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Ultrashort pulsed laser technology for new detectors

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Outline

- Laser ablation: a short introduction
- Laser drilling techniques
- Critical aspects of GEM fabrication via laser ablation
- Laser Materials Processing lab @ CNR-IFN Bari
- Preliminary results
- Outlook

Laser Ablation Definition

Laser ablation is the process of removing material from a solid surface by irradiating it with a laser beam.

At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates.

At high laser flux, the material is typically converted to a plasma.

Usually, laser ablation refers to removing material with a pulsed laser

WIKIPEDIA

Timescales of the laser ablation process

fs → ps → ns → µs

energy **absorption** by free electons

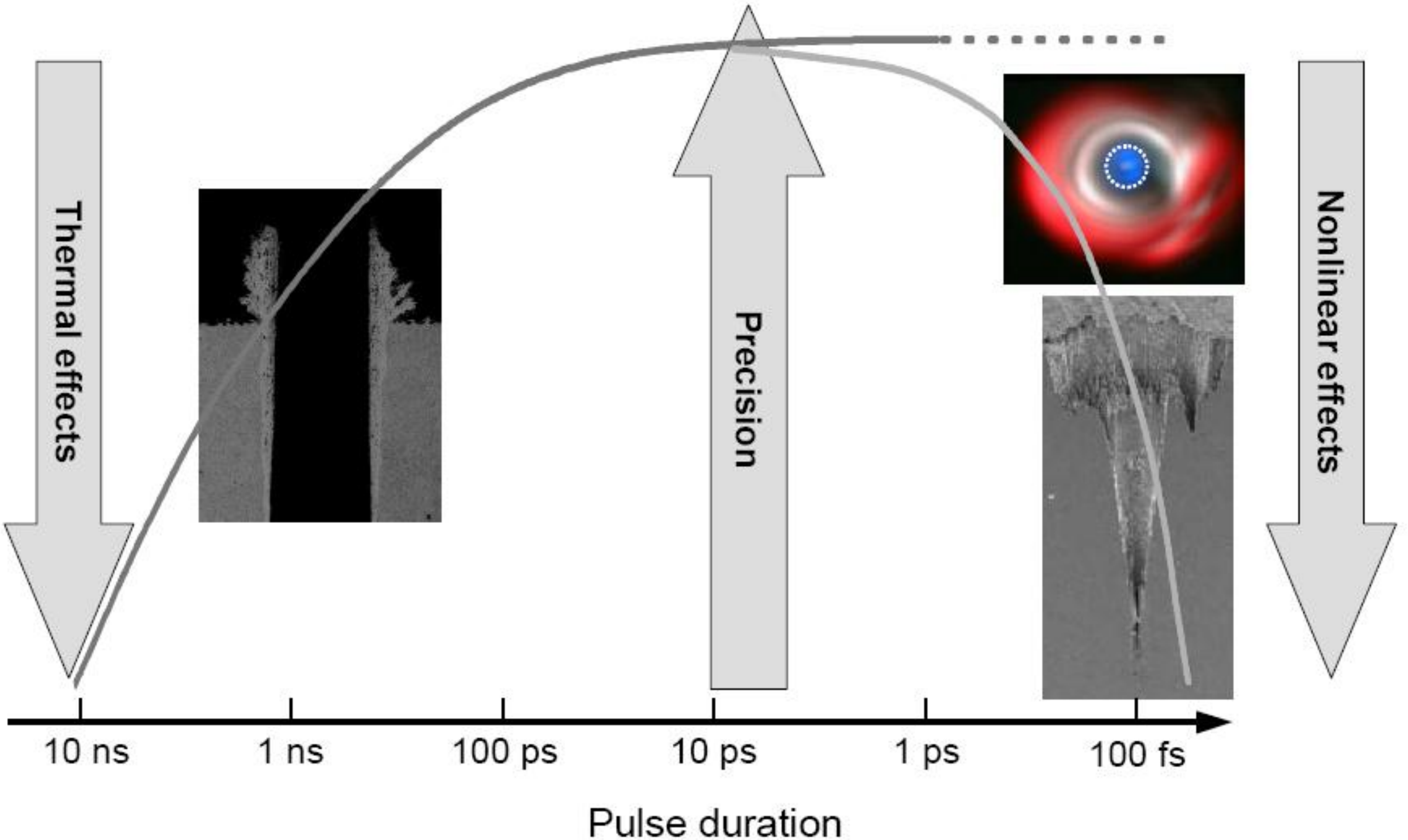
electron - lattice **energy transfer**

ablation
by phase explosion or evaporation

Thermal diffusion
Melting and resolidification

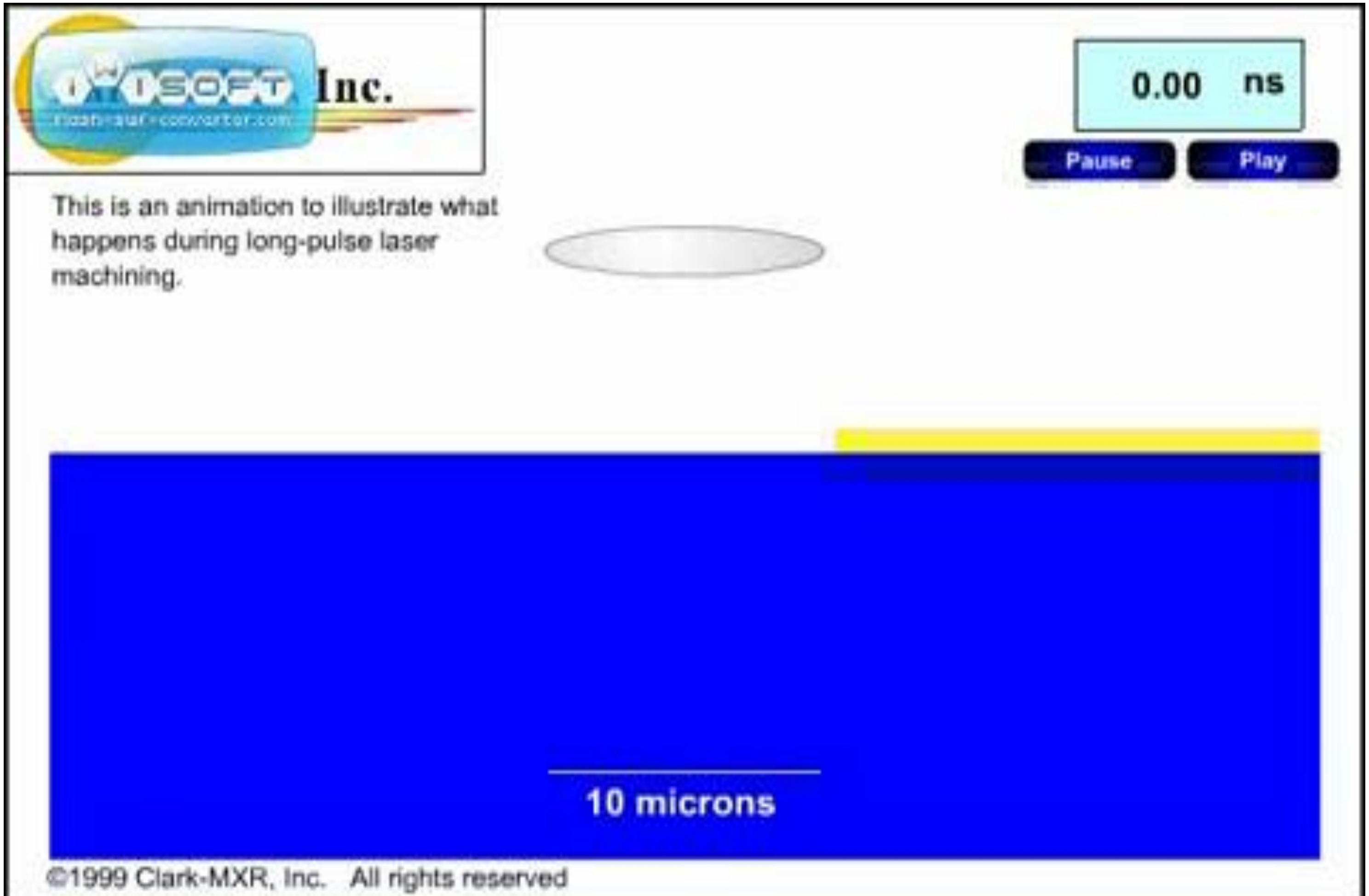
*Mazur et al. Nature Materials **2**, 217 (2002)*

Precision Vs. Pulse duration

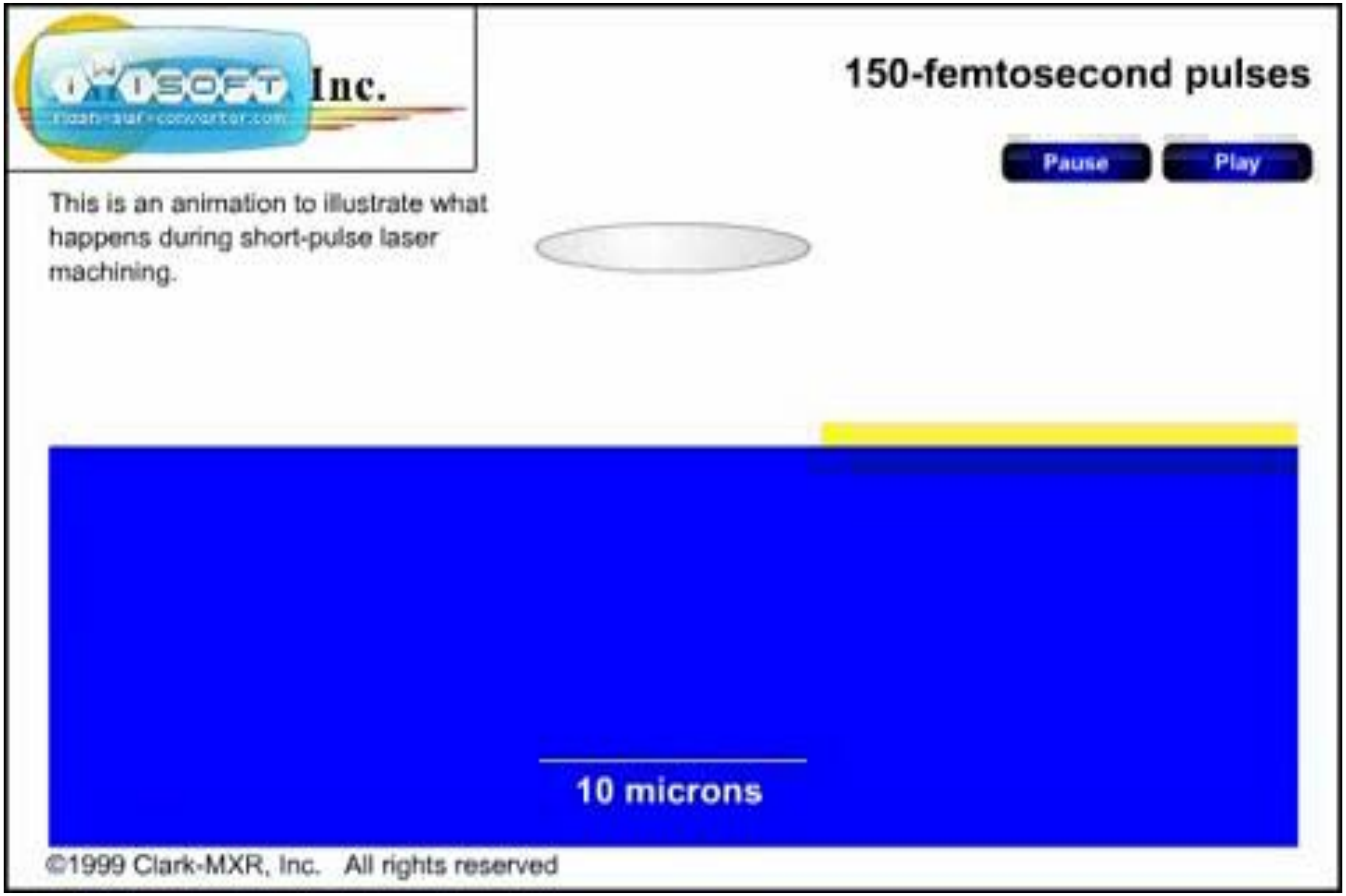


F. Dausinger, Proc. *FTK, 289-308 Stuttgart 2003*

Laser ablation with long pulses



Laser ablation with short pulses



Micromachining of metals

“long” pulses (3.3 ns)

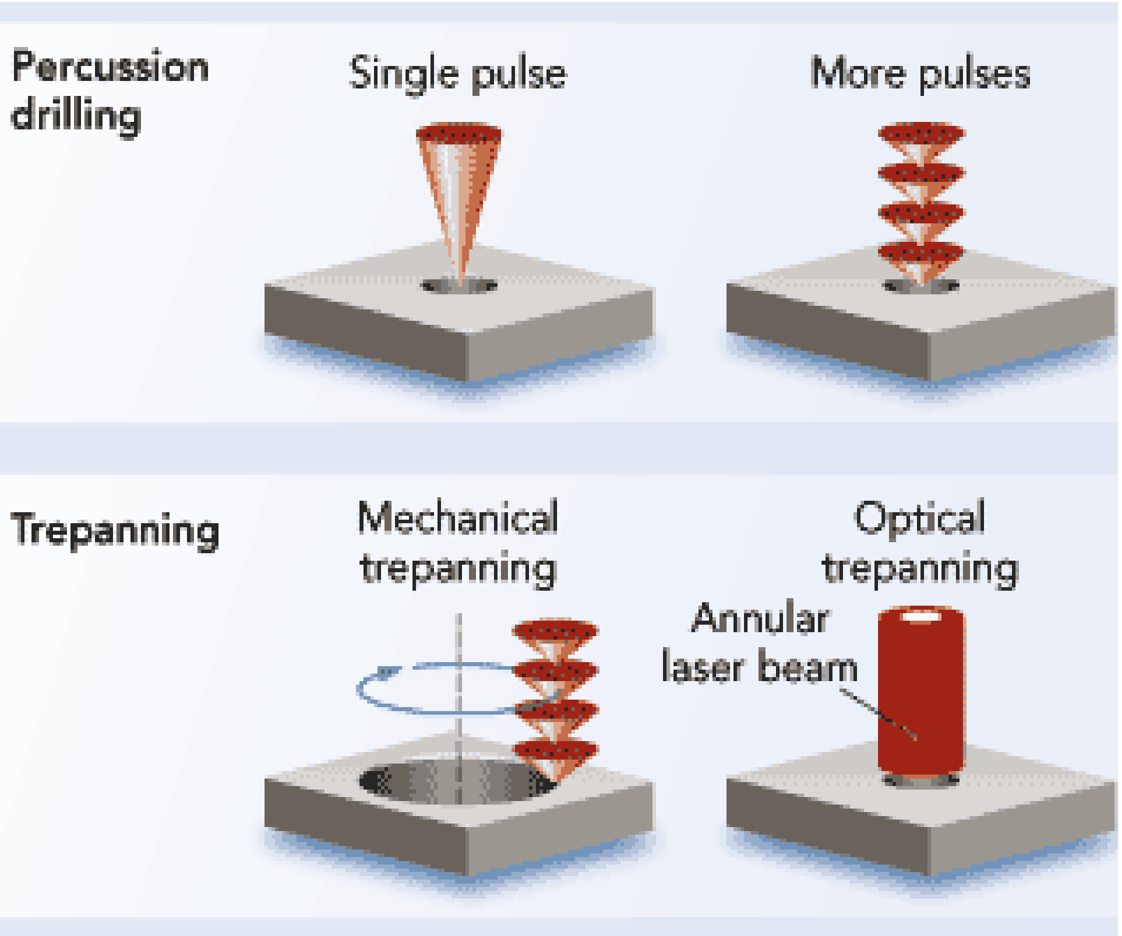
- melting and creation of burr
- heat diffusion
- non reproducible process

Ultrashort pulses (200 fs)

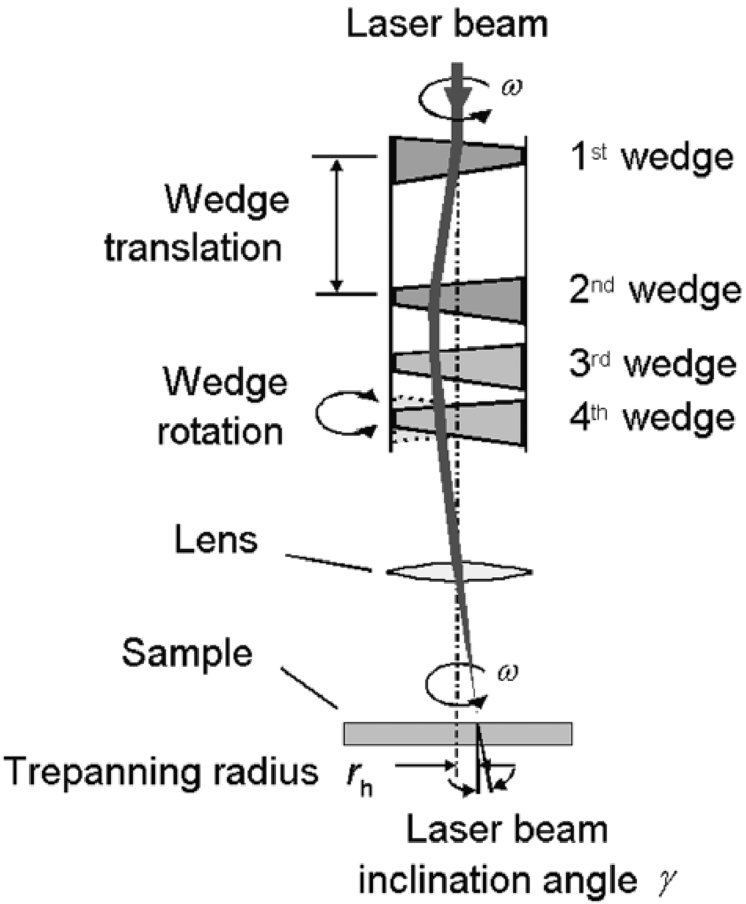
- practically burr- and melting-free ablation
- low ablation threshold
- negligible heat diffusion
  - ➢ minimized heat affected zones
- high process efficiency
- stable ablation process
  - ➢ high reproducibility

C. Momma et al. Opt. Comm. 129 (1996)

Laser drilling strategies for high accuracy

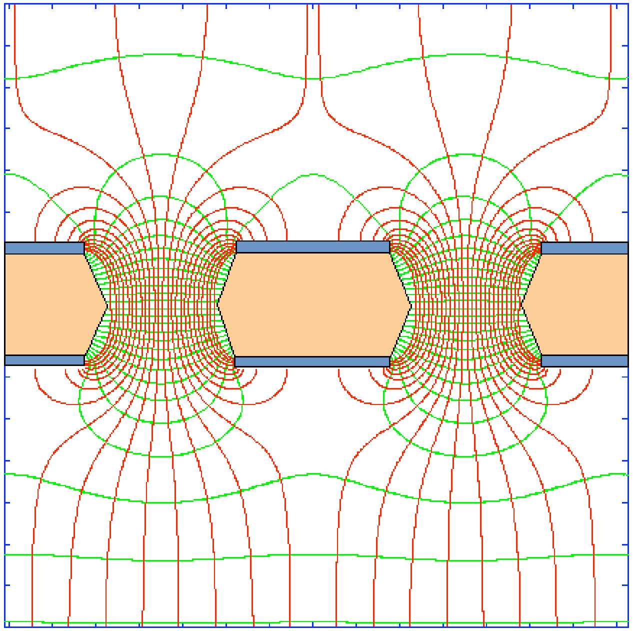


Trepanning optic for helical drilling



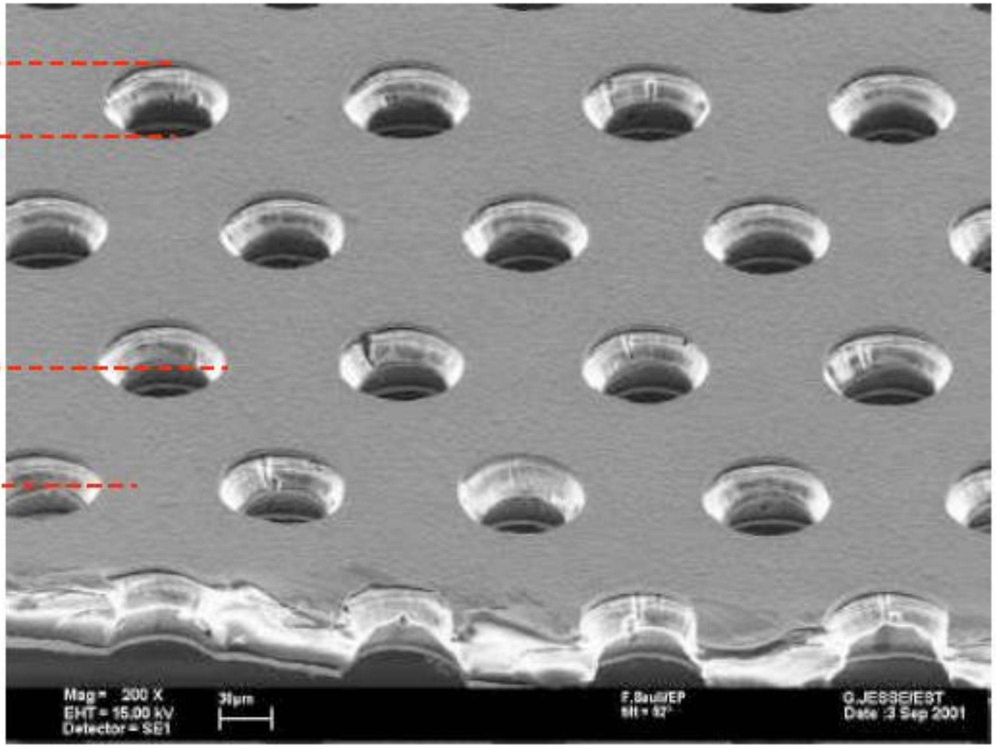
F. Dausinger et al., *Springer* (2004)

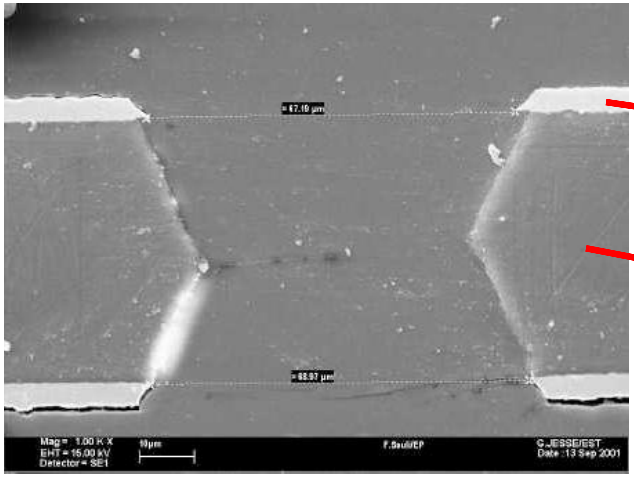
GEM fabrication



70 µm

140 µm





5 µm Copper

50 µm Kapton

Critical asprcts of GEM fabrication via laser ablation

- Kapton and Cu are materials with completely different thermal and physical properties

	Material	Density ($g\ cm^{-3}$)	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Melting point (°C)	Vaporization temperature (°C)
Copper	Metal	8.94	400	1084	2562
Kapton	Polymer	1.42	0.12	none	~ 600

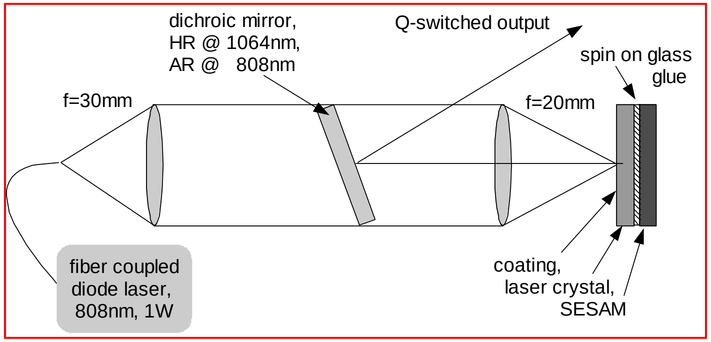
- Finding optimal laser process parameters (pulse duration, wavelength, fluence, drilling strategy)

- Copper particle redeposition inside the hole walls (post process etching could be required)

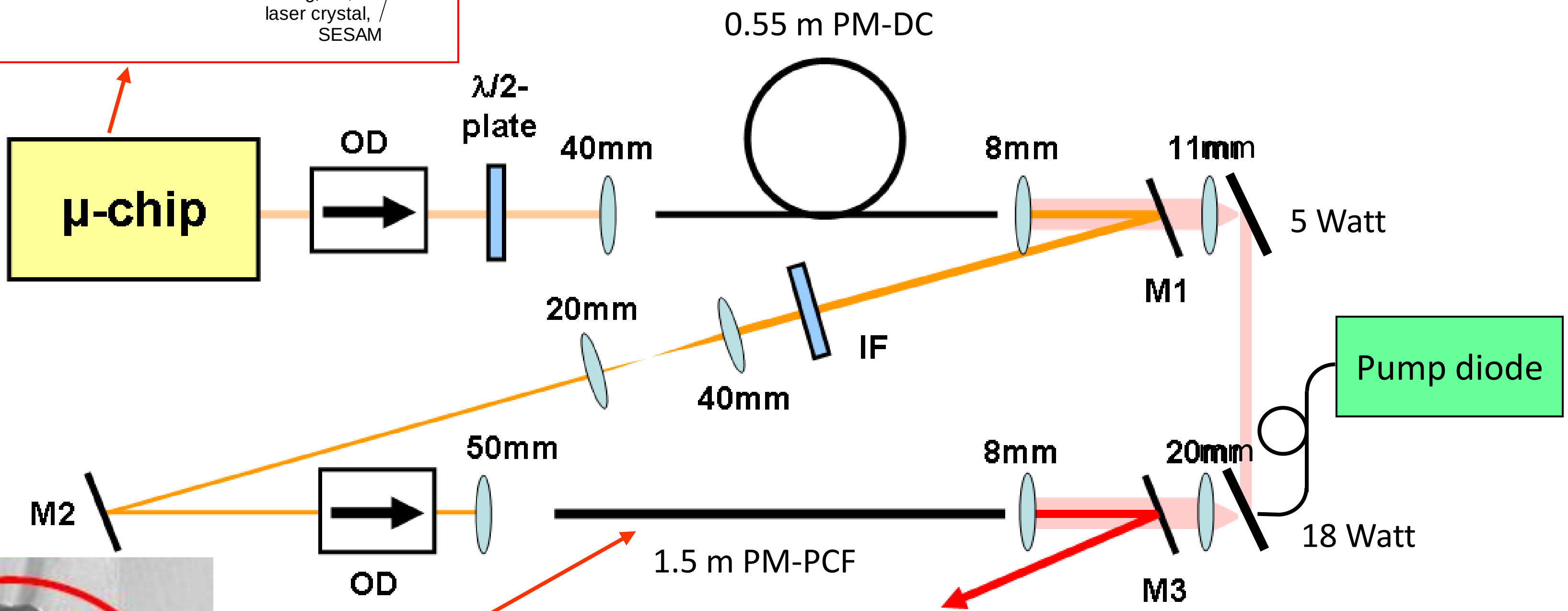
Advantages

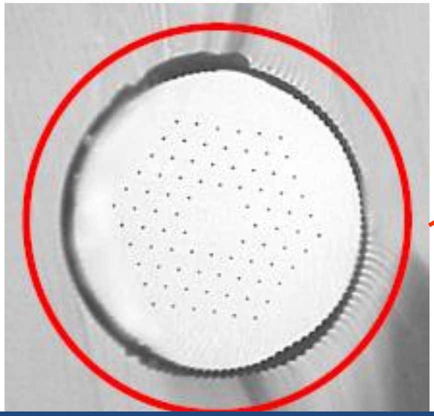
Flexible technology: complete control of the hole morphology (taper, diameter) and geometry (density of the holes mm^{-2}, distribution)

Microchip laser fiber amplifier (100 ps)



Quasi-monolithic Q-switched microchip laser

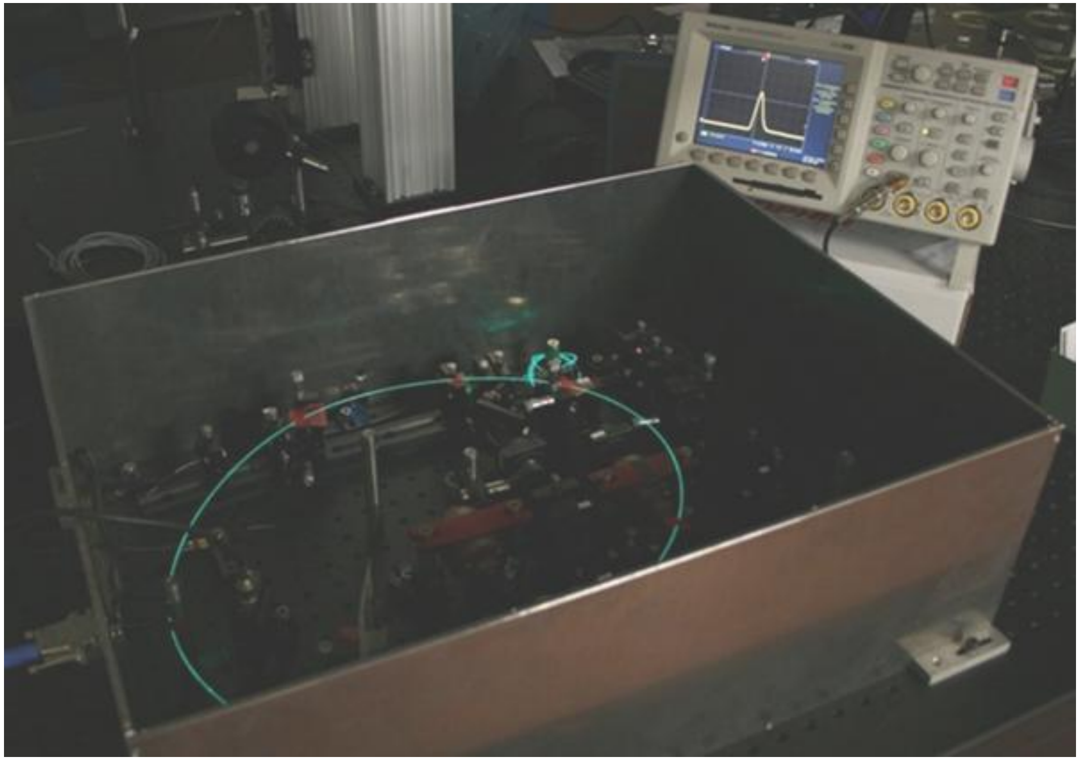


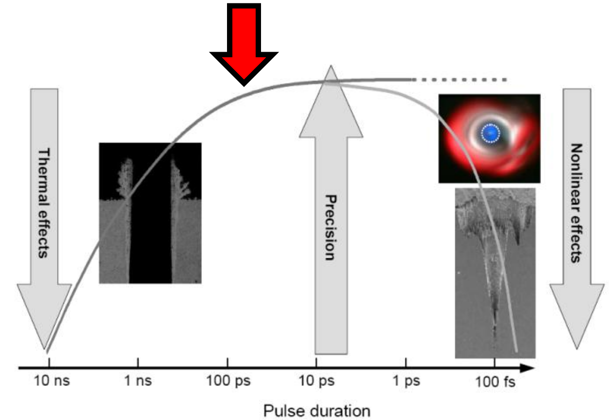


Yb-doped photonic crystal fiber

CNR-IFN Bari - Laser materials processing lab

Short pulse 100 ps fiber laser





Specifications	
Wavelength	1064 nm
Pulse duration	100 ps
Repetition rate	≈ 100 kHz
Pulse energy max.	100 μJ
Average power	10 W
Peak power max.	1 MW

Collaboration

IFN Institute for Photonics and Nanotechnologies

CNR-IFN Bari

seit 1558

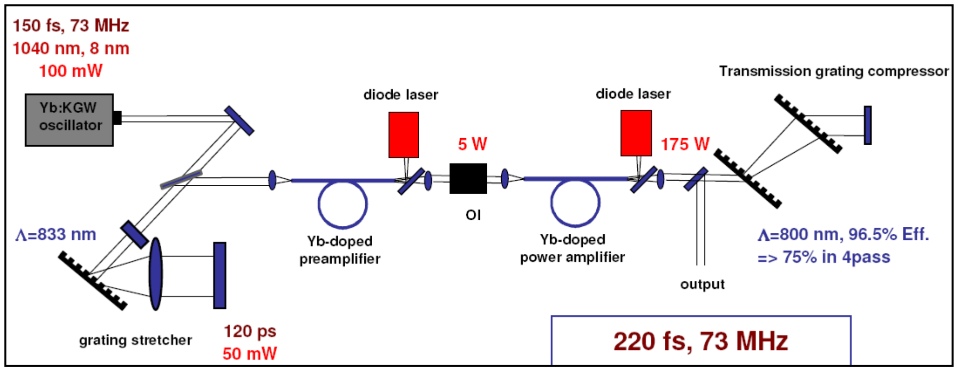
Fraunhofer IOF

iap

FSU JENA

CNR-IFN Bari - Laser materials processing lab

Ultrafast high power fiber CPA lasersystem



Wavelength: 1030 nm

Repetition rate: < 50 kHz … >10 MHz

Average power: up to 50 W

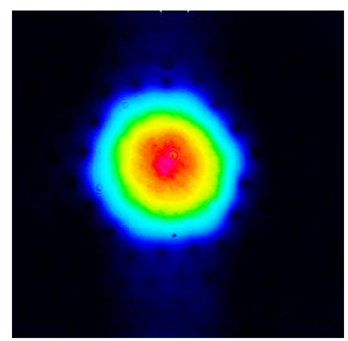
Pulse energy: up to 100 μJ

Pulse duration: **< 500 fs … >20 ps**

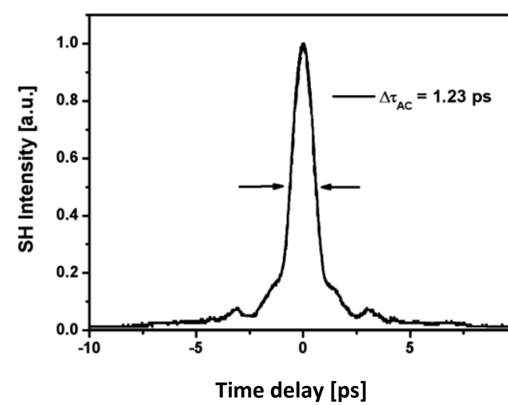
Beam quality: $M^2 < 1.5$

Options: SHG (515 nm), THG (345 nm)

mode profile



autocorrelation



Fraunhofer IOF

Friedrich Schiller University of Jena

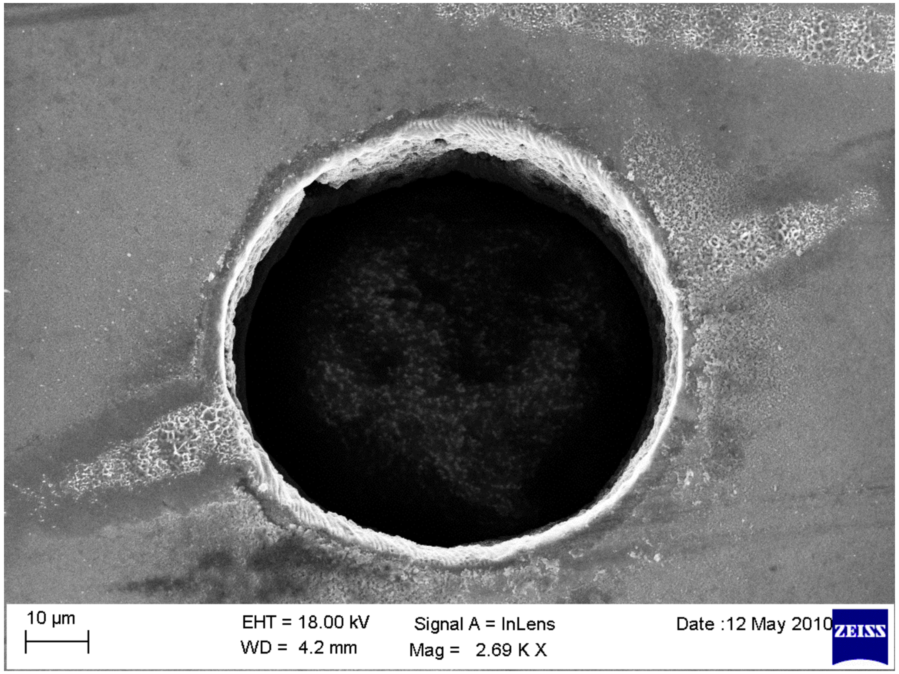
Expected delivery: February 2011

Post process Analysis

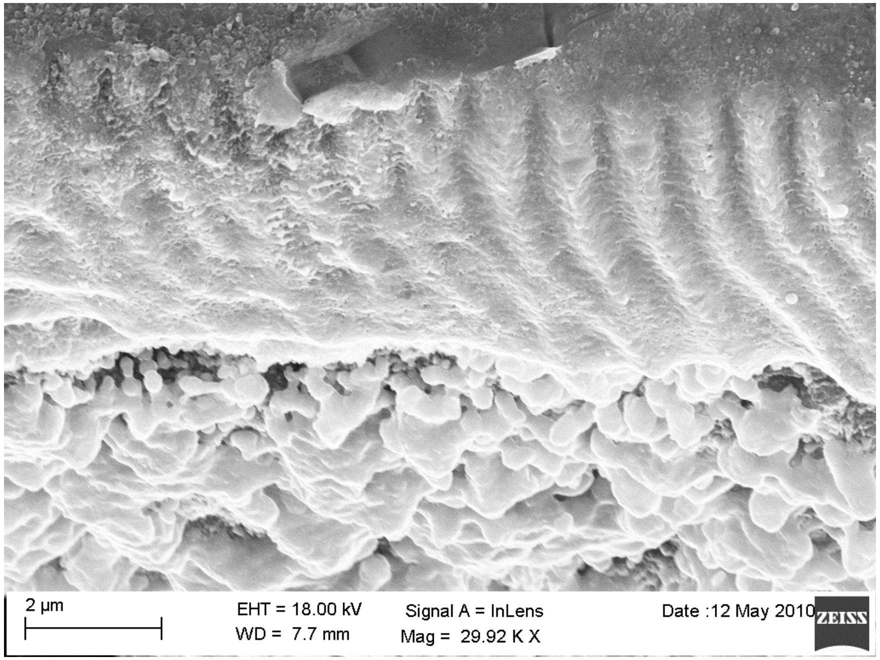
- Electron Microscopy - Field Emission
- EDS (Energy Dispersive X-ray Spectroscopy)
- Optical microscopy
- Profilometry

Preliminary results

Laser trepanned hole



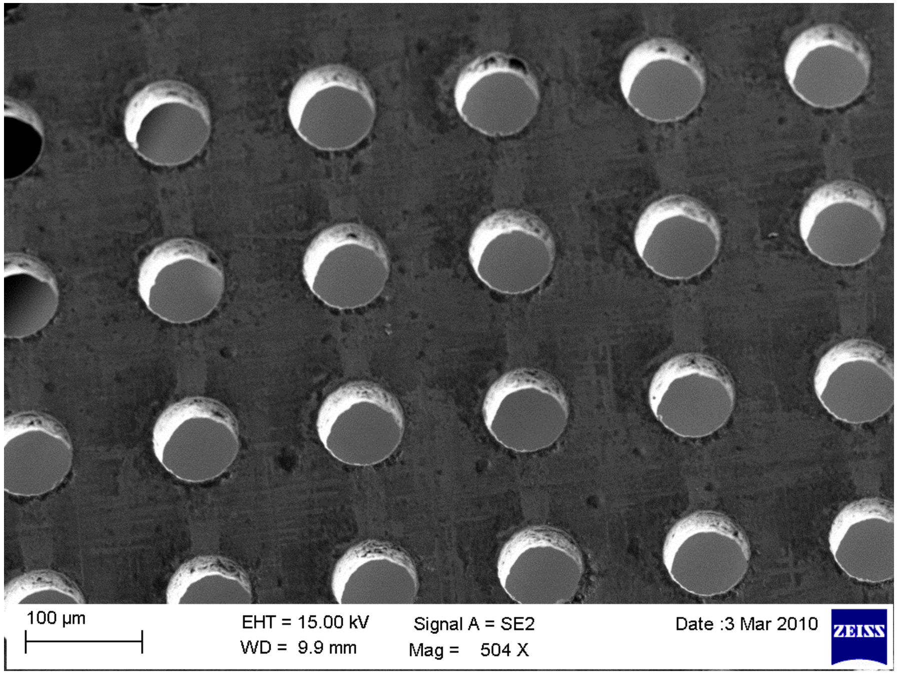
Cu – Kapton internal edge

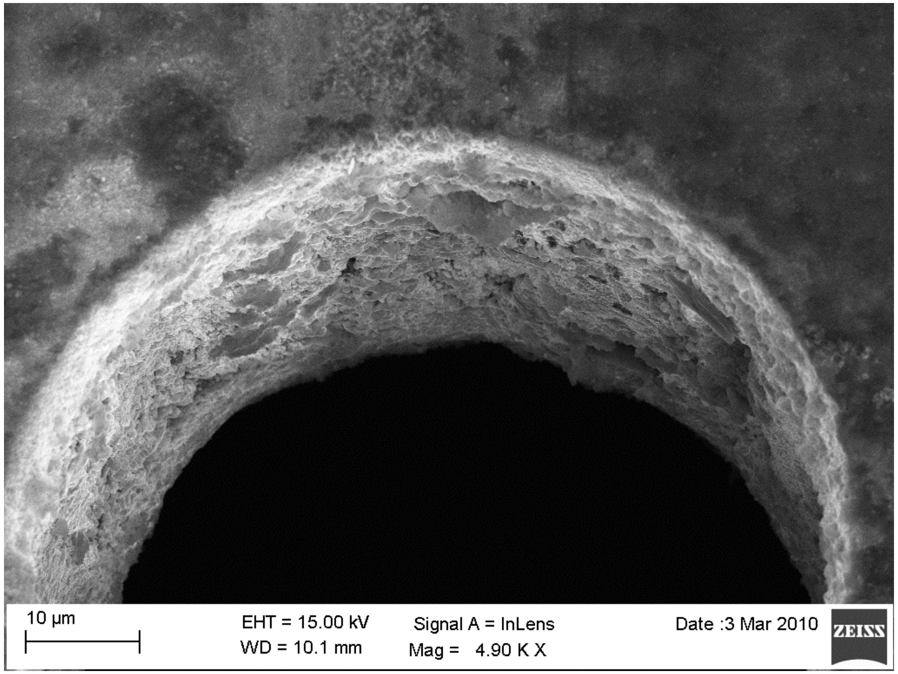


Laser parameters:

- wavelength: 1064 nm
- pulse duration: 100 ps
- repetition rate: 100 kHz
- average power: 0.7 W
- spot size: 30 µm
- trepanning radius: 20 µm

Preliminary results





- ☺ High repeatibility
- ☹ Cu particle redeposition inside the hole
  - ⇨ electric isolation not always guaranteed
  - ⇨ post-process etching needed

Outlook

- ❑ Etching tests to remove the Cu redeposited particles inside the hole in order to prevent voltage failures

- ❑ Laser trepanning assisted by an inert gas flow (or trepanning with smaller spot size) to avoid particle redeposition

- ❑ Micromegas (Cu 5μm/18 μm) small pitch laser machining (focusing spot down to < 10 μm)

- ❑ Ceramic (Al_2O_3) laser drilling for thick GEM fabrication

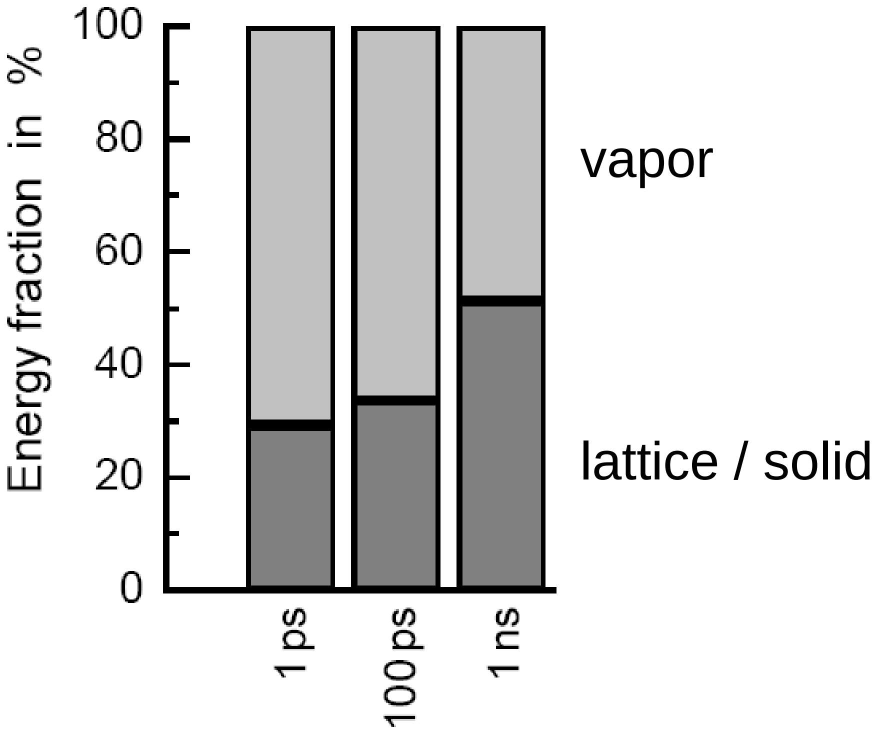
Laser Material Processing Research Group

Antonio Ancona	**CNR-IFN, technologist**
Teresa Sibillano	**CNR-IFN, researcher**
Francesco Mezzapesa	**Politecnico di Bari, post doc**
Domenico Rizzi	**CNR-IFN, research fellow**
Francesca Di Niso	**Università di Bari, PhD student**
Pietro Mario Lugarà	**Università di Bari, full professor**
Gaetano Scamarcio	**Università di Bari, full professor**

INFN Bari Collaboration

Gabriella Catanesi	**INFN, Senior reseracher**
Vincenzo Berardi	**Politecnico di Bari, associate professor**

Pulse energy distribution during laser ablation



absorbed laser energy :

- plasma generation and bond breaking
- particle ablation
- residual thermal energy

D. Breitling et al. „Fundamental aspects in machining of metals with short and ultrashort laser pulses“, Proc. of SPIE **5339** (2004), 49-63