

6th RD51 Collaboration Meeting
7-10 October 2010 Bari, Italy

Ultrashort pulsed laser technology for new detectors

Antonio Ancona



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.

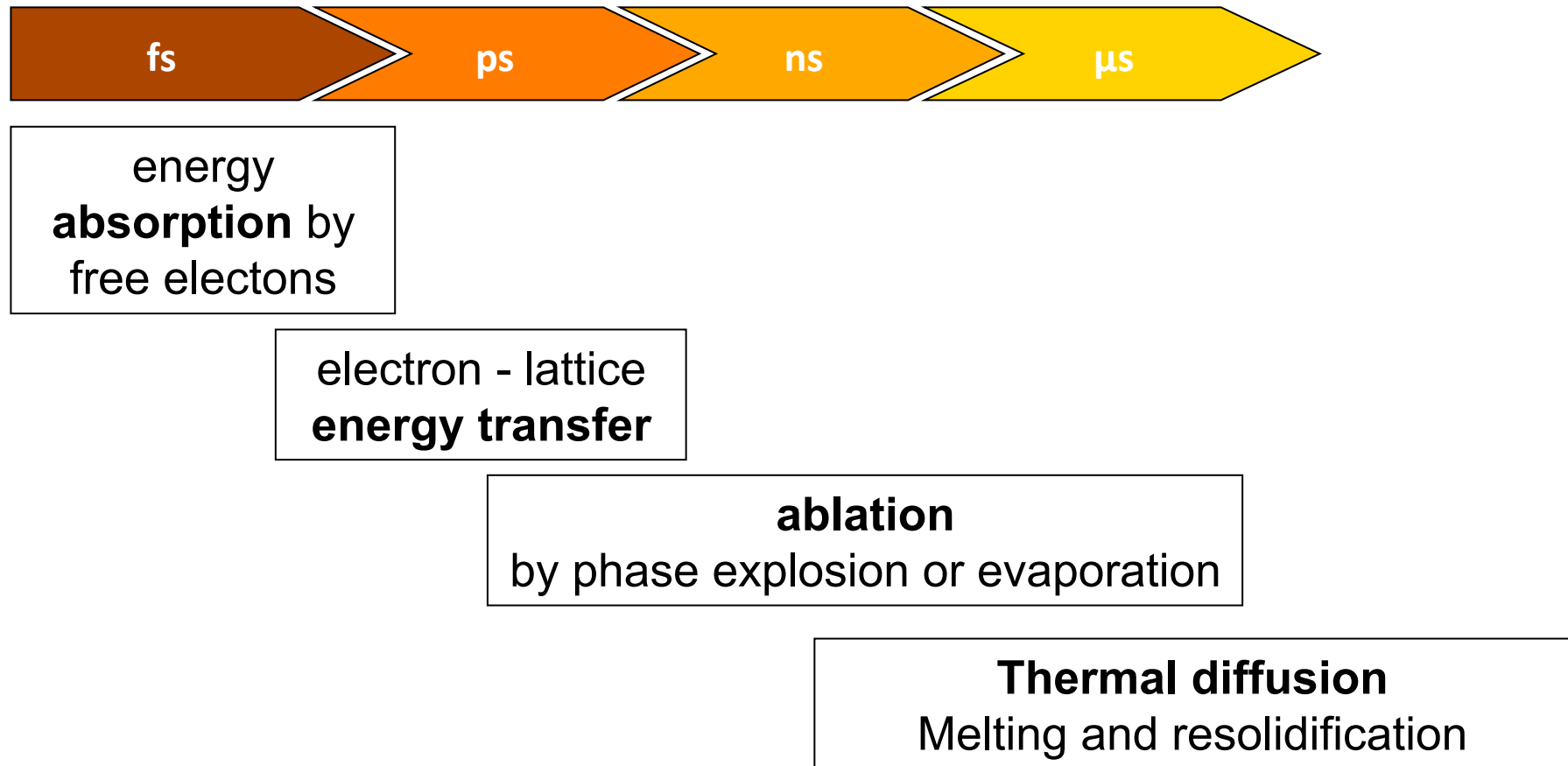
At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates.

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

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

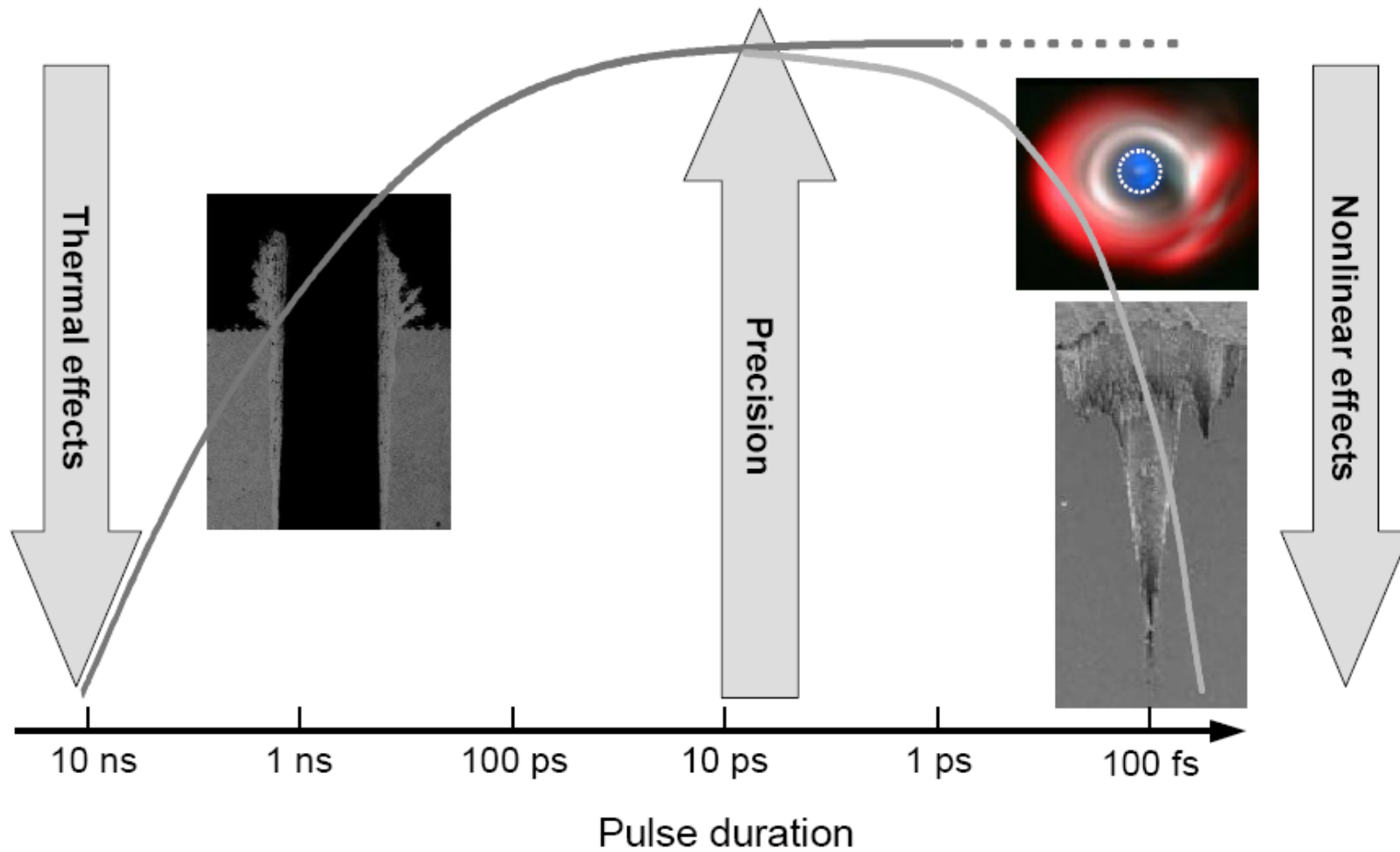


Timescales of the laser ablation process



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

Precision Vs. Pulse duration



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

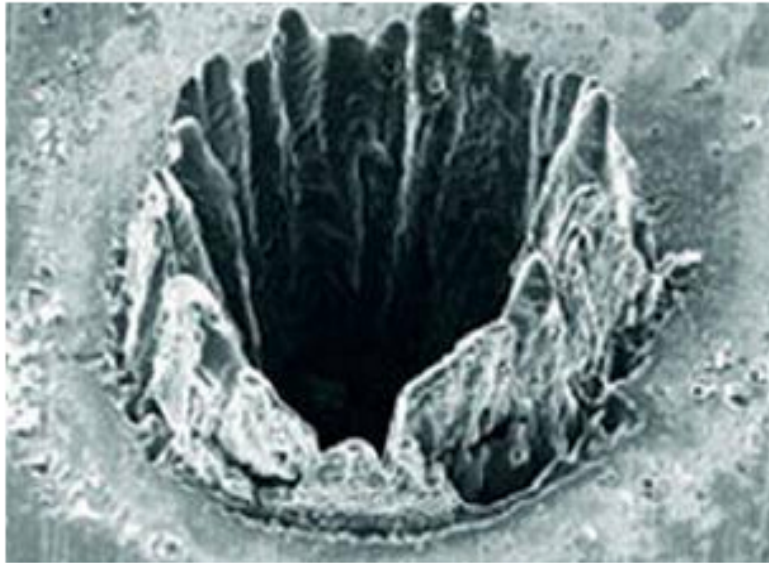
Laser ablation with long pulses

The screenshot shows a software interface for a laser ablation simulation. In the top left corner, there is a logo for 'ISOFT Inc.' with the website 'isoft.com' below it. In the top right corner, a digital display shows '0.00 ns' and two buttons labeled 'Pause' and 'Play'. The main area contains a 3D model of a grey, horizontally-oriented oval. Below the model, a large blue rectangular area represents a cross-section of the material, with a yellow horizontal bar at its top edge. A white scale bar labeled '10 microns' is positioned at the bottom center of the blue area. A text box on the left side of the interface contains the text: 'This is an animation to illustrate what happens during long-pulse laser machining.' At the bottom left of the interface, the copyright notice reads: '©1999 Clark-MXR, Inc. All rights reserved.'

Laser ablation with short pulses

The screenshot shows a software interface for a laser ablation simulation. In the top left corner, there is a logo for "IDISOFT Inc." with the website "http://www.idisoft.com" below it. The main title of the simulation is "150-femtosecond pulses". To the right of the title are two buttons: "Pause" and "Play". Below the title, there is a text box that reads: "This is an animation to illustrate what happens during short-pulse laser machining." In the center of the interface is a 3D rendering of a grey, horizontally-oriented oval representing a laser pulse. Below this, a large blue rectangular area represents the workpiece. A yellow horizontal bar is positioned above the right side of the blue area, indicating the laser's position. At the bottom center of the blue area, there is a white horizontal line with the text "10 microns" below it, serving as a scale bar. In the bottom left corner of the interface, the copyright notice "©1999 Clark-MXR, Inc. All rights reserved" is visible.

Micromachining of metals



“long” pulses (3.3 ns)

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

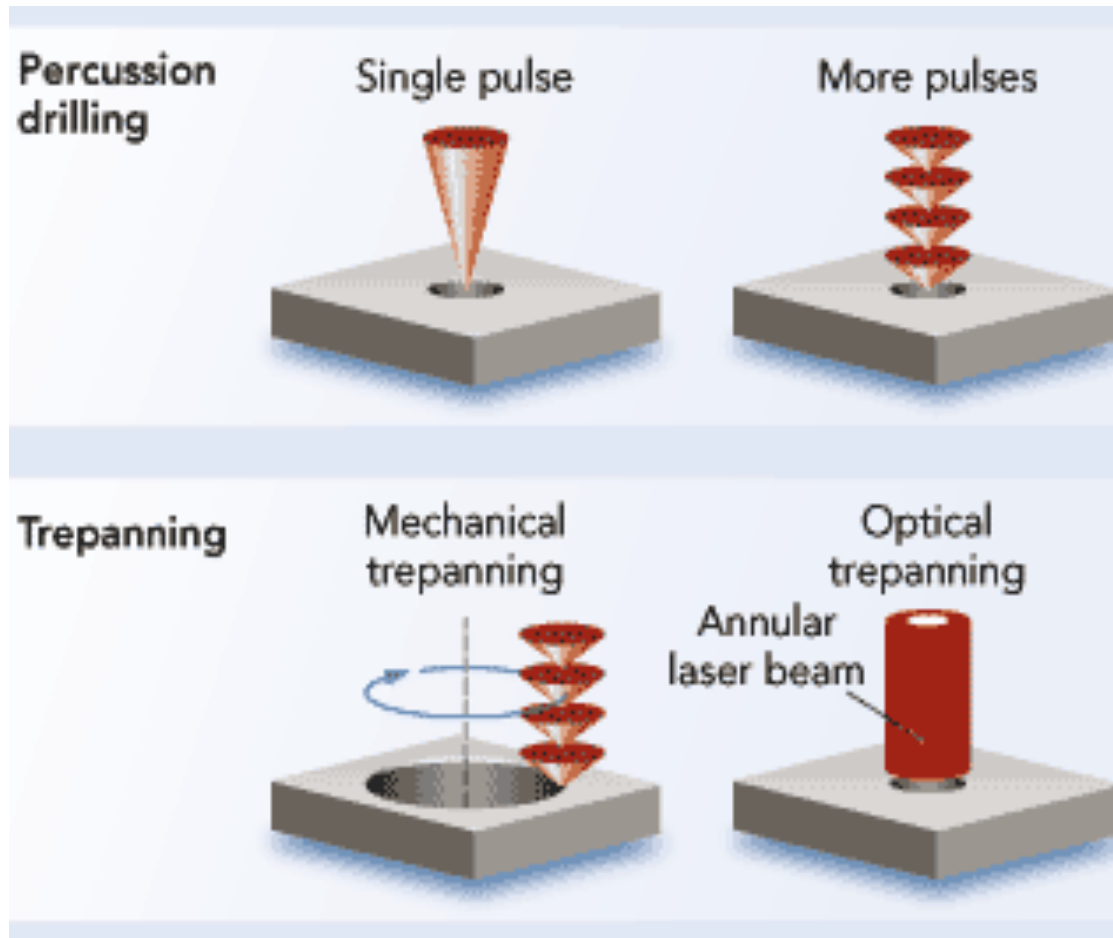


Ultrashort pulses (200 fs)

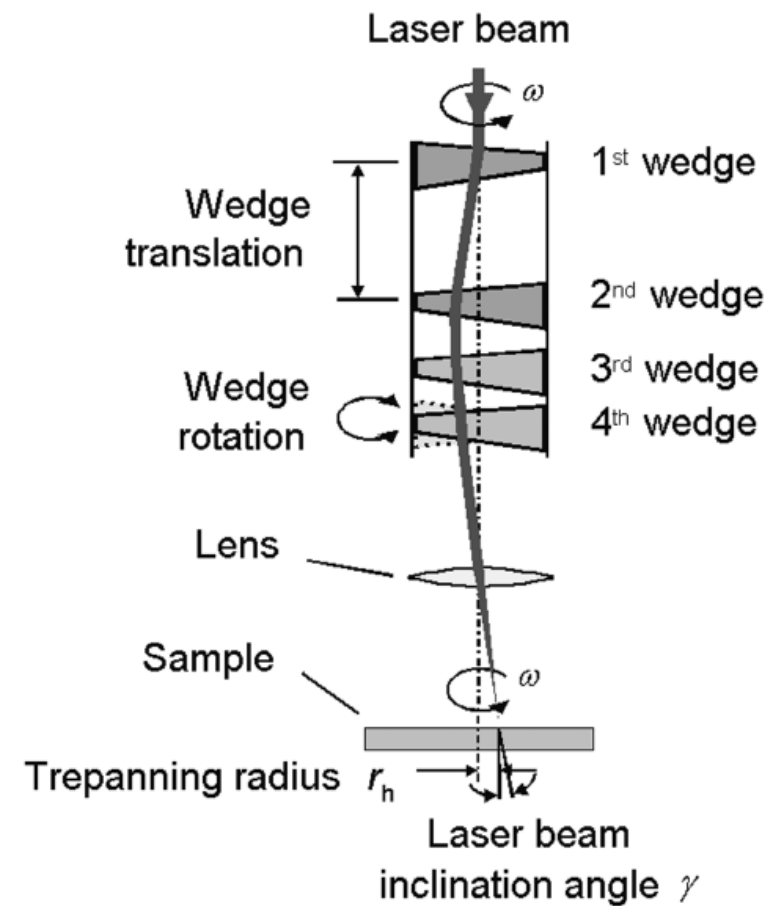
- practically burr- and melting-free ablation
- low ablation threshold
- negligible heat diffusion
 - minimized heat affected zones
- high process efficiency
- stable ablation process
 - high reproducibility

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

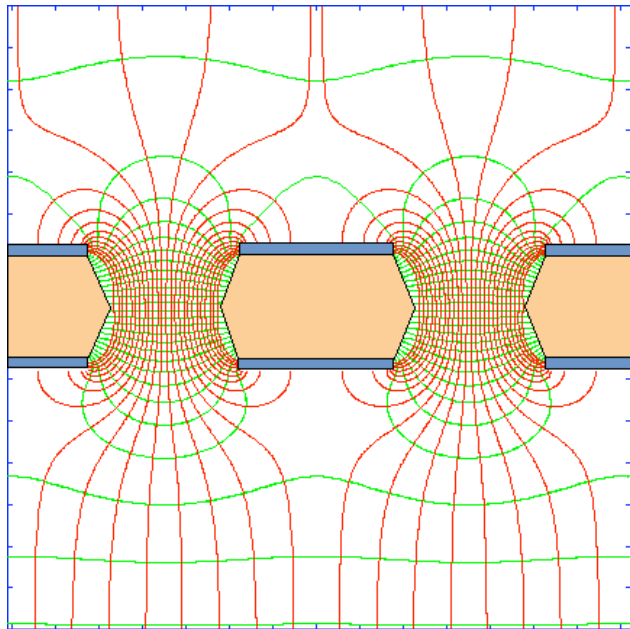
Laser drilling strategies for high accuracy



Trepanning optic for helical drilling

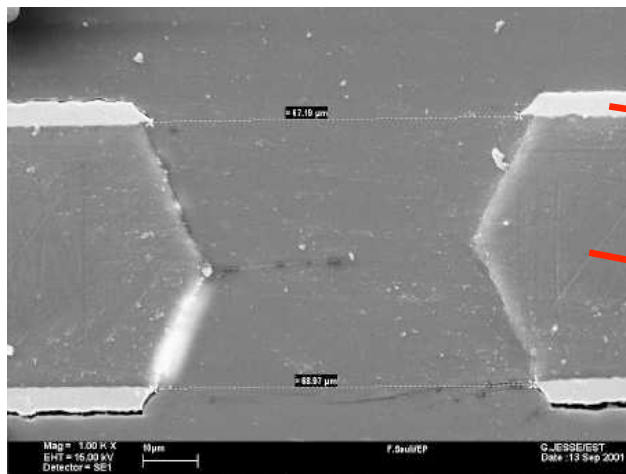
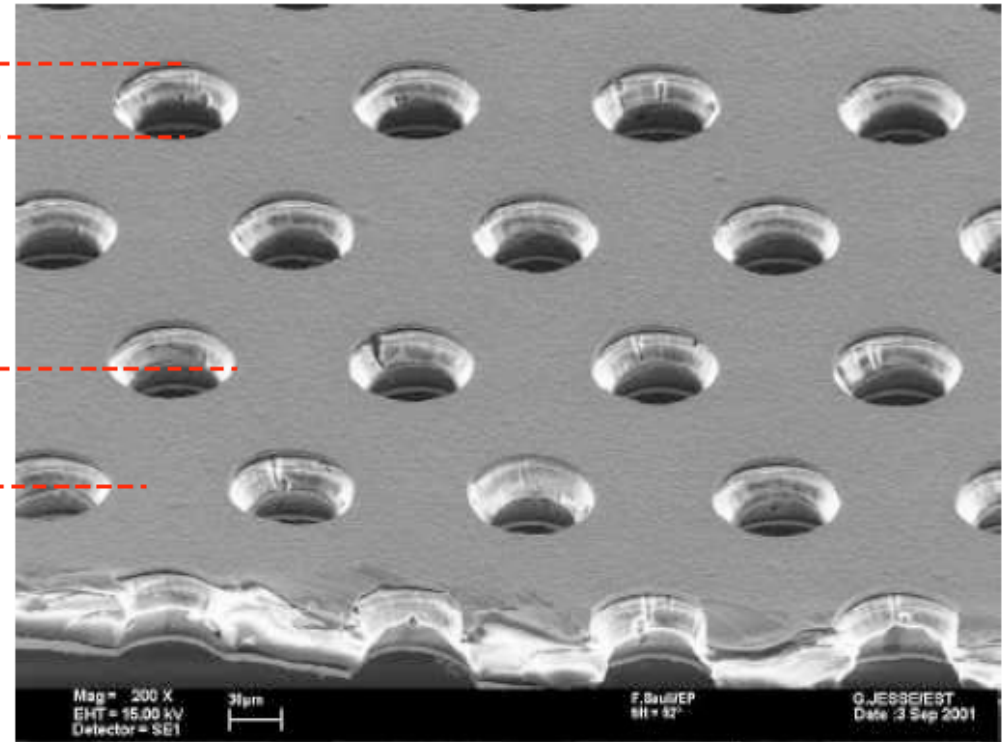


GEM fabrication



70 μm

140 μm



5 μm Copper

50 μm Kapton

Critical aspects of GEM fabrication via laser ablation

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

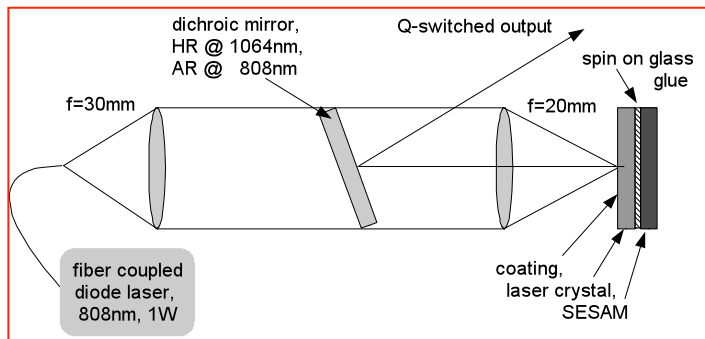
	Material	Density (g cm ⁻³)	Thermal Conductivity (W m ⁻¹ K ⁻¹)	Melting point (°C)	Vaporization temperature (°C)
Copper	Metal	8.94	400	1084	2562
Kapton	Polymer	1.42	0.12	none	~ 600

- Finding optimal laser process parameters
(pulse duration, wavelength, fluence, drilling strategy)
- Copper particle redeposition inside the hole walls
(post process etching could be required)

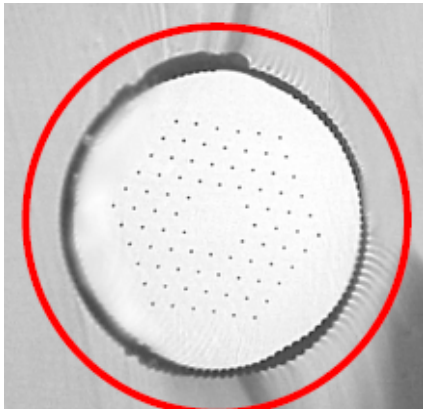
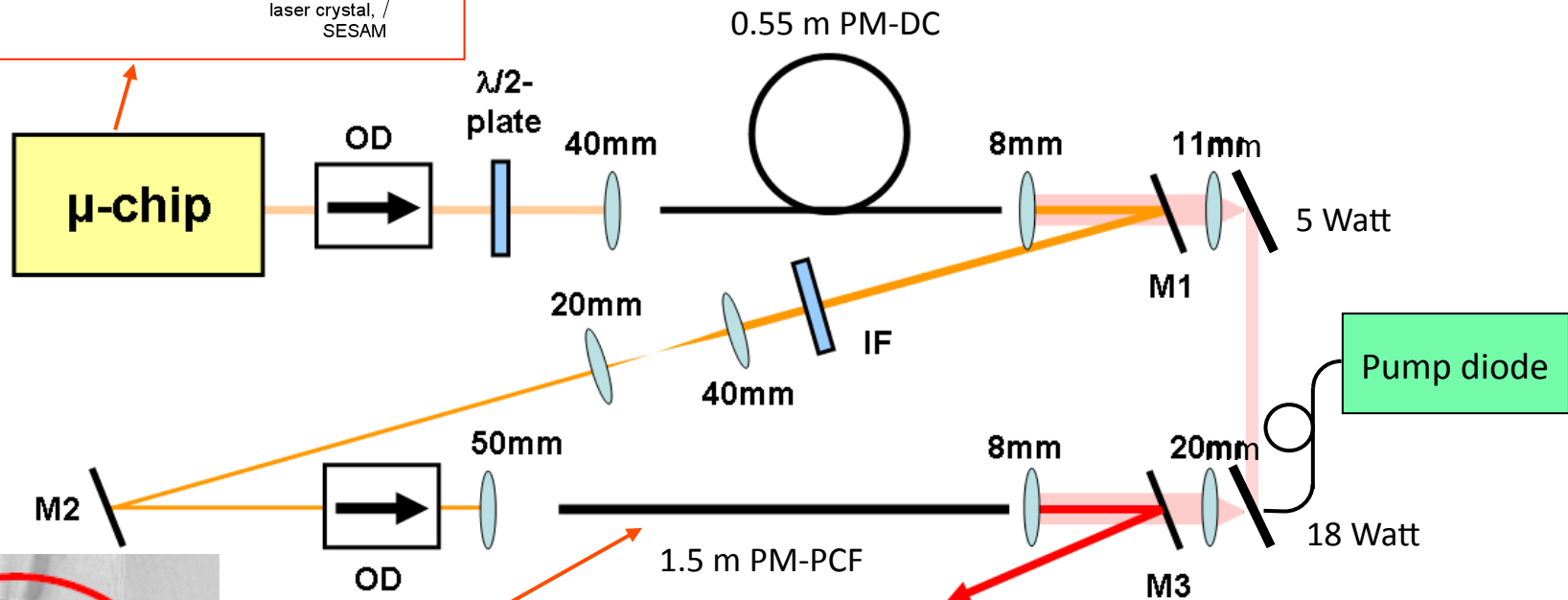
Advantages

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

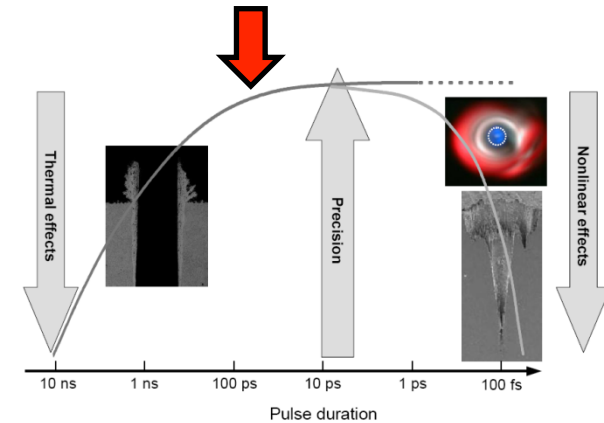
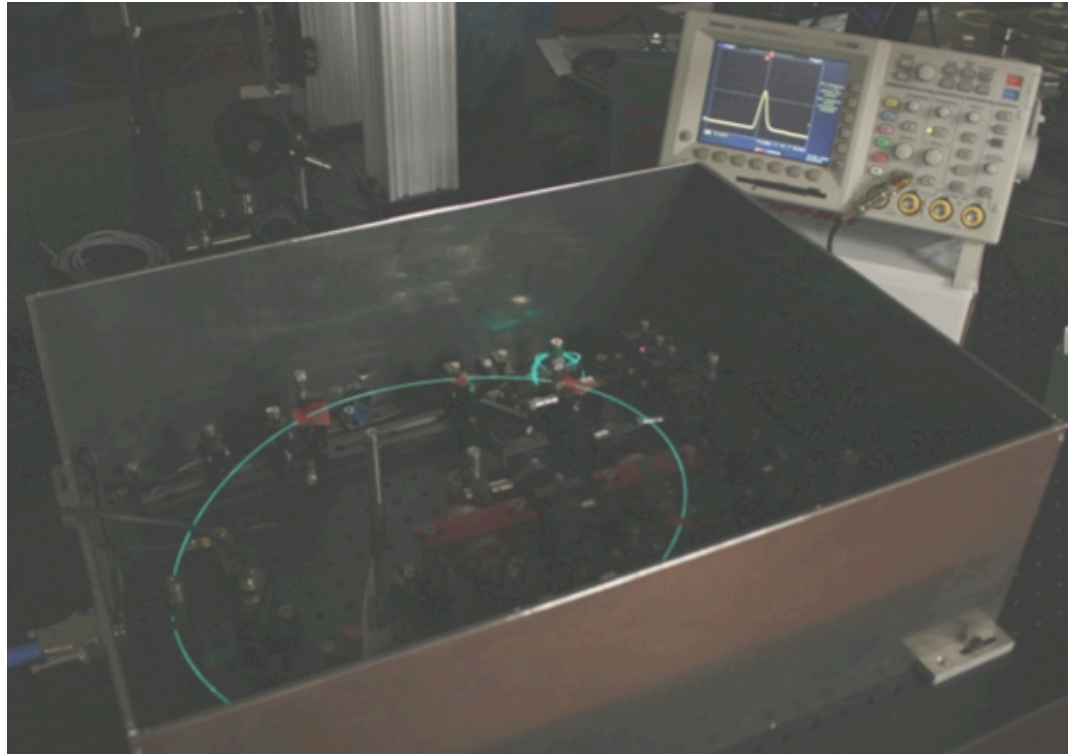


Yb-doped photonic crystal fiber



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



CNR-IFN Bari

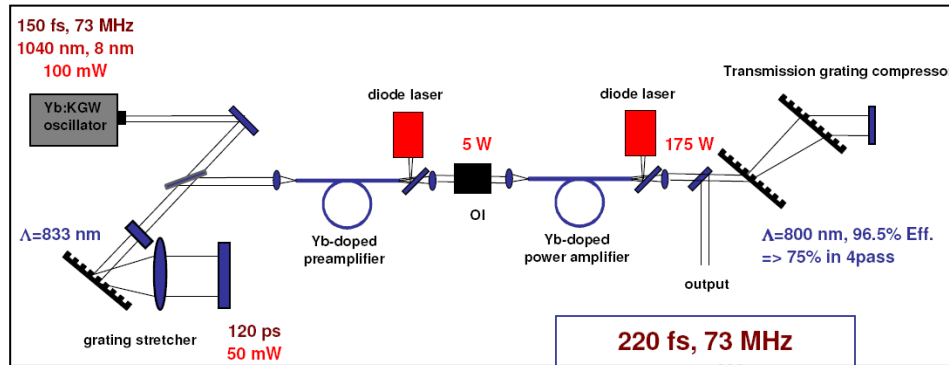


FSU JENA



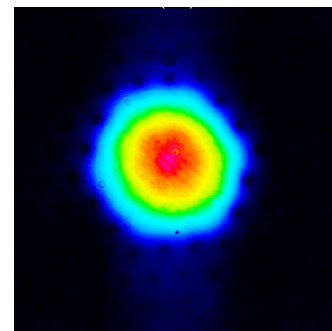
CNR-IFN Bari - Laser materials processing lab

Ultrafast high power fiber CPA lasersystem

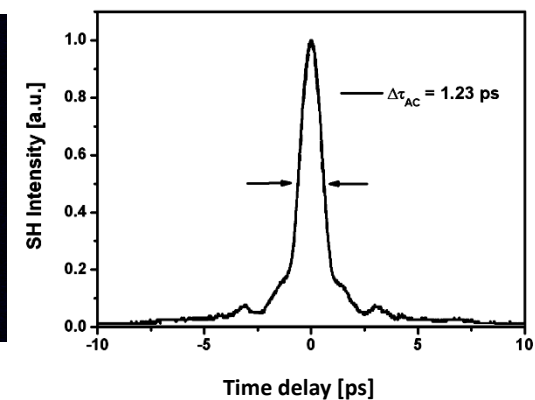


- Wavelength: 1030 nm
- Repetition rate: < 50 kHz ... >10 MHz
- Average power: up to 50 W
- Pulse energy: up to 100 μ J
- Pulse duration: < 500 fs ... >20 ps
- Beam quality: $M^2 < 1.5$
- Options: SHG (515 nm), THG (345 nm)

mode profile



autocorrelation



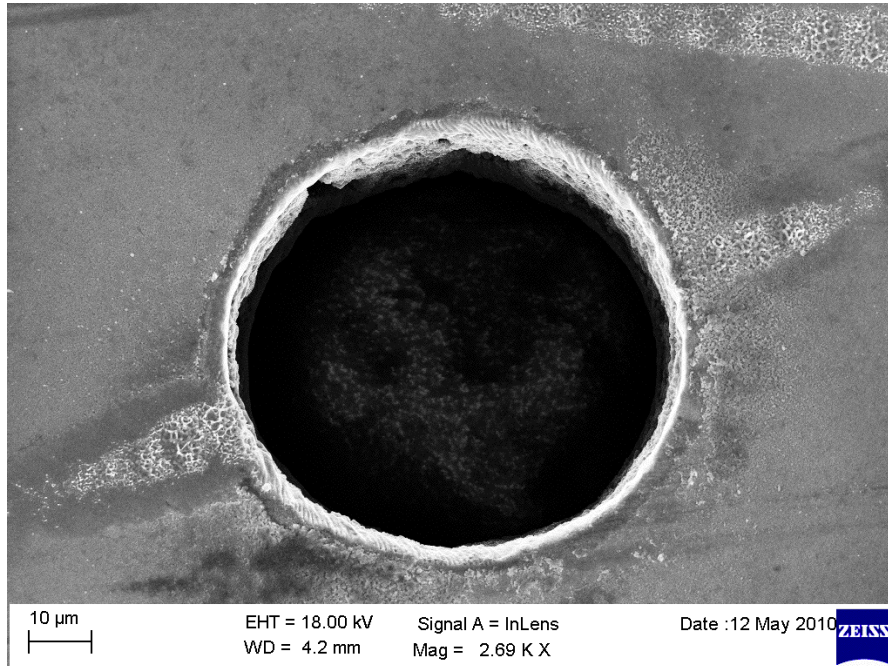
Post process Analysis

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

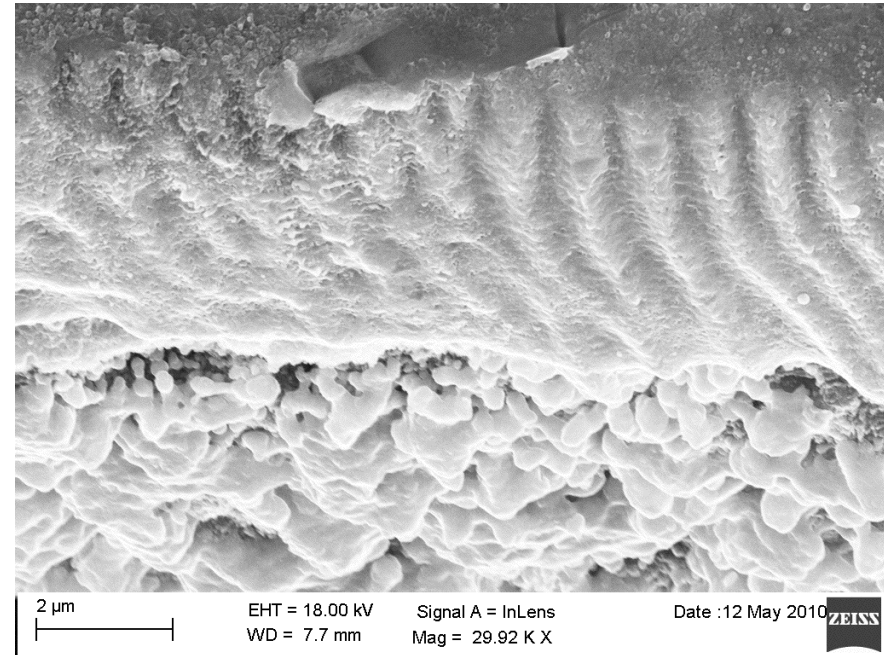


Preliminary results

Laser trepanned hole



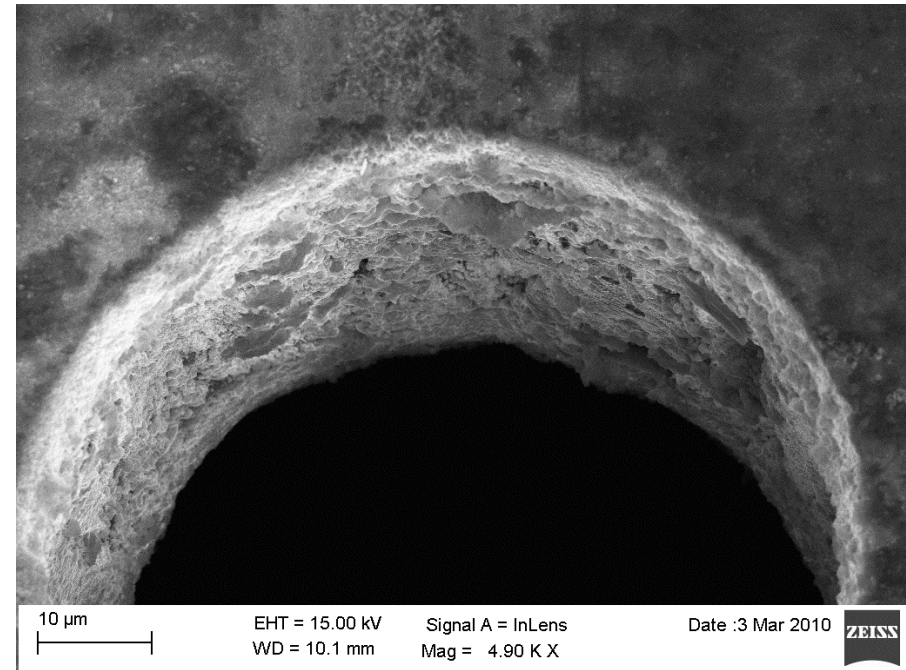
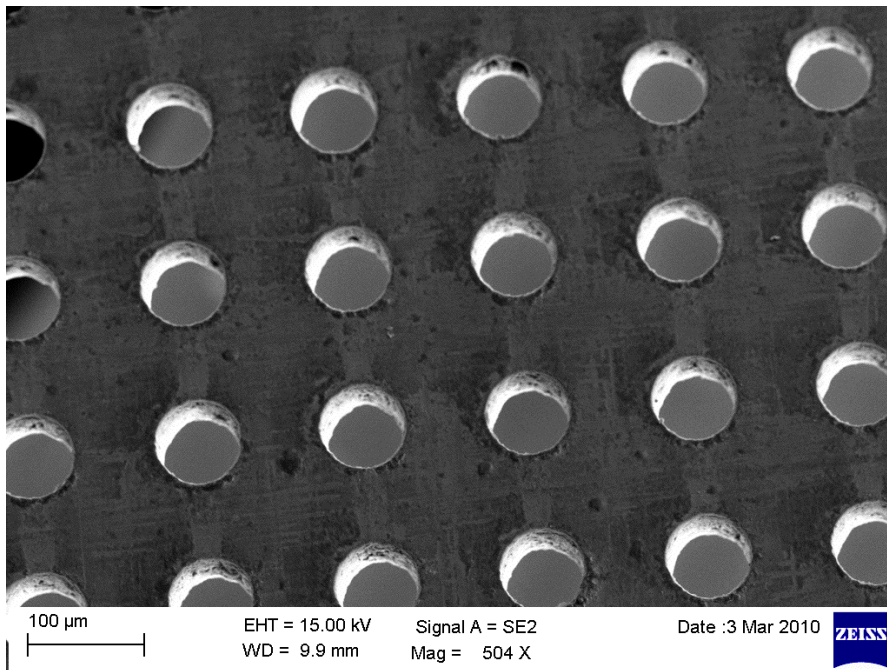
Cu – Kapton internal edge



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 repeatability
- 😞 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 $5\mu\text{m}/18\mu\text{m}$) small pitch laser machining (focusing spot down to $< 10\mu\text{m}$)
- ❑ Ceramic (Al_2O_3) laser drilling for thick GEM fabrication

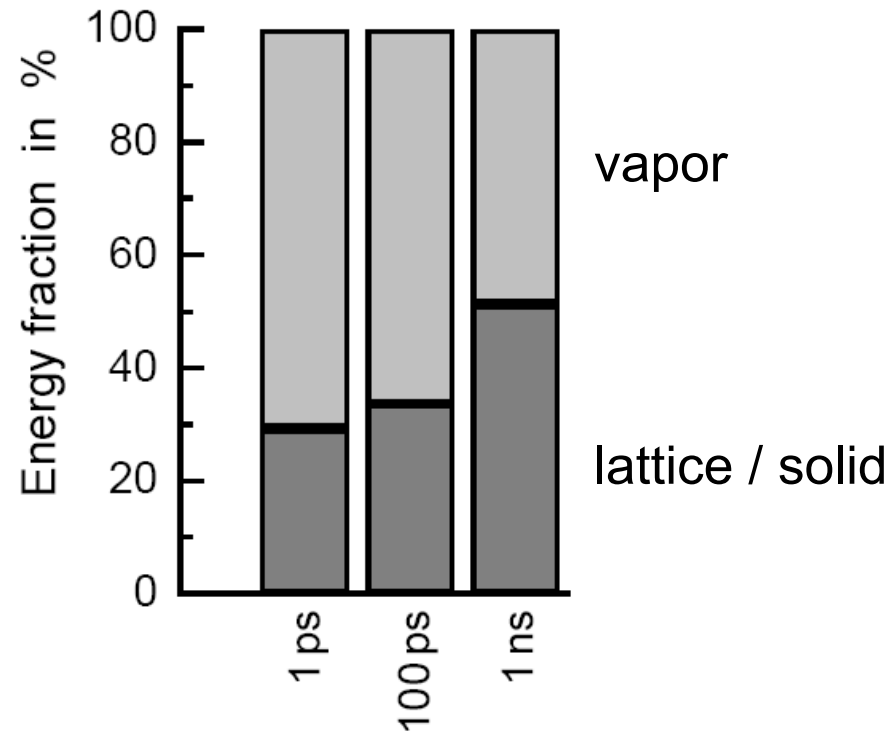
Laser Material Processing Research Group

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