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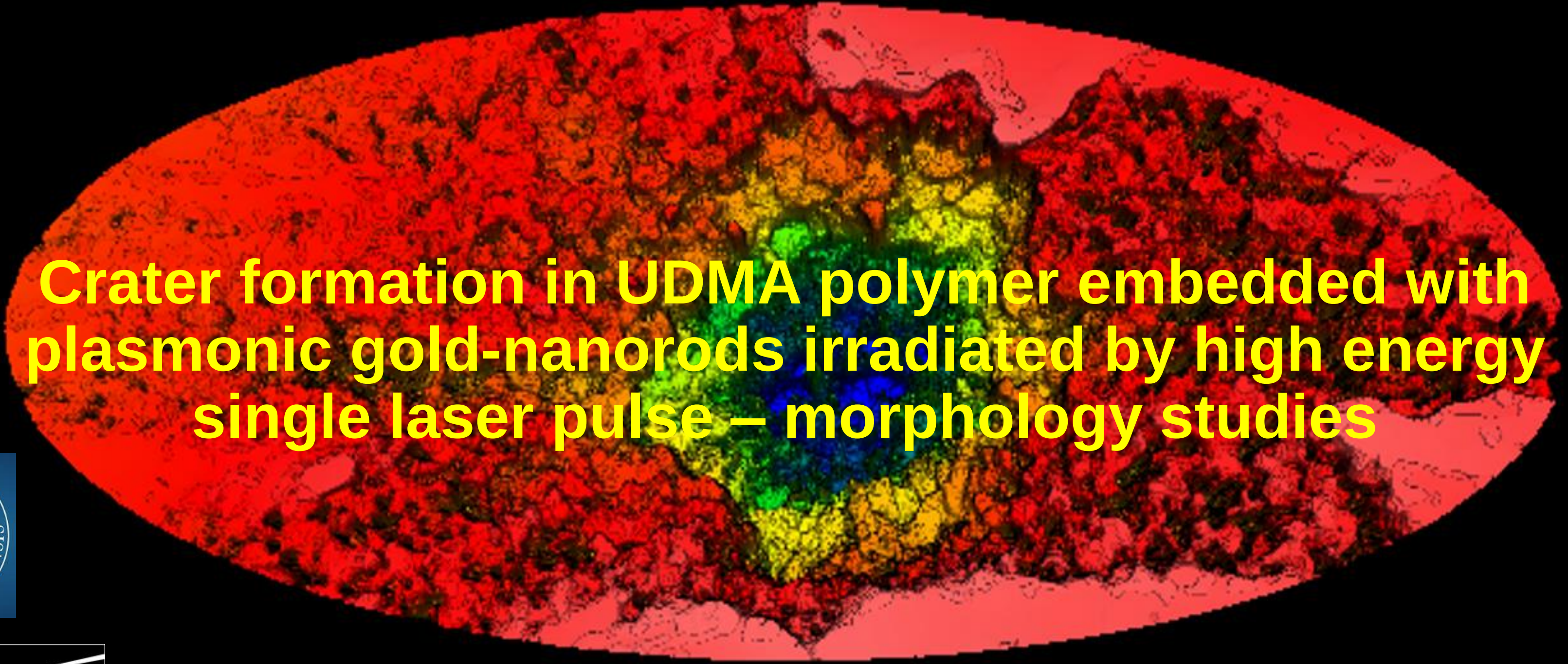

Crater formation in UDMA polymer embedded with plasmonic gold-nanorods irradiated by high energy single laser pulse – morphology studies

NAPLIFE

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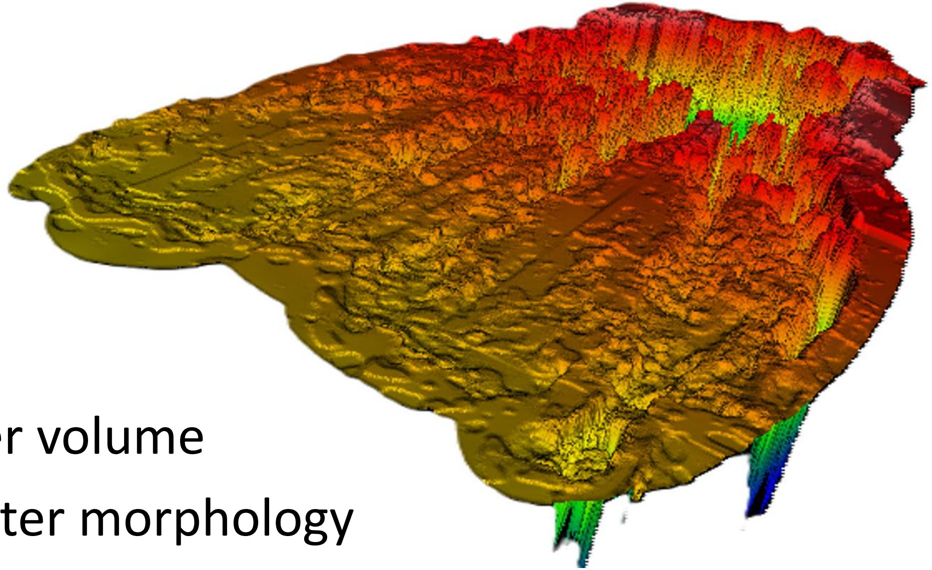
Overview

- Sample preparation
- Laser setup
- Measurements
- Data evaluation
- Energy dependence of the crater volume
- Intensity dependence of the crater morphology
- Crater profiles – pulselength dependence
- Conclusions



Sample preparation

UDMA-TEGDMA monomer

$C_{23}H_{38}N_2O_8 + C_{14}H_{22}O_6$

+

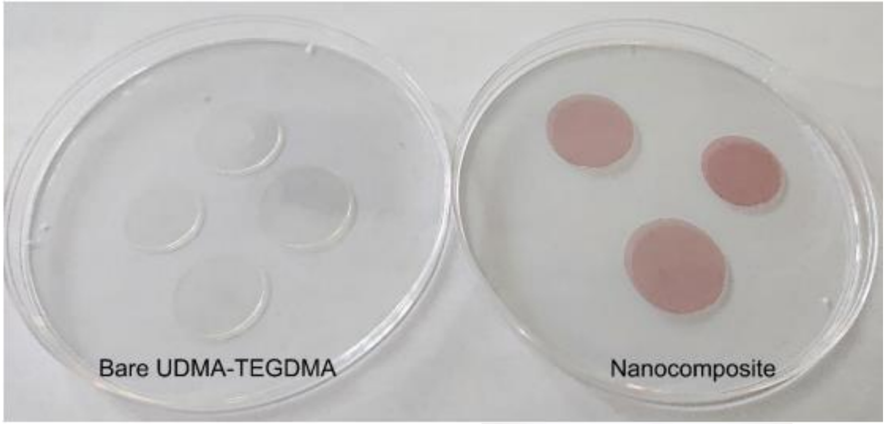
Au nanorods (85 nm x 25 nm)

Polymerized

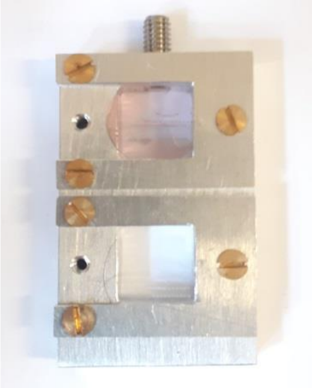
Thickness: 160-180 μm, 400 μm
Diameter: 1,5-2 cm

UDMA–Au0 – without gold
UDMA–Au1 – with gold (lower density)
UDMA–Au2 – with gold (higher density)
UDMA–Au2 OffRes – with different gold nanorods (35 nm x 25 nm)

Samples without and with gold nanorods



A.Bonyar at al. Int. J. Mol. Sci. **2022**, 23, 13575. https://doi.org/10.3390/ijms232113575



Laser setup

Vacuum chamber

Pressure: ~ 10^{-6} Pa

Angle of incidence: 45°

Single laser shots with Ti:Sa laser

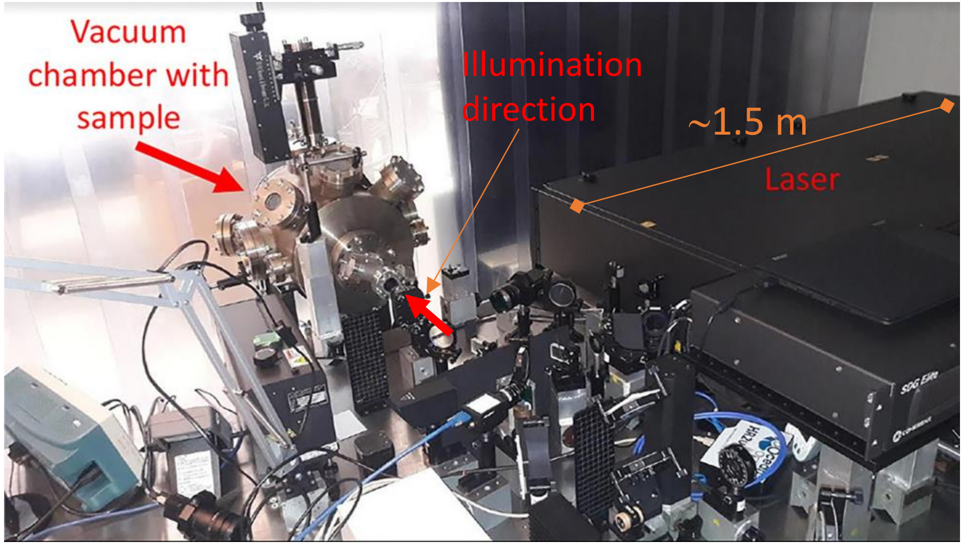
Wavelength: 795 nm

Pulse length: 42 fs

Intensity: 10^{16}-10^{17} W/cm^2

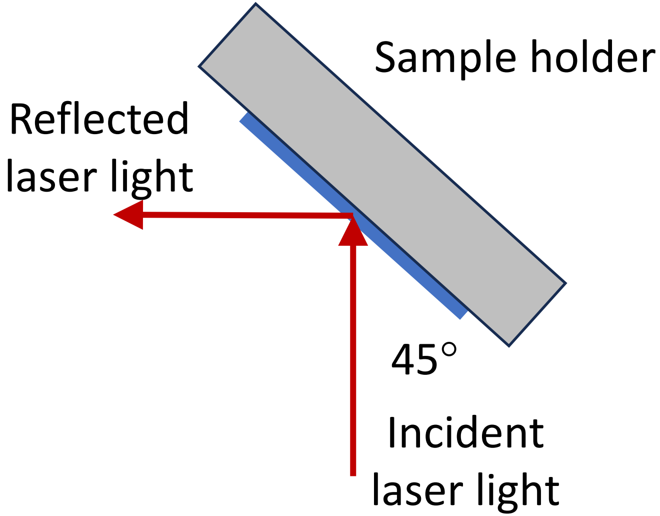
Pulse energy:

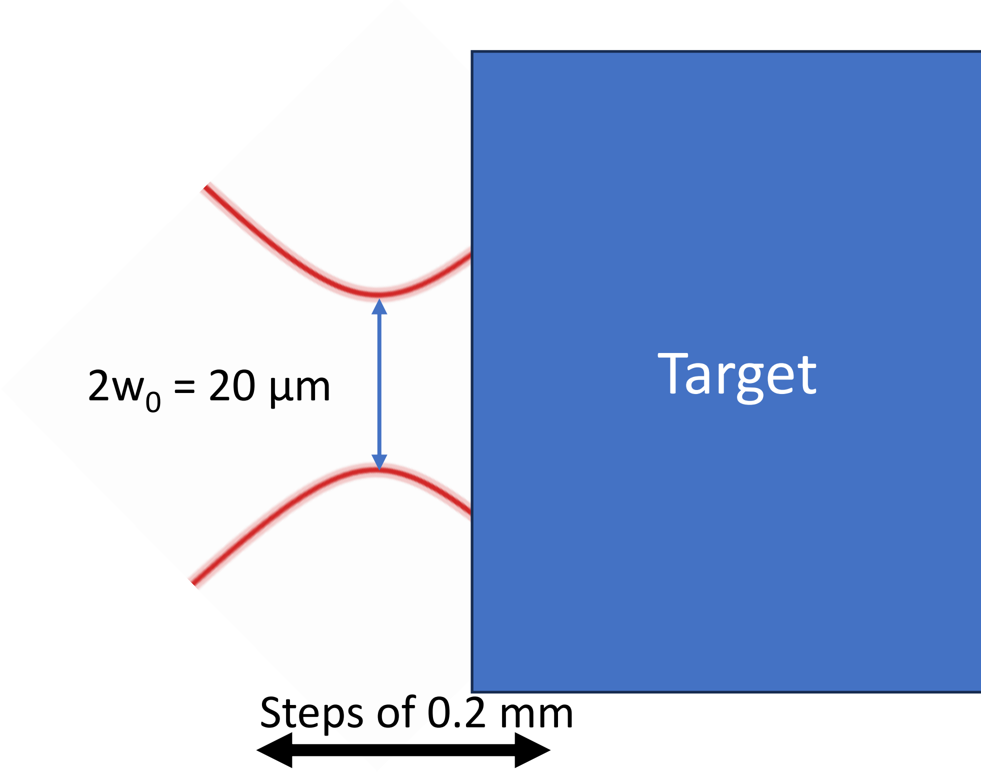
- Pulse energy dependence experiment: 1 mJ, 5 mJ, 10 mJ, 15 mJ, 20 mJ, 25 mJ
- Laser intensity dependence experiment: 10 mJ, 25-27.7 mJ



Coherent Hidra laser system in the Wigner RCP

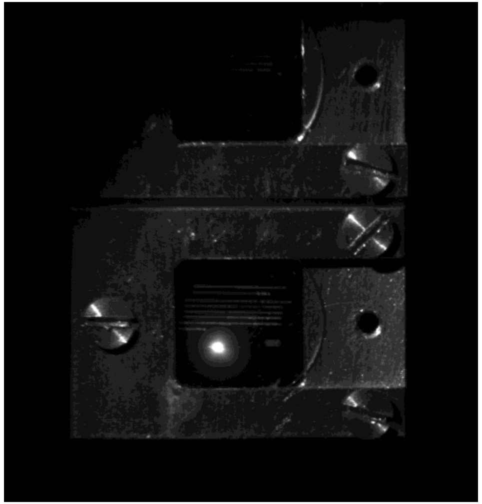
Target position



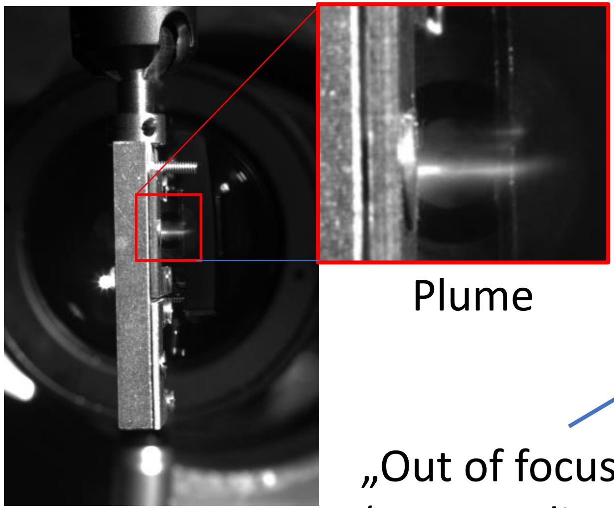


Observations

Target ablation

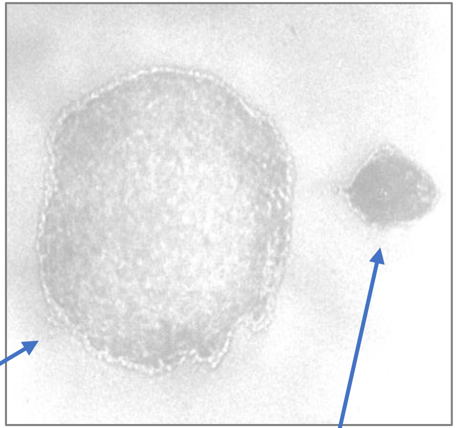


Plasma plume formation



Plume

Crater formation



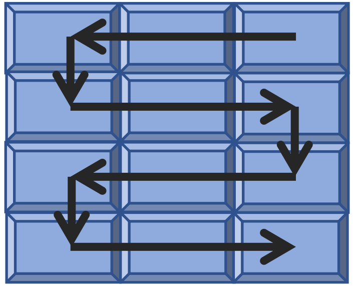
„Out of focus” crater (4.2 mm distance)

„In-focus” crater

Measurements

Morphology of the craters – White light interferometry

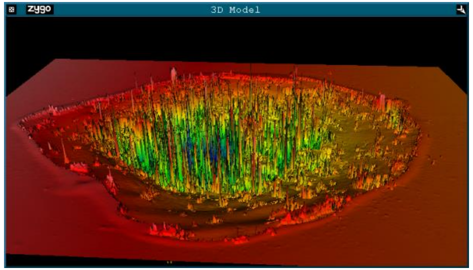
Zygo NewView™ 7100
Central wavelength: 580 nm ($\Delta\lambda$ = 140 nm)
Vertical resolution: 0.1 nm
Optical resolution: 0.52 μm
Objective: Mirau 50x
Scanning length: 20-65 μm
Minimal modulation: 0.001%
Objective's field of view: 0.19 mm x 0.14 mm



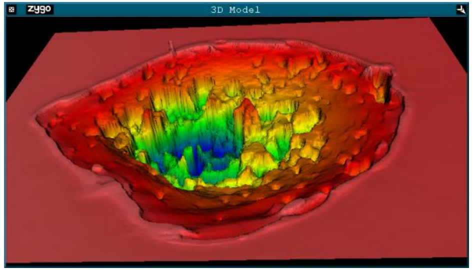
Stitching method

Data evaluation

1. Digital noise reduction



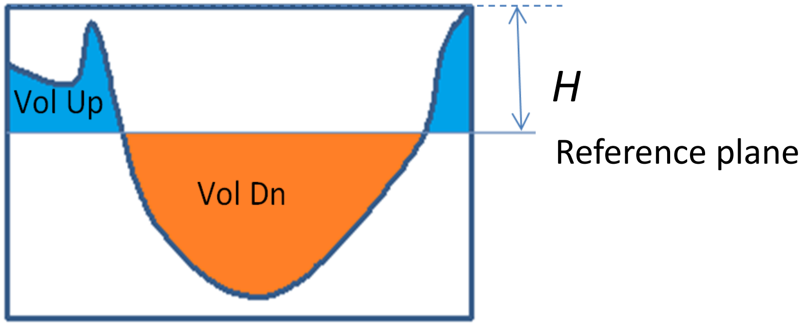
Raw picture



Filtered picture

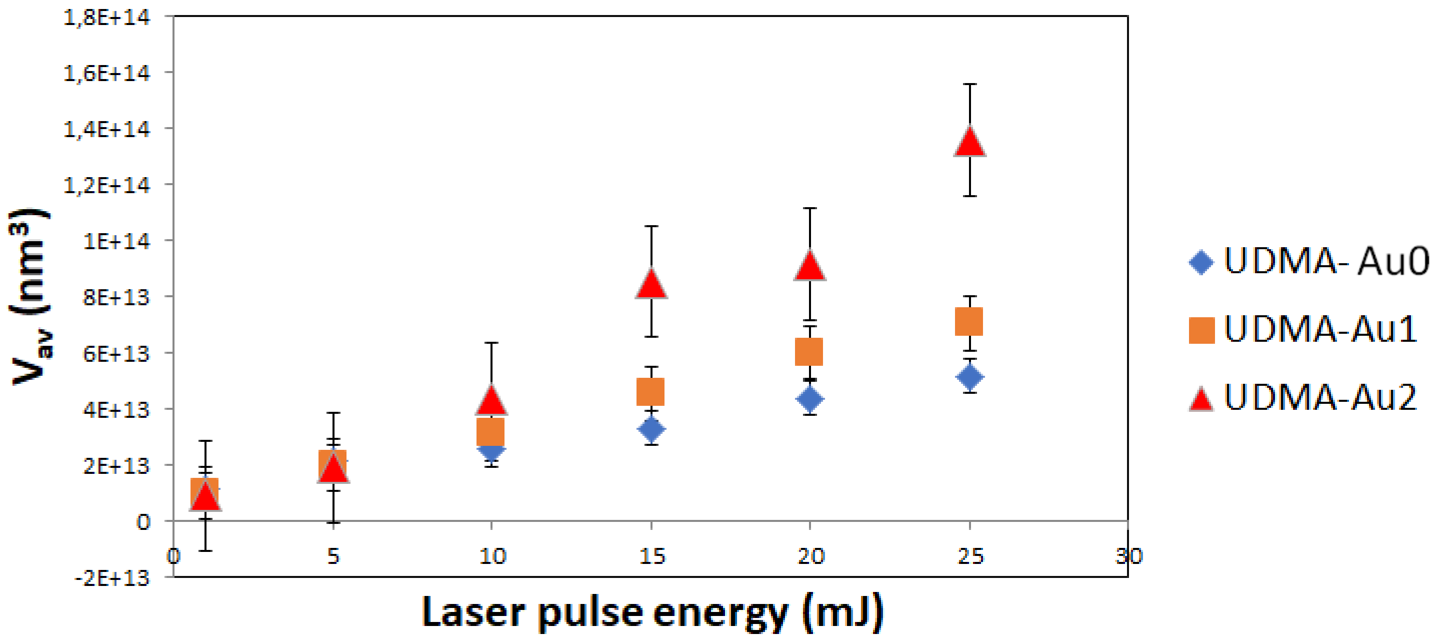
2. Selection of the measurement range
3. Finding the reference plane
4. Calculating the volume of the crater

$$V = VolDn + A_{pixel} \cdot N_{points} \cdot H - VolUp$$



Crater volume vs. Pulse energy

Crater measurements in 5 different points for each energy and target



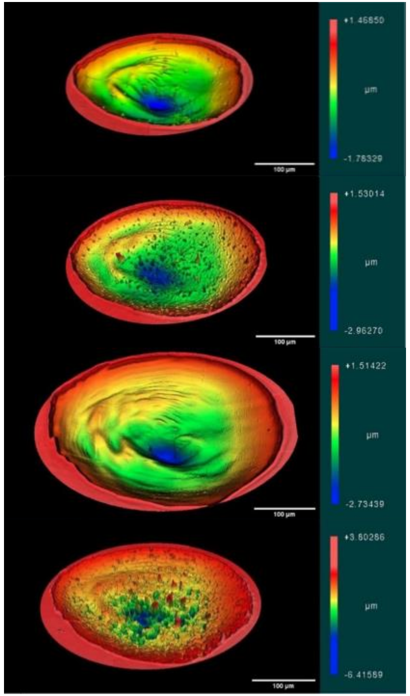
Crater morphology vs. Laser intensity

Laser energy / Target

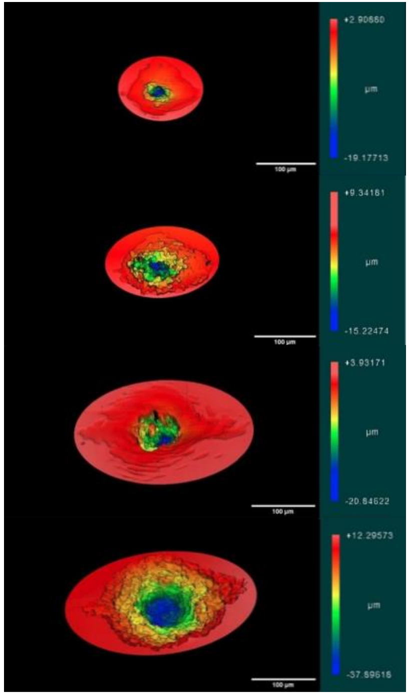
Target position relative to the focal point/Laser intensity compared to the in-the-focus case

Laser energy / Target	-1.8 mm	0.0 mm	+0.6 mm
10 mJ / Au0			
10 mJ / Au2			
27.7 mJ / Au0			
25 mJ / Au2			

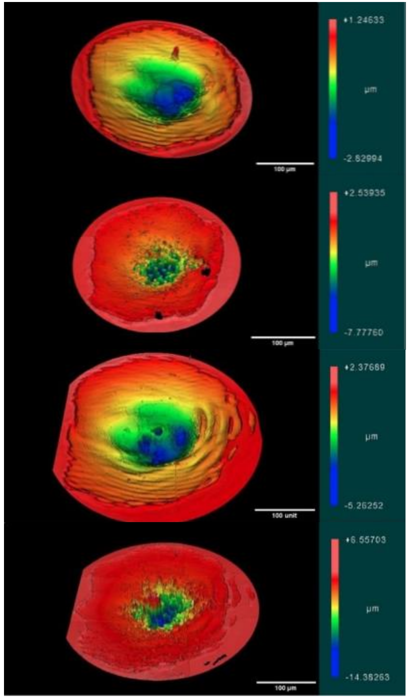
-1.8 mm



0.0 mm



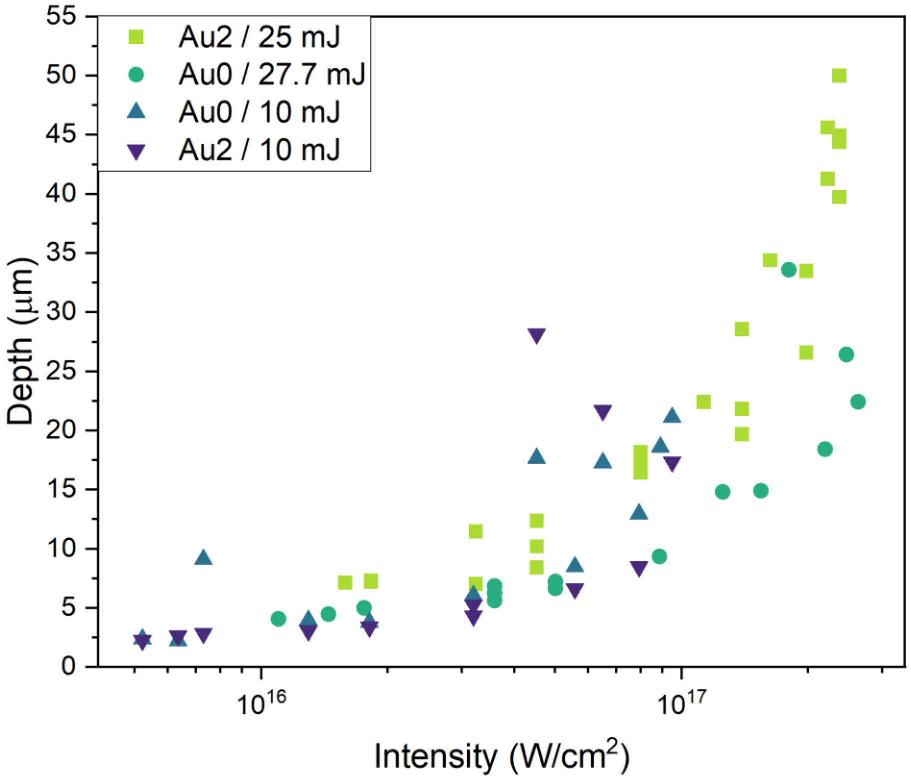
+0.6 mm



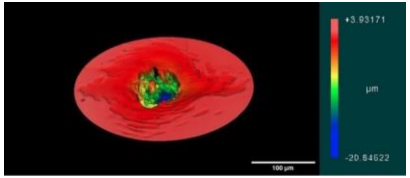
Crater depths

Ratio of the maximum depths

	10 mJ	25 mJ
$\frac{D_{Au2}}{D_{Au0}}$	1.25	1.36

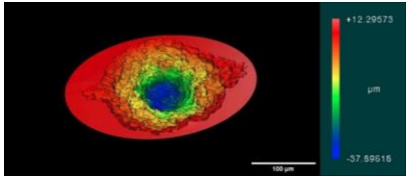


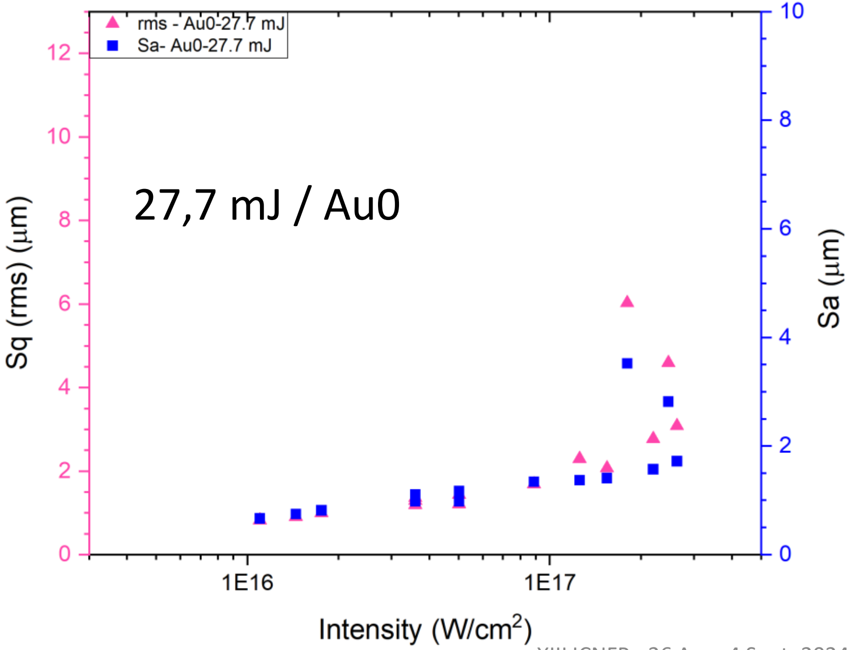
Roughness of the craters

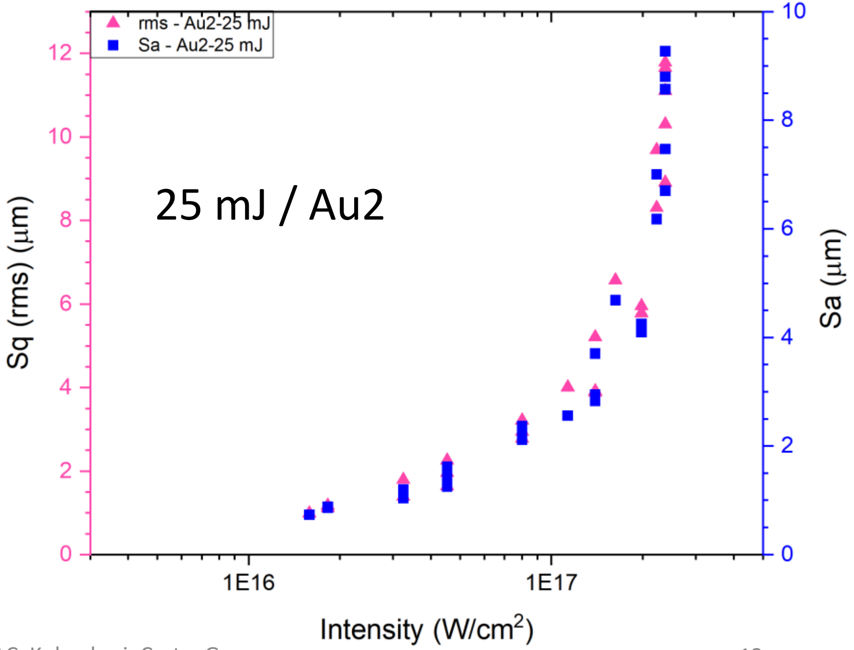


$$S_q = rms = \sqrt{\frac{1}{L}\int_0^L z^2(x)dx}$$

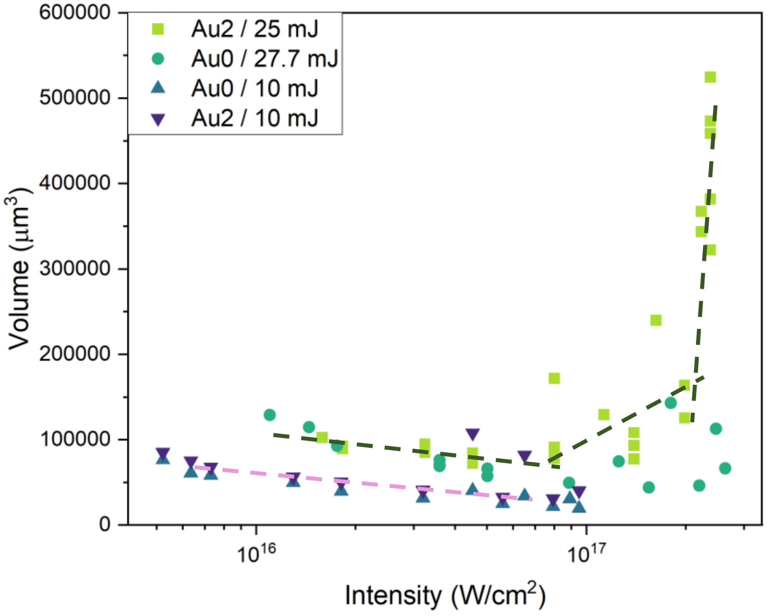
$$S_a = \frac{1}{L}\int_0^L |z(x)|dx$$







Intensity vs. Crater volume



For Au2 almost 7-fold increase of the volume.

Laser setup at the ELI-ALPS, Szeged, Hungary

Sylos Experiment Alignment laser

Vacuum chamber

Pressure: < 10^{-6} Pa

Angle of incidence: 45°

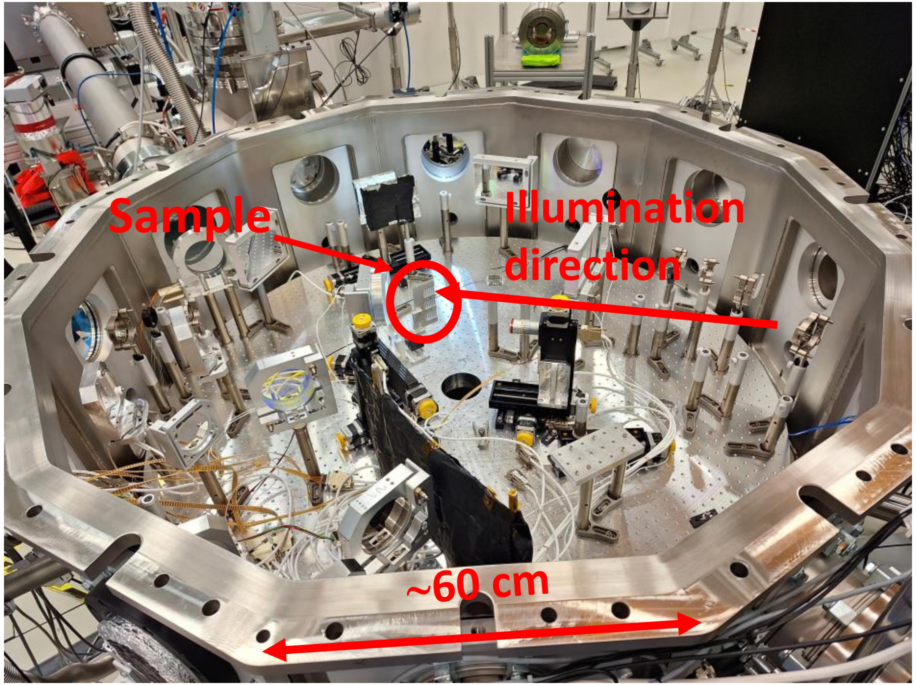
Single laser shots

Central wavelength: 825 nm

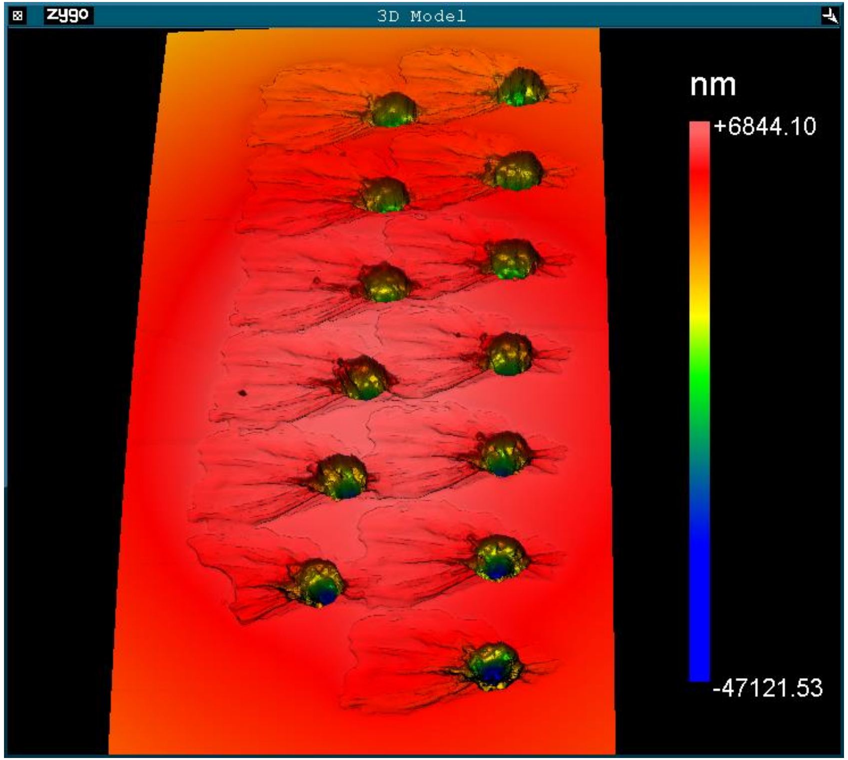
Pulse length: 12.3 fs, 17 fs, 21 fs, 26 fs, 31 fs, 37 fs, 43 fs, 48 fs, 59 fs, 120 fs

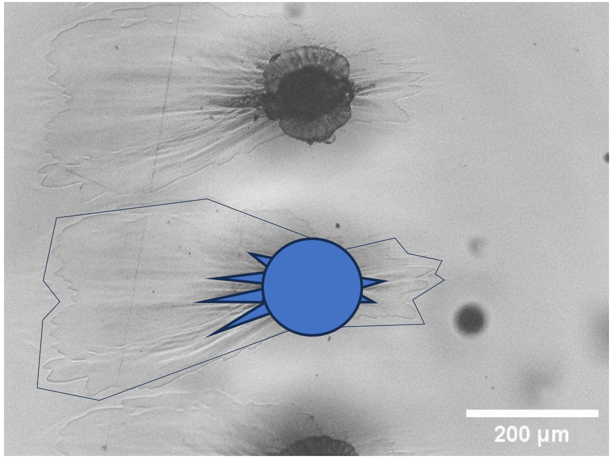
Intensity: 0.56-5.4 · 10^{18} W/cm^2

Pulse energy: 25 mJ



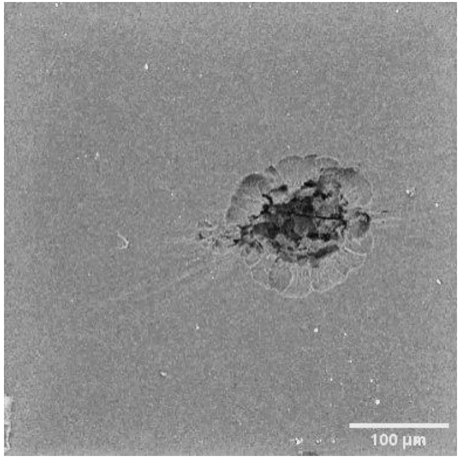
Craters created at the ELI-ALPS



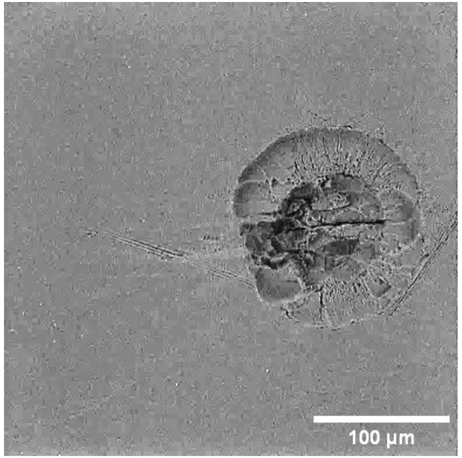


Craters created at the ELI-ALPS – Morphology studies

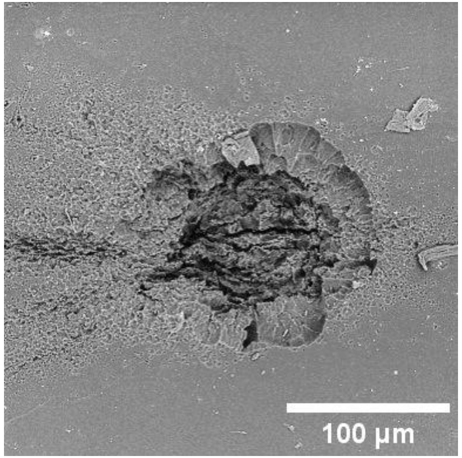
Au0 - 43 fs



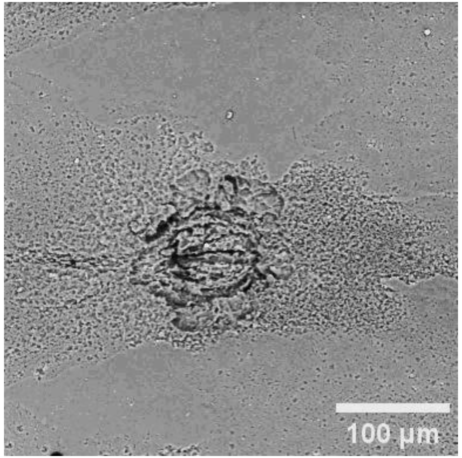
Au0 - 43 fs



Au2 - 12,3 fs

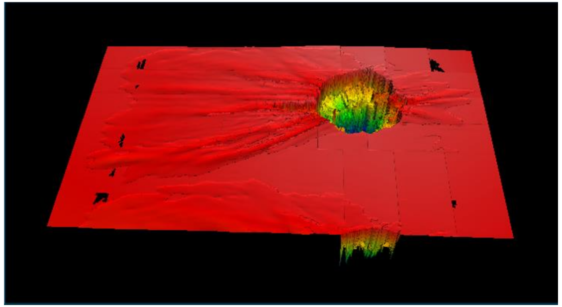


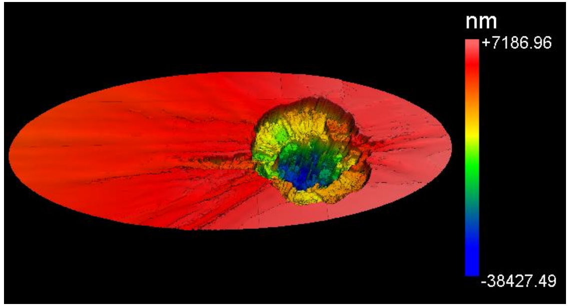
Au2 - 43 fs



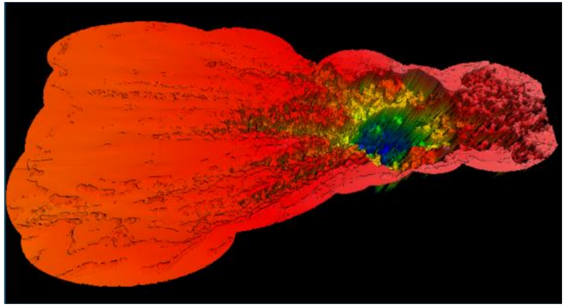
Craters created at the ELI-ALPS – 12,3 fs

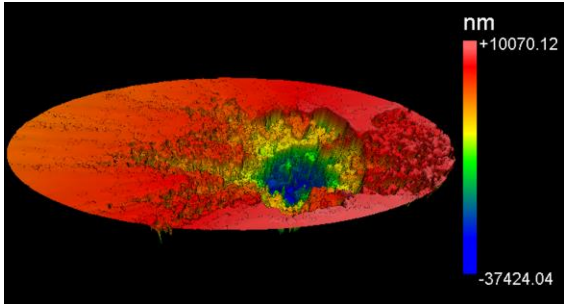
Au0



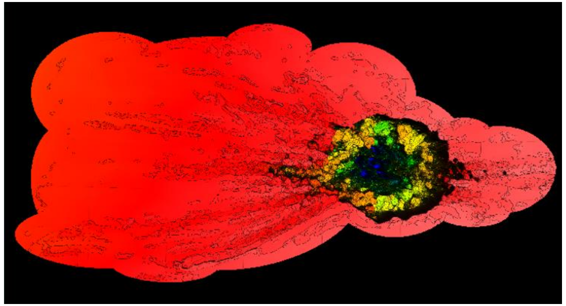


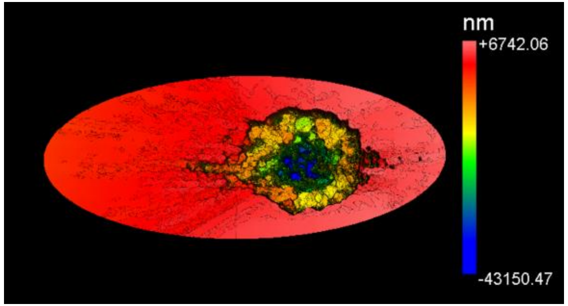
Au2





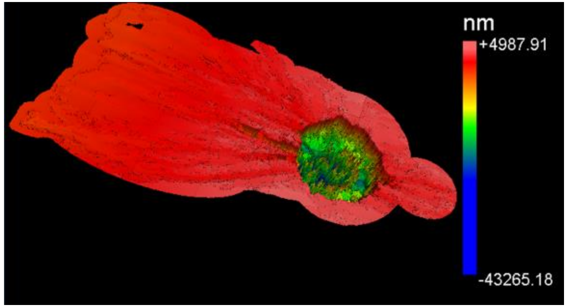
Au2 - OffResonant

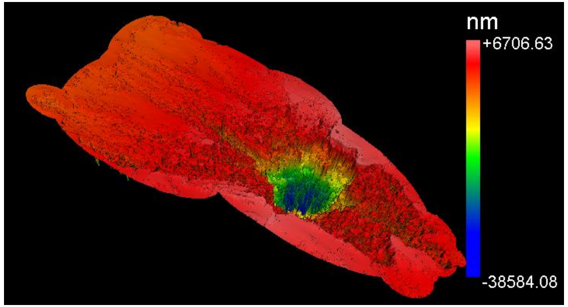


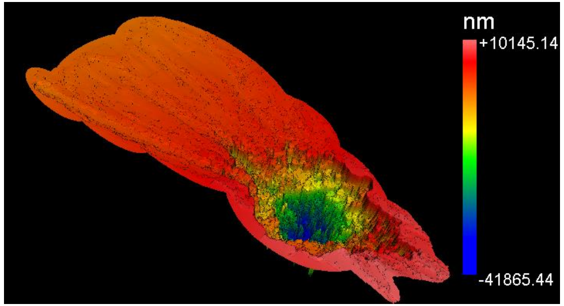


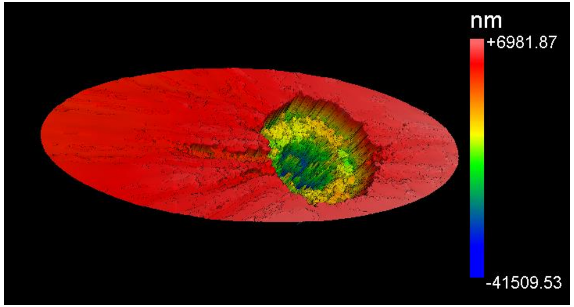
Craters created at the ELI-ALPS – 43 fs

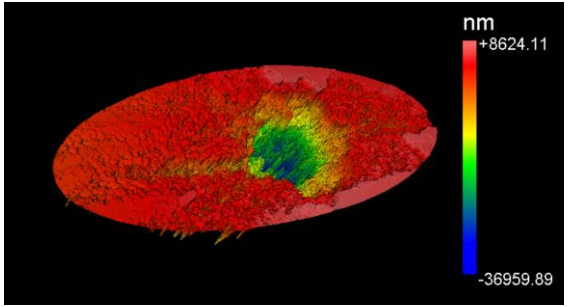
Au0 | **Au2** | **Au2 - OffResonant**

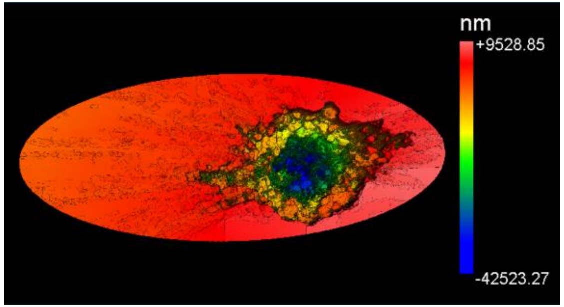




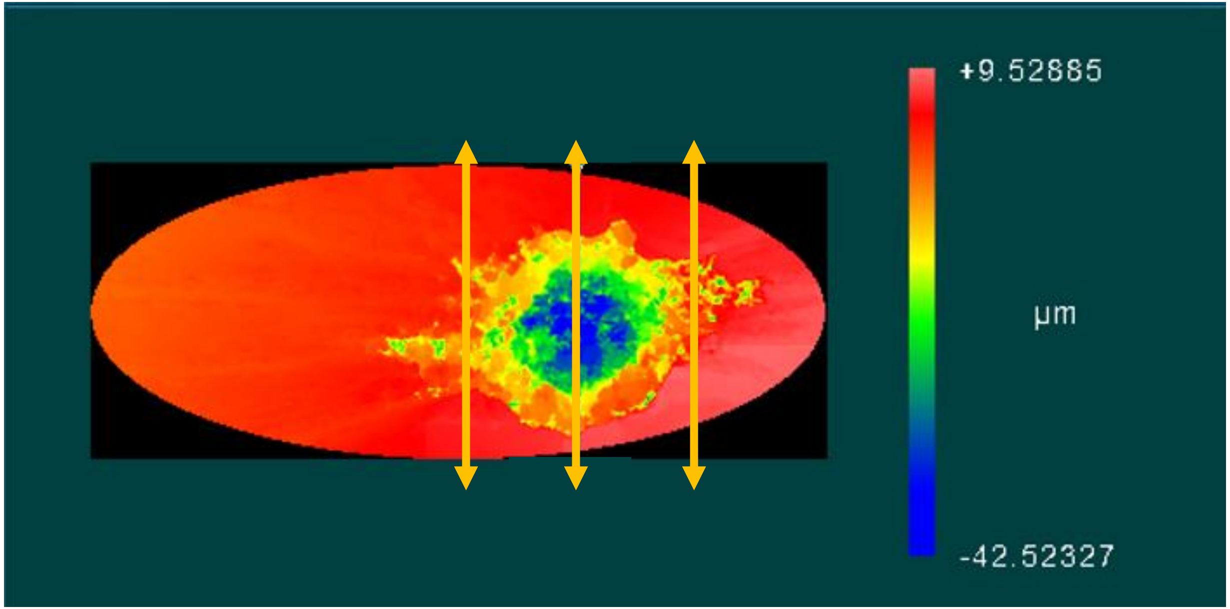




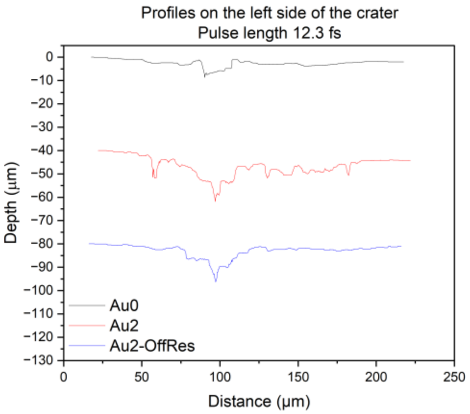


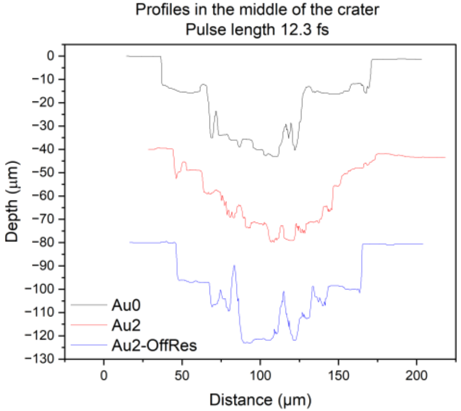


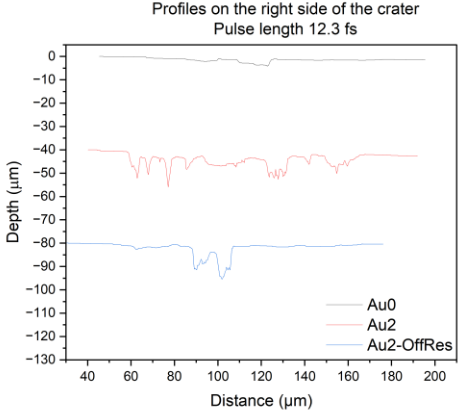
Craters created at the ELI-ALPS – Profiles

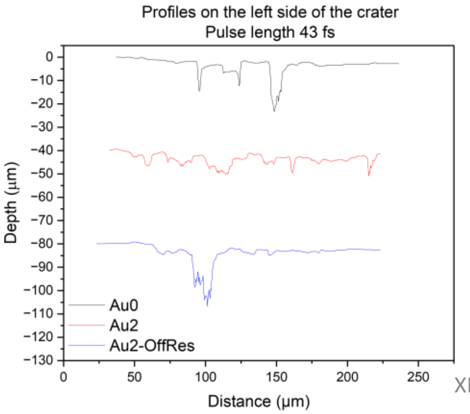


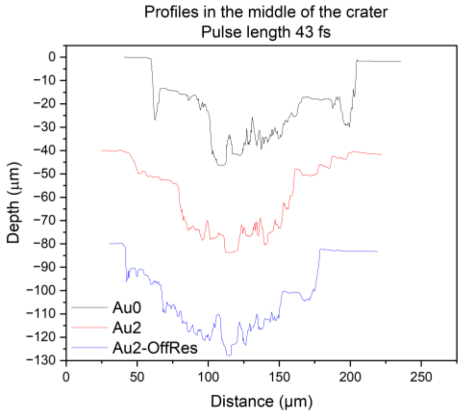
Craters created at the ELI-ALPS - Profiles

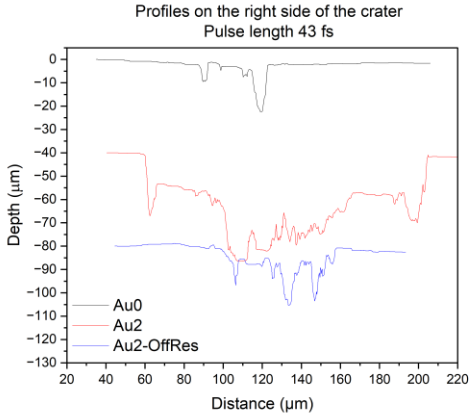












Conclusions

Crater morphology was studied in UDMA-TEGDMA polymer targets with and without embedded gold nanorods, irradiated with 42 fs long laser pulses.

It was observed, that the crater volume is higher:

- in the presence of gold nanorods above 10 mJ irradiation energy;
- at higher gold nanoparticle densities.

With increasing intensity of irradiation

- the diameter of the craters decreased;
- the depth of the craters increased;
- the craters depth was higher in the presence of gold nanorods.

Over $1.25 \cdot 10^{17}$ W/cm^2 intensity in the presence of gold nanorods

- the roughness values doubled;
- the volume of the craters rapidly increased – almost 7 times.

Morphology studies prove the effect of plasmonic gold nanorods on the surface structure formation.

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Thank you for your attention!

We are at the dawn of the fusion era.