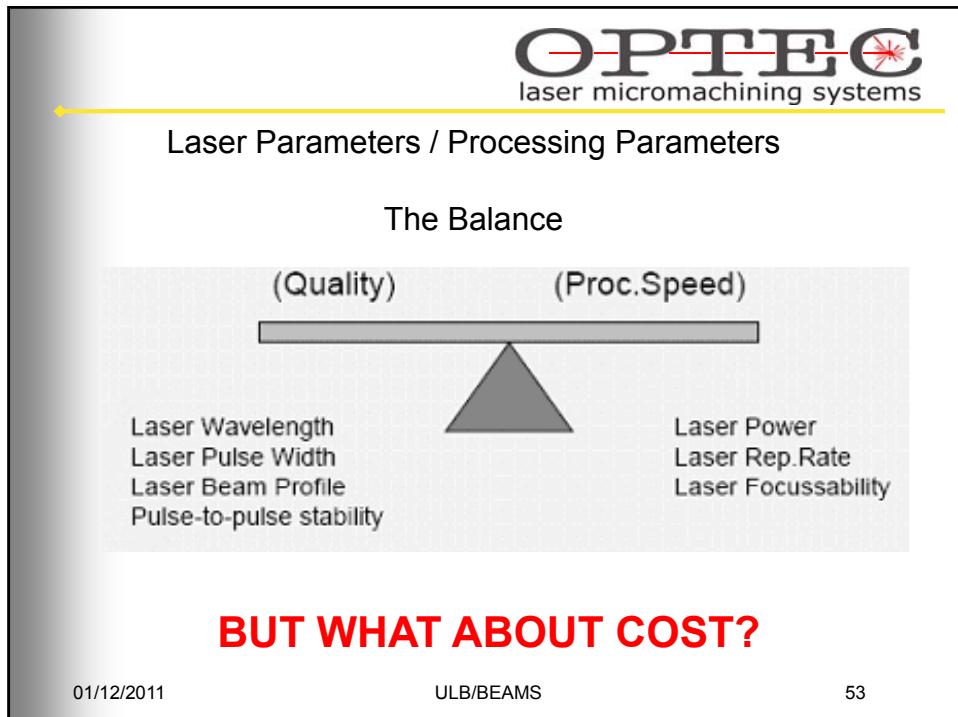


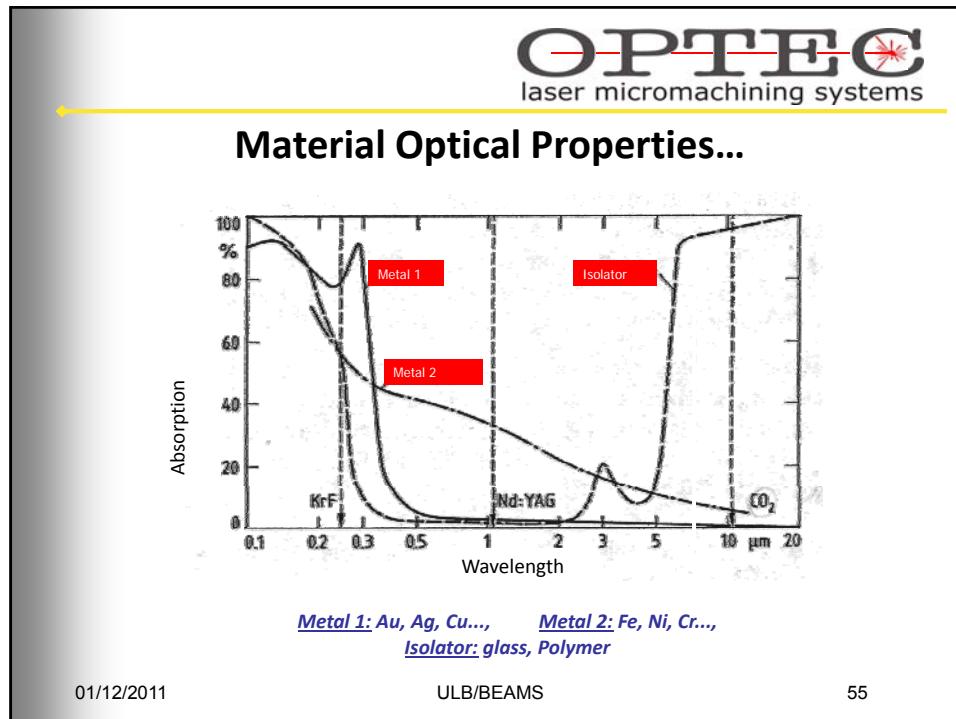

Pulse length: 2.8ms  
Peak power: 8.5 kW  
20 pulses (5Hz, 12.9J)

thickness: 6mm  
Fiber core diameter: 0.4mm  
Material: 1.4301

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**OPTICAL**

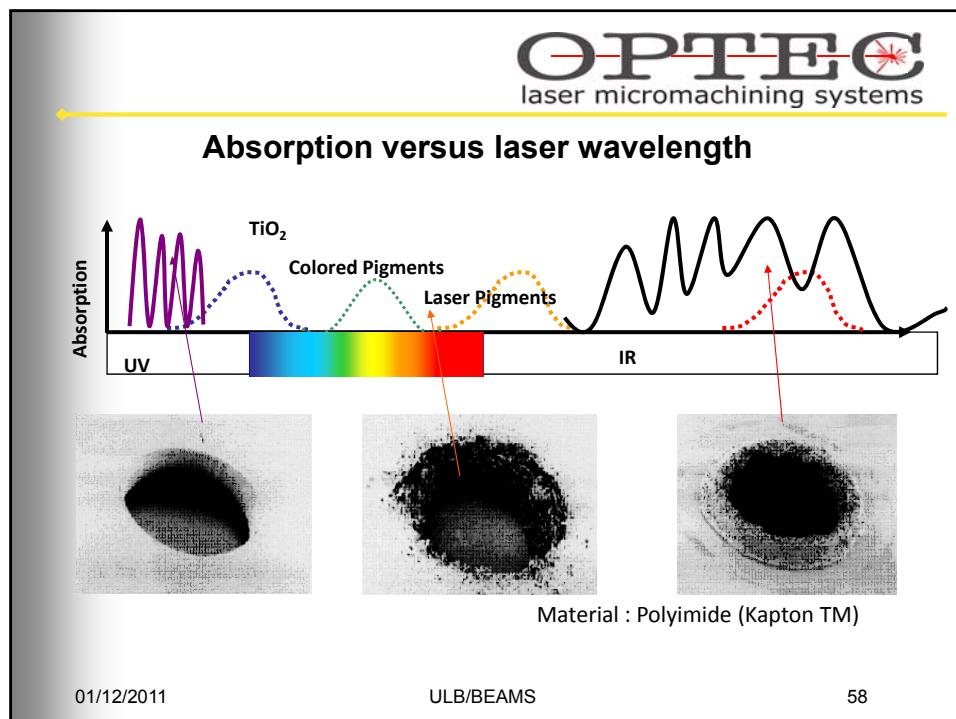
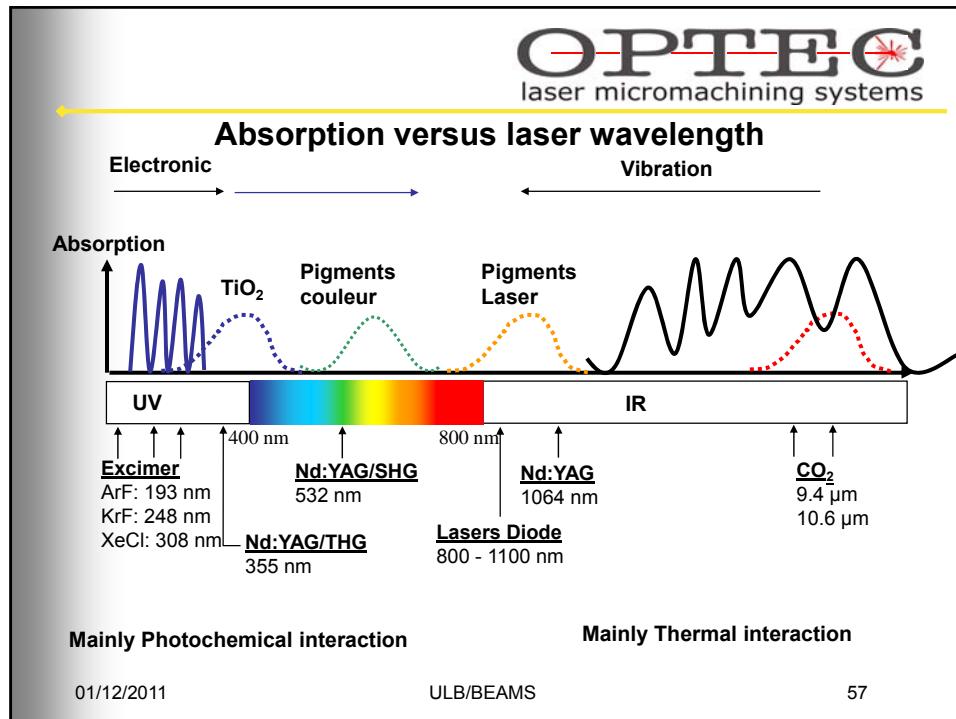
- Absorptivity
- Reflectivity
- Refractive Index
- Surface Roughness

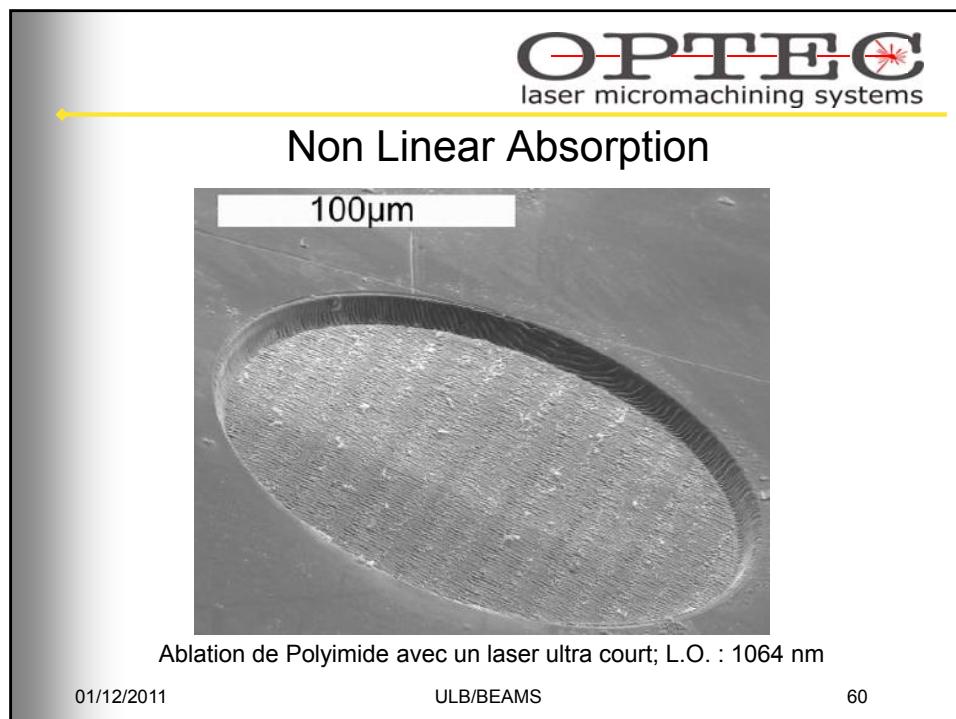
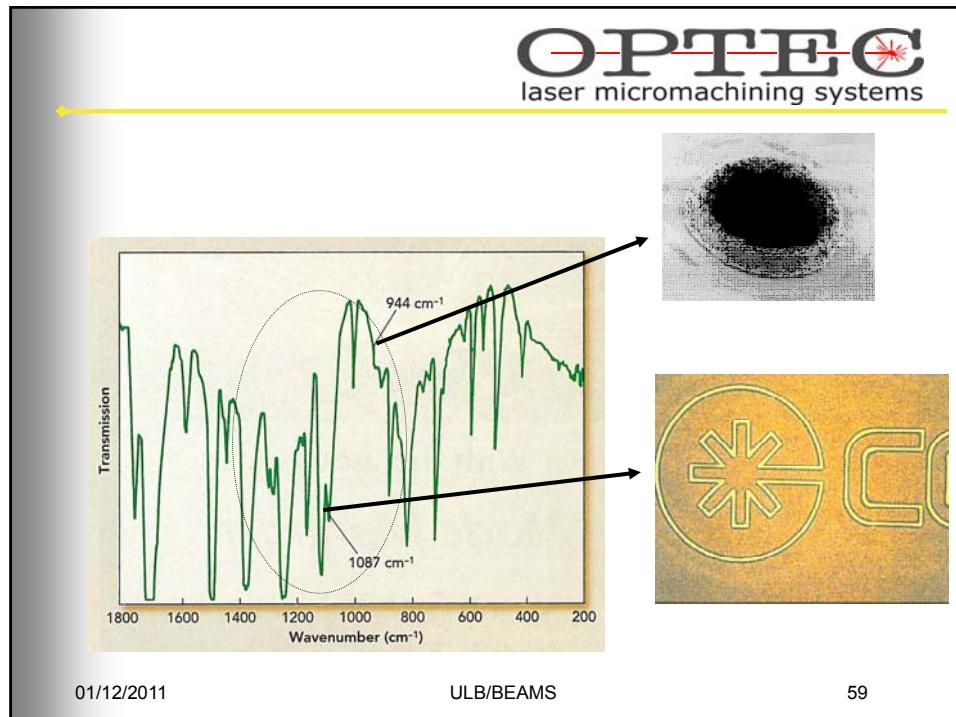
**Laser**

- Type
- Wavelength

Metal	At 10.6 $\mu\text{m}$	At 1.06 $\mu\text{m}$	At 0.25 $\mu\text{m}$
Aluminum	2	10	18
Iron	4	35	60
Copper	1	8	70
Molybdenum	4	42	60
Nickel	5	25	58
Silver	1	3	77

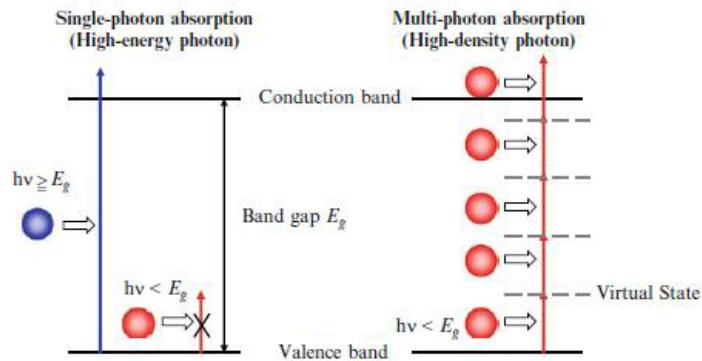
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## Non Linear Absorption: Multiphoton effect

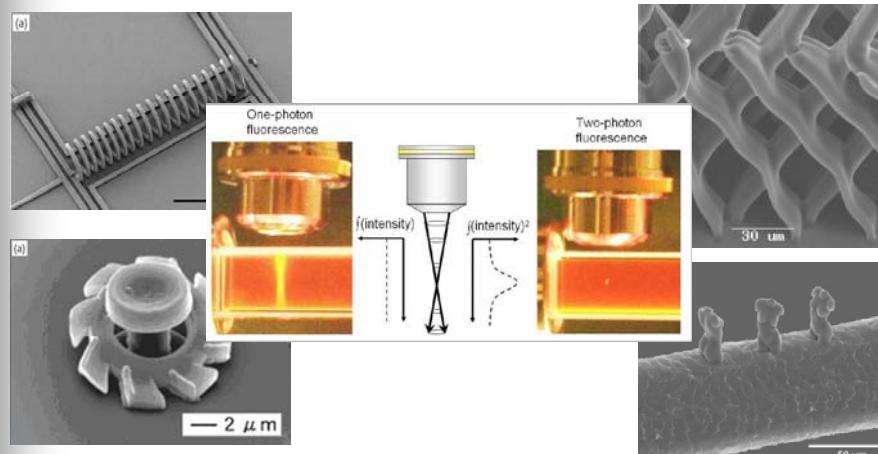


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## Materials Properties

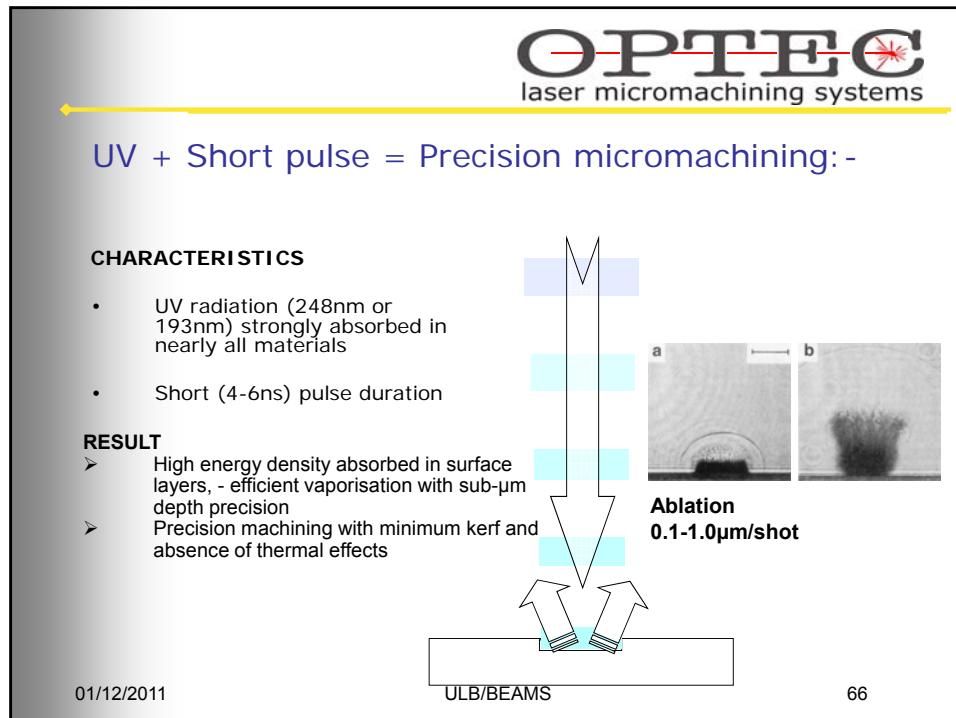
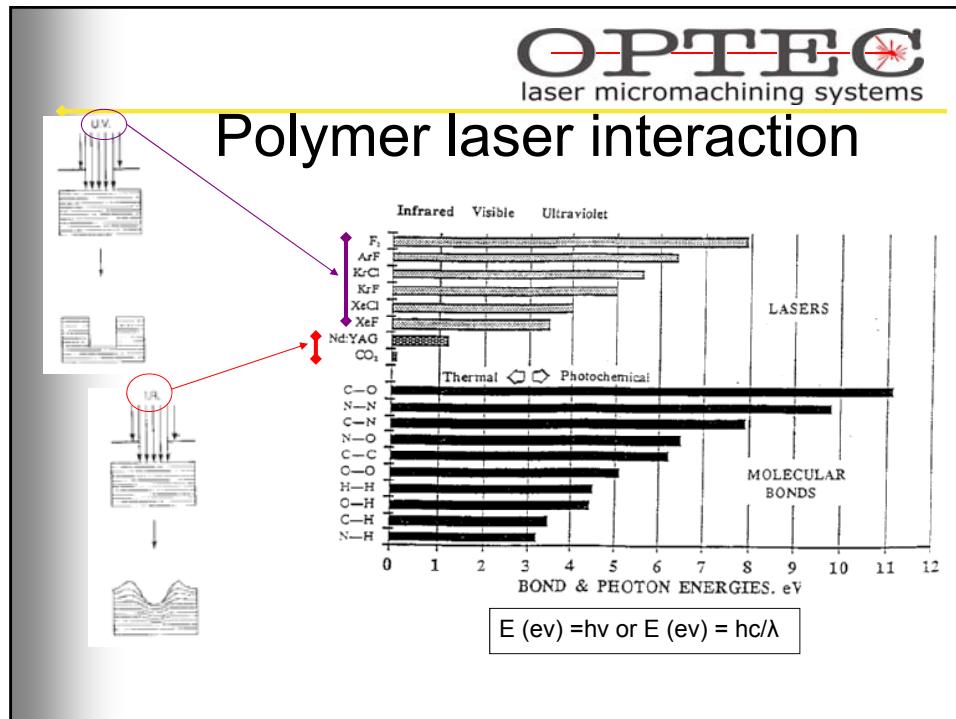
### THERMOPHYSICAL

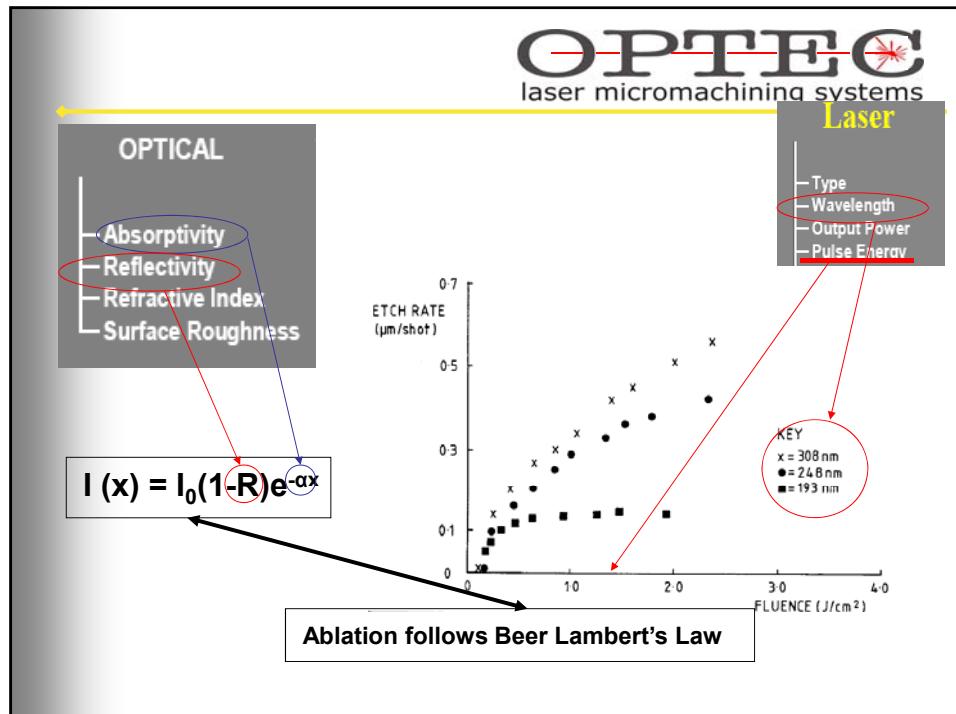
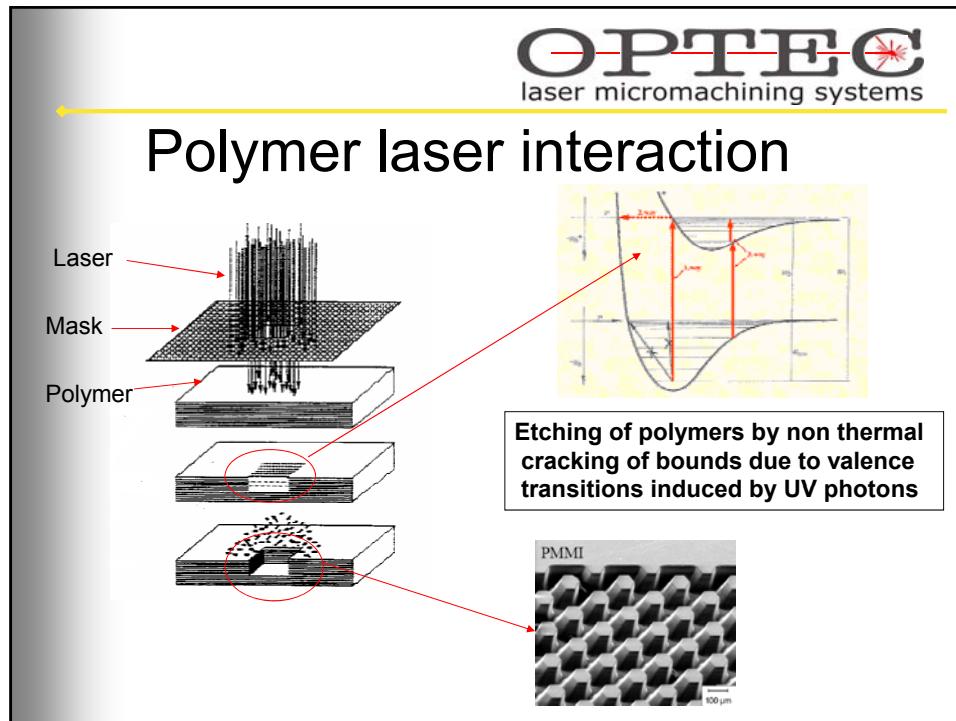
- Thermal Conductivity
- Specific Heat
- Melting Point
- Boiling Point
- Evaporation Enthalpy
- Surface Tension
- Vapour Pressure

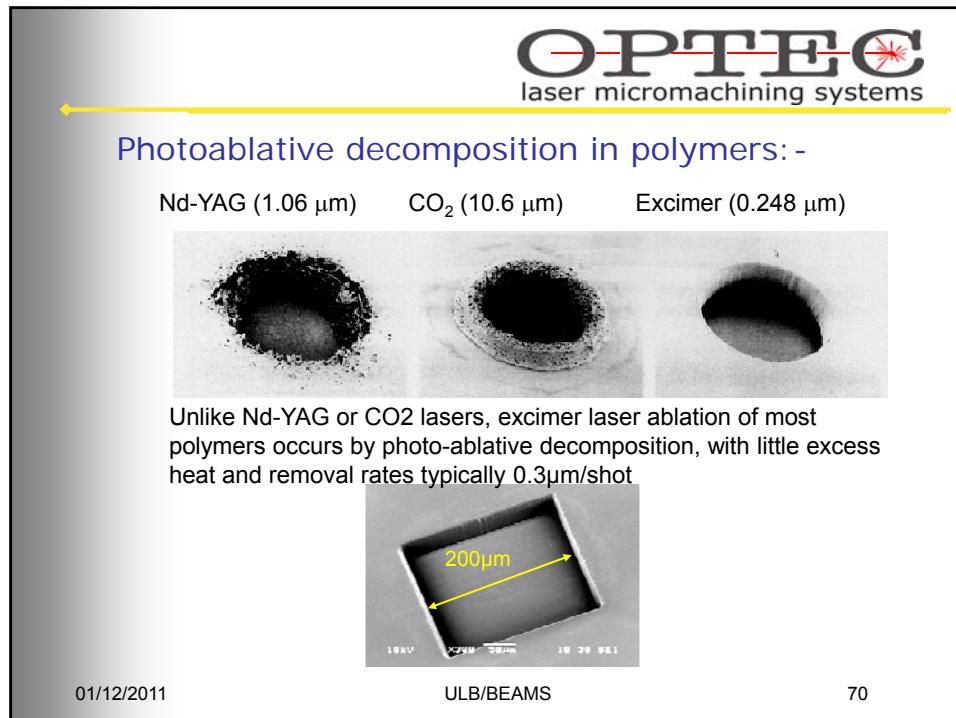
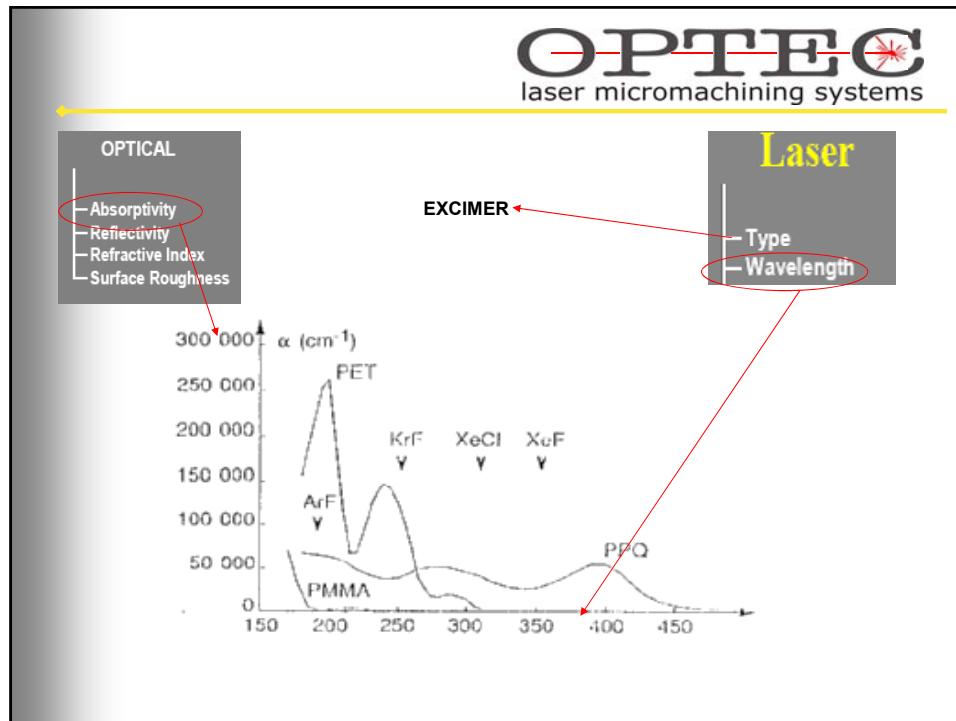
- Metals
- Ceramics
- Polymers
- Glass
- Composites



## POLYMER LASER INTERACTION









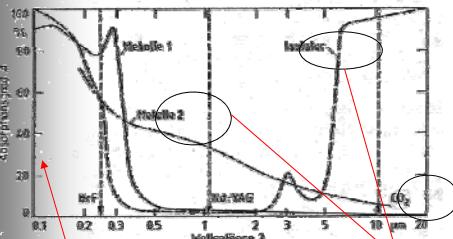
## COMBINED MATERIALS LASER INTERACTION

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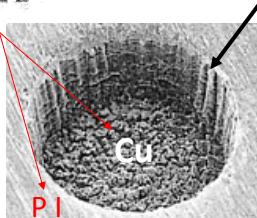
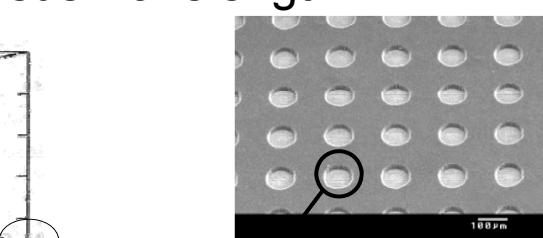
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### Absorption versus wavelength



OPTICAL

- Absorptivity
- Reflectivity
- Refractive Index
- Surface Roughness



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Laser Blind Vias Drilling

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Ablation threshold...

Exitech Limited      40um

Ablation Rate  
Fluence

Polymer  
Silica

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Selective machining, polymers from metals:-

The graph plots Ablation Rate (Y-axis) against Fluence (X-axis). The 'Polymer' curve shows a sharp increase in ablation rate at a low fluence, while the 'Metal' curve shows a more gradual increase at a higher fluence.

SAW filters  
Flex contacts

Humidity Sensor  
Wire Strip  
Implant  
Stent

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laser micromachining systems

## Processing

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique

**Laser Processing**

*Direct writing*: A laser beam passes through a lens and focuses onto a sample, which is moving under the beam. The beam path is curved.

*Projection*: A laser beam is shaped and directed through a series of lenses (beam shaping, homogenizers, condenser lens, field lens, mask, projection lens) onto a sample.

**Others: Maskless, DOEs**

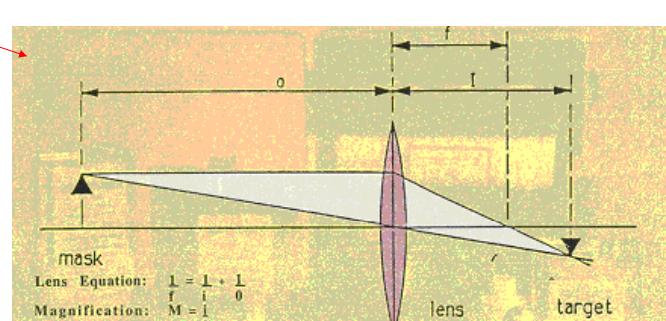
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# Drilling Techniques / Projection

**Processing**

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique



mask      lens      target

Lens Equation:  $\frac{1}{f} = \frac{1}{I} + \frac{1}{0}$

Magnification:  $M = \frac{I}{0}$

Beam Reduction Equation:  $E_{\text{Target}} = E_{\text{Mask}} \times M^2$

Figure 6.  
Imaging parameters.

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## Drilling Techniques / Projection

### Processing

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique

- Static Mask and workpiece
- Moving Mask
- Moving Workpiece
- Synchronised Scanning
- Synchronised overlay scanning
- Bow Tie scanning
- Half Tone & Gray Scale Mask

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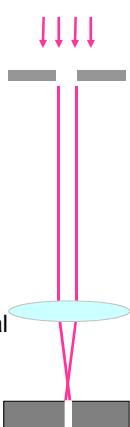
79

### Processing using simple motifs: - ...particularly suitable for small lasers!

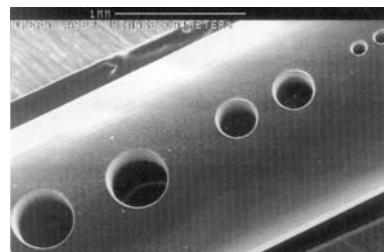
Laser illumination,  
generally around  
50mJ/cm<sup>2</sup>

Mask, in this case  
with a single hole

Process lens to  
project mask  
image with typical  
demag. 4-20X  
1-20J/cm<sup>2</sup> on the  
part



- Drill/mill simple holes or shapes
- Drill many holes sequentially using X,Y part motion
- Use mask selector to change motifs, incl. alphanumeric
- For small features, energy requirements modest, but high rep. rate useful.



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## Static Mask & Workpiece

50mJ/cm<sup>2</sup>

↓↓↓

Typical demag.  
4-20X

1-20J/cm<sup>2</sup>

50mJ/cm<sup>2</sup>

1-20J/cm<sup>2</sup>

- Drill simple holes or shapes
- Drill many holes sequentially using X,Y part motion or X,Y Galvo Scanners (also known as step & Repeat)
- Use mask selector to change motifs, incl. Alphanumeric (also known as indexed mask projection)

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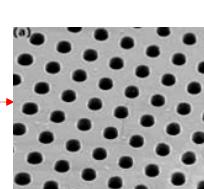


## Static Mask & Workpiece

- Drill simple holes or shapes



- Drill many holes sequentially using X,Y part motion or X,Y Galvo Scanners (also known as step & Repeat)



- Use mask selector to change motifs, incl. Alphanumeric (also known as indexed mask projection)



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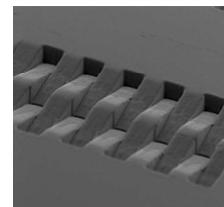
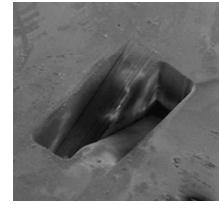
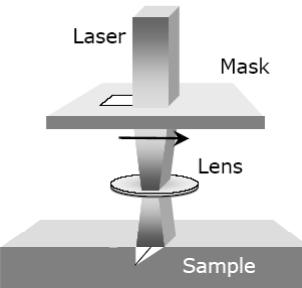
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## Drilling Techniques / Projection

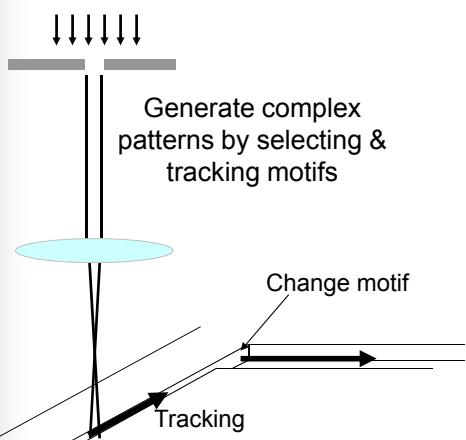
### Moving Mask



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- Laser firing + motion generates a groove, or cuts through the part.
- For a given material, groove depth depends mainly on average shot dose(rep. rate x motif size/tracking speed)
- Use different motifs to generate complex patterns

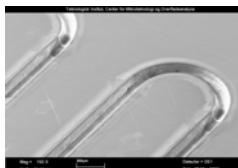
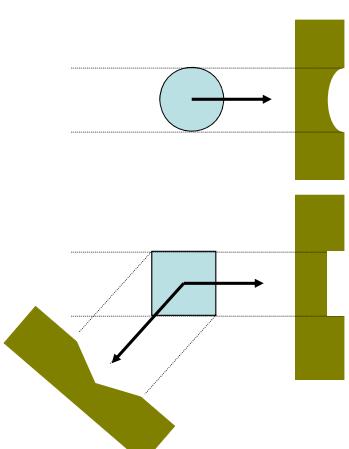
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- tracked circle always makes elliptical-shaped profile, independently of direction

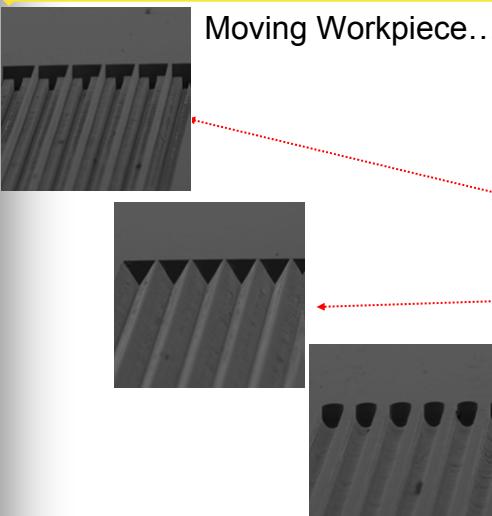
- For other shapes, profile depends on tracking direction

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Moving Workpiece...more

- Mask Shape:
  - T Mask
  - Triangle Mask
  - Round Mask

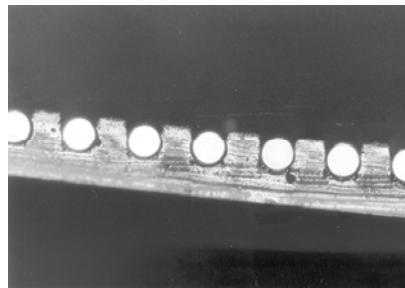
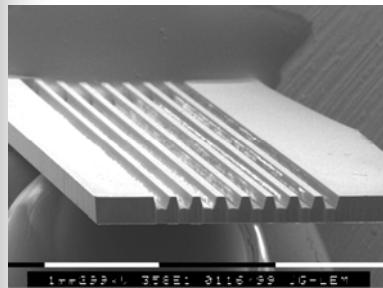


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## Moving Workpiece

### Microgrooving: some examples



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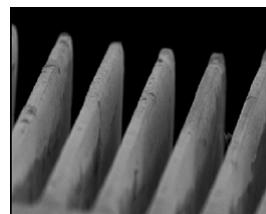
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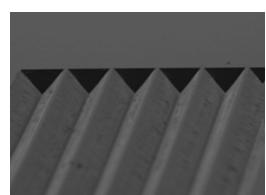
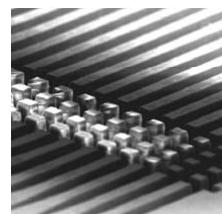
(INTEC - Ghent University - B)



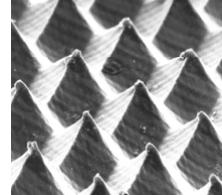
## Moving Workpiece...more



Turn by 90°



Turn by 90°



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laser micromachining systems

### Synchronised Scanning

EXCIMER LASER BEAM  
BEAM-UTILIZATION FACTOR  
4 5 6  
3 8 7  
2 9 10  
1

MOVING MASK  
LENS  
X-Y STAGE

**Figure 6.**  
*Opposing motion*

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**OPTEC**  
laser micromachining systems

### Laser Processing

**Processing**

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique

**DIRECT WRITING**

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laser micromachining systems

## Drilling Techniques / Direct Writing

**Processing**

- Lens NA
- Spot Size
- Shot Overlap
- Gas Assist
- Focal Plane
- Processing Speed
- Drilling Technique

$$K = \frac{1}{M^2} = \frac{4 \lambda F}{\pi D_0 D} = \frac{4 \lambda}{\pi D_0 \theta}$$

$$D_0 = M^2 \times \frac{4 \lambda \times F}{\pi} \times \frac{1}{D}$$

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## XY Galvo Mirrors

Pre-focus lens

F-Theta objective

Dynamic pre-focussing

F-Theta & Dynamic pre-focussing

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laser micromachining systems

### Drilling Strategies...Contd

	single shot	percussion	trepanning	Helical drilling
Aspect (d/T)	max. 1:15	max. 1:100	open	Source: IFSW Stuttgart <b>open</b>
Tolerance %	5-10	5	5	<3

**Pulsed Laser**

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### Drilling Techniques / Direct Writing

helical drilling

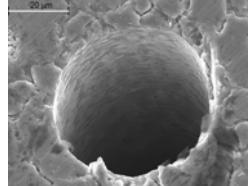
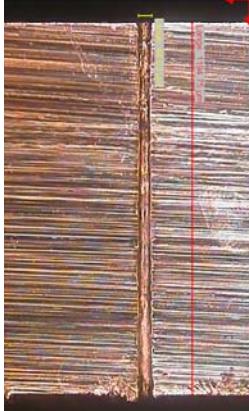
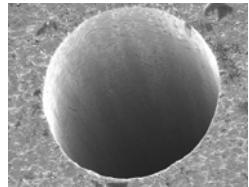
Rayon laser

Pièce à percer

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## Process Results

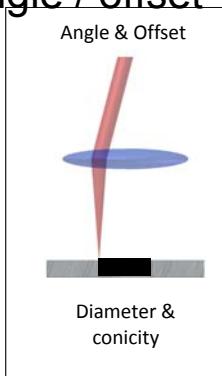
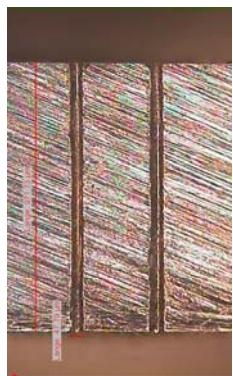
<b>Material:</b> stainless steel <b>Thickness:</b> 1.2 mm <b>Diameter:</b> $50 \mu\text{m} \pm 2 \mu\text{m}$ <b>Time:</b> 10 s		
<b>Material:</b> stainless steel <b>Thickness:</b> 1 mm <b>Diameter:</b> $200 \mu\text{m} \pm 3 \mu\text{m}$ <b>Time:</b> 20 s		

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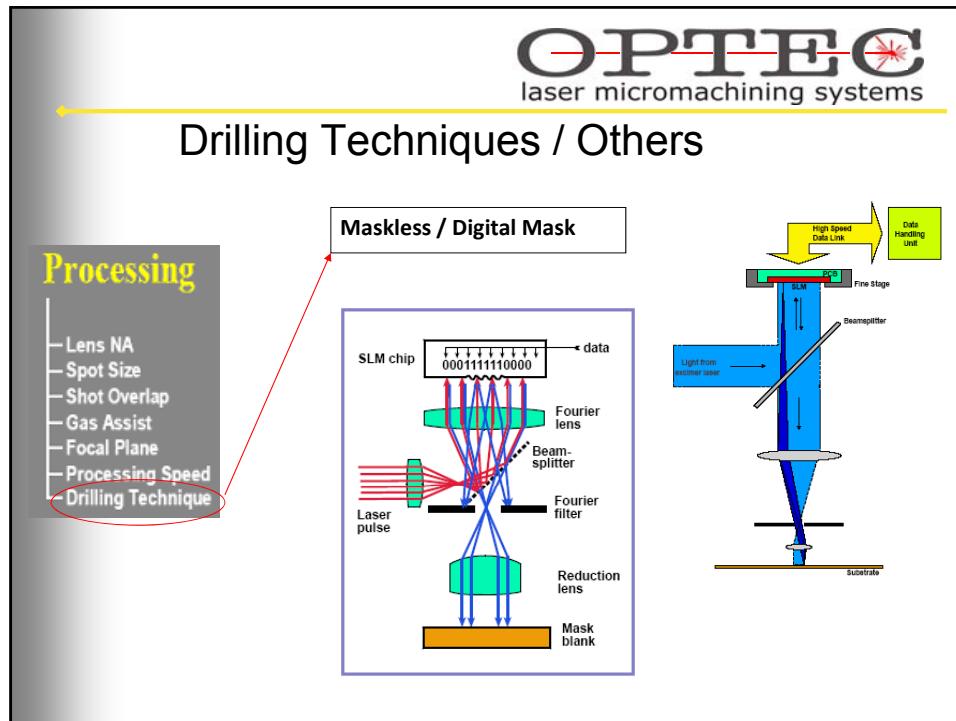
**OPTEC**  
laser micromachining systems

## Process Parameters...Contd

- Angle / offset

 <b>Angle &amp; Offset</b> <b>Diameter &amp; conicity</b>	 stainless steel d=50 μm depth=1 mm, t=8 s	 stainless steel d=100/250 μm depth 1 mm, t=20 s
--	--	---

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**OPTEC**  
laser micromachining systems

## Drilling Techniques

DOE's: -

The diagram illustrates a optical system for micromachining. An 'INCOMING BEAM' passes through a lens with focal length  $F$ . The beam is diffracted by a grating with period  $D$ , creating multiple parallel beams. The distance between the lens and the grating is labeled as  $F$ . A red arrow points from the text 'DOE's: -' to this diagram. To the right, there is a grayscale micrograph of a pattern of concentric circles, with a small inset showing a cross-section of the holes.

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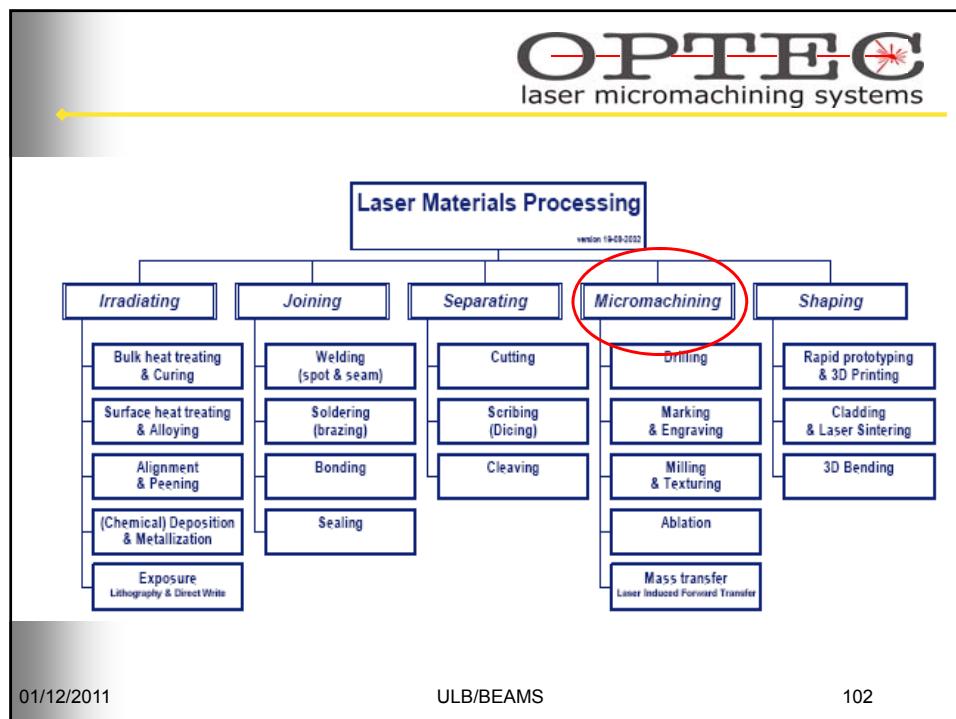
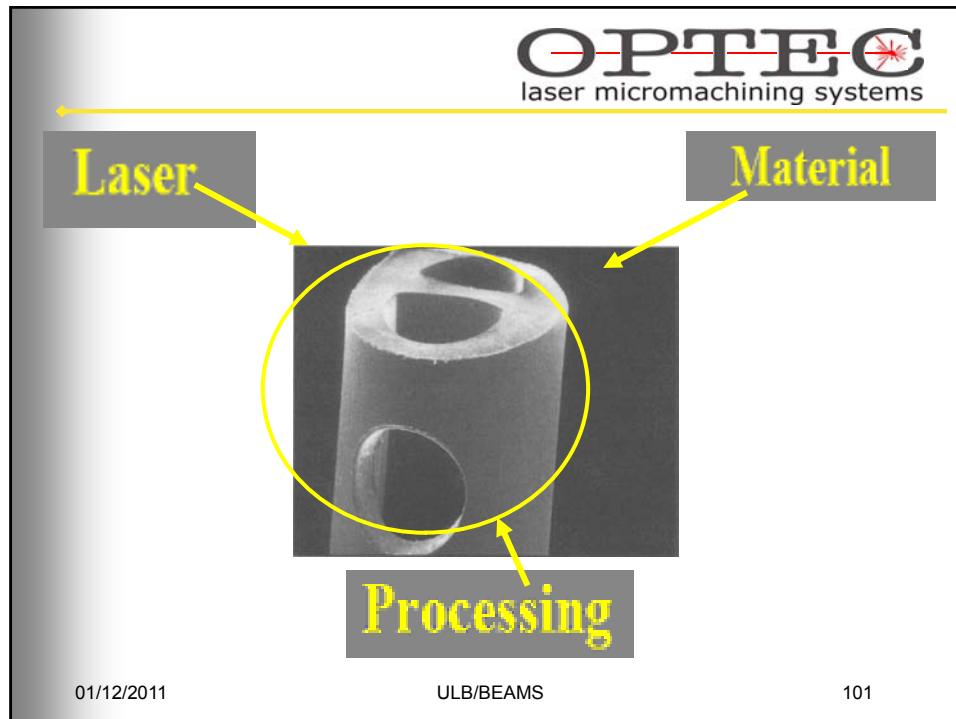
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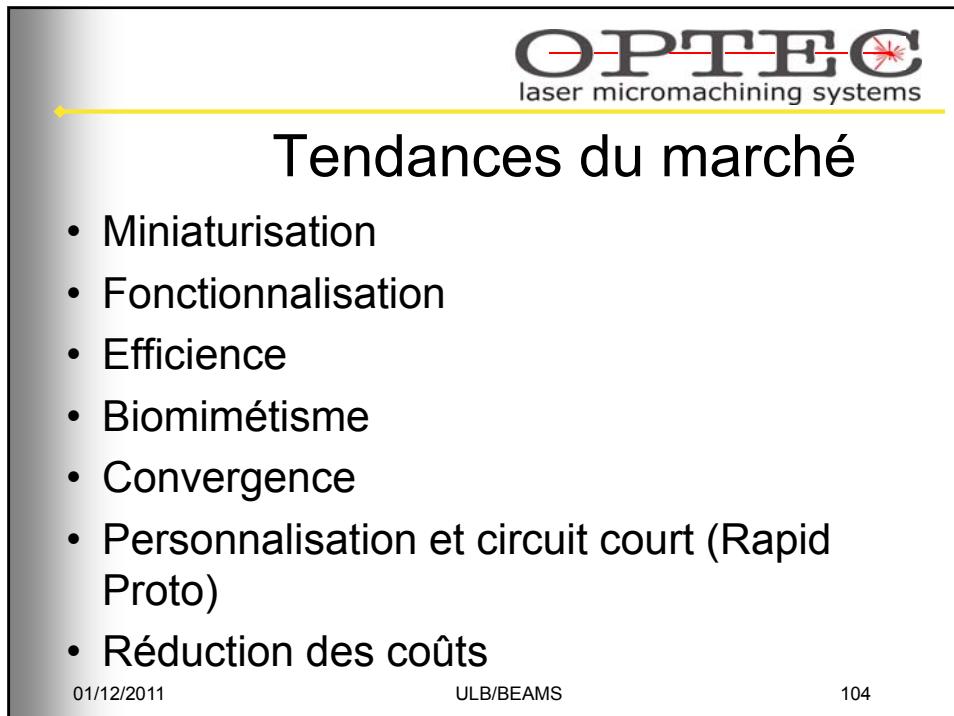
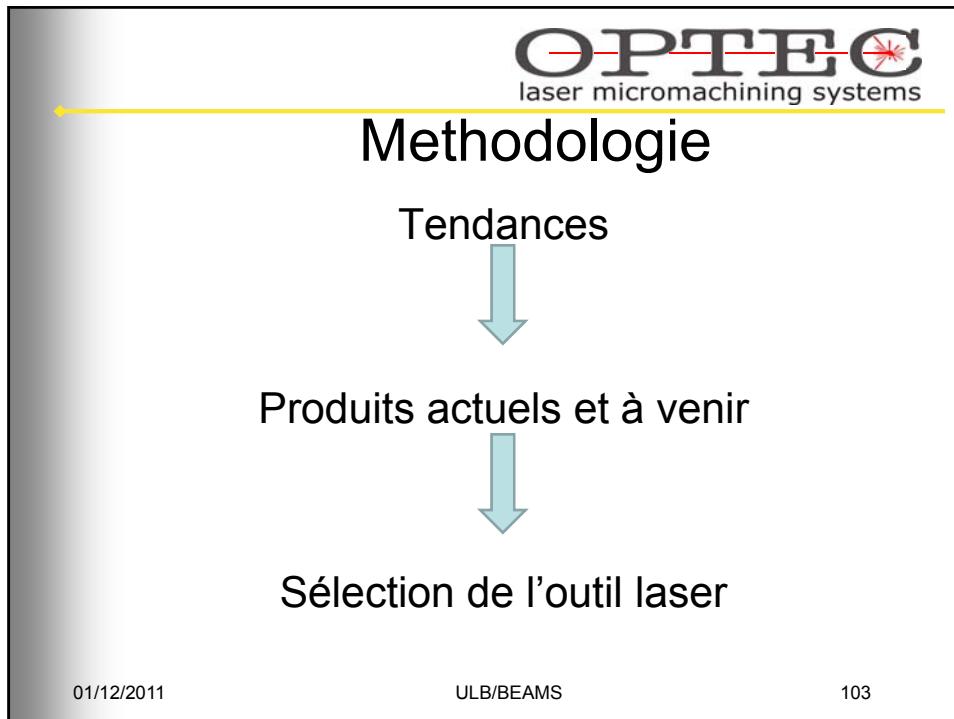
## Drilling Techniques

Many holes at once: -

A photograph on the left shows a laser micromachining setup with a lens and a beam splitter. A red line connects this image to a larger photograph on the right, which shows a square array of numerous small holes produced by the machine.

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Miniaturisation: Perçage laser de micro-via

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Miniaturisation...suite

HDD

Suspension  
Laser  
Slider  
Roll angle  
Pitch angle

Structure of suspension in HDD

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## Fonctionnalisation

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## Efficiency

The diagram illustrates the classification of various laser applications in solar technology, centered around the "laser & solar application technology". It is organized into four main categories: cutting, inspection, material modification, and patterning.

- Cutting:** Singulation, Ribbon Cutting, Glass Cutting.
- Inspection:** Cell & Wafer Inspection, Glass Panel Inspection.
- Material Modification:** Dopant Diffusion, Laser Fired Contacts.
- Patterning:** Isolation & Interconnection, Contact Openings, SINx/SiO<sub>x</sub> Removal, abitative patterning, Texturing, Etch Barrier, ITO Removal, Edge Isolation, ITO Marking, Border Deletion, Defect Repair, Laser Grooved Buried Contacts, Contact Openings, Emitter Wrap-Through, Interconnection, Crystallization, Sintering, Metal Wrap-Through.

Classification of the different laser applications in solar by laser / material interaction process

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## Convergence

CONVERGING TECHNOLOGIES  
FOR IMPROVING HUMAN PERFORMANCE

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## Convergence...suite

Solar cell module  
Electrical interconnects  
Biosensor module  
Sensor readout and control circuit  
Energy storage module  
Semitransparent display and micro lens array  
Telecommunications and power reception antenna  
Display control circuit  
Radio and power conversion circuit

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## Convergence...suite

Video Imaging

Pulsed UV Laser

Microscope Objective

Ink

Ribbon

X-Y Translation

Transferred Voxels

Substrate

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## Biomimétisme

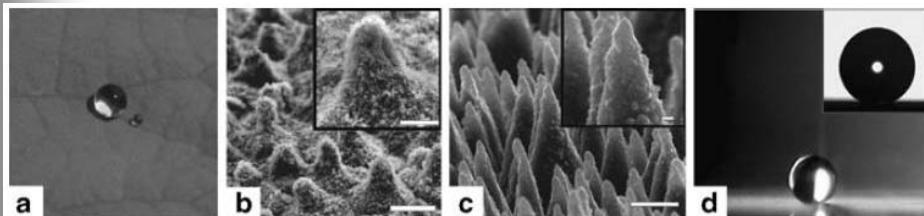
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## Biomimétisme...suite



**Fig. 4.5** (a) A bead of water on a lotus leaf [55]. (b) SEM image of the microscale (scale bar 10  $\mu\text{m}$ ) and *inset*: nanoscale structures (scale bar 5  $\mu\text{m}$ ) on the surface of a lotus leaf [56]. (c) SEM images of femtosecond laser textured Si surface showing microscale (scale bar 5  $\mu\text{m}$ ) and *inset*: nanoscale (scale bar 1  $\mu\text{m}$ ) structures [56]. (d) Image of a water droplet on a laser-structured, silane-coated, Si surface with a static contact angle of  $\theta = 154 \pm 1^\circ$  [57]

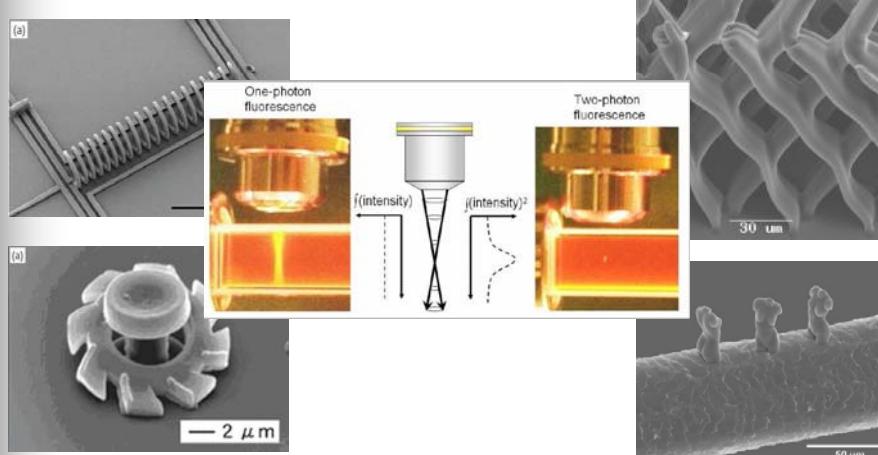
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## Construction additive



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## Réduction des coûts

**fusion TECHNOLOGY**  
NITINOL TO STAINLESS STEEL TUBE WELDING

Nitinol tube performance without the cost

Creganna-Tactx Medical introduces Fusion Technology for Nitinol to Stainless Steel tube joining. A patented break-through welding solution enables you to combine the unique attributes of Nitinol with the tractability of Stainless Steel for a cost effective product design.

Nitinol offers a unique range of characteristics when designing medical device delivery shafts including superelastic and shape memory behaviour, superb crush resistance and flexibility. Yet, many designers are reluctant to specify Nitinol in the catheter design due to its high cost. Instead, more economical tubing such as Stainless Steel that exhibits good overall tractability is more often specified.

When designers choose Nitinol tubing for catheter design, it is typically in the distal section of the shaft that the unique attributes of the metal are employed. By using Nitinol in the distal section only and an economical metal tube for the proximal section, designers can optimise both the performance and cost of the overall design.

**Nitinol Delta**  
Stainless steel proximal section  
fused

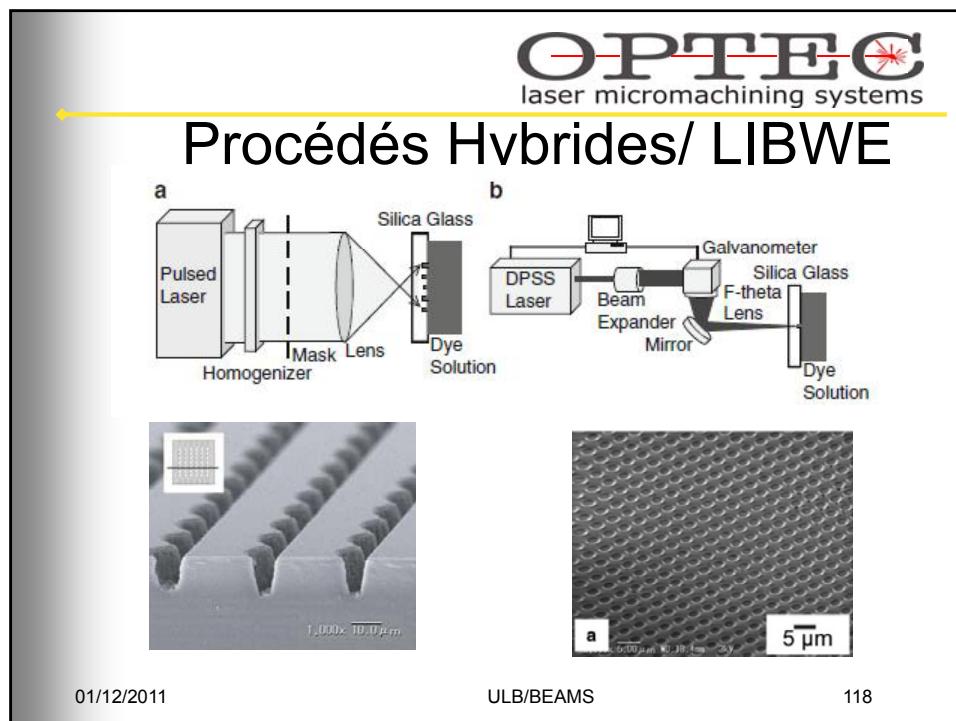
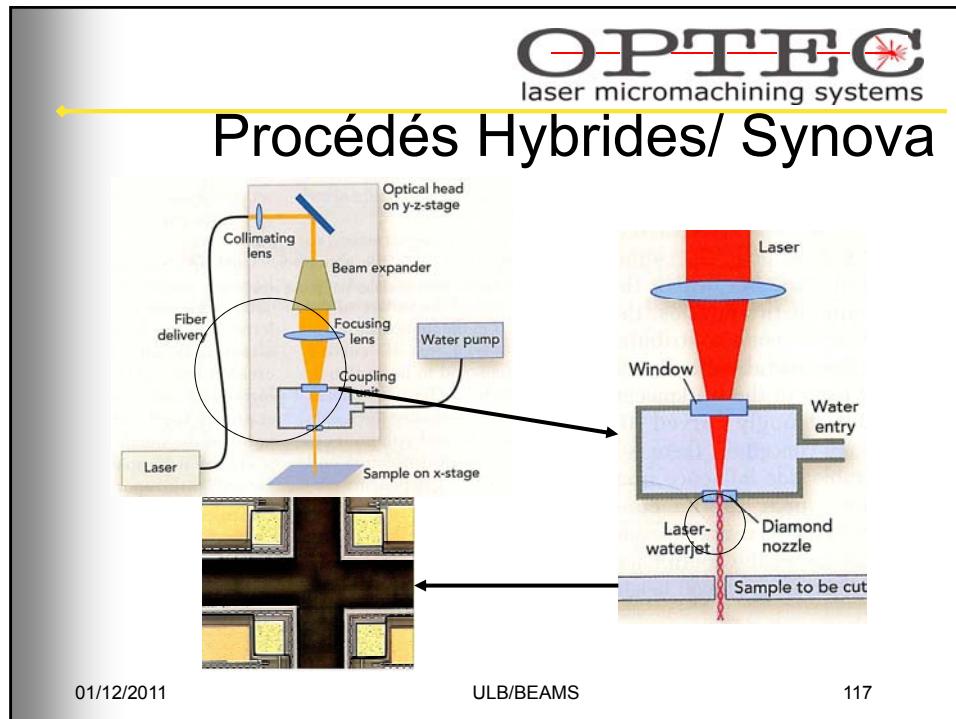
Creganna-Tactx Medical's unique technology demonstrates a strong weld zone not achieved by standard welding technologies or other joining methods such as bonding, heat shrinks or mechanical joining.

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## Procédés Laser Hybride

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Typical Laser Tasks for MDM:

- NEUROSTIMULATION
- OCULAR IMPLANTS
- DENTAL IMPLANTS
- EMBOLIC PROTECTION
- CARDIAC RHYTHM MANAGEMENT
- ANGIOPLASTY BALLOONS
- DRUG DELIVERY CATHETERS
- BIOABSORBABLE/POI YMFR STNTS
- STENT GRAFTS
- CATHETER/STENT DELIVERY SYSTEMS
- DIABETES MANAGEMENT
- PERIPHERAL CATHETERS

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**OPTEC** ...the specialist in laser tools for medical device fabrication....

...non-contact, precise & clean laser machining of a wide range of technical polymers.....

Drilling... (Pebax, PU)  
...2.5µm dia.

Insulation removal  
360° stripping of insulation from ultra-fine wires & bundles.

Generating structures..  
...channels, nozzles, collectors... lab on a chip(PC, PMMA...)

Opening contacts to  
specially laid cable(PLER)

Opening to embedded contacts(PTFE & silicone)

Cleaning of contact pads., patterning of polymer coated stems...

...want to talk to some experts in laser machining of medical devices? .... Try us.

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Processing using Complex Motifs:-  
...parallel patterning, generally suitable for big lasers

Illumination of a complex mask

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- The complete pattern is projected in a single operation using a complex mask
- Inflexible but inherently suitable for mass production
- Stencil-type masks are limited to simply-connected motifs
- Metal/FS masks – any feature possible, & more precise, but costlier and lower damage threshold

Telecentric imaging using a field lens

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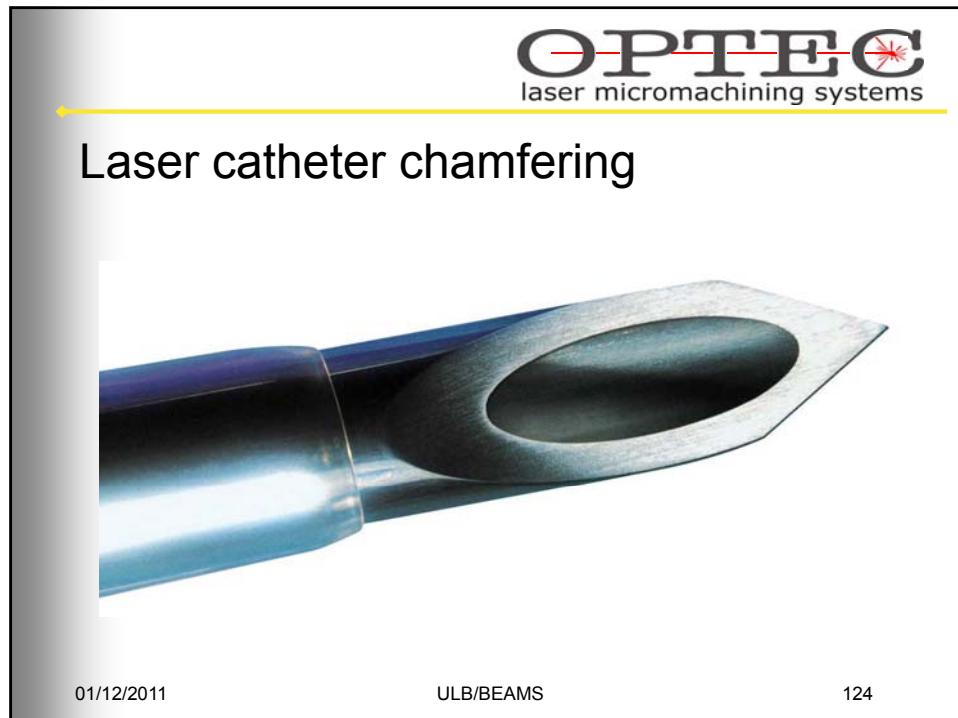
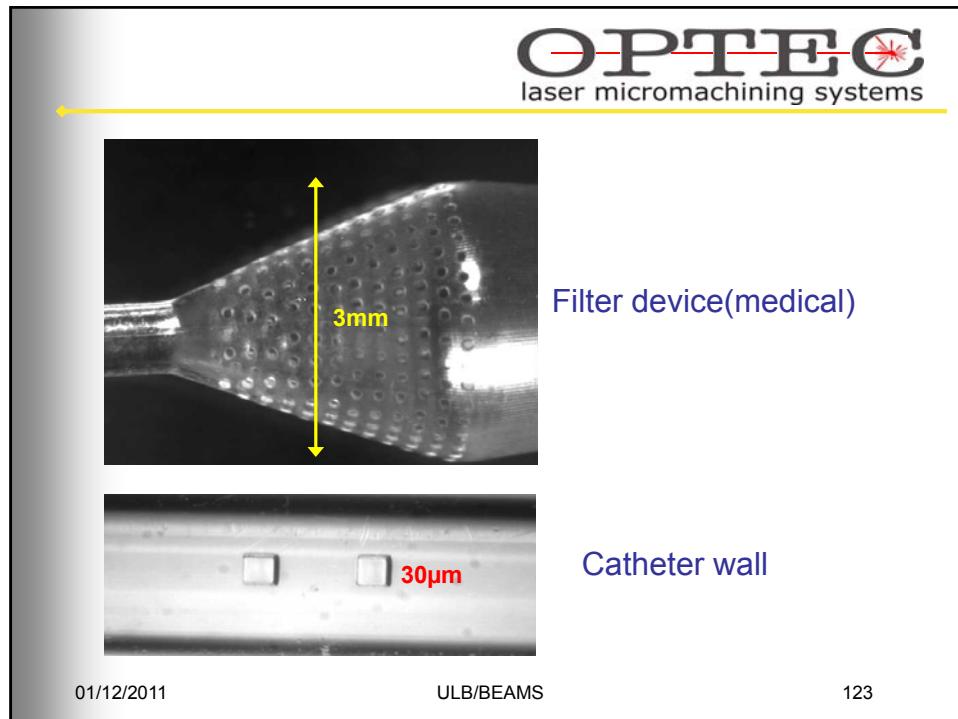
Catheters machining

36.1X 25KV WD:25MM S:0.00000 P:0.00000  
1MM IMPRO LASER MACHINING CATHETER

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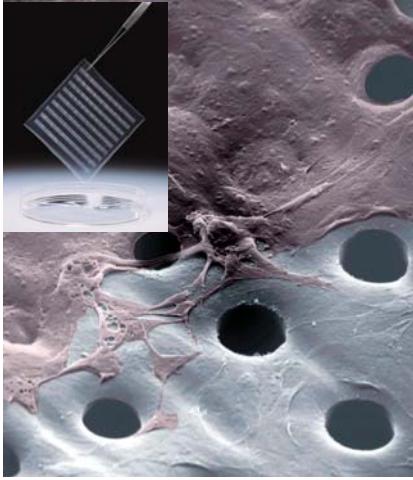
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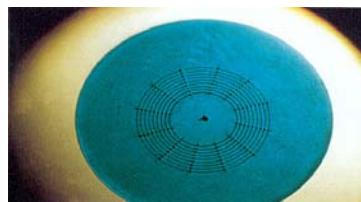
### Laser drilling of artificial skins

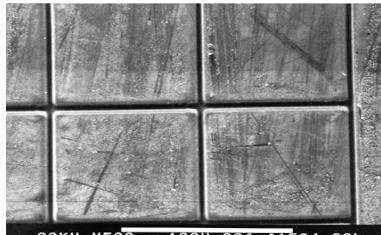
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### Laser machining of medical components



- Machining of glass substrates



- Machining of counting grids

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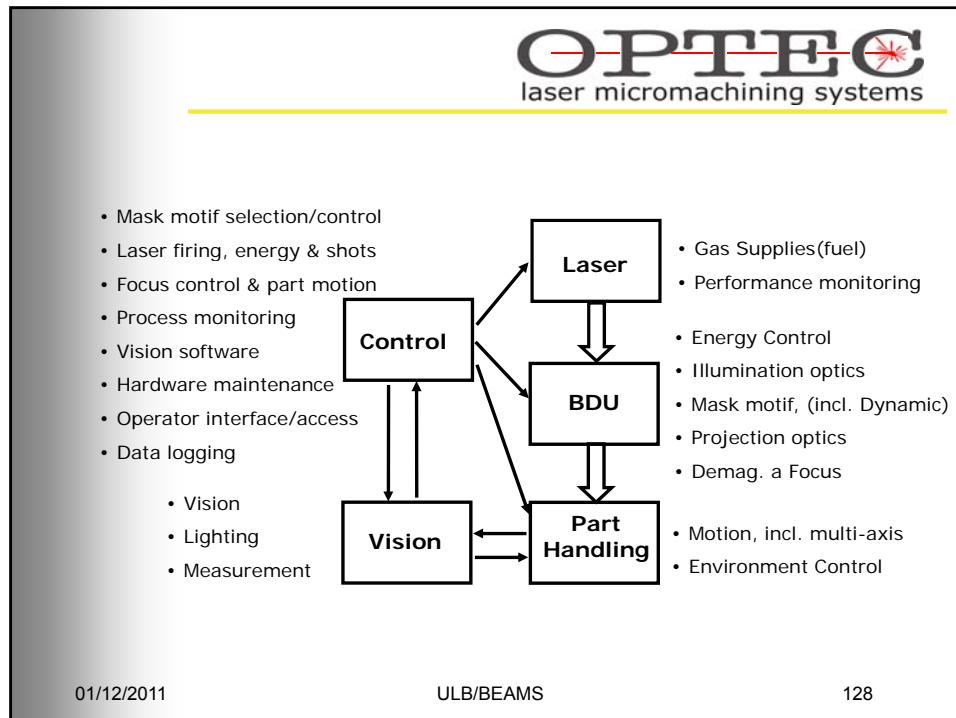
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### Laser machining of microfluidics: lab on a chip

Martin Jensen - Danish Technological Institute (Dk)

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Nigel Kent - NCSR (Ir)



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## Remerciements

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FGSW, GSIG, IREPA LASER, Lasag,  
Lightmotif, LPKF, LZH, Optec, Oxford Laser,  
Rofin, Synova, TI

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Merci pour votre attention

QUESTIONS....

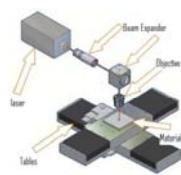
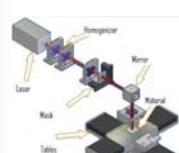
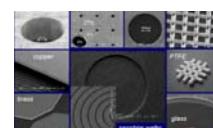
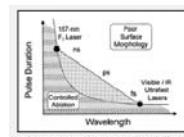
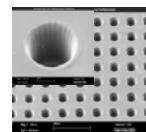
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**Notre expertise dans le domaine du traitement Athermique par laser :**



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Typical Micromachining Tasks:-

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