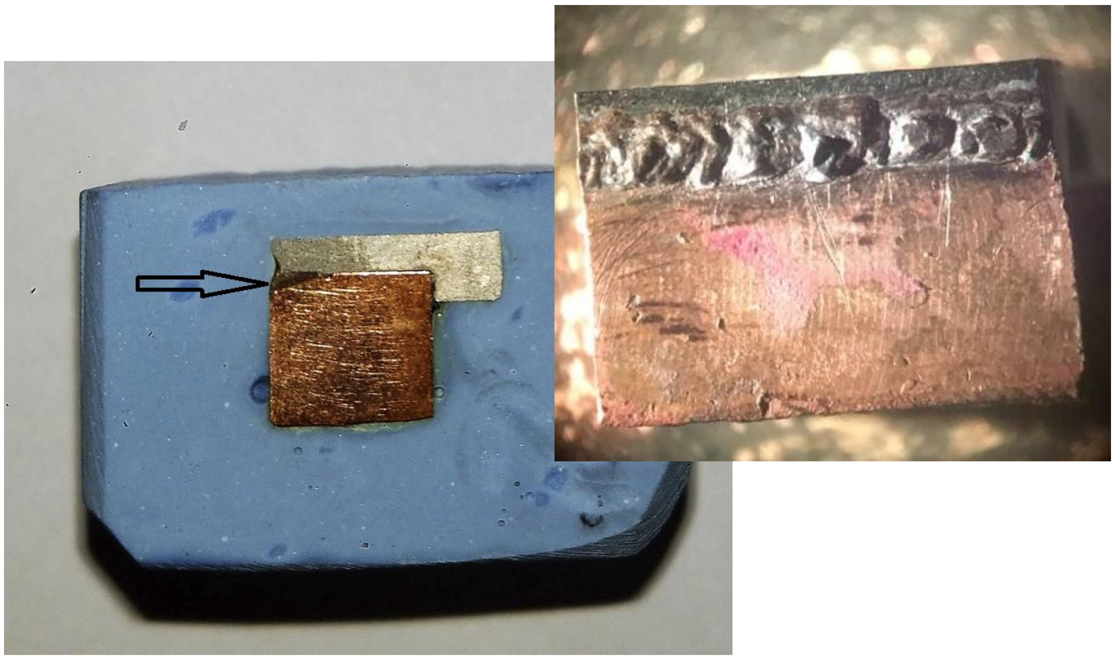
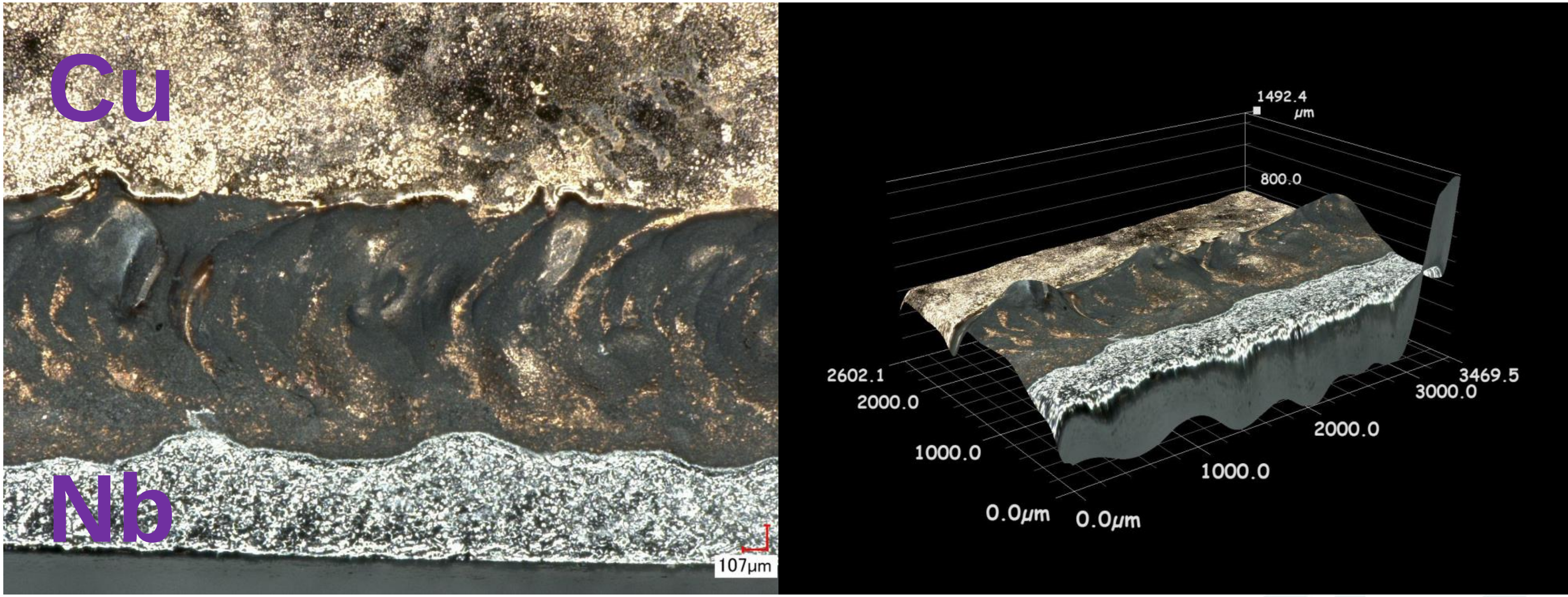
Tasks

1. Shine the laser at high power on the welding seam in the direction of the arrow and try to clean it and possibly re-melt it, maybe reduce the oxygenation of the interface. Compare the result optically with the welding seam before laser treatment.
2. Improvement the surface roughness of the copper sample by a laser treatment.



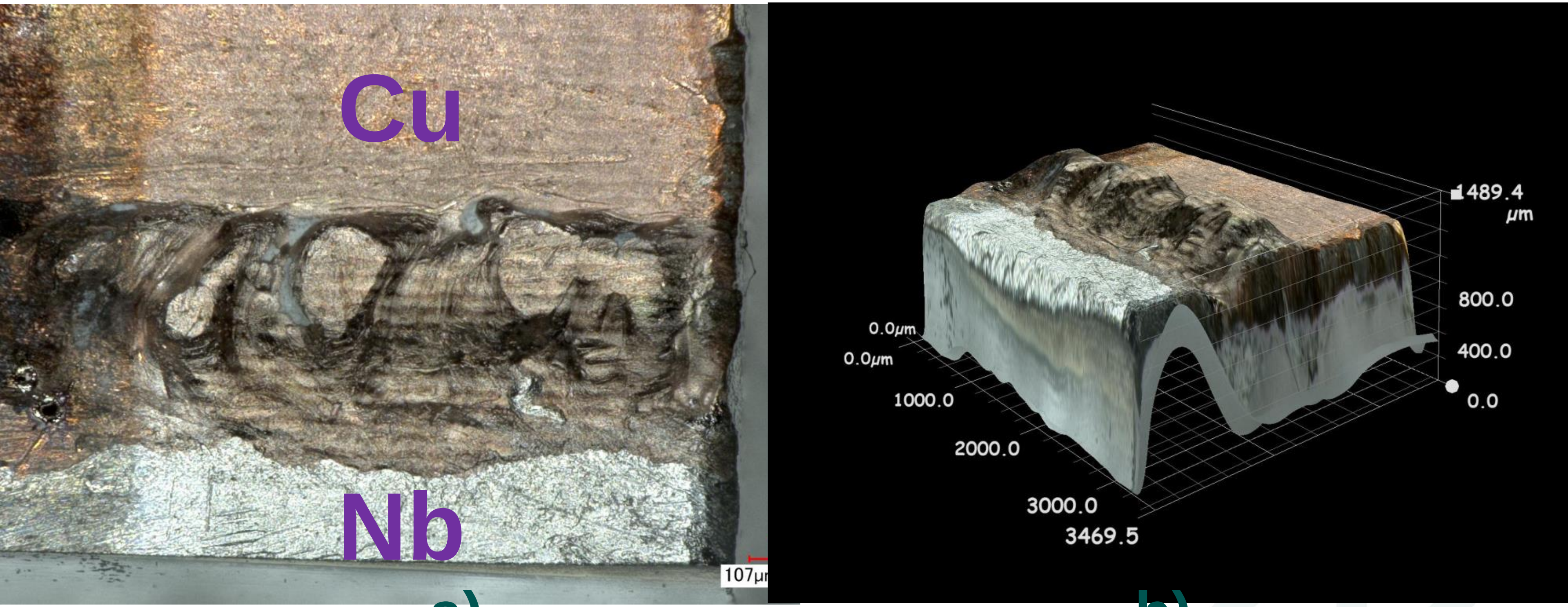
Before irradiation

After irradiation by Nd:YAG



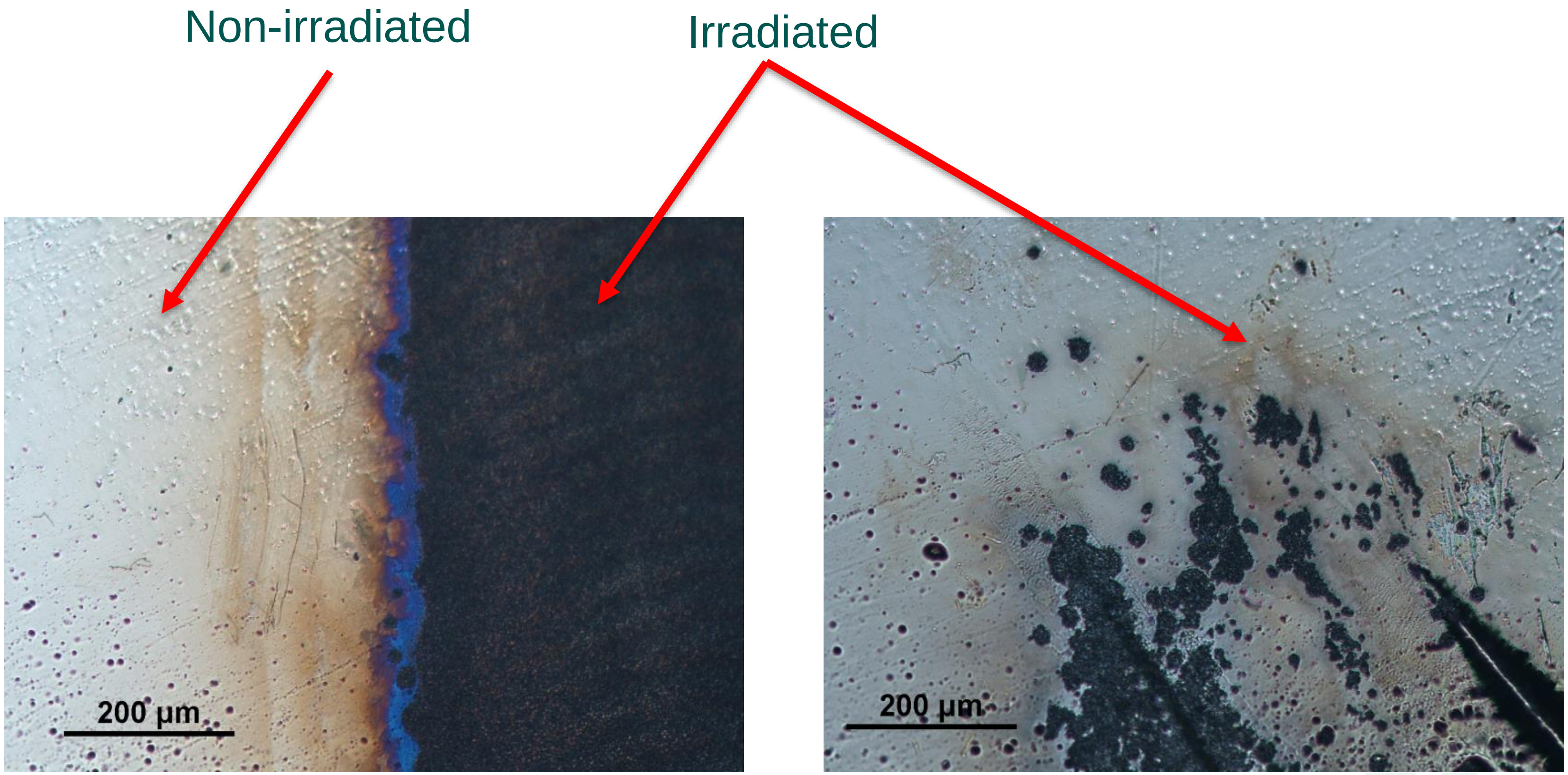
a) b)

Fig.2. a) 2D and b) 3D optical microscope images of non-irradiated Cu/Nb sample



a) b)

Fig.2. a) 2D and b) 3D optical microscope images of irradiated Cu/Nb sample by Nd:YAG laser (1064 nm)



a) b)

Fig.6. Optical microscope images of the border of non-irradiated (a) and irradiated (b) single crystal Cu samples.
Parametrs Nd:YAG laser (λ=1064 nm, τ=6ns), scanning speed 0.50 mm/s

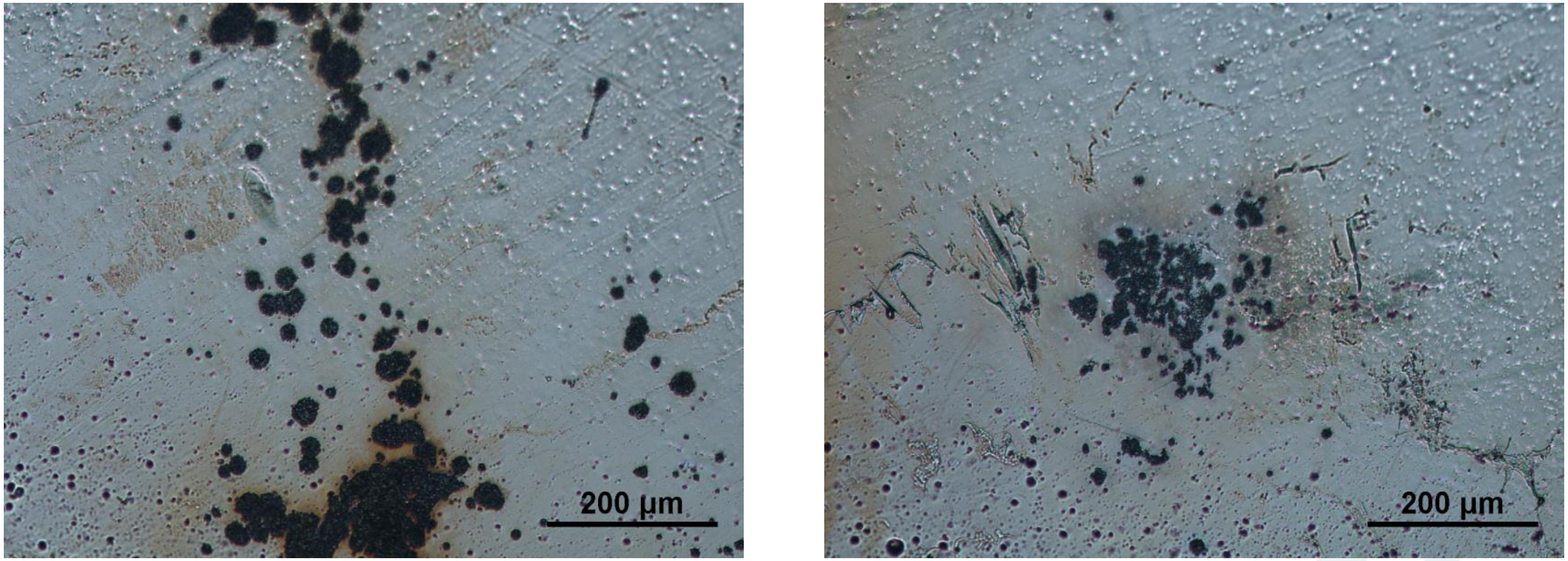


Fig.6. Optical microscope images of the border of non-irradiated (a) and irradiated (b) single crystal c-Cu samples in Ar.
Parametrs Nd:YAG laser (λ=1064 nm, τ=6ns), scanning speed 0.75 mm/s

Non-irradiated

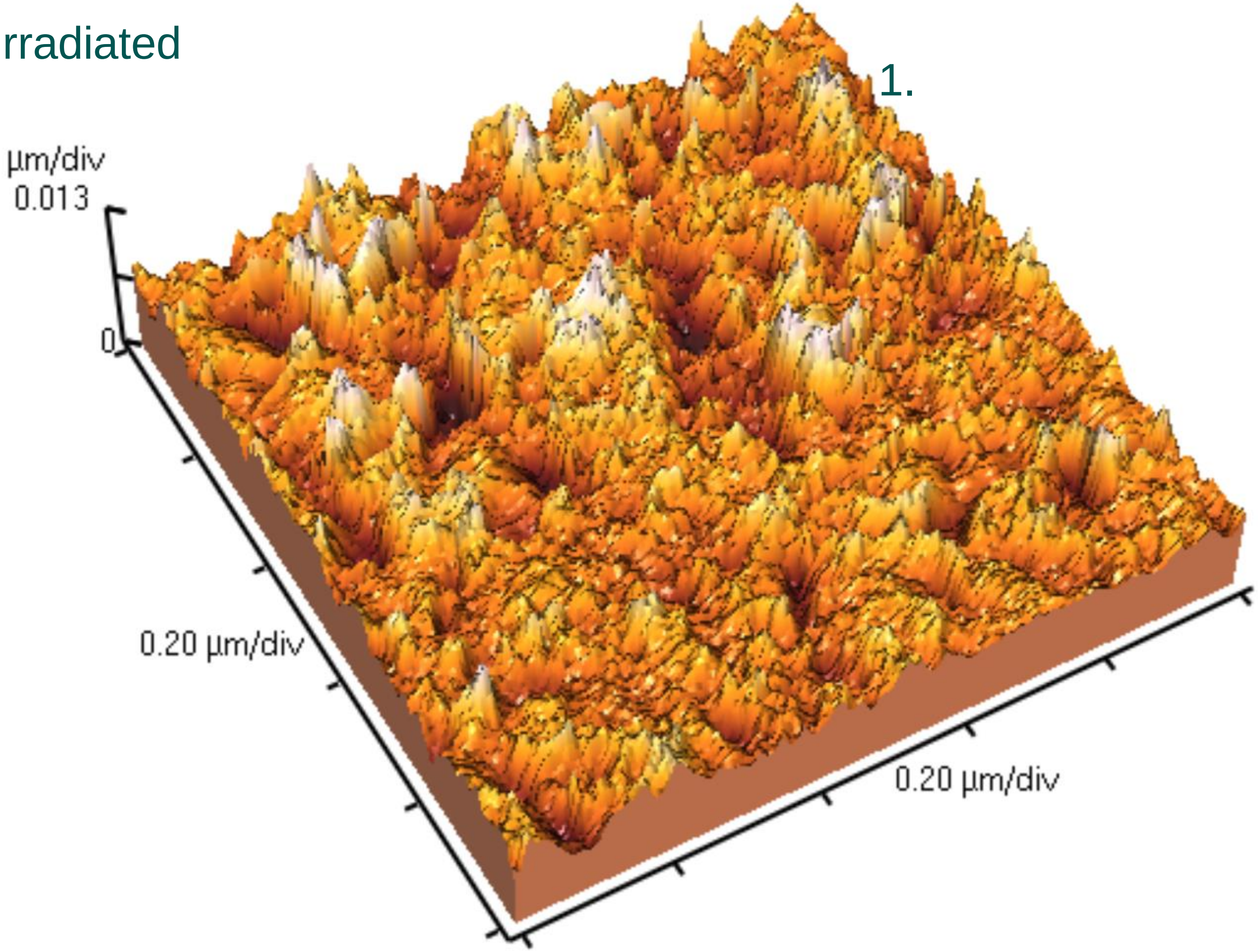


Fig.9. 3D AFM image of single crystal Cu irradiated

	Rpv	Rrms	Ra, nm
Non-irradiated	108,3	4,65	2,71
10-1-1-sa	177,3	12,25	7,18
10-1-2-sa	229,7	12,3	5,91
10-3-1-	1378	257,4	218,7
10-3-2-	784,2	130,9	104,6

Thank you for your kind attention!

Experiment 1. Nb/Cu structure polishing

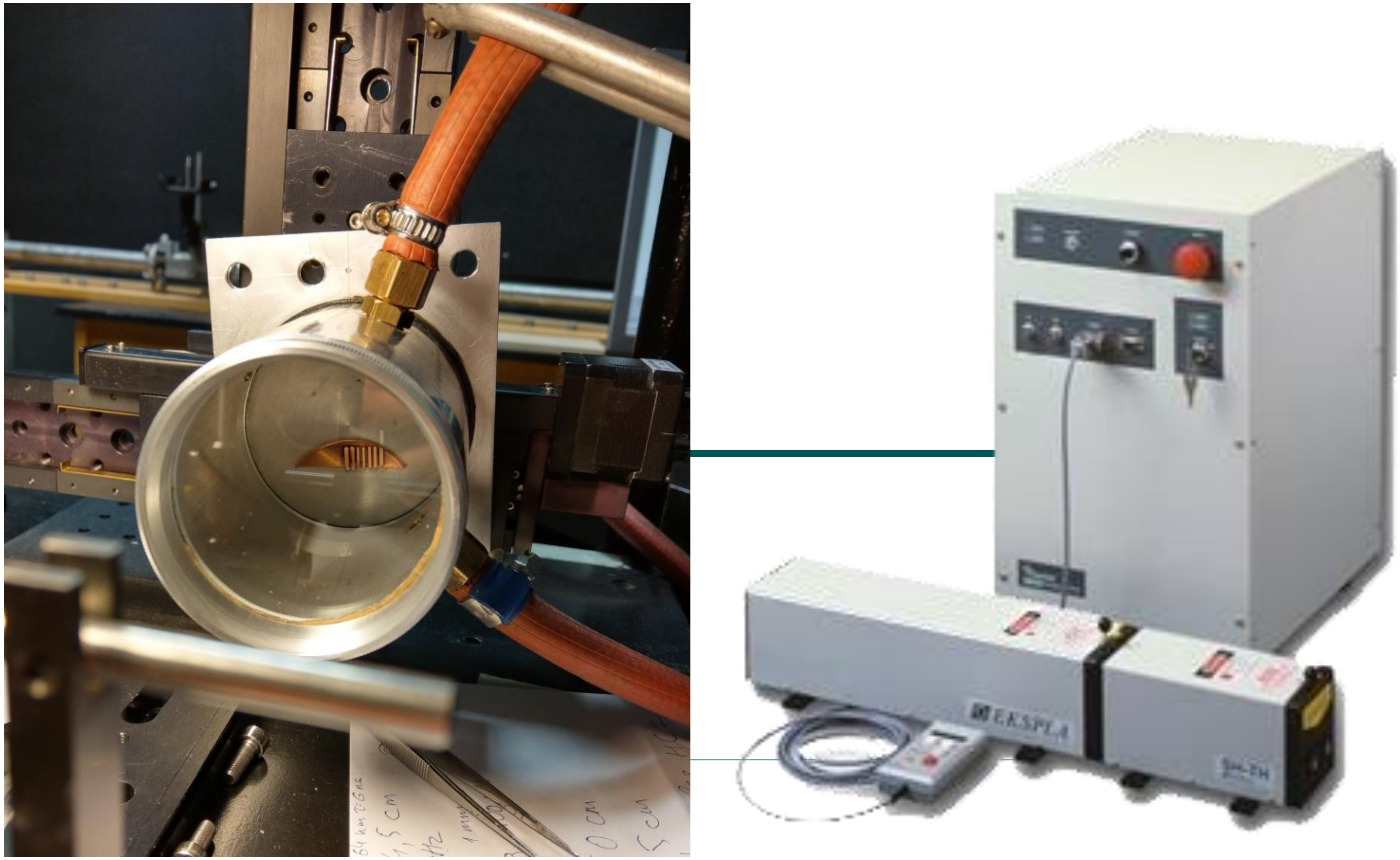
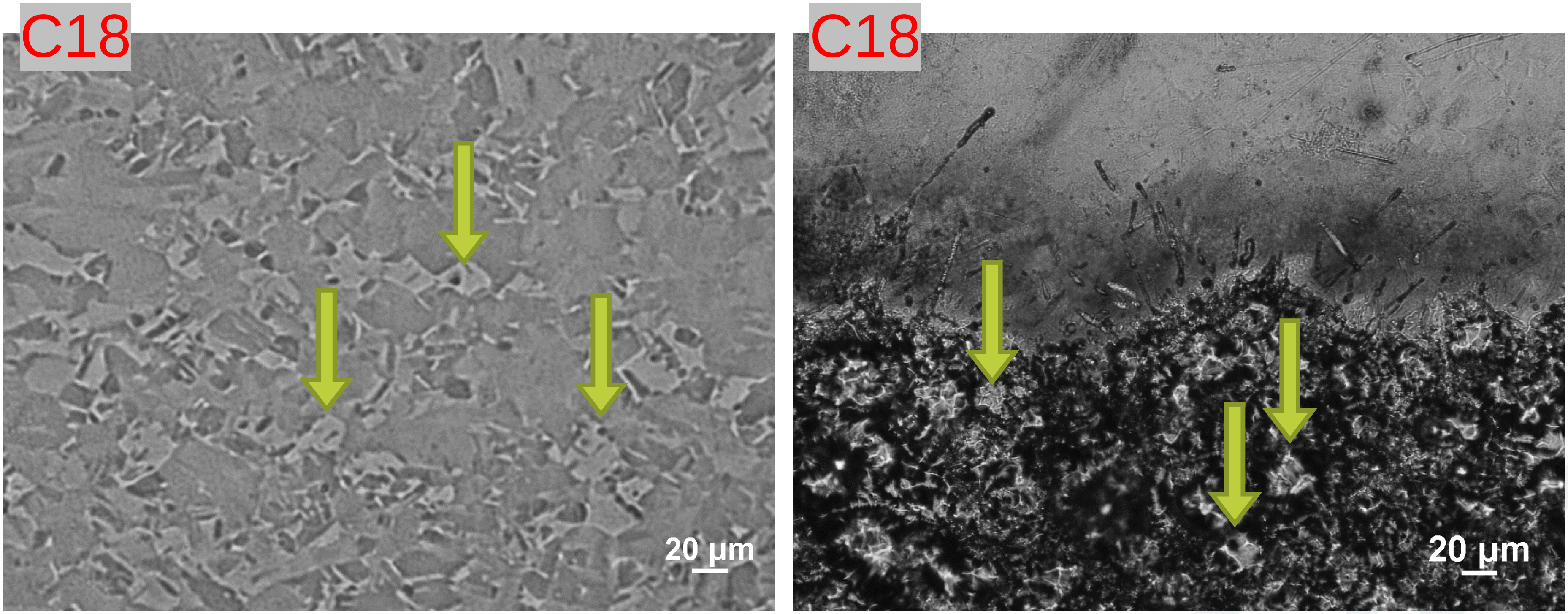


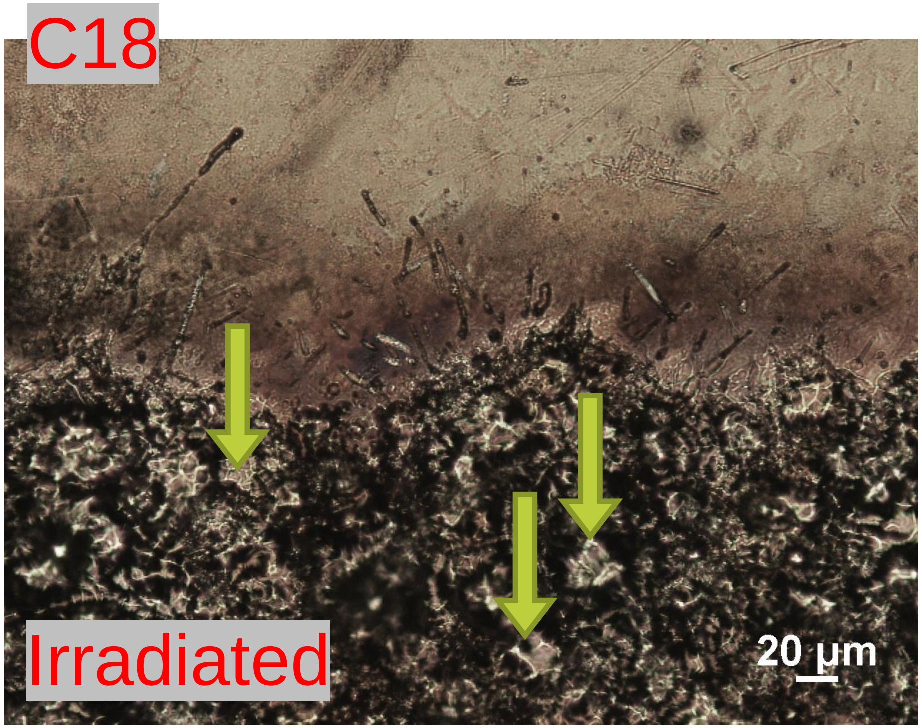
Fig.4.Chamber with inert gas Argon for laser cleaning and polishing of Cu samples. Nd:YAG laser “EKSPLA”.

The Cu samples C18 and Cu single crystal were irradiated by pulsed Nd:YAG laser (λ= 523 nm, τ =4 ns and intensity up to 1.6 GW/cm^2) in scanning mode with step 5µm and using point-to-point mode in Ar atmosphere.

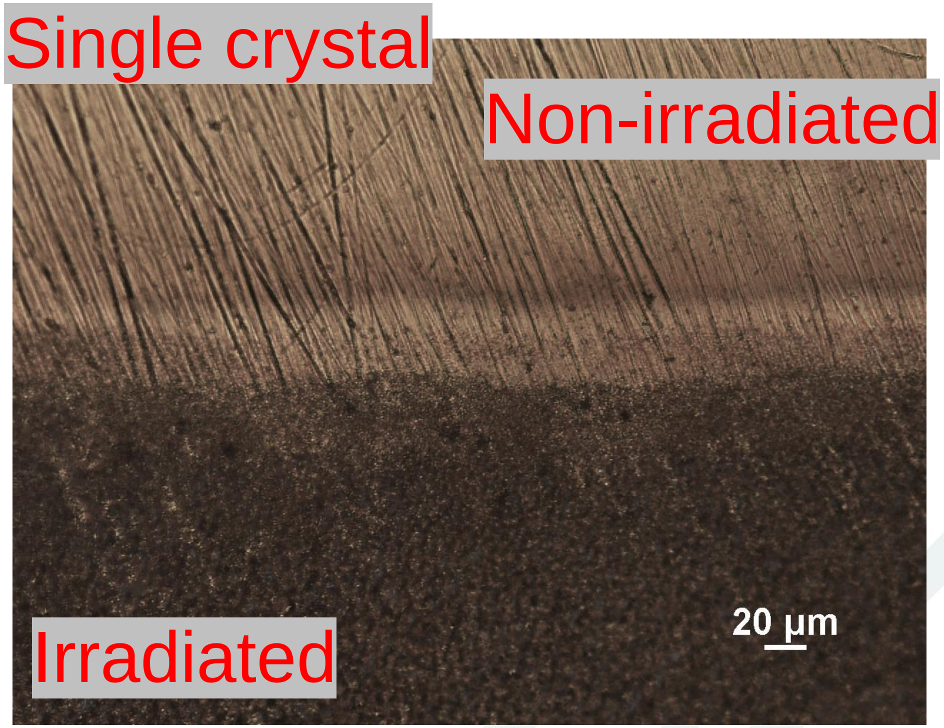


a b

Fig.5. Optical microscope images of C18 sample:
a) Non-irradiated
b) Irradiated by nanosecond Nd:YAG laser radiation



a



b

Fig.6. Optical microscope images of Cu samples:

a) The border of non-irradiated and irradiated sample C18 by Nd:YAG laser (λ=532 nm, τ=4ns)
b) The border of non-irradiated and irradiated single crystal sample by Nd:YAG laser (λ= 532 nm, τ=4ns)

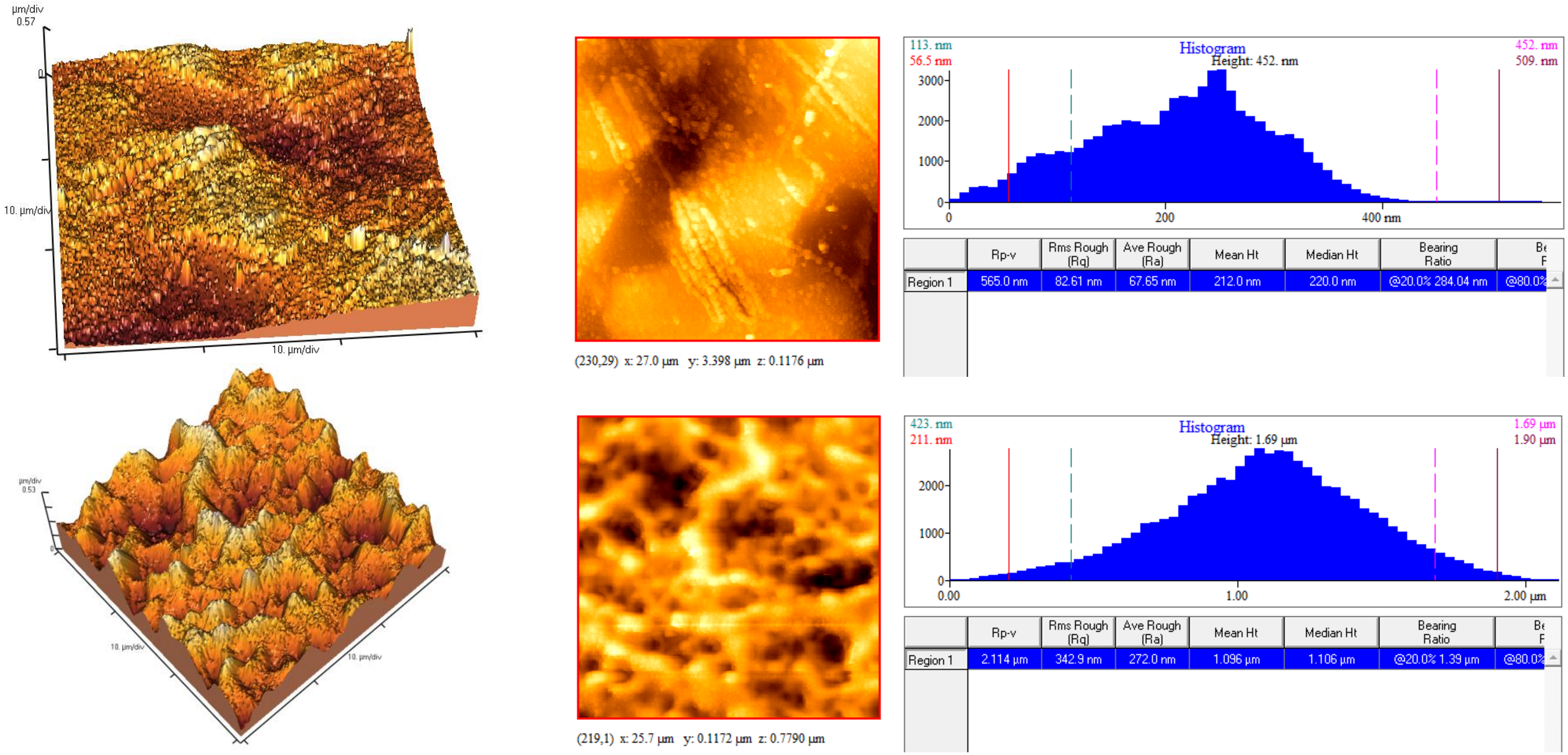
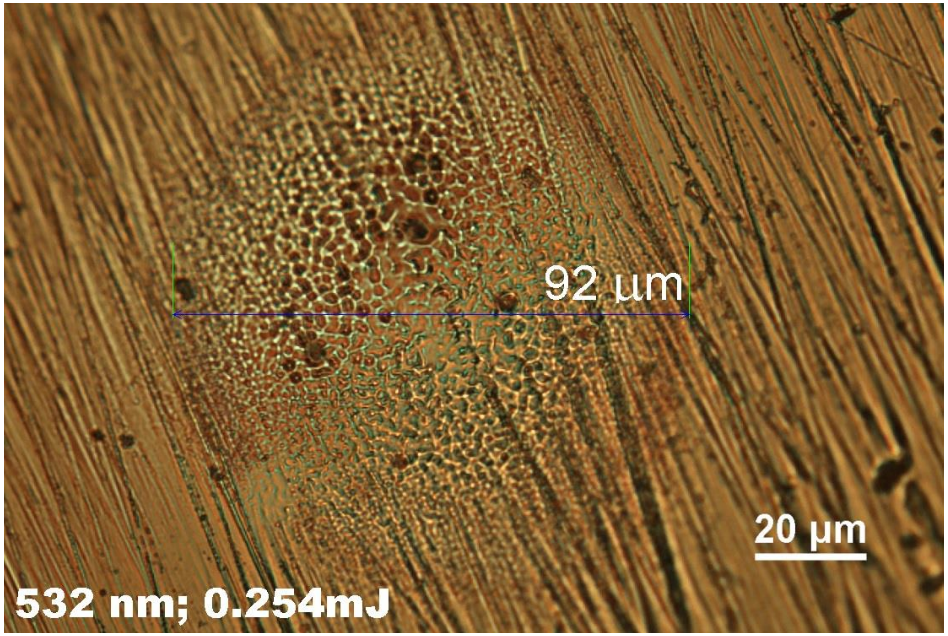
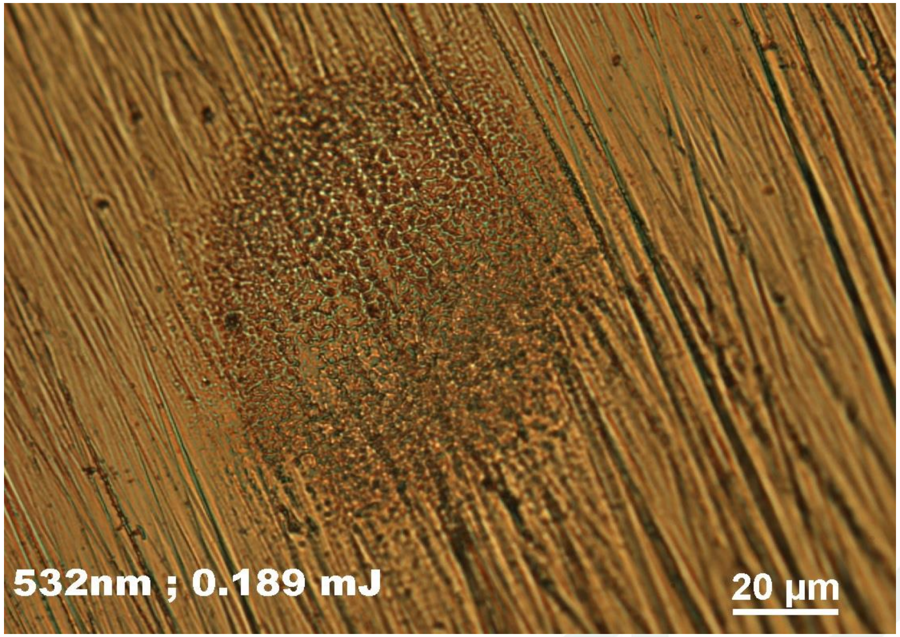


Fig.7. AFM images of C18 sample

a) Non-irradiated
b) Irradiated by nanosecond Nd:YAG laser radiation



a



b

Fig.8. Optical microscope images of single crystal Cu irradiated by Nd:YAG laser with different intensity(a- I_1=1.6 GW/cm^2, b – I_2=1.2 GW/cm^2) using “point-to-point” method.
Cu samples were polished by 1 micron diamond lapping paste.

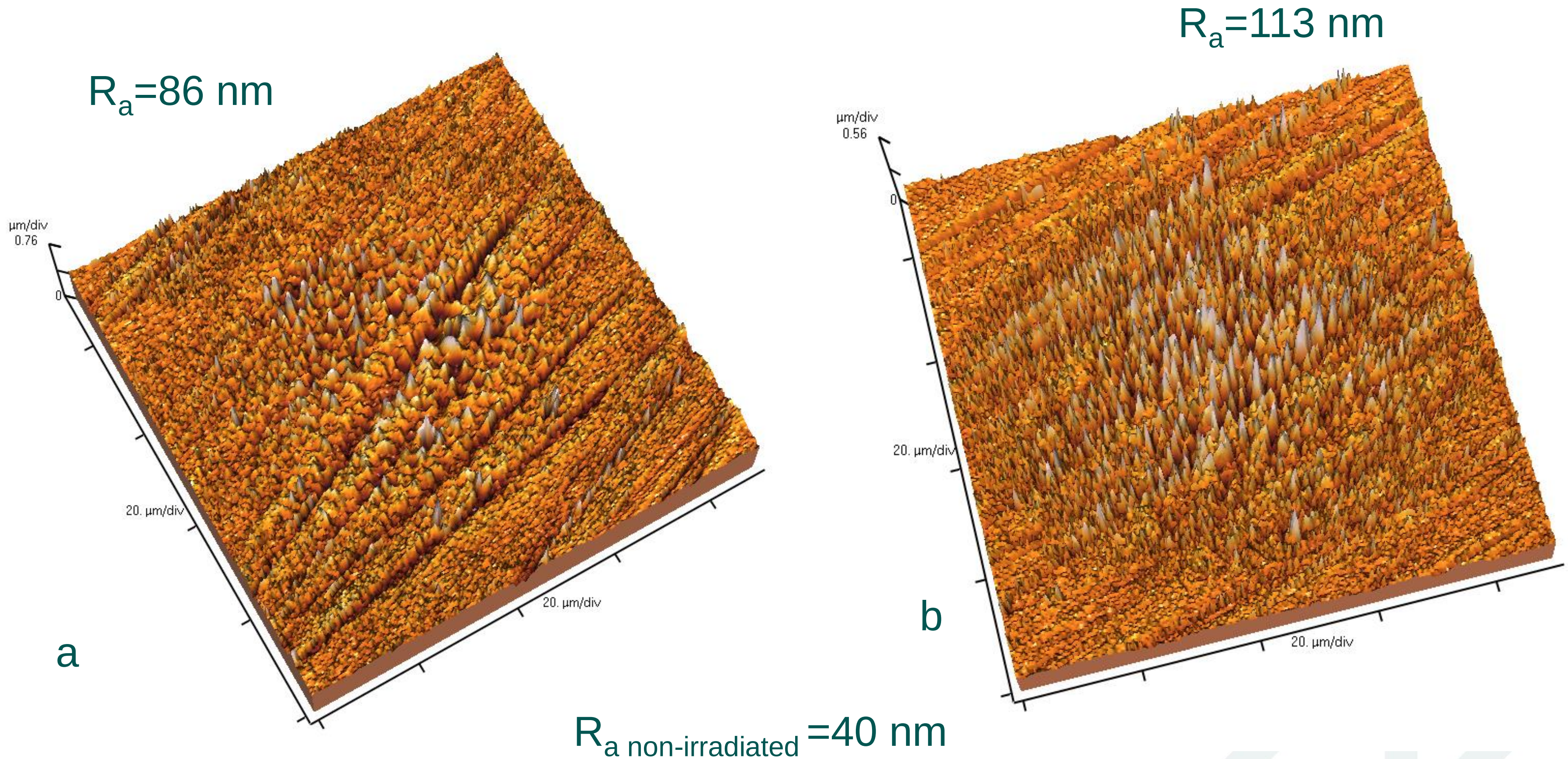


Fig.9. 3D AFM images of single crystal Cu irradiated by Nd:YAG laser with different intensity(a- I_1=1.6 GW/cm^2, b – I_2=1.2 GW/cm^2) using “point-to-point” method.
Cu samples were polished by 1 micron diamond lapping paste.

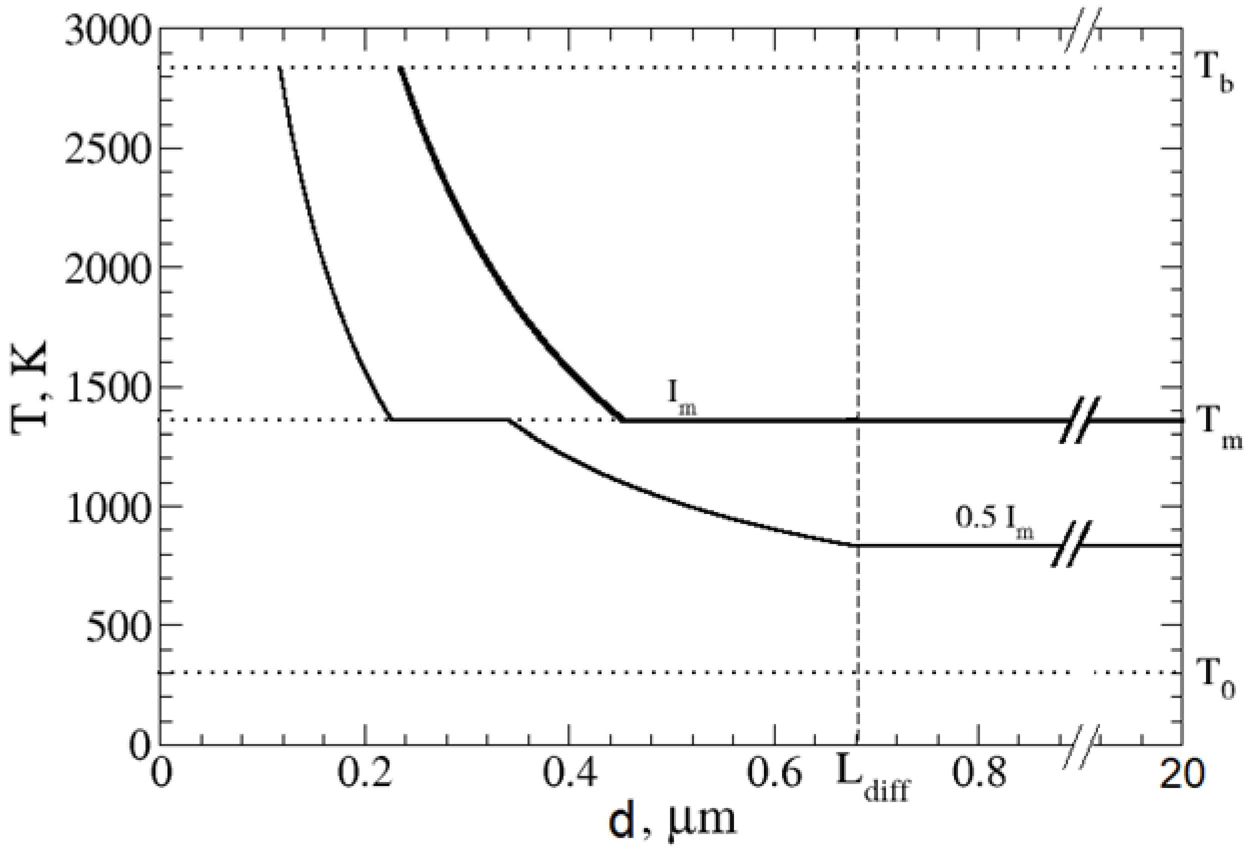


Fig. 9. Temperature at the surface of Cu crystallite depending on its size d and intensity of laser pulse. Here I_m is the laser intensity at which the melting of bulk monocrystal starts, and L_{diff} is the heat diffusion length. A model is used, where a crystallite of size $d<L_{diff}$ is heated uniformly, and only a layer of thickness L_{diff} is heated for larger crystallites.

The latent heat of fusion is taken into account in calculations.

Model

In the proposed model of laser radiation interaction with polycrystalline Cu, the light is absorbed within a surface skin layer. It is assumed that temperature is uniform in whole crystallite, if the size of crystallite d is smaller than the heat diffusion length $L_{diff}=\sqrt{D\tau}$, where D is the heat diffusivity and τ is the laser pulse duration. Only a layer of thickness L_{diff} is significantly heated for larger crystallites, therefore we assume that the temperature T at crystallite surface does not further change if d increases above L_{diff}. Melting of a crystallite requires certain energy, which is the same as required for its heating by $\Delta T^* = L_m/c$, where L_m is the latent heat of fusion and c is specific heat.

If the latent heat is neglected, then the surface of a crystallite with $d<L_{diff}$ is heated to the temperature $\breve{T} = T_0 + (L_{diff}/d)\ (I/I_m)\ (T_m-T_0)$, where I is the laser intensity, I_m is the intensity at which bulk monocrystal starts to melt,

T_0 is the initial temperature and T_m is the melting temperature. Taking into account the latent heat of fusion, the final result is:

$$T(d) = \begin{cases} \breve{T}(d), & \breve{T}(d) \le T_m \\ T_m, & T_m \le \breve{T}(d) \le T_m + \Delta T^* \\ \breve{T}(d) - \Delta T^*, & \breve{T}(d) \ge T_m + \Delta T^* \end{cases} \qquad \text{for } d \le L_{diff}$$

$$T(d) = T\left(L_{diff}\right) \qquad \text{for } d \ge L_{diff}$$

Conclusions

1. Cu samples consists of microcrystals with maximal size 20 μm and smaller;
2. Irradiation of Cu samples C18 by nanosecond Nd:YAG laser leads to ablation the smallest crystals. As a result surface roughness R_a of the sample increase.
3. Irradiation of Cu single crystal by Nd:YAG laser (1.6 GW/cm^2) with roughness 40 nm leads to melting of the surface.