Short pulse laser milling effects on surface integrity

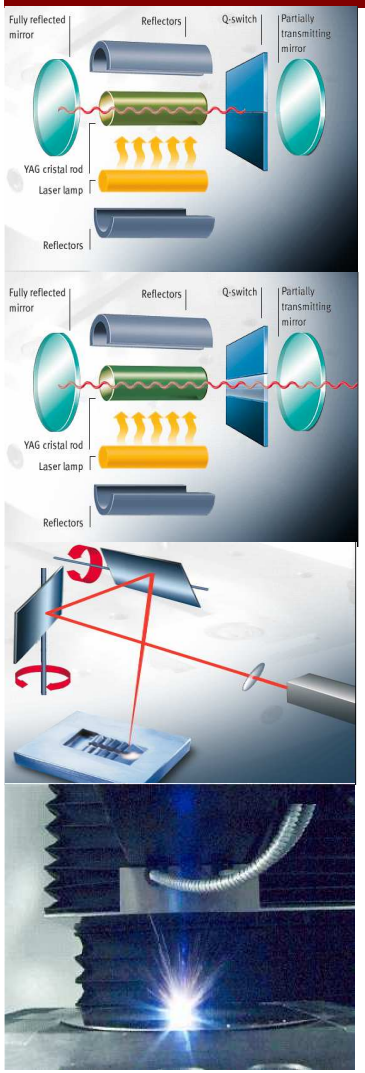
P V Petkov, S S Dimov, R. Minev and D T Pham

Centres of Excellence
Canolfannau Rhagoriaeth

Presentation Outline

- Overview
- Process description
- Experiments & Results
- Conclusions

Overview

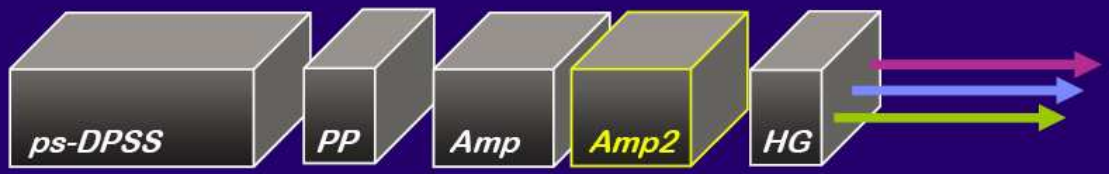


Pictures courtesy of Lasertech

LUMERA LASER

New: "SUPER RAPID"

- Proven and reliable concept, keeps RAPID benefits, with additional amplifier for higher output power



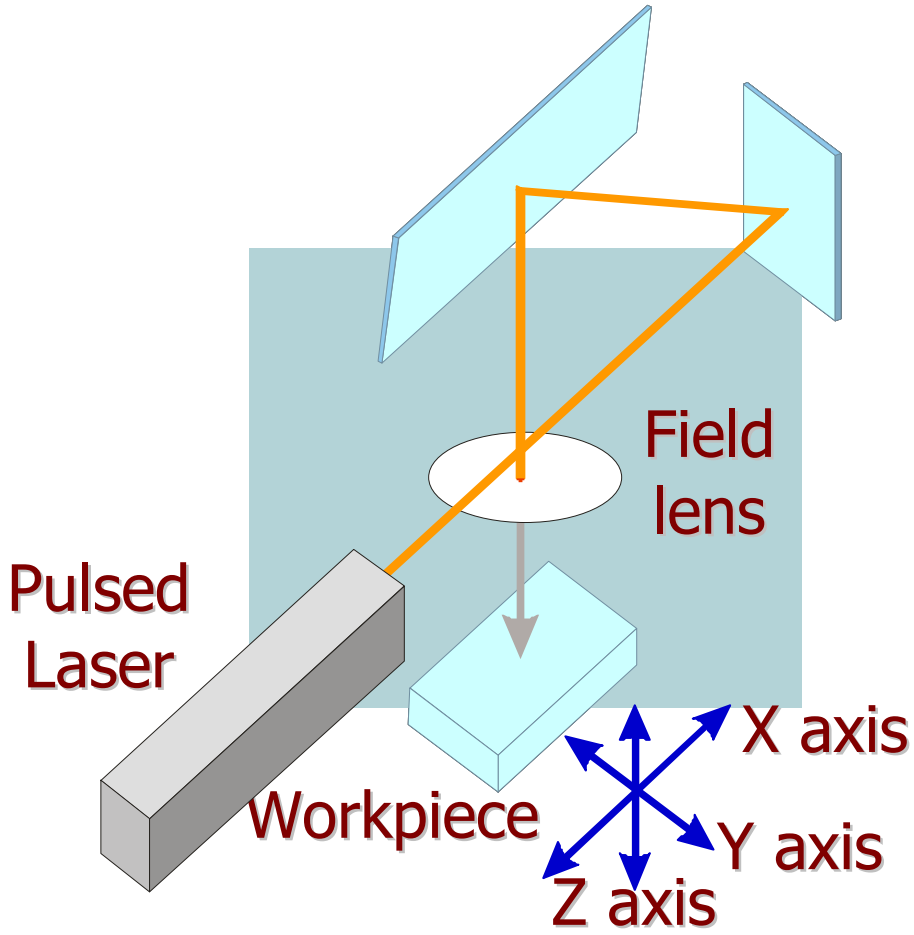
- High IR Power: > 8W @ 500 kHz (Single Pulse)
- Efficient harmonic generation (2ω, 3ω, 4ω)

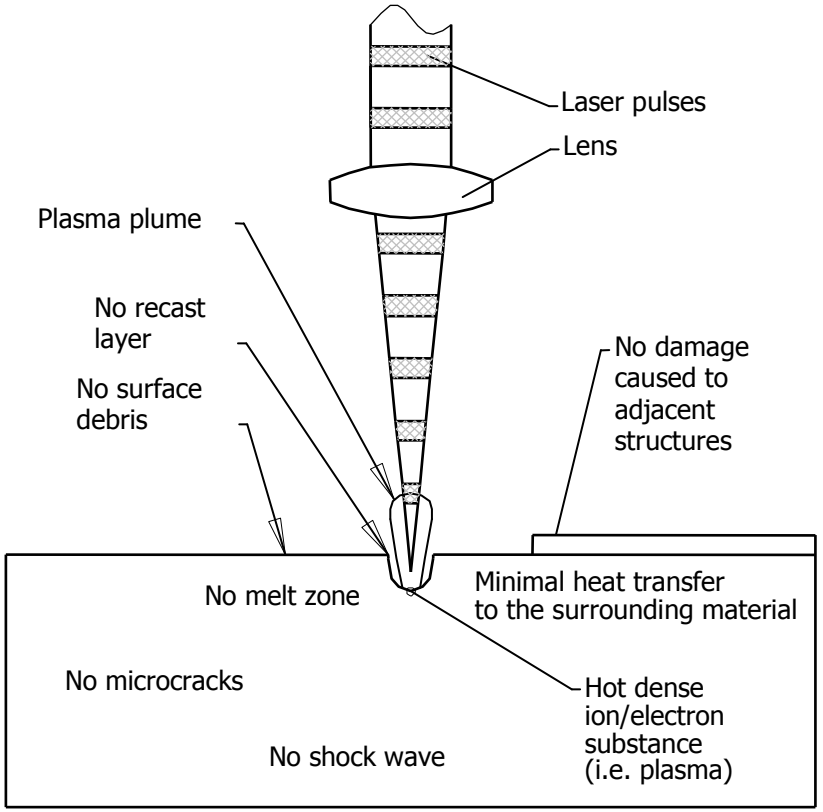
Launched on Photonics West 2006

LASE: Commercial and Biomedical Applications of Ultrafast Lasers VI 2006 *53 (55)*

Picture courtesy of Lumera

Process description

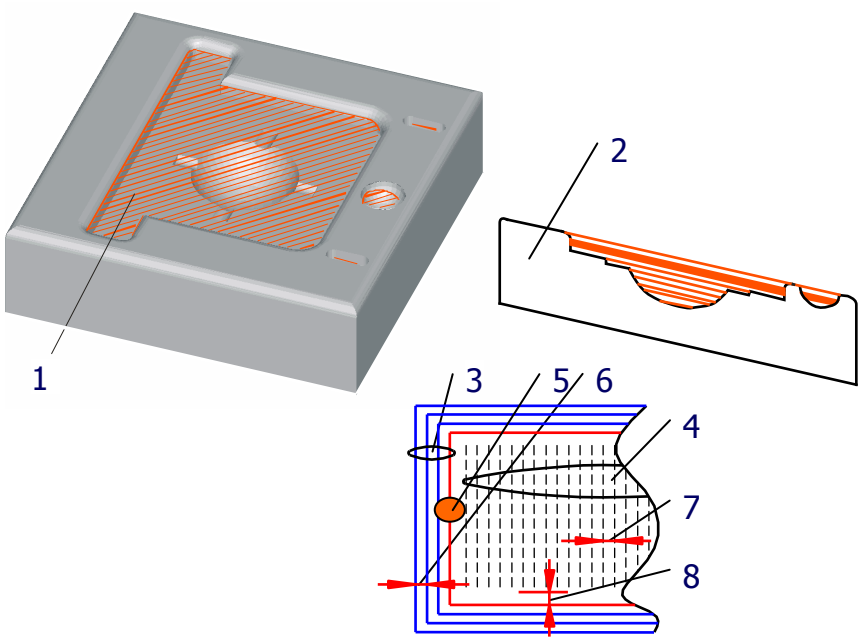




Femto and picosecond
laser ablation

Short pulse laser milling effects on surface integrity

Process description



Material removal in the laser milling process

1. cavity with a hatched slice
2. cross-section of the cavity with slices
3. border cuts
4. hatching cuts
5. laser spot
6. border cut track displacement (step-over)
7. hatch track displacement (step-over)
8. distance between the end of the hatch line and the innermost border cut

Experiments & Results

A series of experiments were conducted to assess the impact of the laser pulse duration on surface integrity. Two main effects were studied, in particular :

- **changes in material microstructure and**
- **surface quality**

by carrying out metallographic and surface profile analyses. In particular, to estimate the thermal load exercised on the substrate, the processed areas were analysed for **phase transformations** and changes in the **grain structure**.

EXPERIMENTS steps

- **Familiarisation with the material**
- **Machining of a series of 1 x 1 mm fields.**
- **Analysis**

The experiments were conducted on a BS EN ISO 4957 - X40CrMoV5-1 annealed tool steel work piece (0.35%C, 1%Si, 5%Cr, 1.4%Mo, 1% V). This material was selected because it is commonly used to manufacture tooling inserts for micro injection moulding and hot embossing, and thus to endure many thermal cycles.

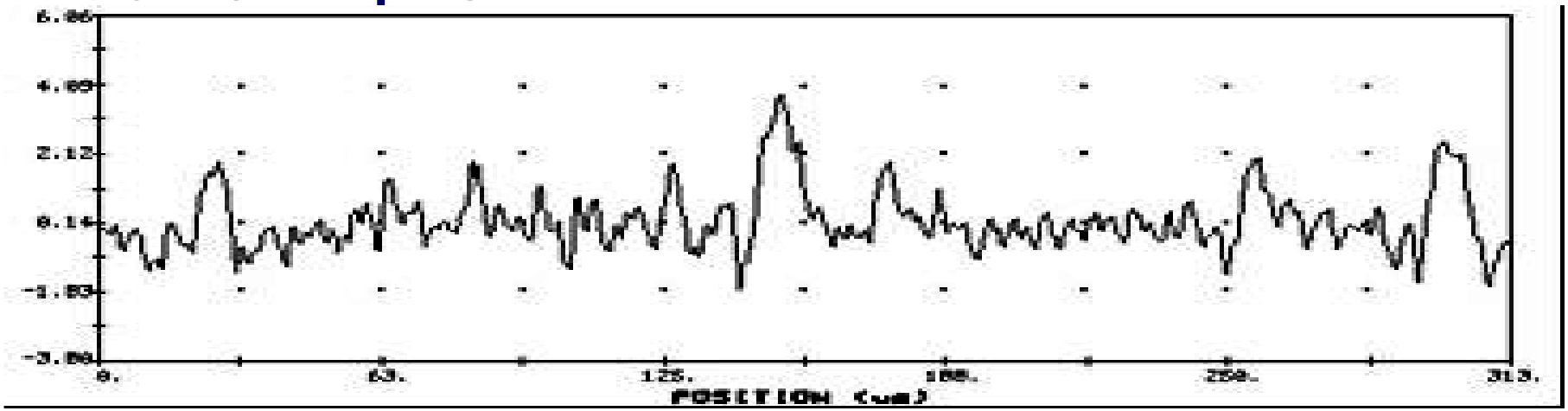
Experiments & Results

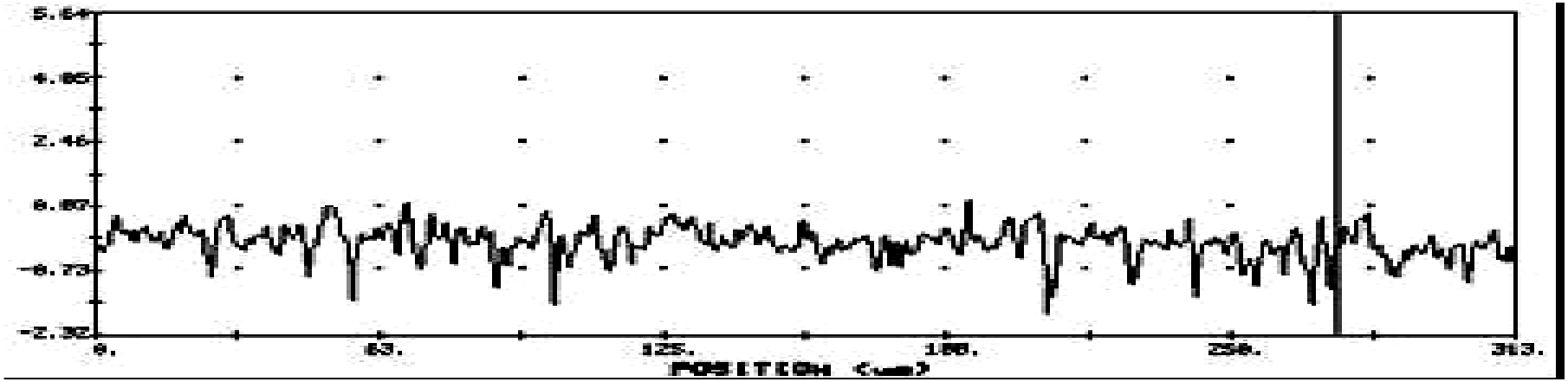
Laser Sources:

Laser Source	Laser process parameters	Roughness acjieved, Ra µm
Femtosecond Laser source SP Hurricane (amplified Ti:Sapphire) Wavelength = 800nm Rep. Rate = 5kHz Pulse = 130fs	Power = 20 mW Scanning Speed = 1.67 mm/s Number of passes = 4 Step = 0.01 mm Fluence = 0.25 J/cm^2	0.35
Picosecond laser source – Stacatto (Lumera) Wavelength = 1064 nm Rep. Rate = 50 kHz Pulse = 12 ps	Power = 100 mW Scanning Speed = 100 mm/s Number of passes = 10 Step = 0.002 mm Fluence = 1.13 J/cm^2	0.29

Experiments & Results

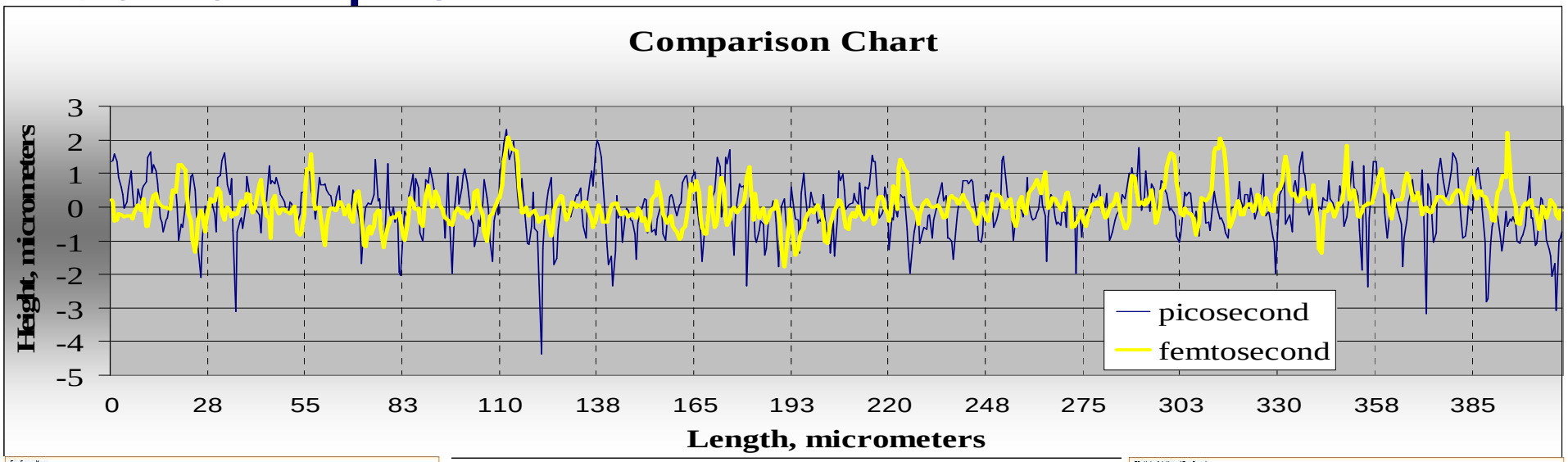
Surface profile:

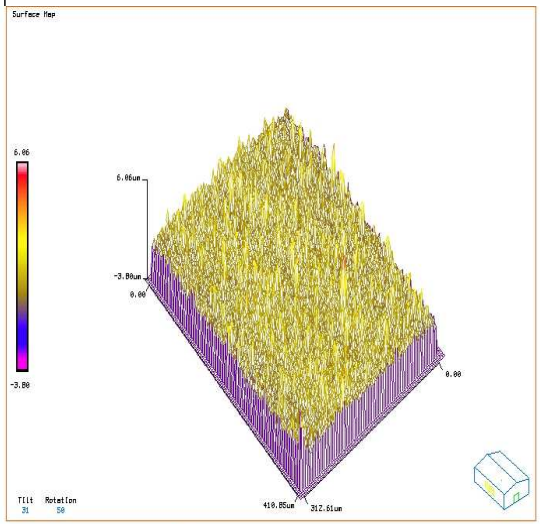




Experiments & Results

Surface profile:

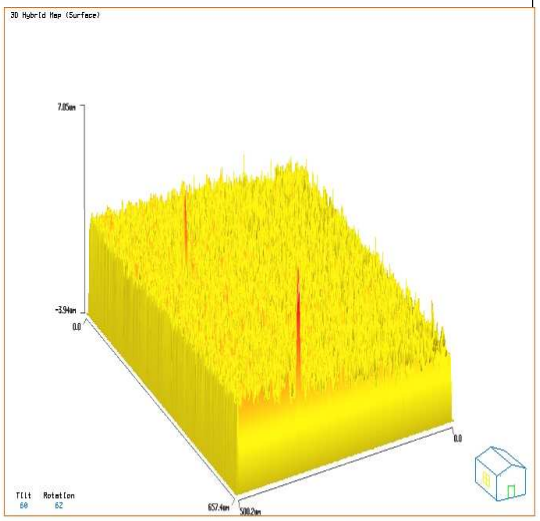




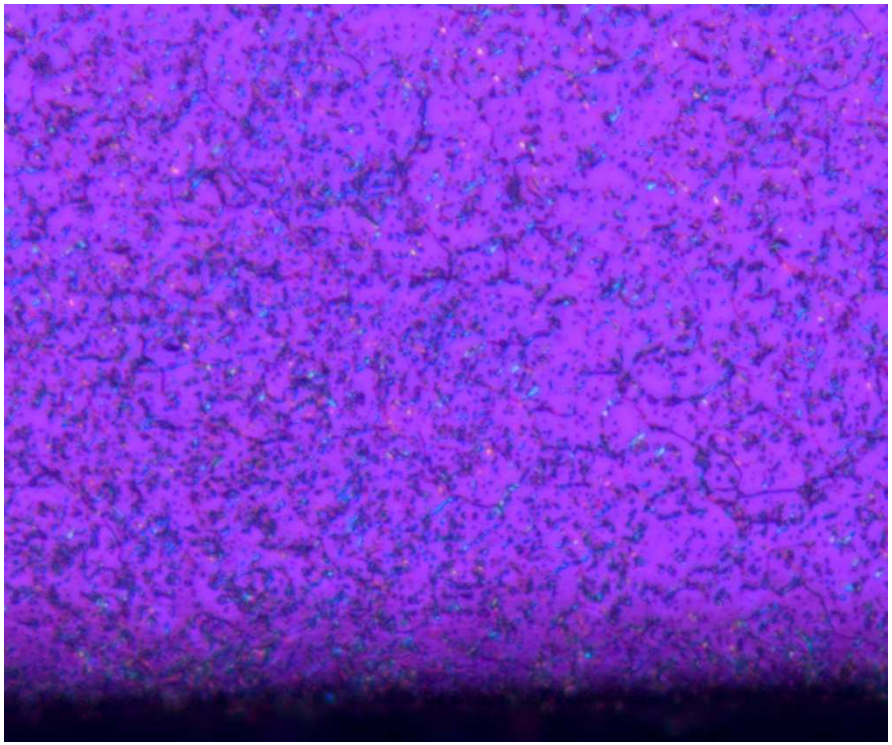
Best Roughness achieved:

<-Femtosecond source – 0.35 µm Ra

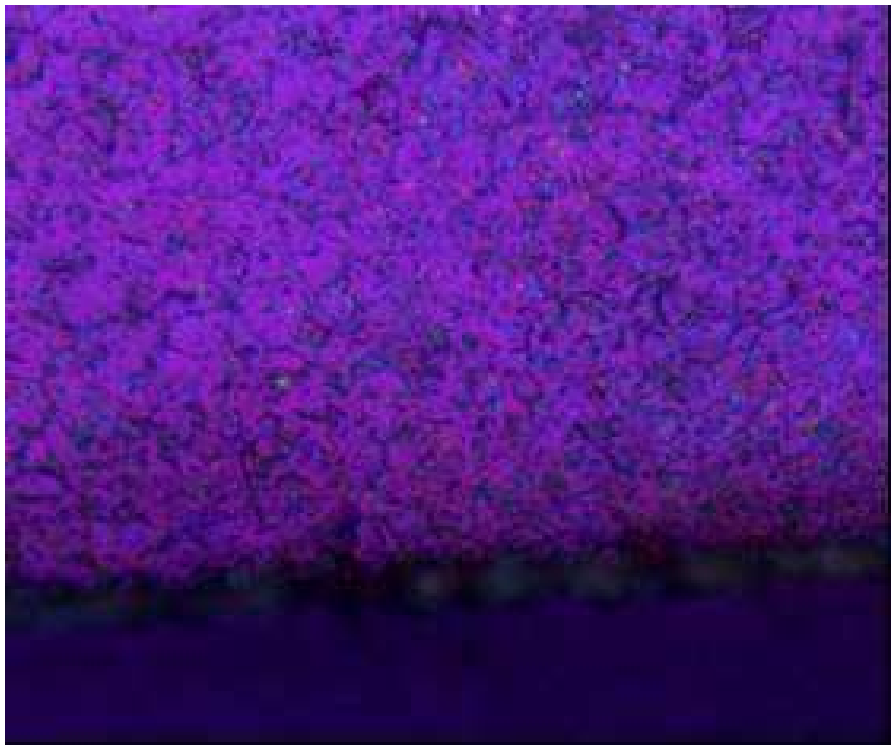
Picosecond source – 0.29 µm Ra ->



Microstructure



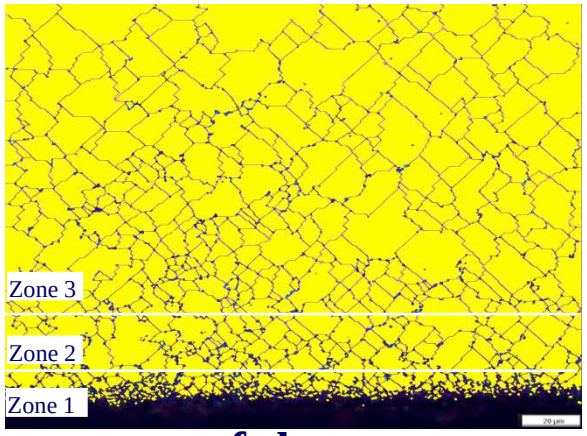
fs laser



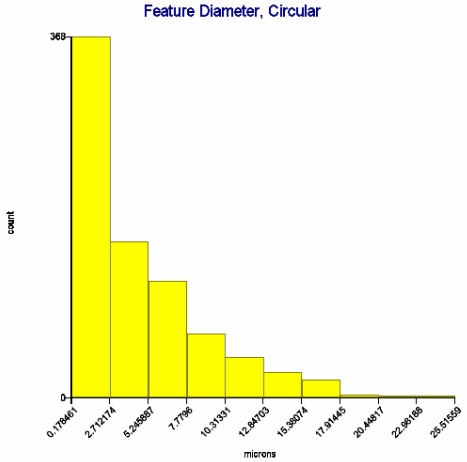
ps laser

Experiments & Results

Microstructure



fs laser



Field Summary

Bitplane(s):
Feature

Statistics:

Min:	0.178461 µm
Max:	25.51559 µm
Mean:	4.52923 µm
Std Dev:	4.368767 µm
95% CI:	0.308341 µm
% RA:	6.807798 %

Field Information:

Field Area:	30016.43 µm²
Total Area:	30016.43 µm²
Field Count:	1

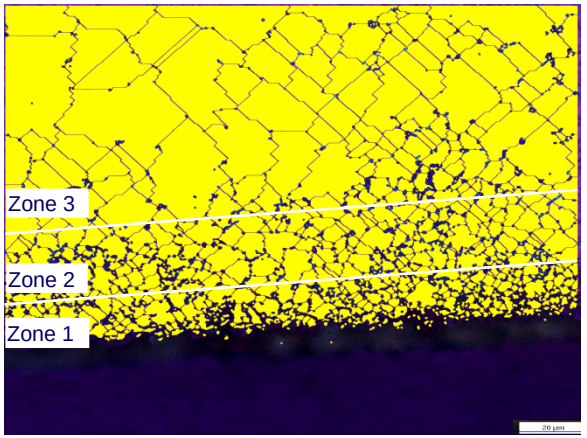
Object Information:

Object Count:	803
Data Points Over:	0
Data Points Under:	0
% Data Points Displayed:	100 %

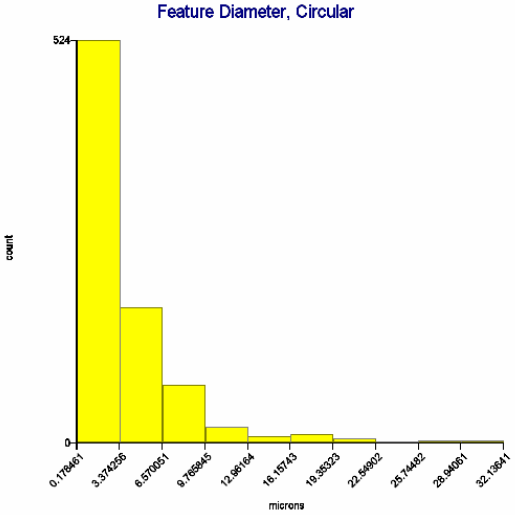
Zone 1 below 10 µm,

Zone 2 from 10 to 30µm

Zone 3 above 30 µm.



ps laser



Field Summary

Bitplane(s):
Feature

Statistics:

Min:	0.178461 µm
Max:	32.13641 µm
Mean:	3.661427 µm
Std Dev:	3.993609 µm
95% CI:	0.278248 µm
% RA:	7.599438 %

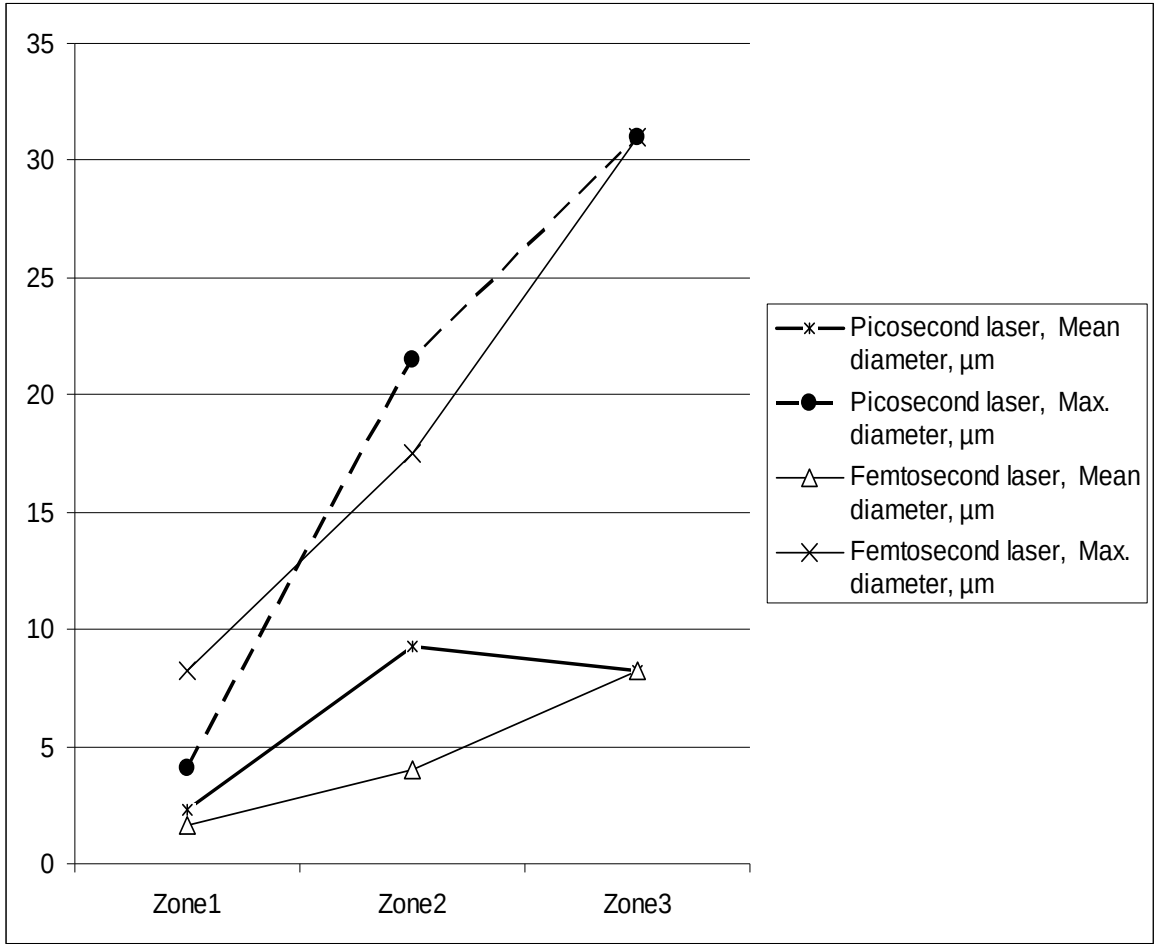
Field Information:

Field Area:	30016.43 µm²
Total Area:	30016.43 µm²
Field Count:	1

Object Information:

Object Count:	824
Data Points Over:	0
Data Points Under:	0
% Data Points Displayed:	100 %

Microstructure



Short pulse laser milling effects on surface integrity

Conclusions

-When performing ultra short pulsed laser ablation, some heat is transferred into the bulk, but it is not sufficient to trigger significant structural changes. Heat penetration is small and grain refinement is minimal. The effects of pulse duration on the resulting material microstructure are more evident in the micrograph of the field exposed to ps laser ablation than that of the area which underwent processing with fs laser pulses.

-In this research, a marginally better surface quality was achieved when performing laser milling with a ps laser source. This could be explained with nonlinear effects that are typical for processing materials at fs regimes, and also with the specific machining response of the tooling steel to the selected processing parameters, especially the laser's wavelength.

THE END

Thank you !

The authors would like to thank Dr. Martyn Knowles and Dr. Dimitris Karnakis of Oxford Lasers, Steven Wheeler of Lumera, and Dr. Nadeem Rizvi of UK Laser Micromachining Centre for their help in conducting this experimental study.

CENTRES OF EXCELLENCE
CANOLFANNAU RHAGORIAETH