Effect of the embedded plasmonic gold nanorods on the interaction of high intensity laser irradiation with UDMA polymer – volume loss during crater formation

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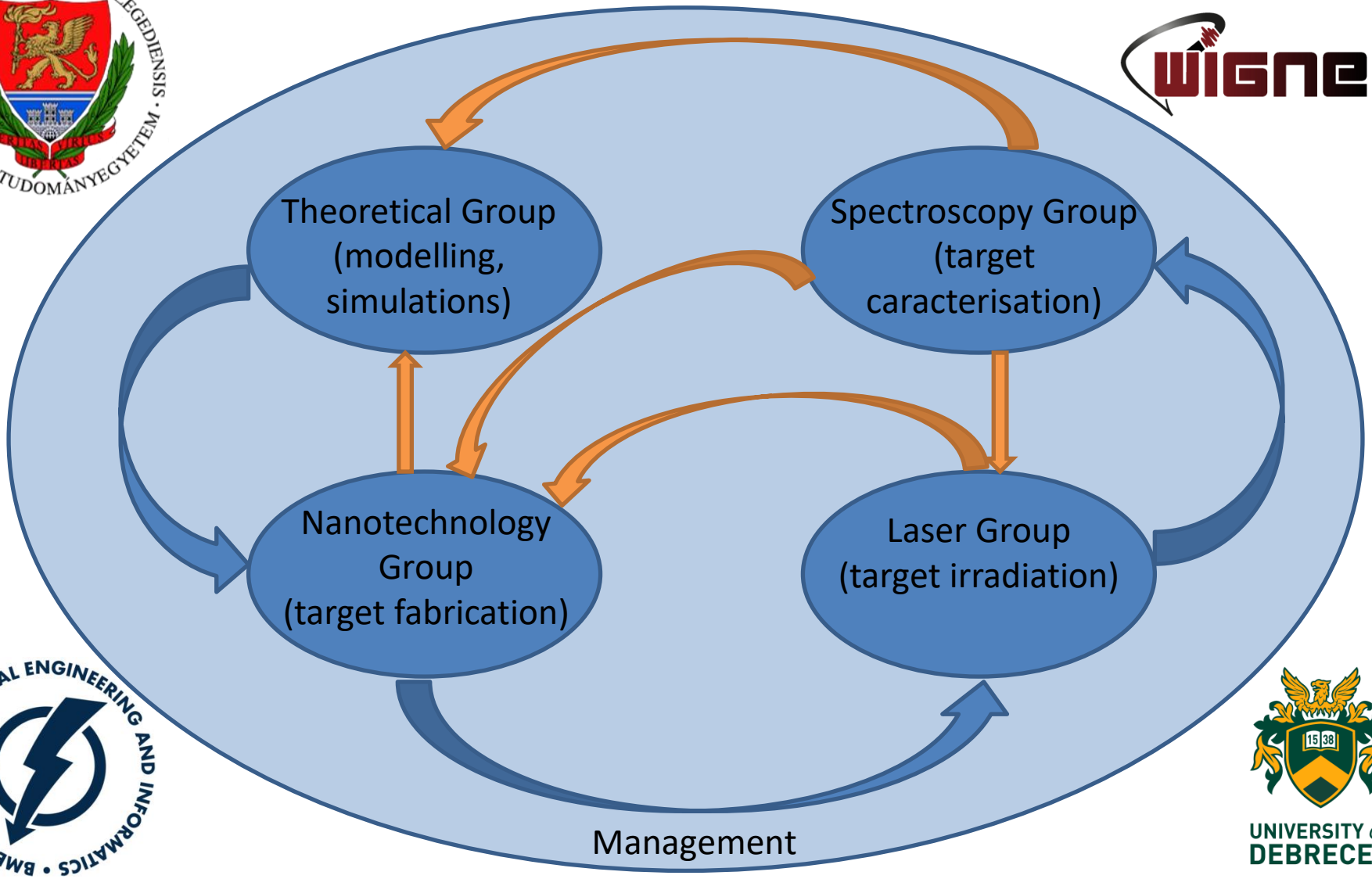
Overview

- The NAPLIFE project
- Targets and treatment
- Questions – induced by craters
- Preliminary measurements
  - White light interferometry
  - Settings
  - How to measure the volume of the craters?
- Results of the measurements
- Conclusions
- Acknowledgements

The NAPLIFE project

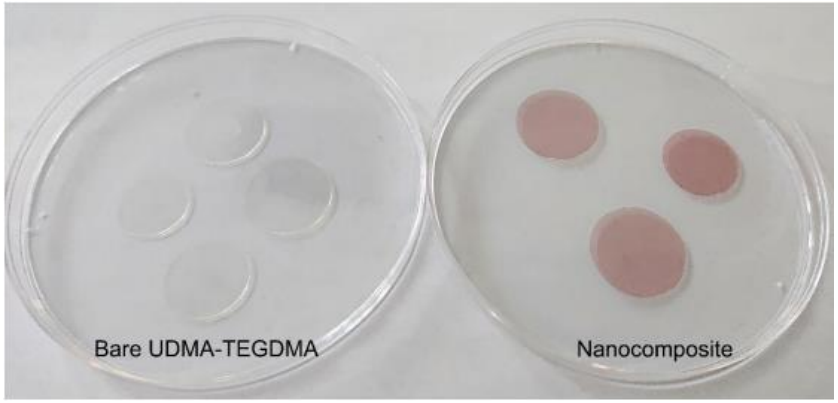


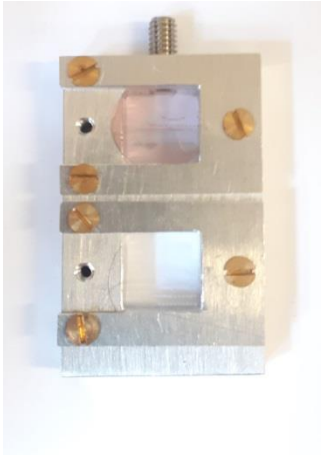
Targets

The target is a polymer (UDMA (Urethane dimethacrylate) with TEGDMA (Triethylene Glycol Dimethacrylate) dilution monomer) with CQ photoinitiator and EDAB co-initiator

Three targets:

1. UDMA-X – without gold nanoparticals
2. UDMA-Au1 - embedded with gold nanorods (25 x 85 nm)
3. UDMA-Au2 - embedded with gold nanorods (25 x 85 nm) in higher density

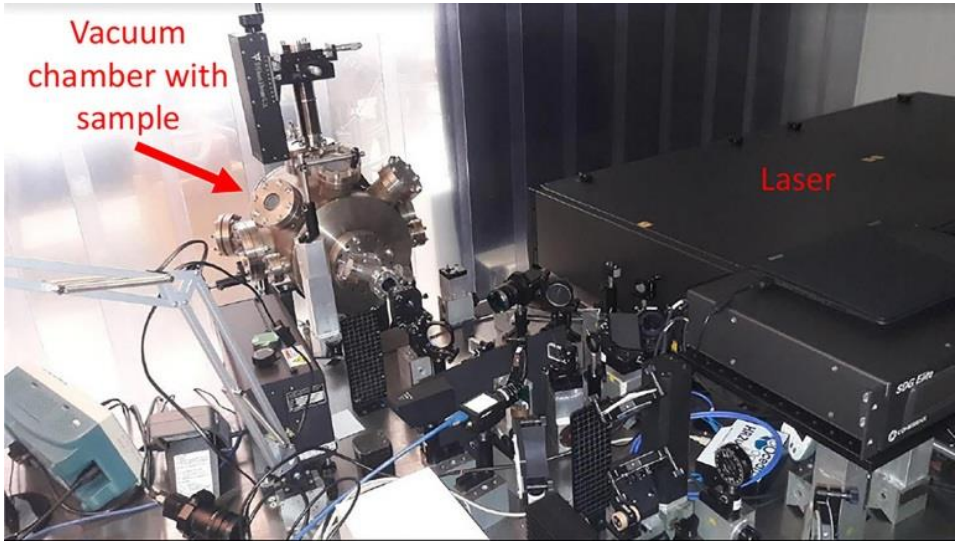


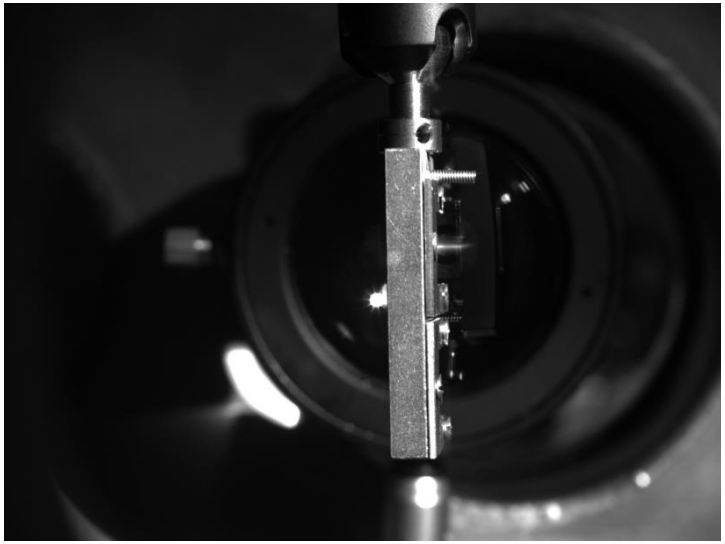


Laser treatment

Irradiation with Ti:Sa laser:

Wavelength: 795 nm
Pulse length: 40 fs
Intensity: 10^{16}-10^{17} W/cm^2





Questions

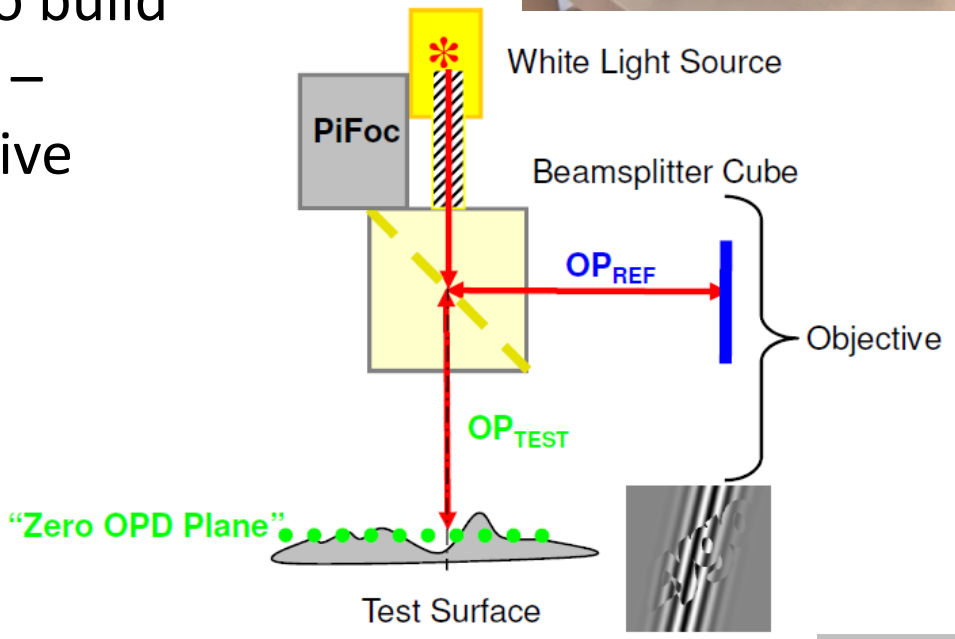
- What kind of atoms are emitted? – LIBS, mass-spectrometry
- Is all the energy of the pulse used? – Reflexion, transmission
- How the bonding configuration changes in the target? – Raman spectroscopy
- Is material removed from the target? – Surface examination with white light interferometry
- …

White light interferometry with Zygo NewViewt™ 7100

Non-contact, 3D, scanning with white light.
Why **white light**?

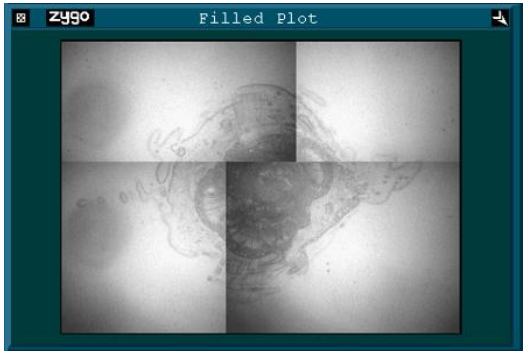
We have to use white light to build „Equal path" interferometer – incorporated into the objective lens.

Equal path requirement:
$OP_{REF} = OP_{TEST}$



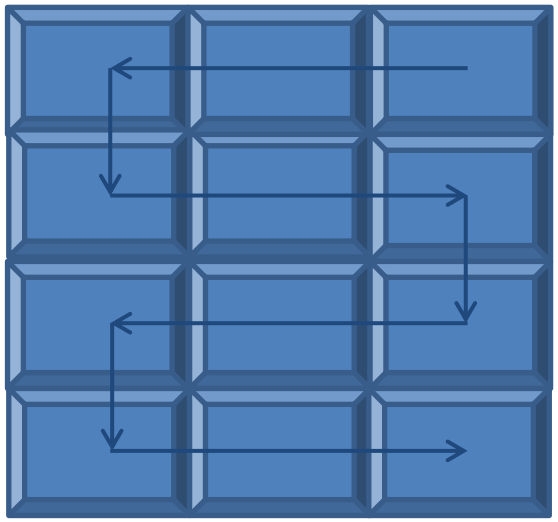
Stitching method

Field of view is not large enough to cover the craters produced with higher laser pulse energy.

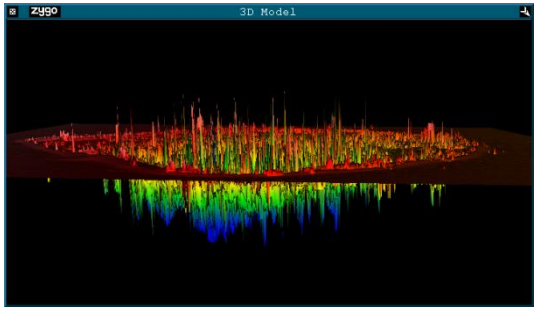


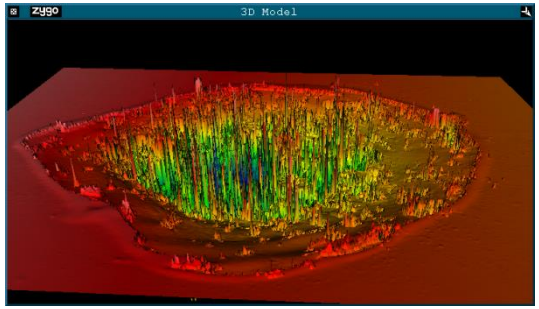
Stitching:

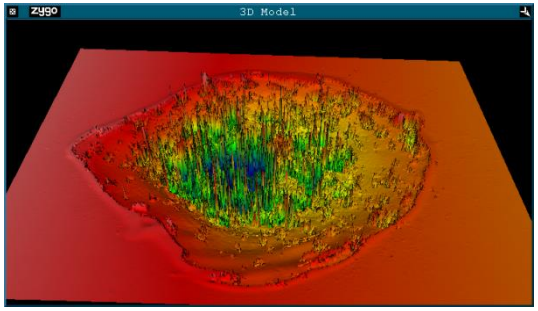
- 2 x 2 single measurement
- 25%-70% overlapping



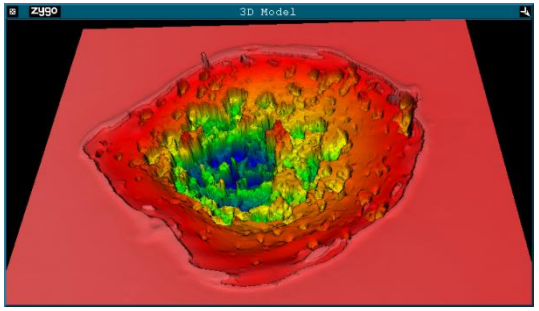
Preliminary measurements



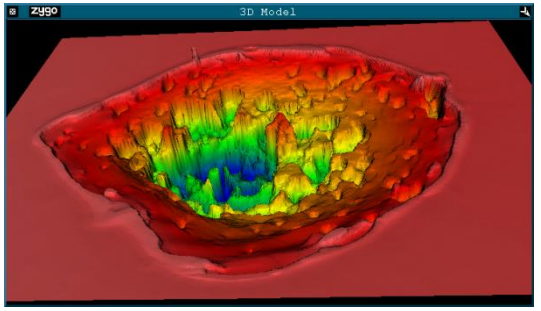




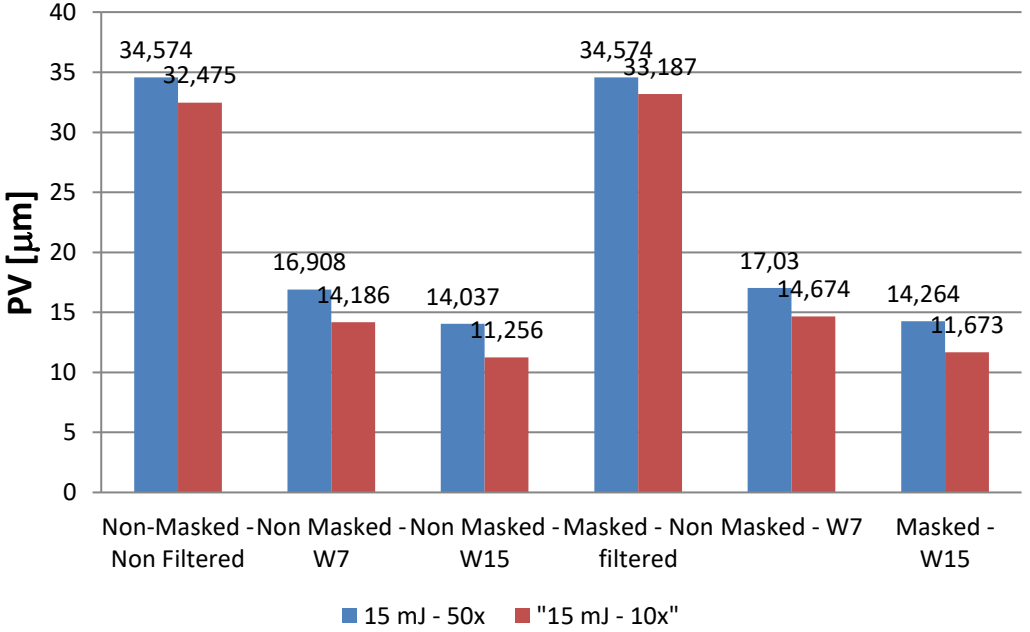
Non-Filtered



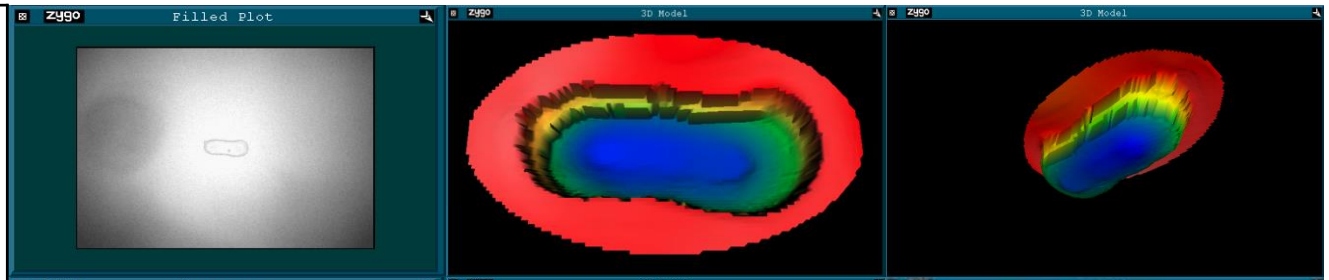
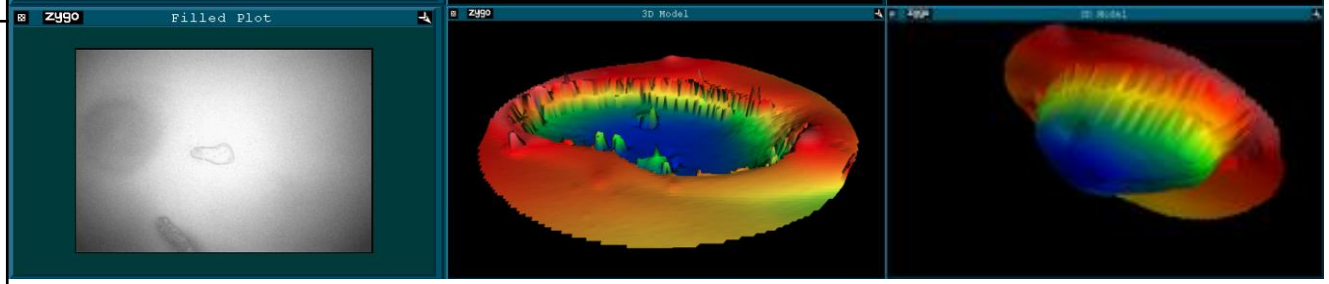
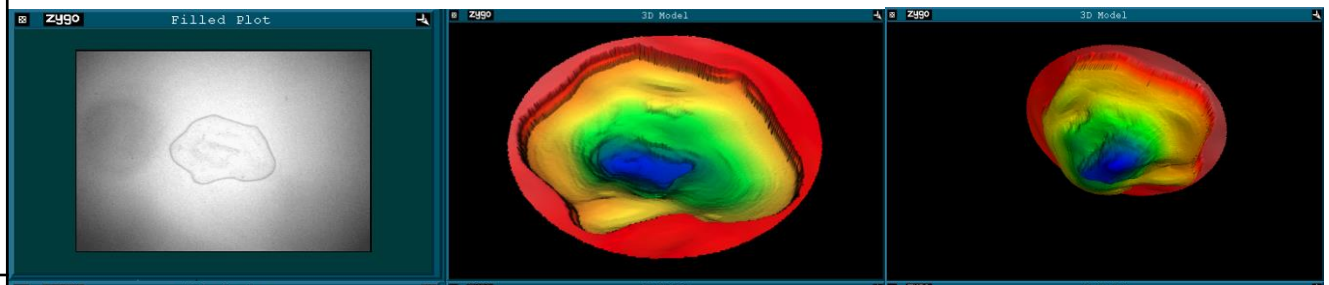
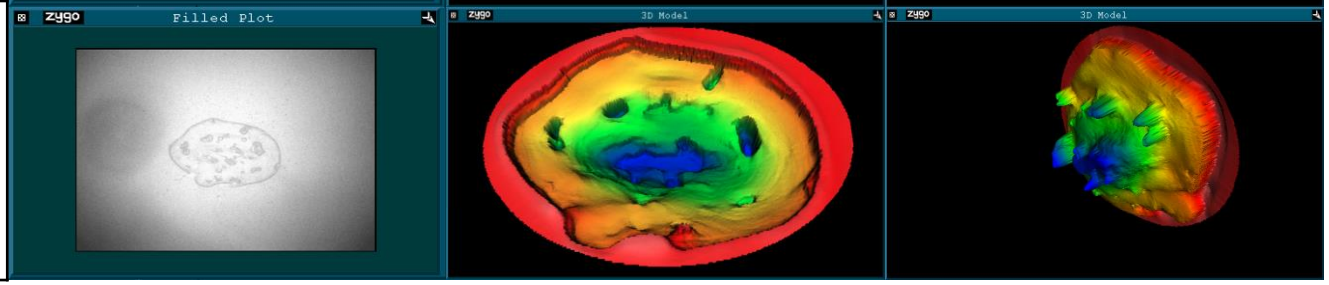
Low Pass, Median,
Window size: 7



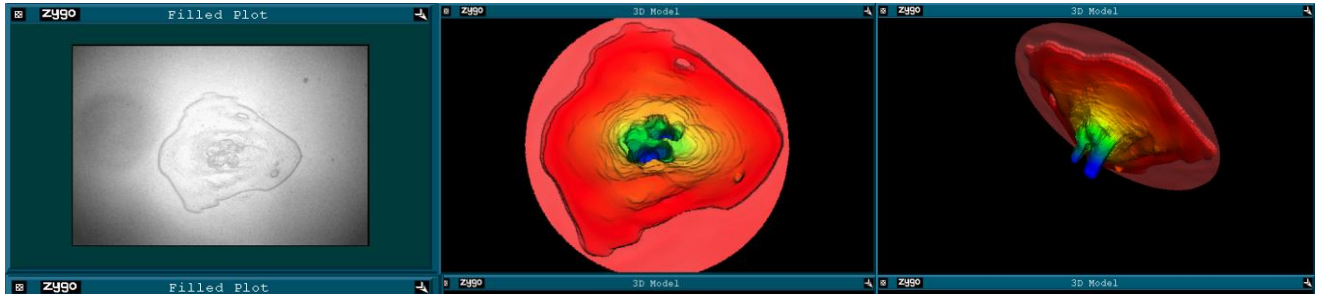
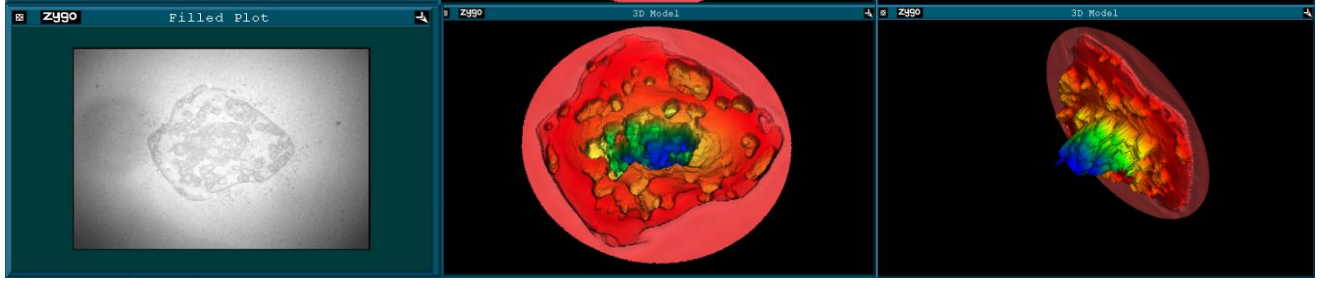
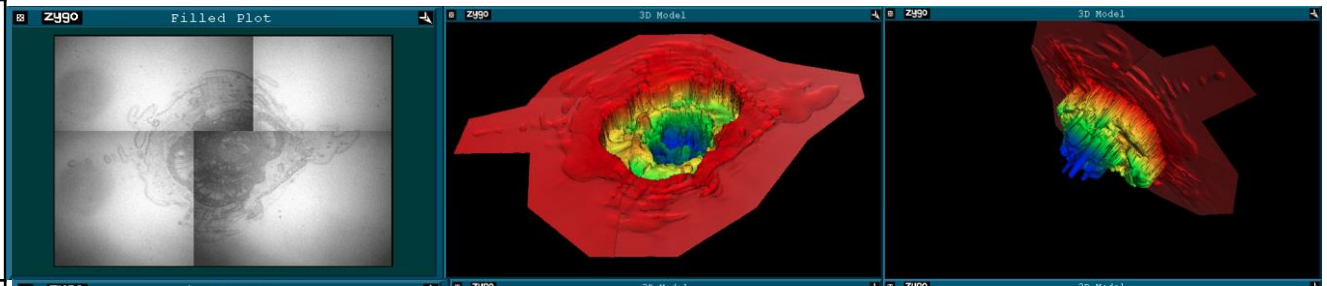
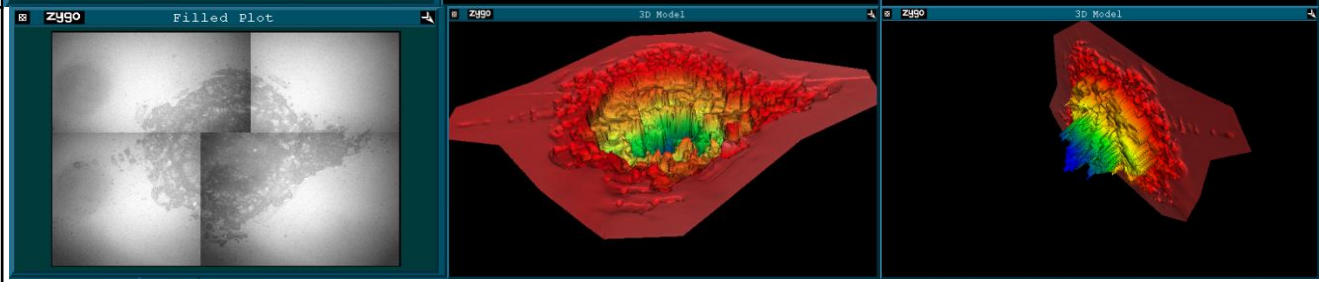
Low Pass, Median,
Window size: 11



Preliminary measurements

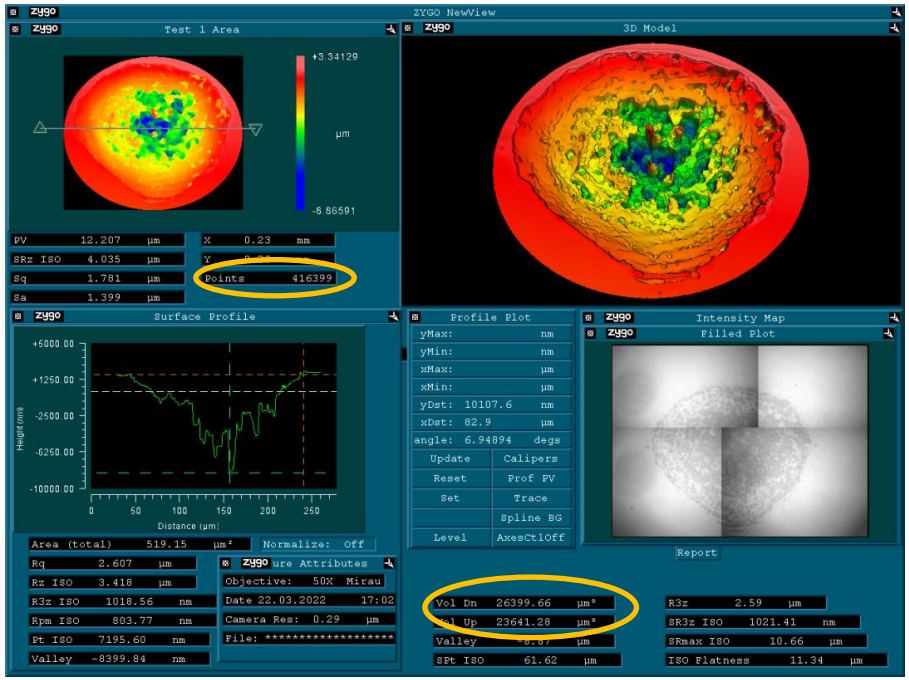
0,028 mJ	Without gold	
	With gold nanorods	
0,28 mJ	Without gold	
	With gold nanorods	

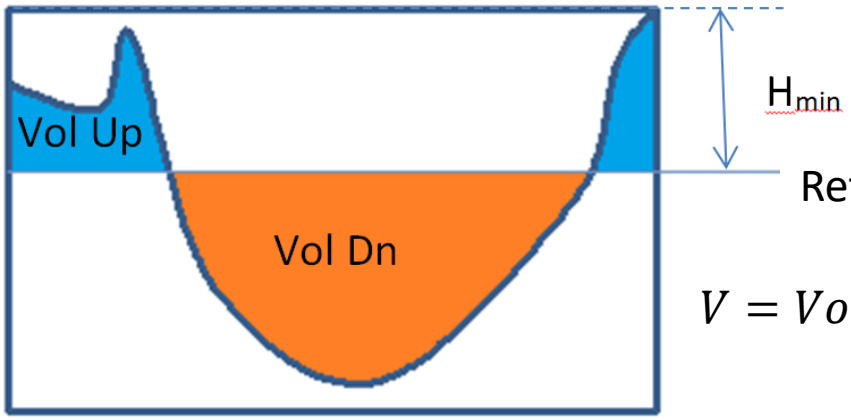
Preliminary measurements

2,5 mJ	Without gold	
	With gold nanorods	
25 mJ	Without gold	
	With gold nanorods	

Volume determination method

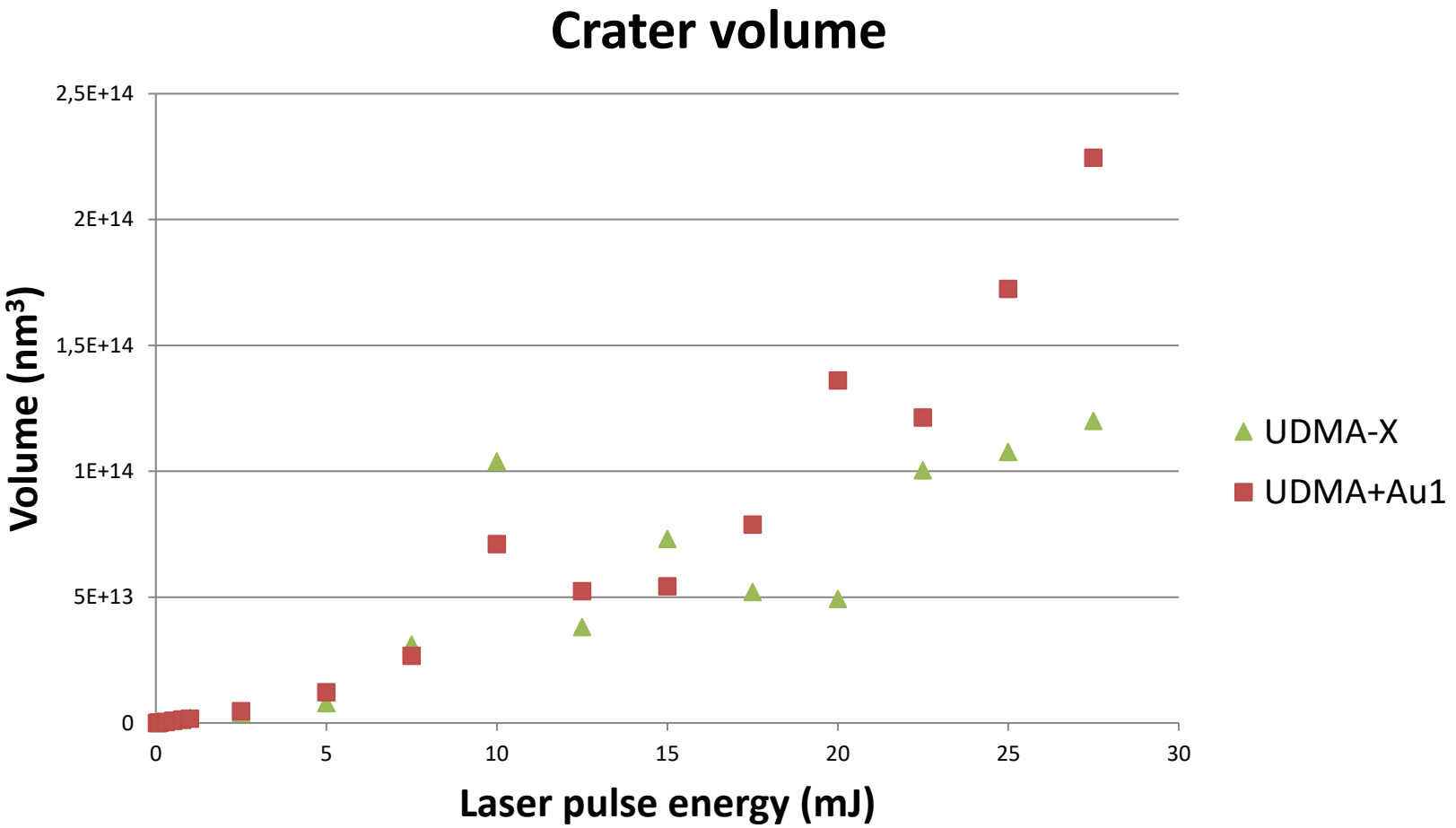
1. Setting of the reference plane
2. Mesuring of the H_{min} value on 4 different points, and averaging them
3. Recording the values VolUp, VolDn and the number of the points
4. Calculating the area of the pixels
5. Calculating the volume of the cylinder over the reference plane





$$V = VolDn + T_{pixel} \cdot Points \cdot H_{min} - VolUp$$

Preliminary measurements



Measurements and results

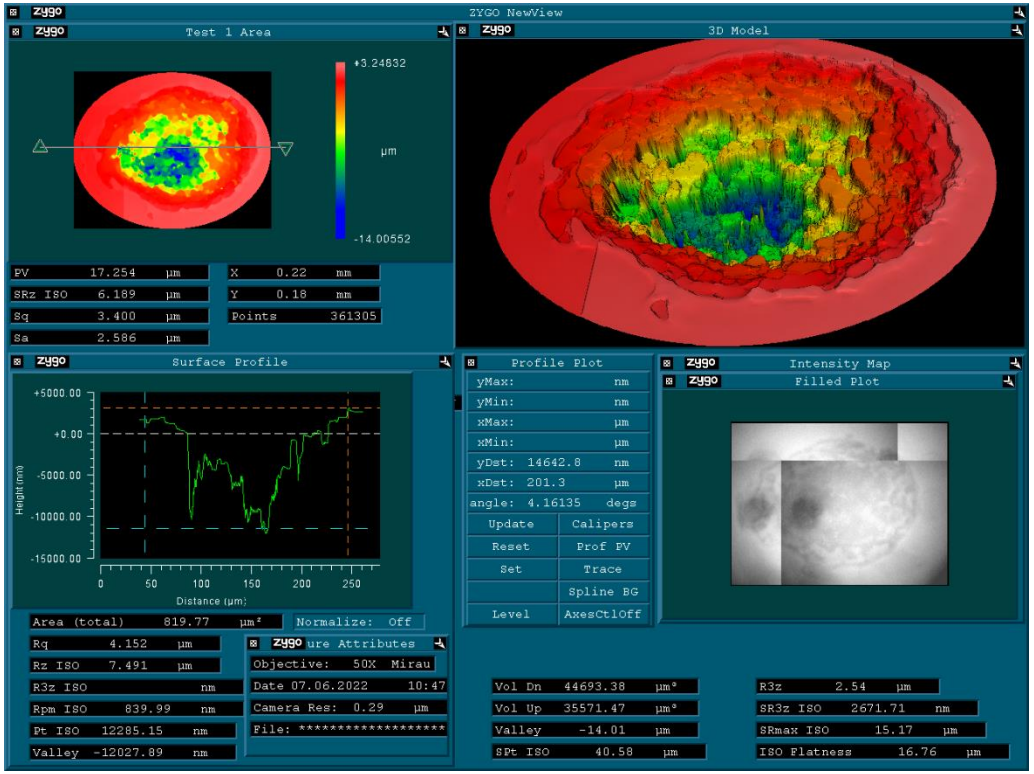
Laser pulse energy	1 mJ	5 mJ	10 mJ	15 mJ	20 mJ	25 mJ
	In 5 different points 1-1 independent shots for every energy					

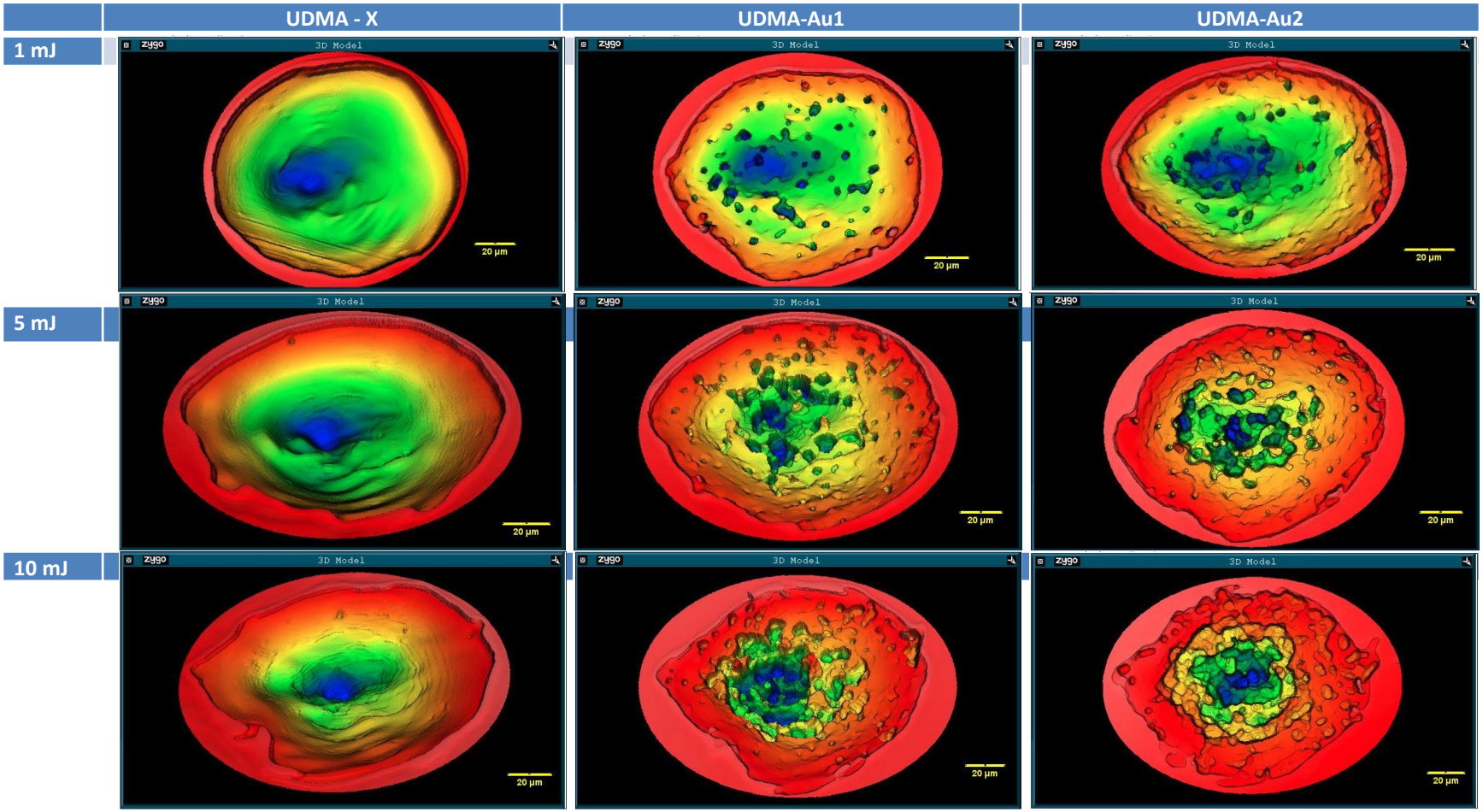
Targets:

UDMA-X

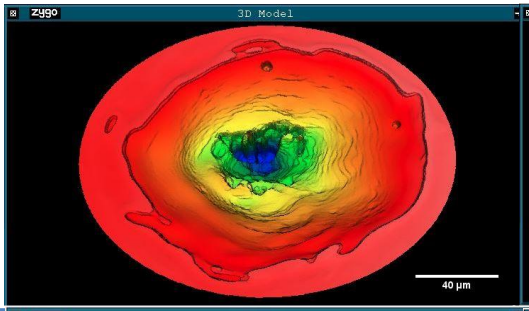
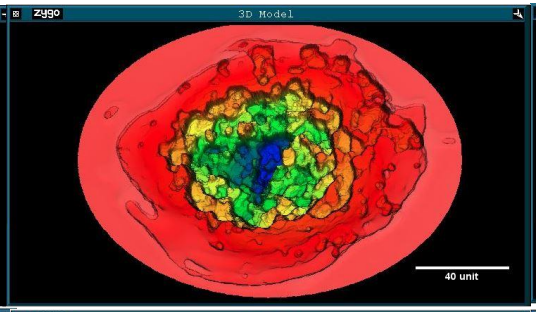
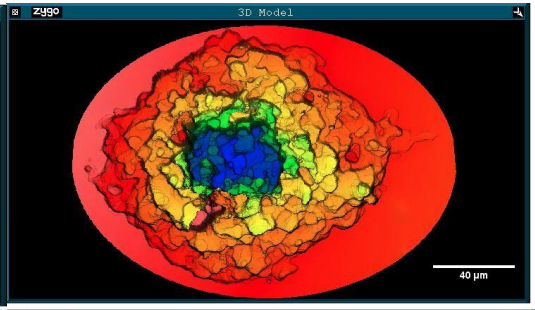
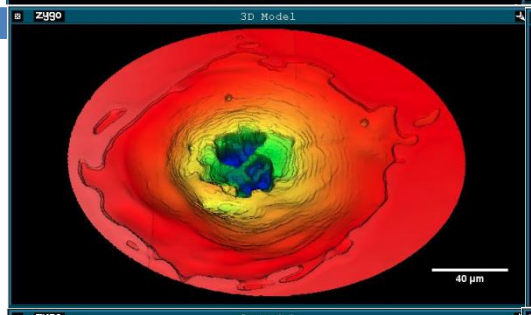
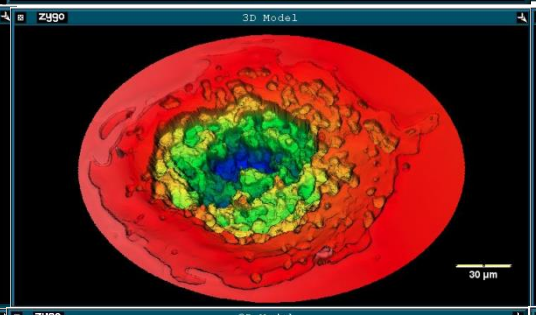
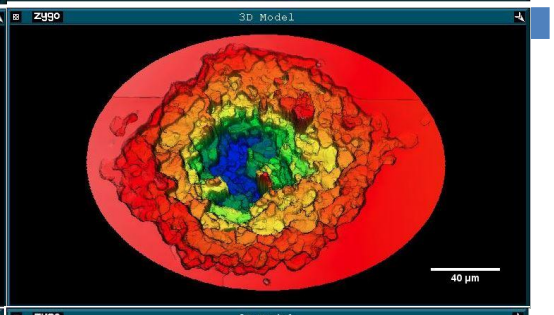
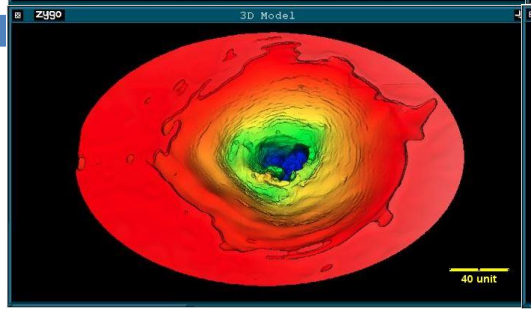
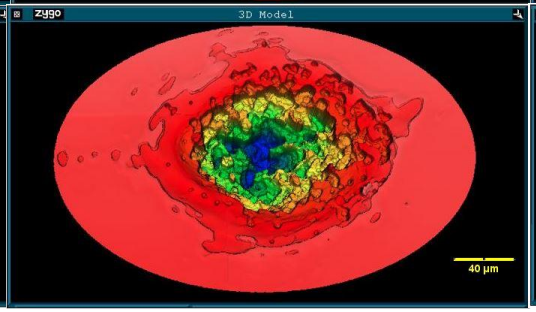
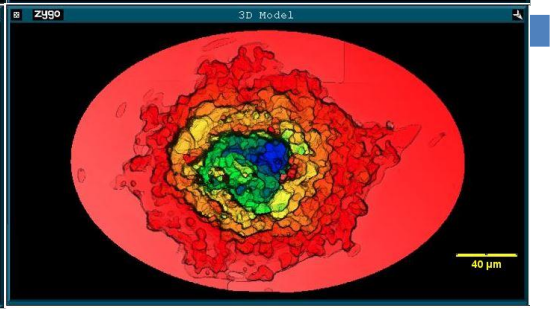
UDMA-Au1

UDMA-Au2



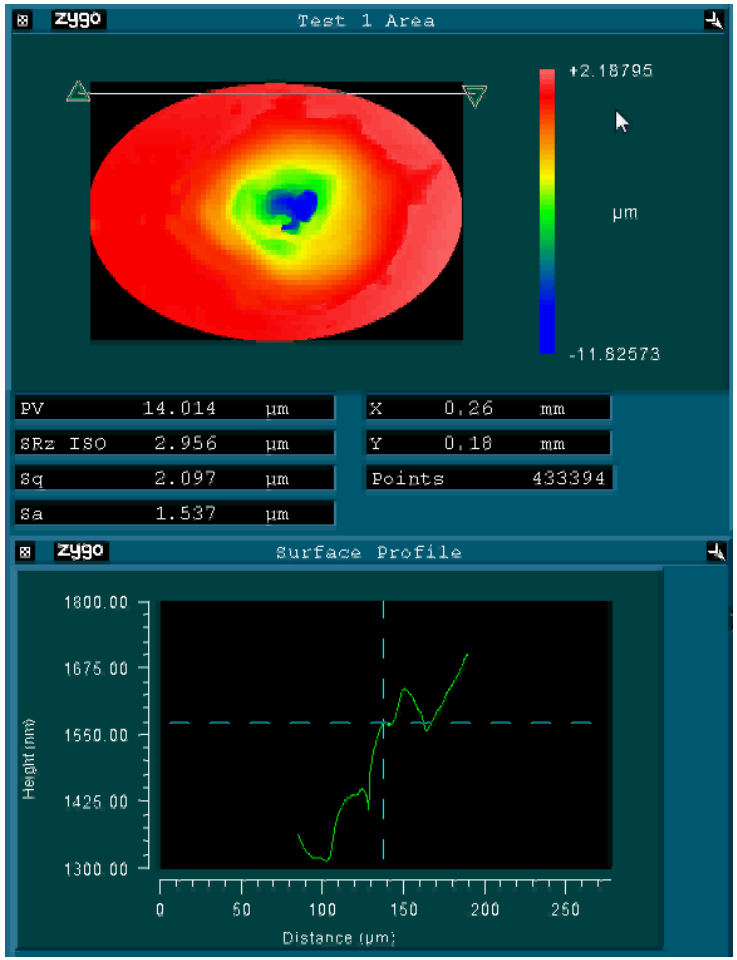


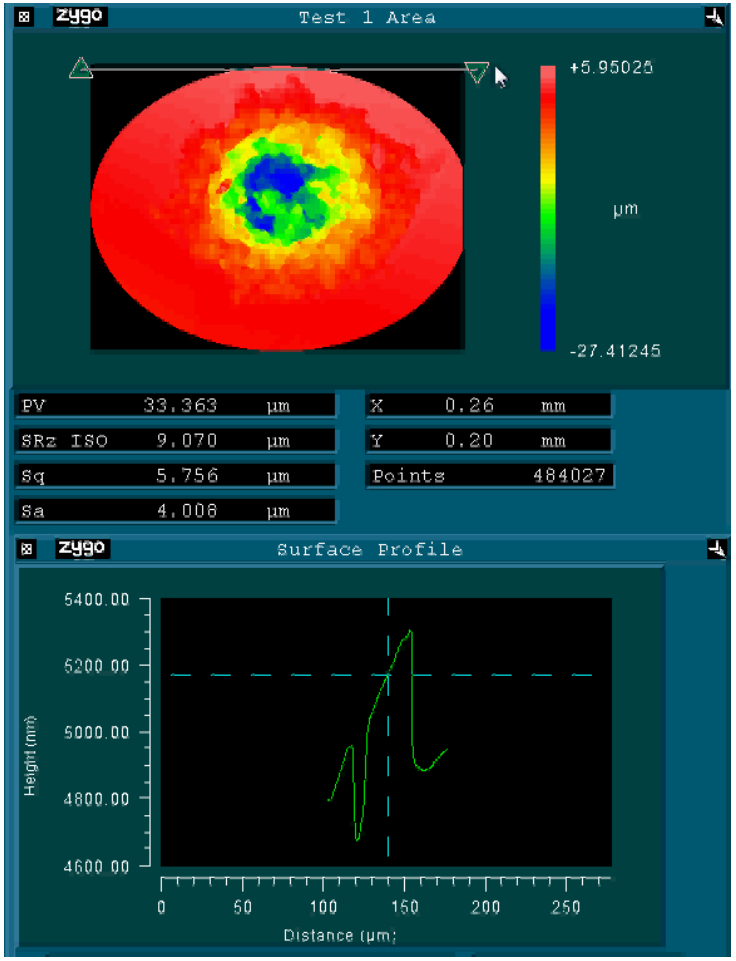
Diameter (avg)	UDMA-X	UDMA-Au1	UDMA-Au2
1 mJ	107 µm	109 µm	100 µm
5 mJ	127 µm	121 µm	116 µm
10 mJ	124 µm	126 µm	121 µm

	UDMA – X	UDMA-Au1	UDMA-Au2
20 mJ			
25 mJ			
			

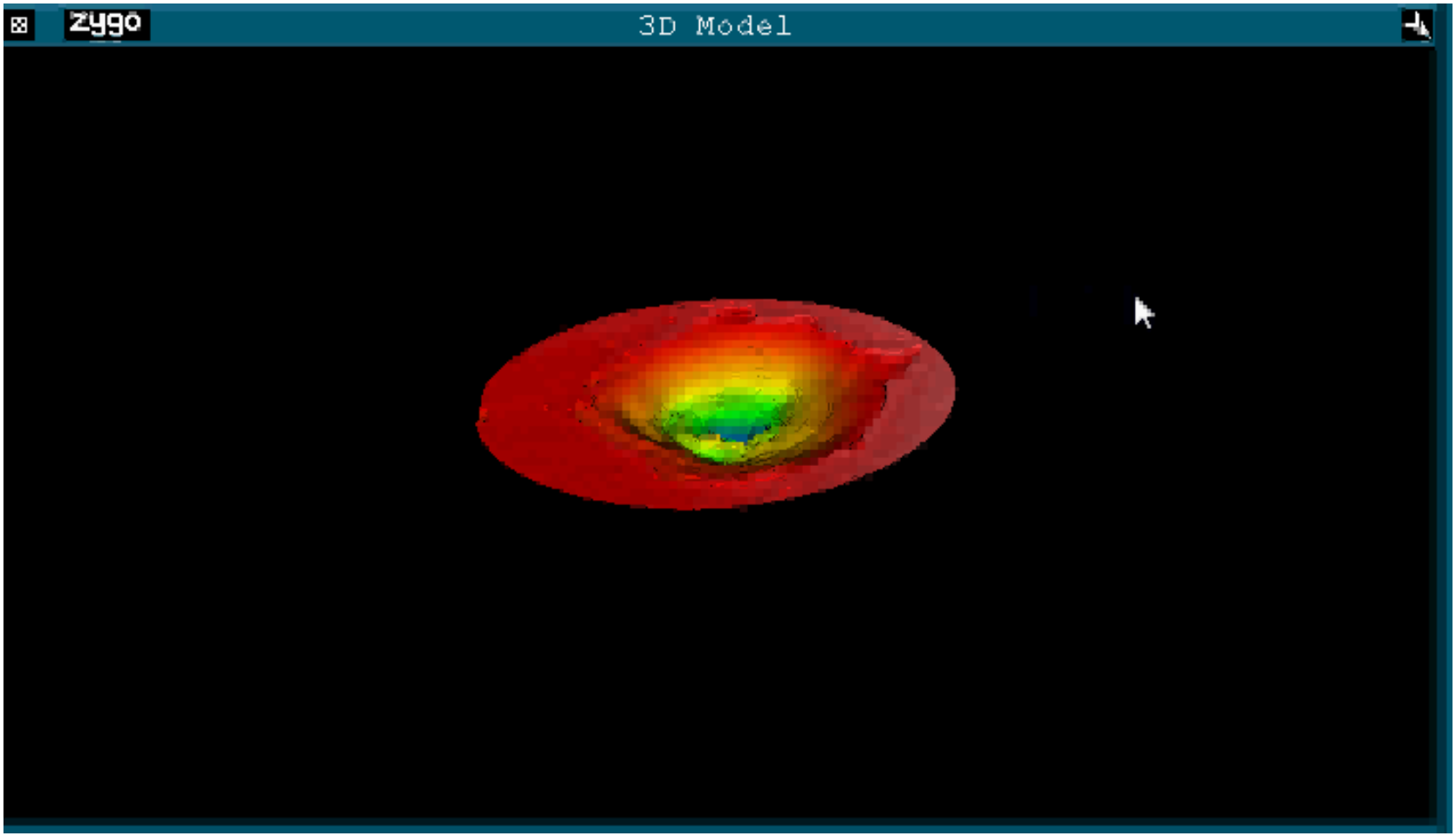
Diameter (avg)	UDMA-X	UDMA-Au1	UDMA-Au2
15 mJ	130 μm	137 μm	145 μm
20 mJ	159 μm	153 μm	165 μm
25 mJ	194 μm	201 μm	190 μm

Profiles in UDMA-X and Au2 – 25 mJ

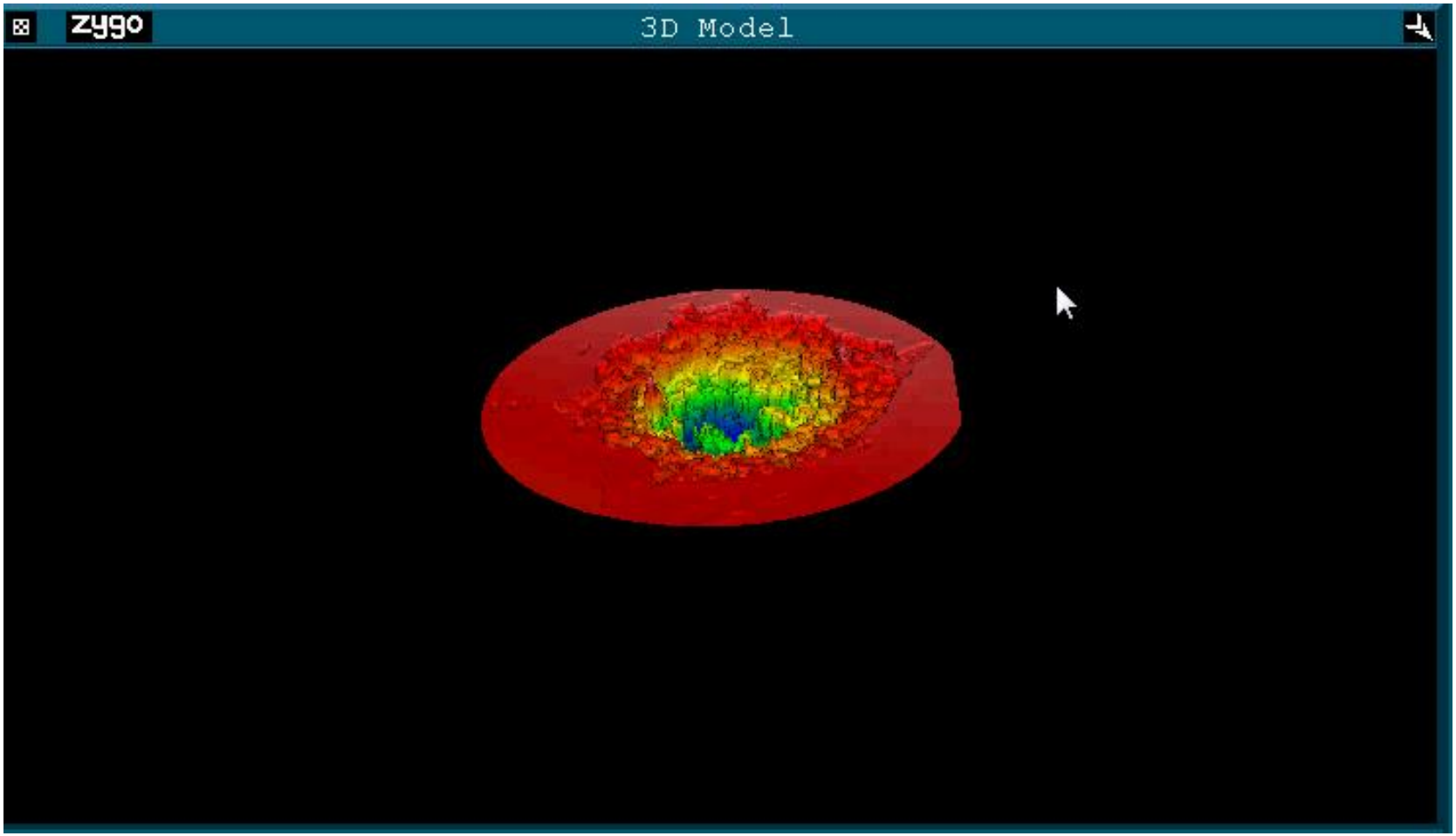




Surface in 3D – UDMA-X– 25 mJ

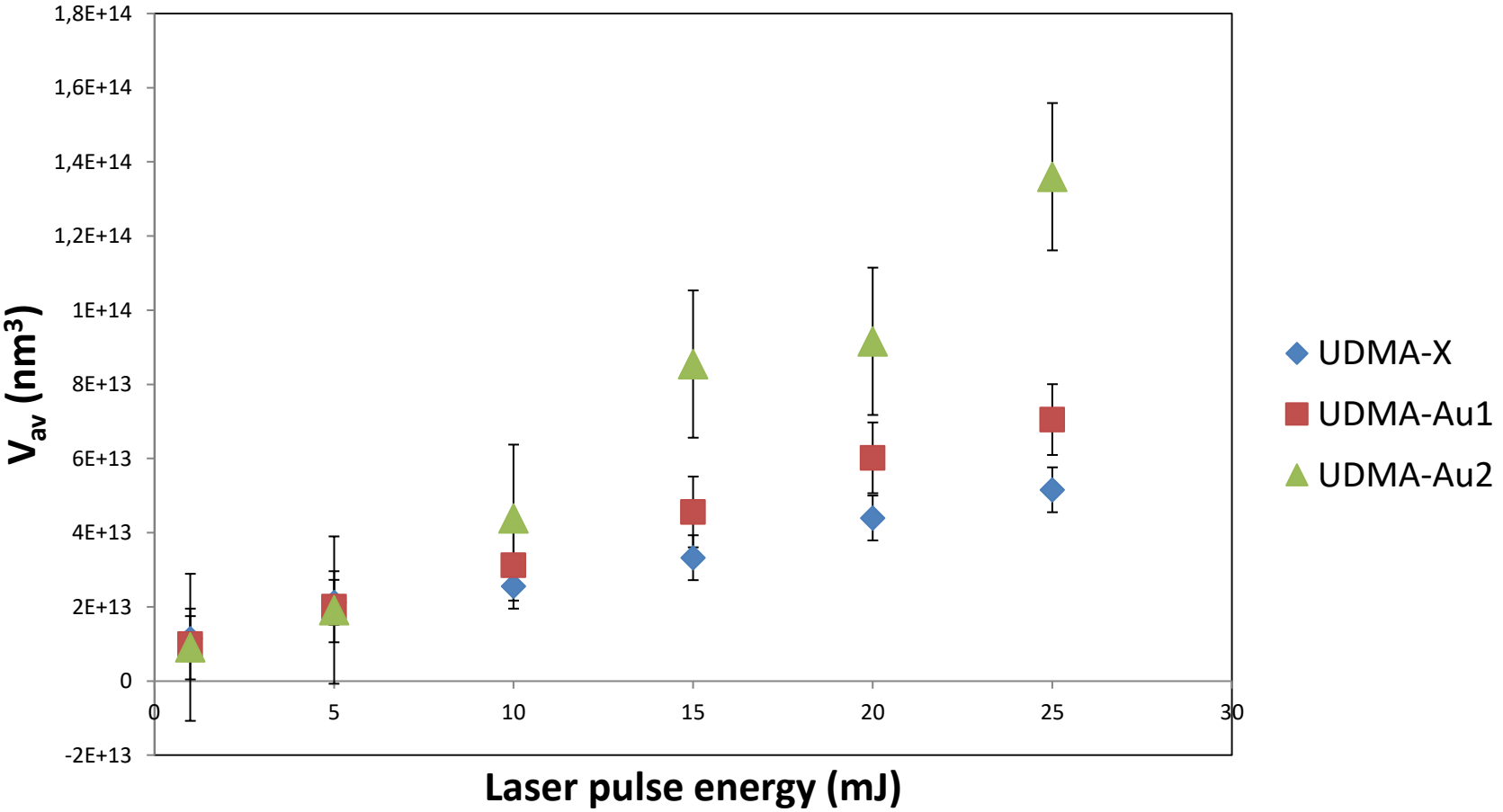


Surface in 3D – UDMA-Au2– 25 mJ



Crater volume

The analysis of the crater volumes – in 5 different points for every energy and target



Conclusions

Comparative study of the interaction of high intensity laser irradiation with UDMA polymer with/without gold nanorods shows that the embedded plasmonic gold nanoparticles cause significantly higher material loss in the polymer, than in UDMA without gold nanorods.

The change of the crater volume formed in UDMA polymer with/without gold nanorods separates from 10 mJ pulse energy.

Acknowledgements

- NAS group (Miklós Veres, Judit Kámán, István Rigó)
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NEMZETI KUTATÁSI, FEJLESZTÉSI ÉS INNOVÁCIÓS HIVATAL

ELKH
Eötvös Loránd
Research Network

Thank you for your attention!