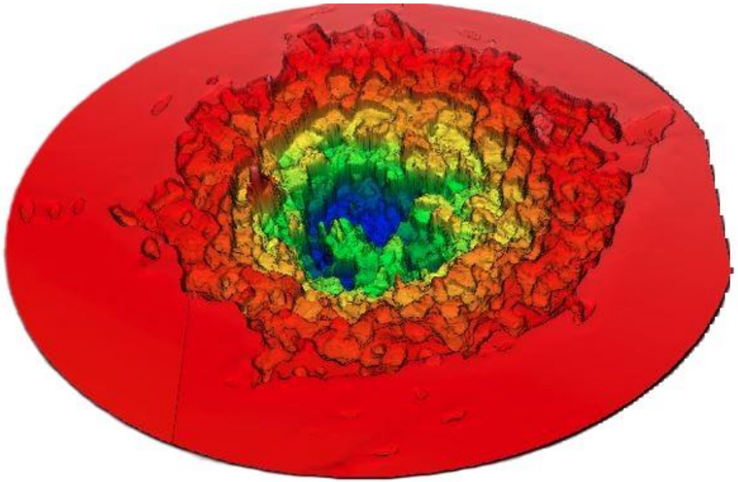
Particles & Plasmas Symposium 2024



Morphology studies on craters created by femtosecond laser irradiation in UDMA polymer targets embedded with plasmonic gold nanorods

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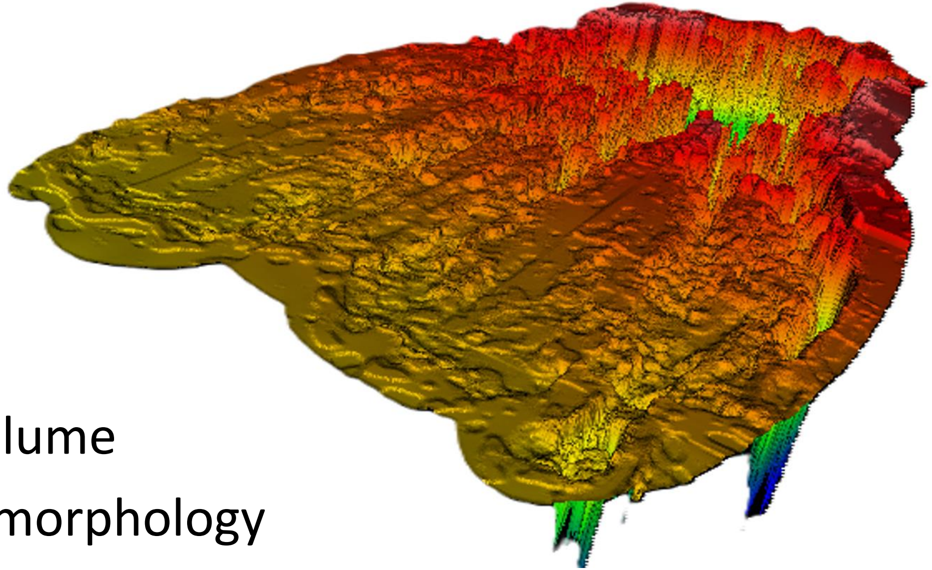
Overview

- Sample preparation
- Laser setup
- Measurements
- Data evaulation
- Energy dependence of crater volume
- Intensity dependence of crater morphology
- Conclusions



Sample preparation

UDMA-TEGDMA monomer

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

+

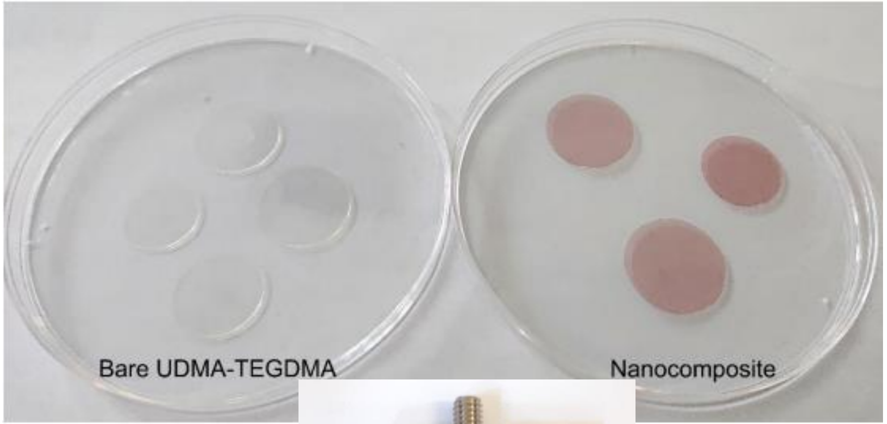
Au nanorods (85 nm x 25 nm)

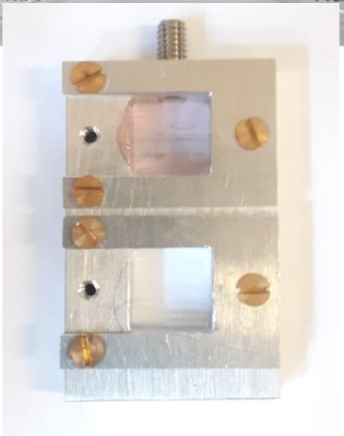
Polymerized

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)

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

Illumination direction: 45°

Single laser shots with Ti:Sa laser

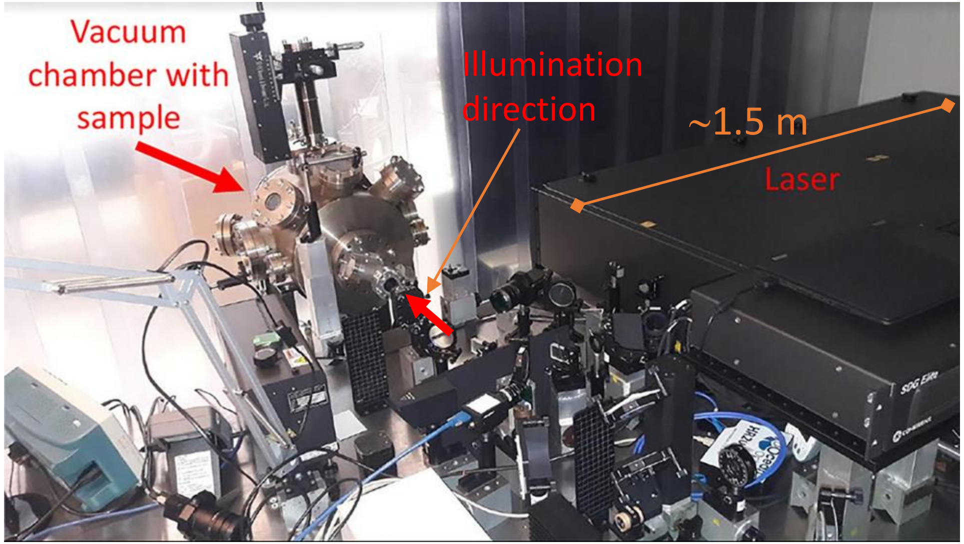
Wavelength: 795 nm

Pulse length: 42 fs

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

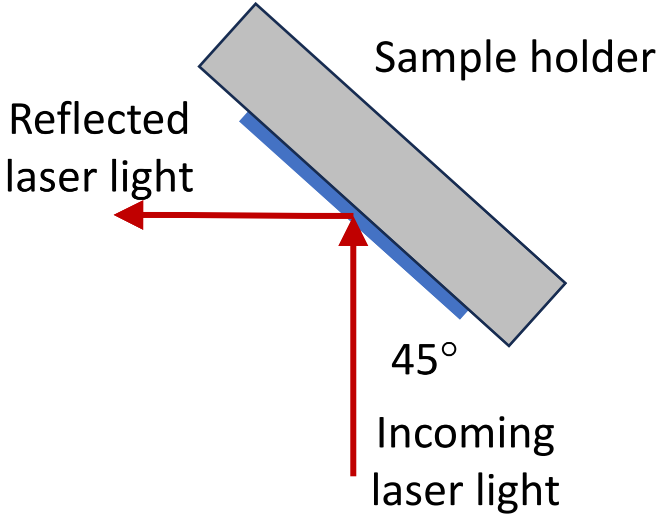
Pulse energy:

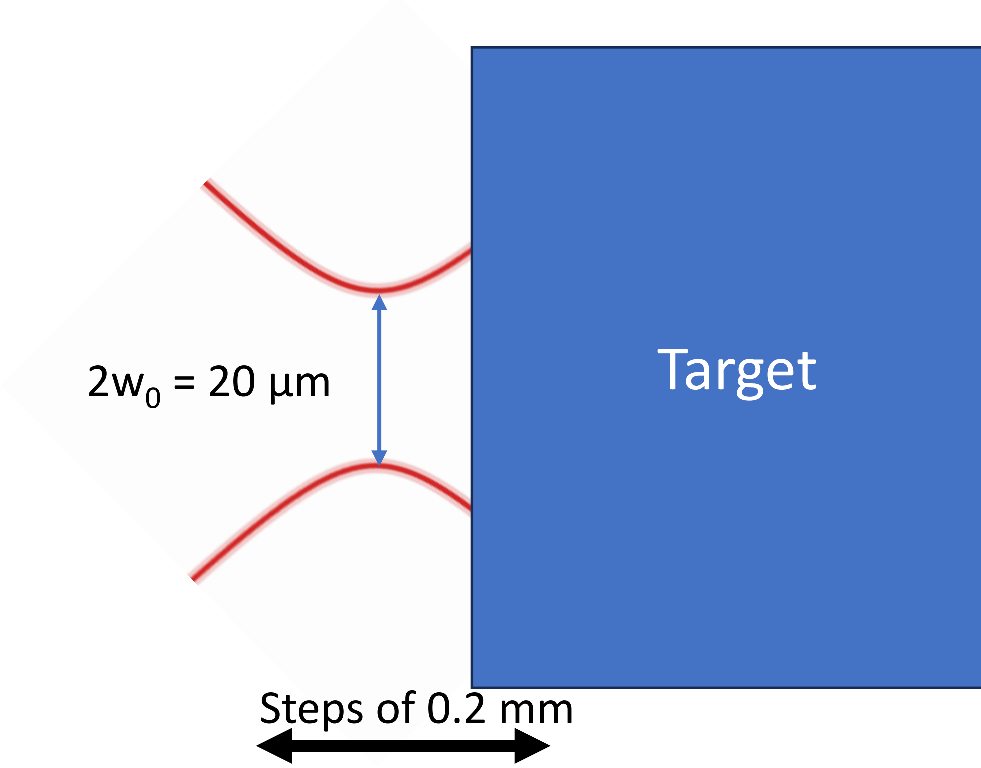
- Pulse energy dependence experiment: 1 mJ, 5 mJ, 10 mJ, 15 mJ, 20 mJ, 25 mJ
- Laser intensity dependence experiment: 10 mJ, 25-27.7 mJ



Coherent Hidra laser system in the Wigner RCP

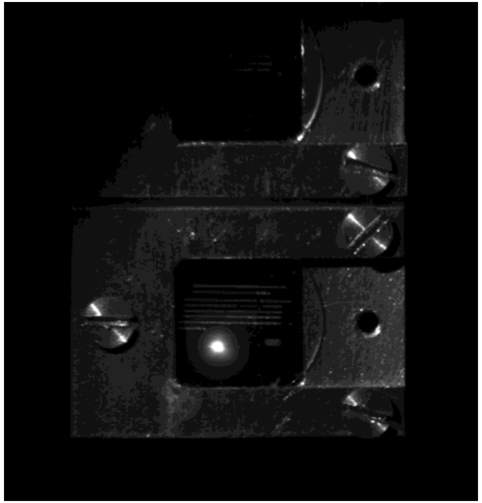
Target position



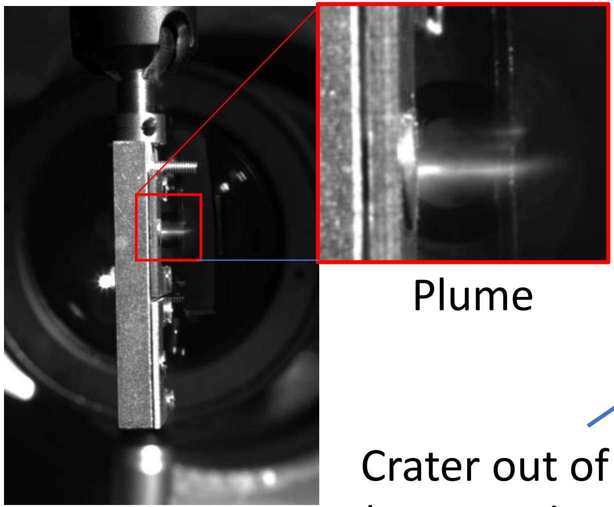


Observations

Target ablation

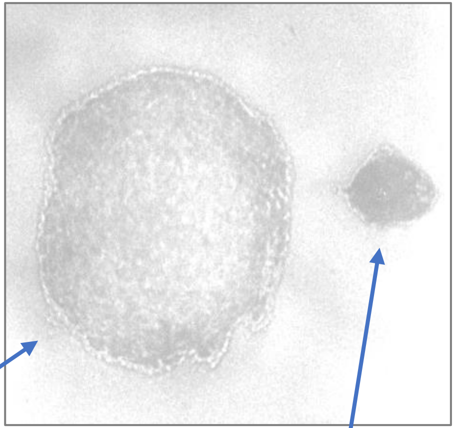


Plasma plume



Plume

Crater formation



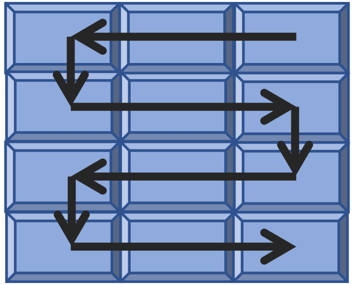
Crater out of the focus (4.2 mm distance)

Crater in the focus

Measurements

Morphology of the craters – White light interferometry

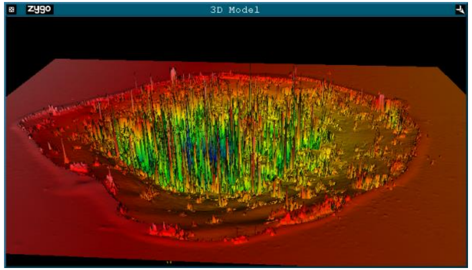
Zygo NewView™ 7100
Central wavelength: 580 nm ($\Delta\lambda$ = 140 nm)
Vertical resolution: 0.1 nm
Optical resolution: 0.52 μm
Objective: Mirau 50x
Scanning length: 20-65 μm
Minimal modulation: 0.001%
Objective's field of view: 0.19 mm x 0.14 mm



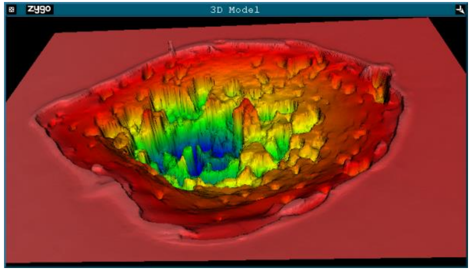
Stitching method

Data evaluation

1. Digital noise reduction



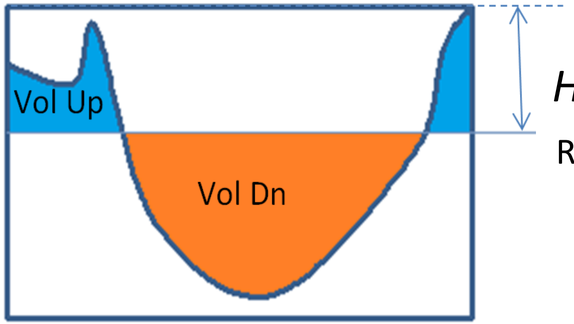
Raw picture



Filtered picture

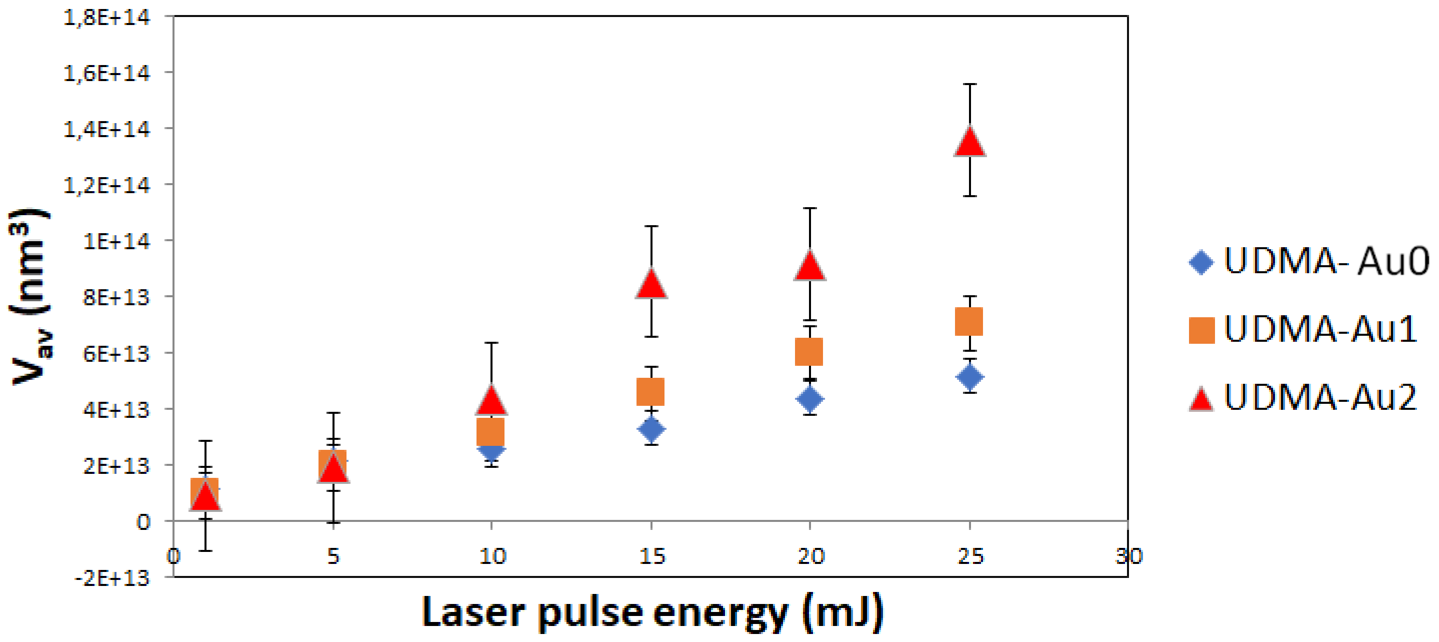
2. Selection of the range for measuring
3. Finding reference plane
4. Calculate the volume of the crater

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



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

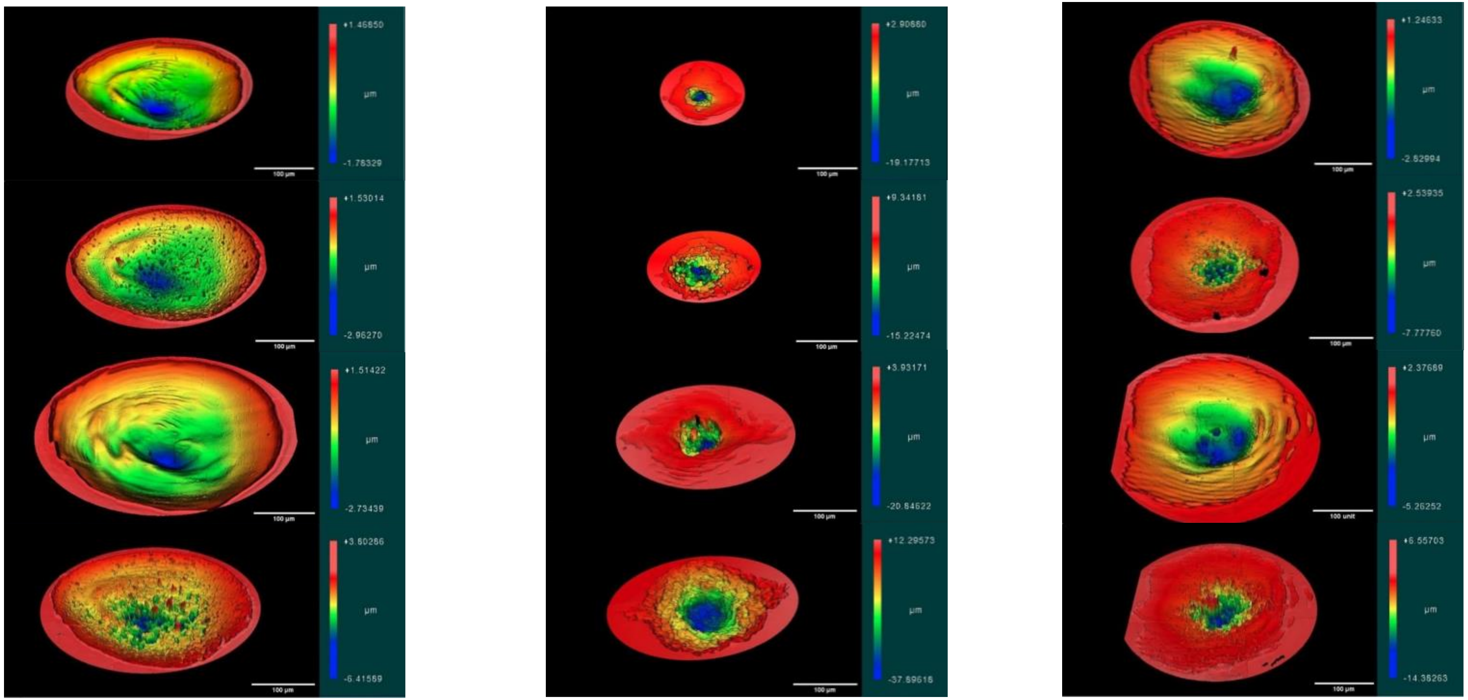
-1.8 mm | 0.0 mm | +0.6 mm

10 mJ / Au0

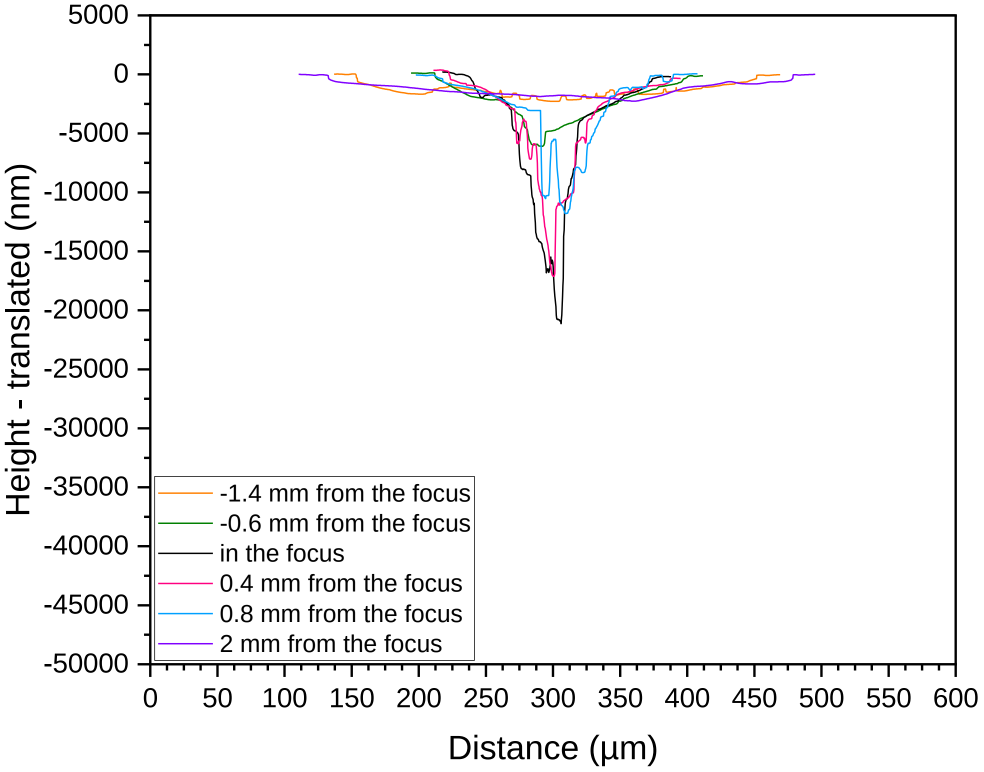
10 mJ / Au2

27.7 mJ / Au0

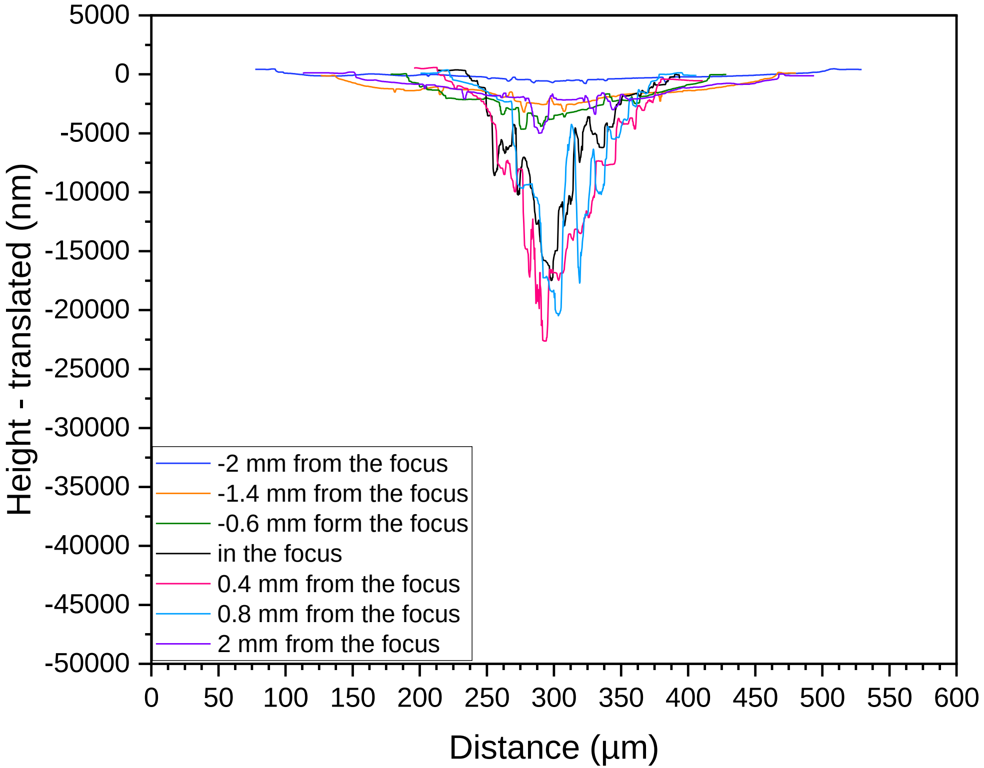
25 mJ / Au2



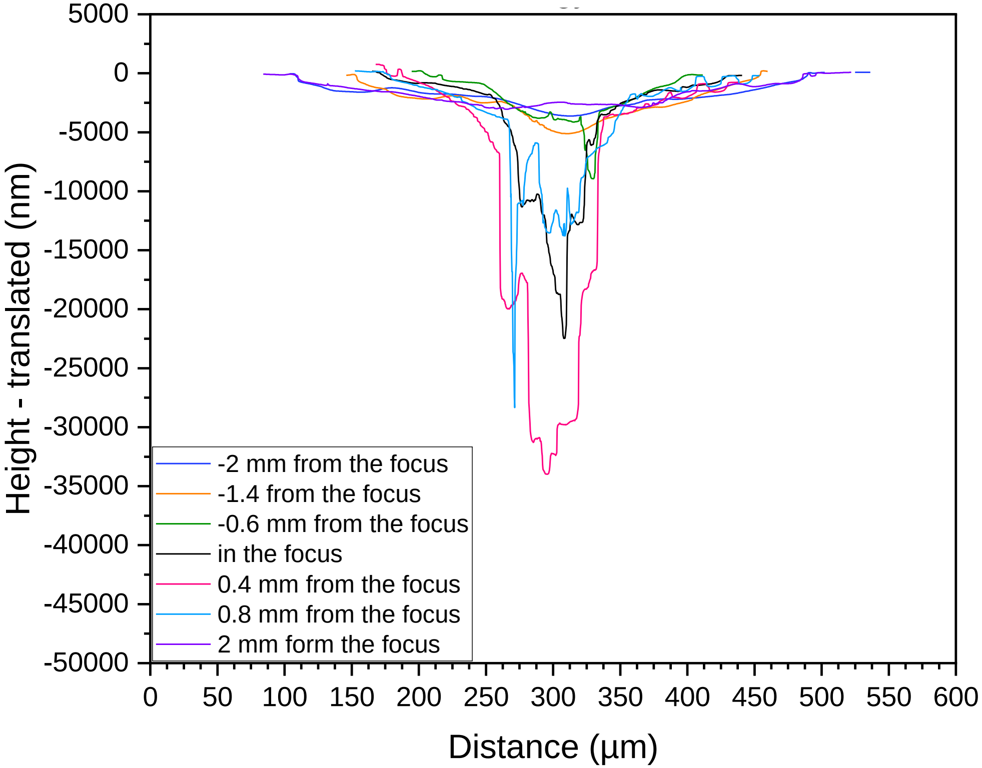
Deepest profiles at 10 mJ for Au0



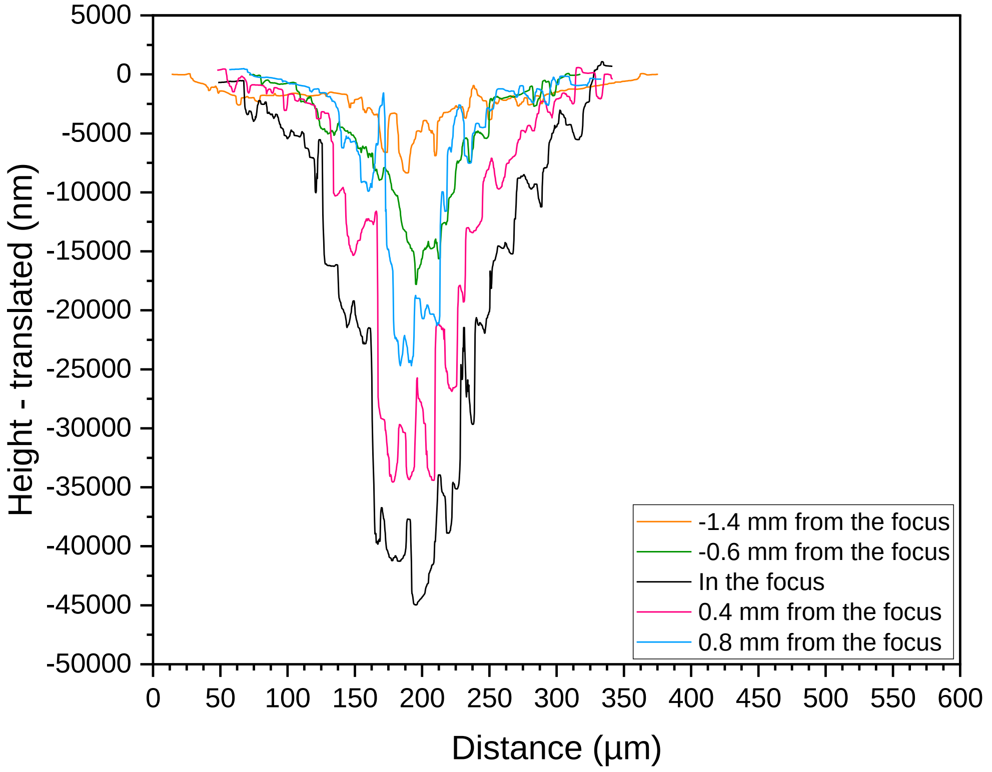
Deepest profiles at 10 mJ for Au2



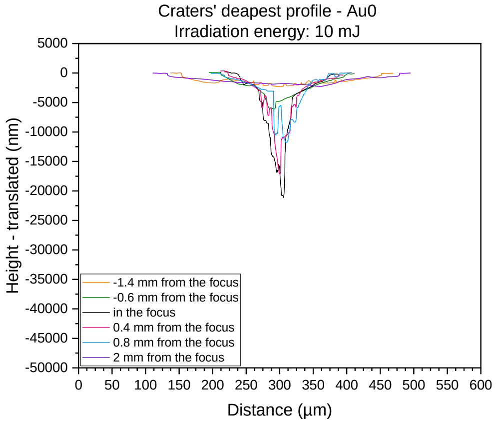
Deepest profiles at 27.7 mJ for Au0

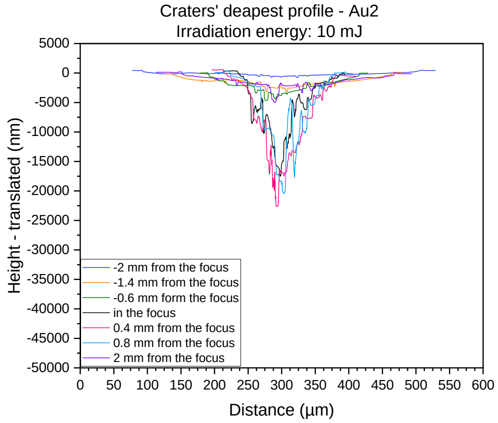


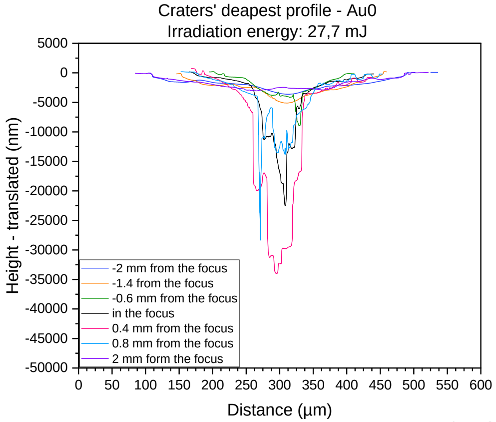
Deepest profiles at 25 mJ for Au2

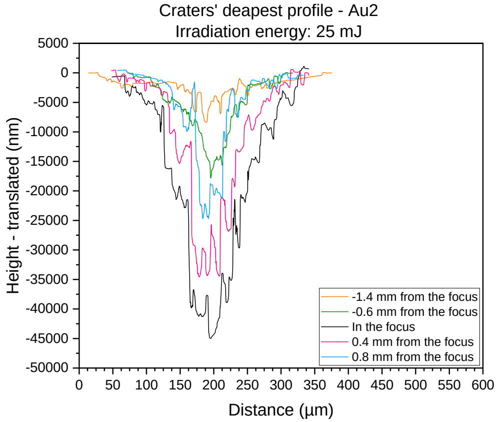


Comparison of the deepest profiles





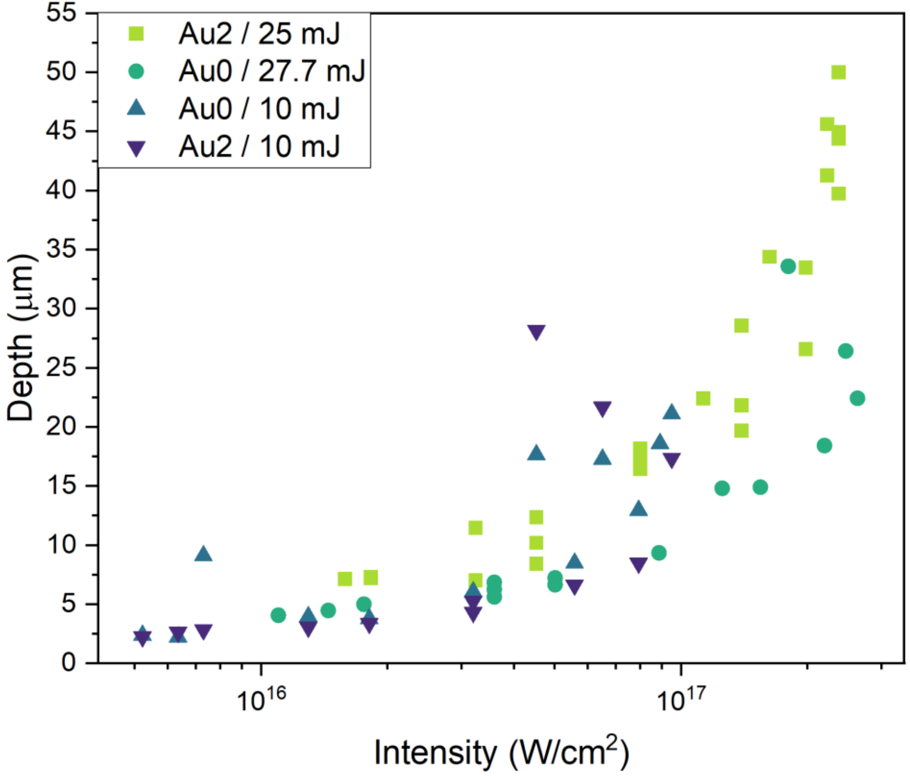




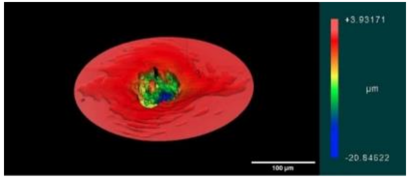
Single craters depth

Ratio of the maximum depth

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

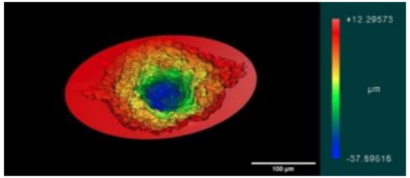


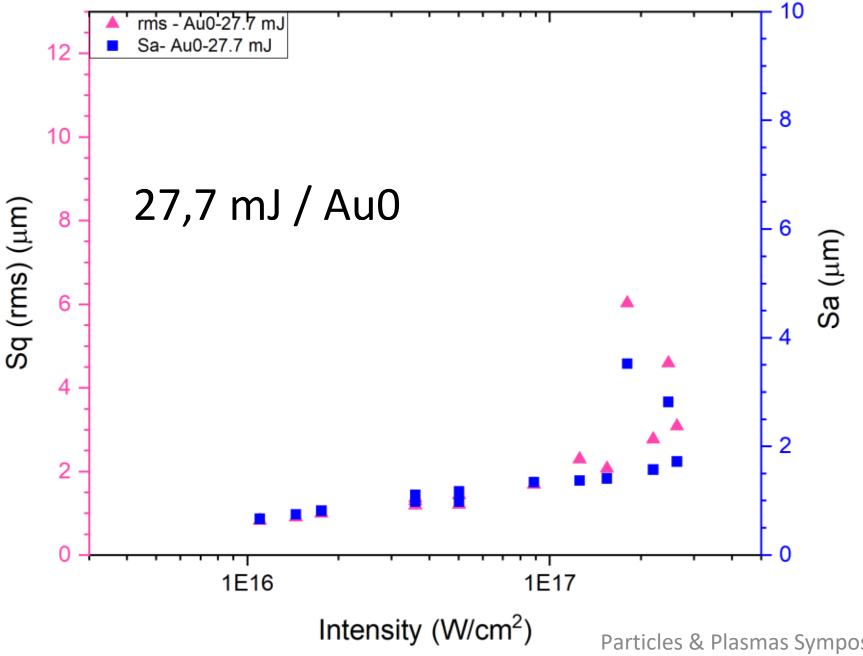
Roughness of the craters

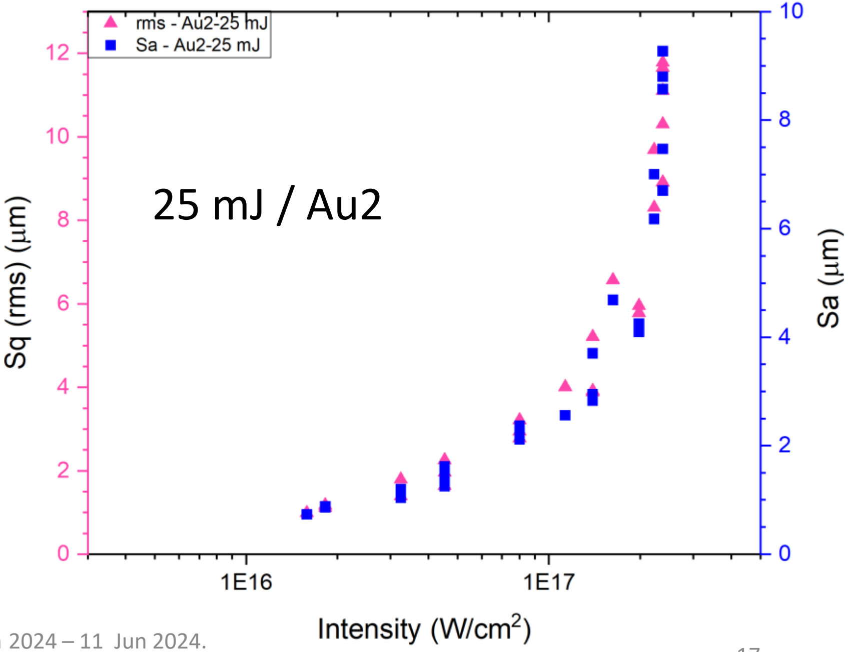


$$S_q = rms = \sqrt{\frac{1}{L}\int_0^L z^2(x)dx}$$

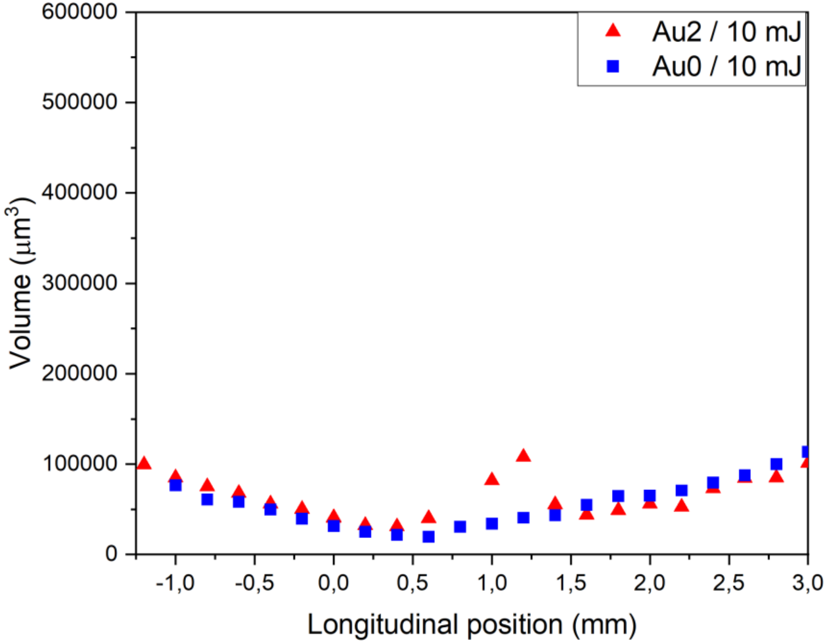
$$S_a = \frac{1}{L}\int_0^L |z(x)|dx$$

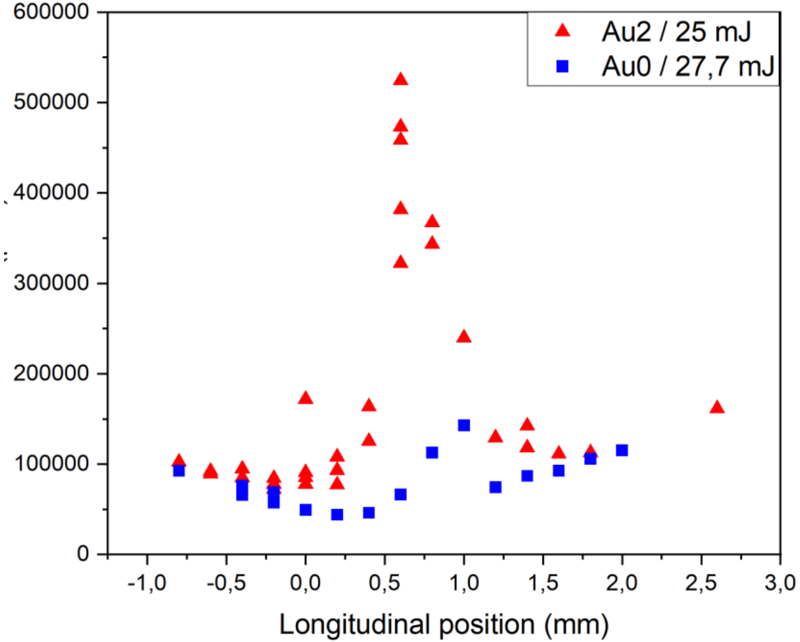






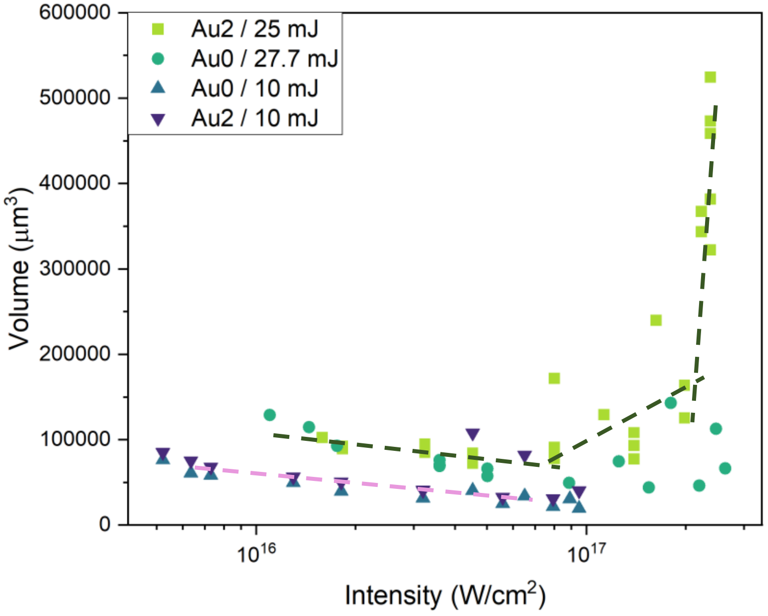
Crater volume vs. Focus position





Á. N. Szokol at al, *arXiv:*2402.18138. 2024

Intensity dependence - crater volume



For Au2 almost 7-fold increase of the volume.

Conclusions

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

It was observed, that the crater volume is higher:

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

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.

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Thank you for your attention!