Laser pulsed heating – first experiments

Kovalenko's model *

Pulsed heating

- The surface layer is heated and as a consequence of the temperature rise it would expand in size
- However it is kept at fixed size by the rest of the metal which is cold, building up mechanical stress
- If the stress is less than the elastic limit then this temperature rise is safe and can be repeated indefinitely

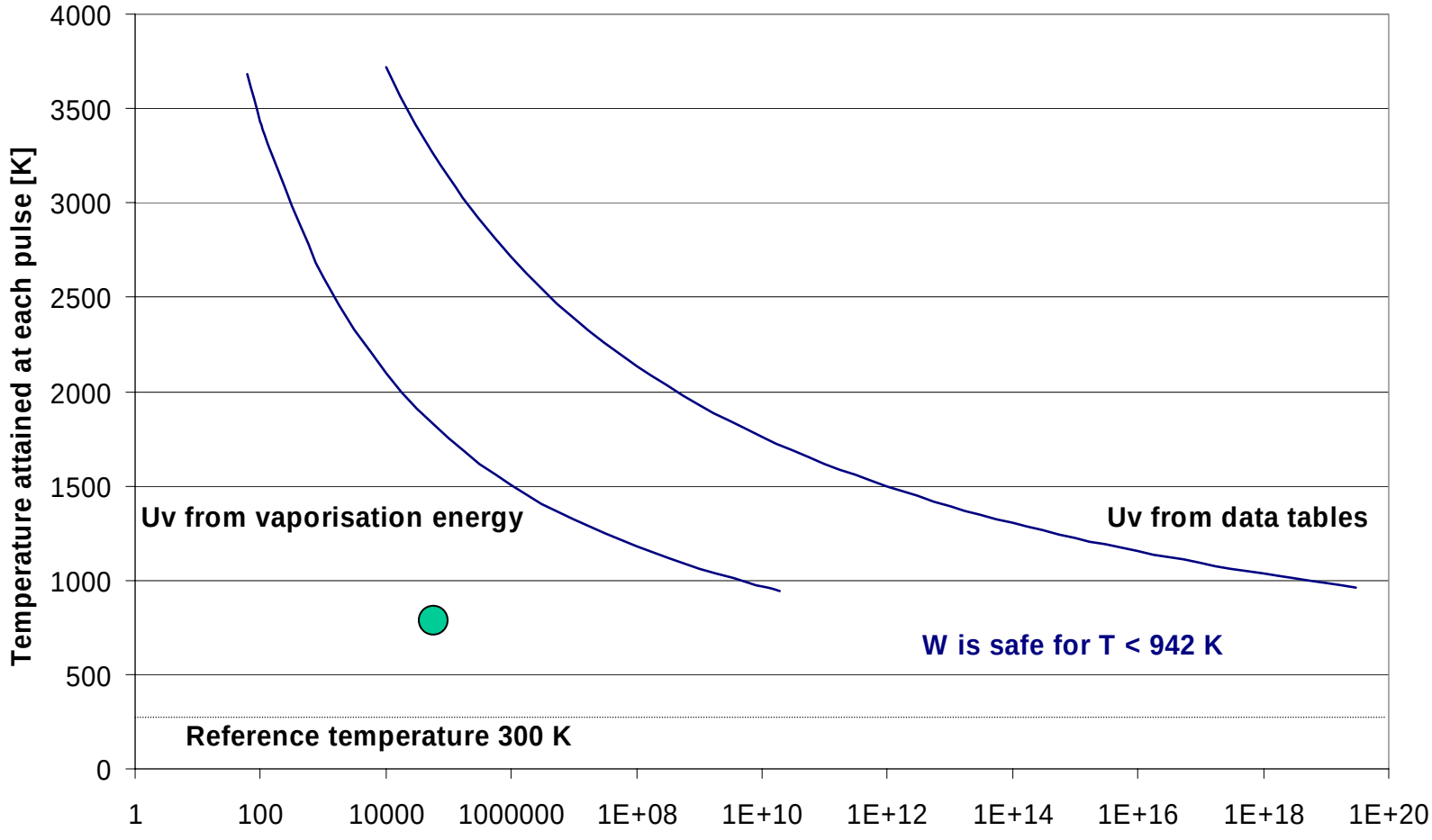
Surface breakup

- When the temperature increases above the "safe" limit, vacancies are created in the material and are "frozen in" when it cools down again
- More vacancies are created at each additional pulse
- When the total energy loss due to the number of vacancies accumulated is comparable to the vaporisation energy, the metal breaks apart

** Physics of Heat Transfer and Electro-Vacuum Devices, chapter 7 (Pulsed Heating), translated by B. Podobedov*

Laser pulsed heating – first experiments

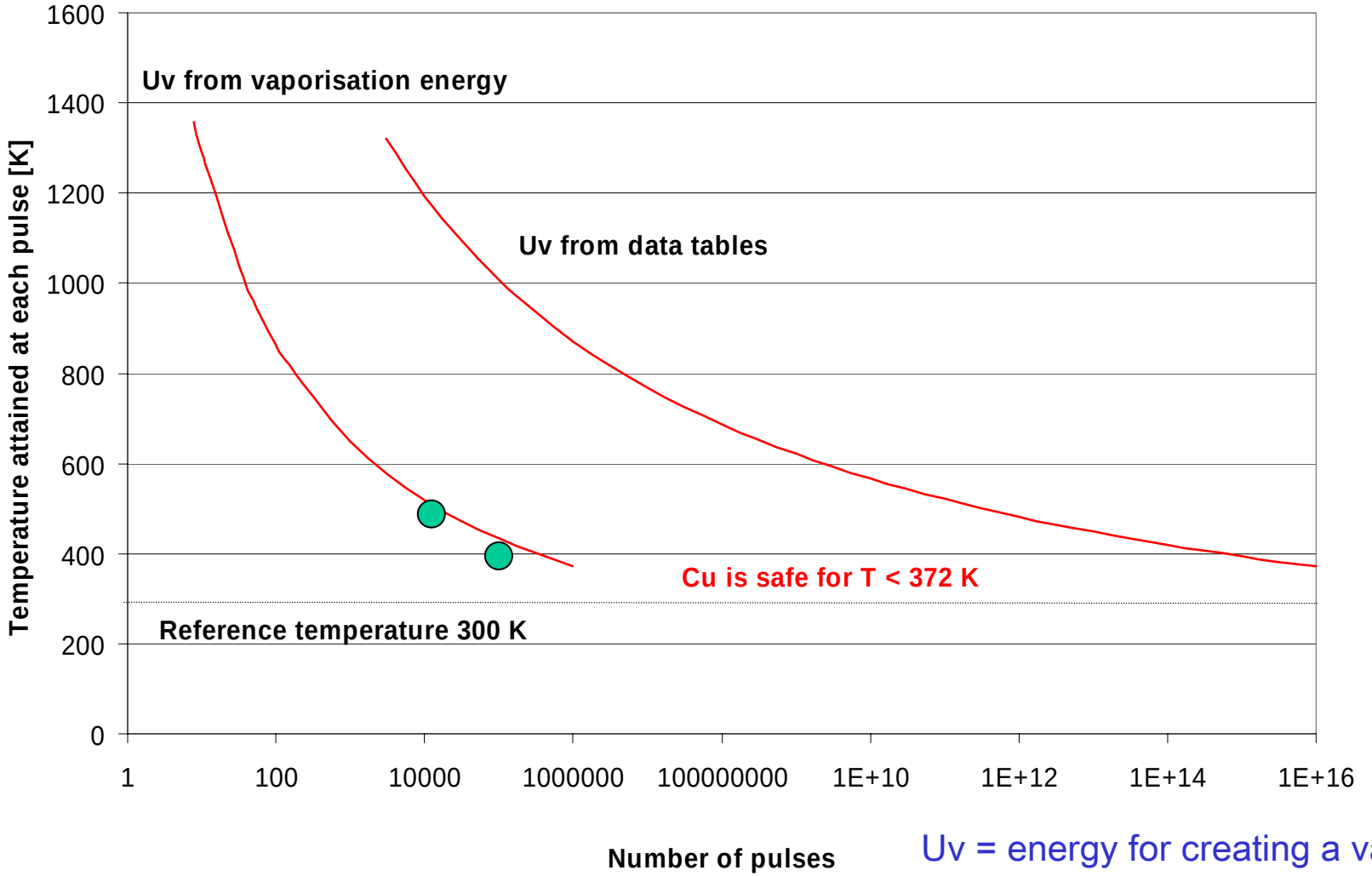
Calculations for tungsten



Uv = energy for creating a vacancy

Laser pulsed heating – first experiments

Calculations for copper



Uv = energy for creating a vacancy

Laser pulsed heating – first experiments

Using an excimer laser to study pulsed heating

Reduction of lifetime

- Kovalenko's model says that a larger temperature rise reduces the number of pulses required to destroy the material
- CLIC note 52 / 1987:

160 MV/m (0.69 MW/cm^2)	11.3 ns pulses	$\Delta T \approx 22K$
150 MV/m (0.61 MW/cm^2)	130 ns pulses	$\Delta T \approx 155K$

CLIC expected lifetime: ~ 3×10^{10} pulses

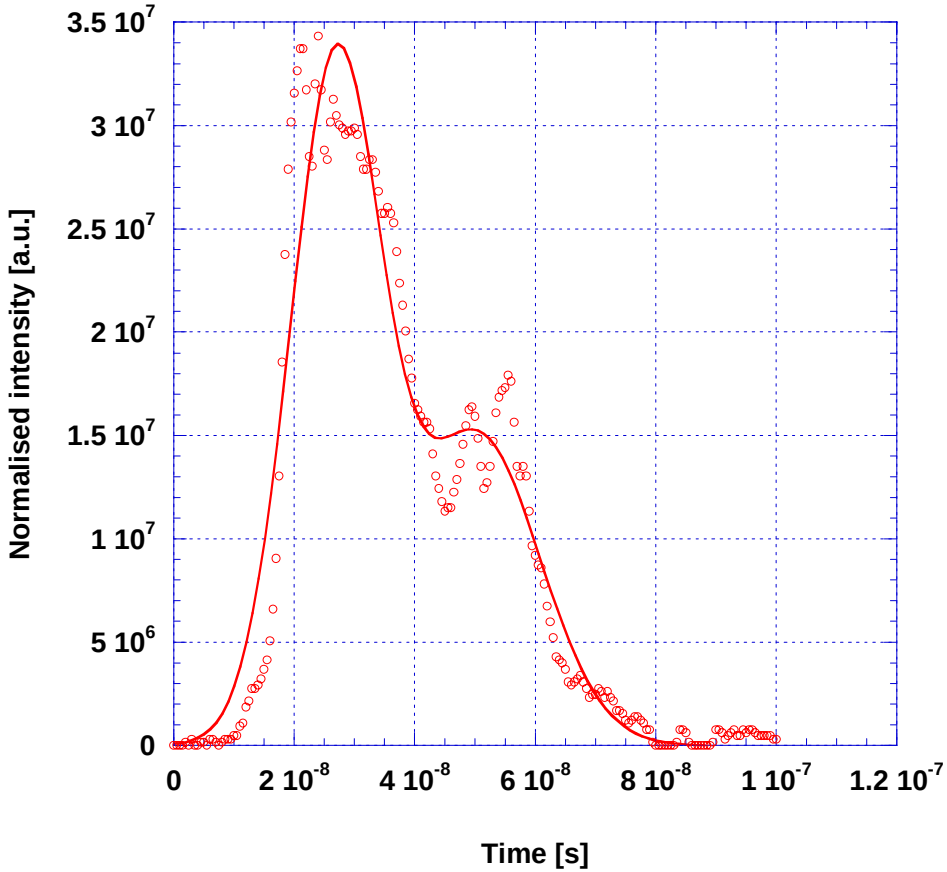
- SLAC: 8.5 MW, 120 µs pulses, $\Delta T = 120$ K damages after 5.5×10^7 pulses
- An UV pulsed laser of high power can deposit a much larger energy per pulse. UV light is absorbed at the very surface (penetration depth of a few nm)

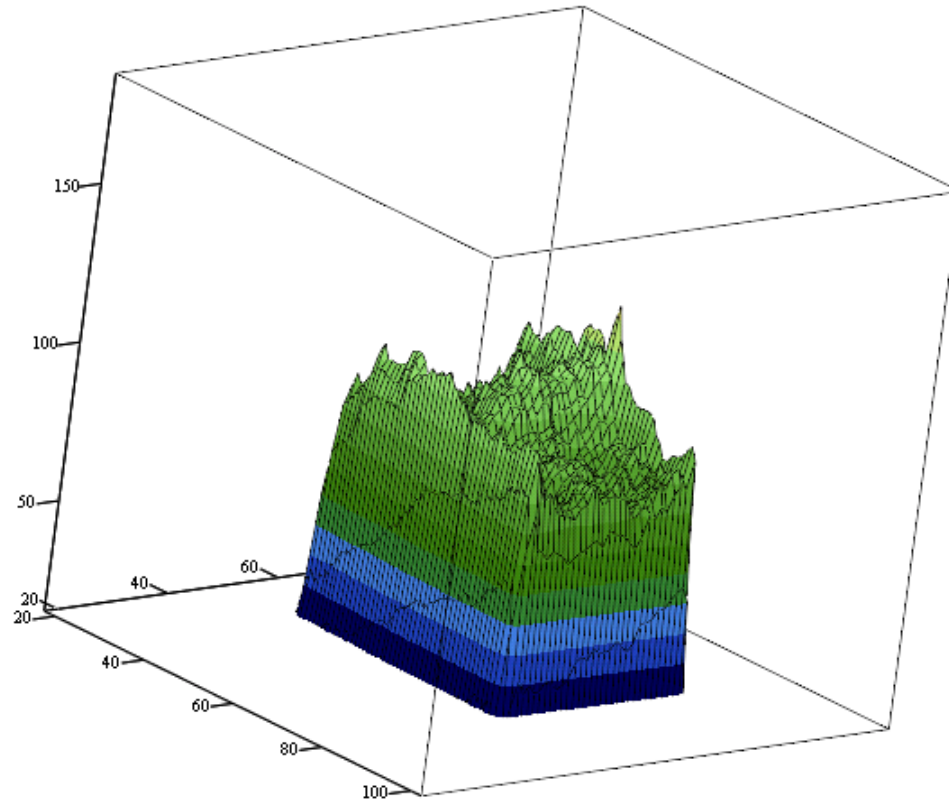
Our excimer laser

- 308 nm UV laser, pulses of ~30 ns, 25 mJ per pulse (after beam shaping)
- Energy densities up to 16 J/cm^2 are easily attained after focussing, resulting in more than 500 MW/cm^2

Laser pulsed heating – first experiments

Excimer laser 308 nm





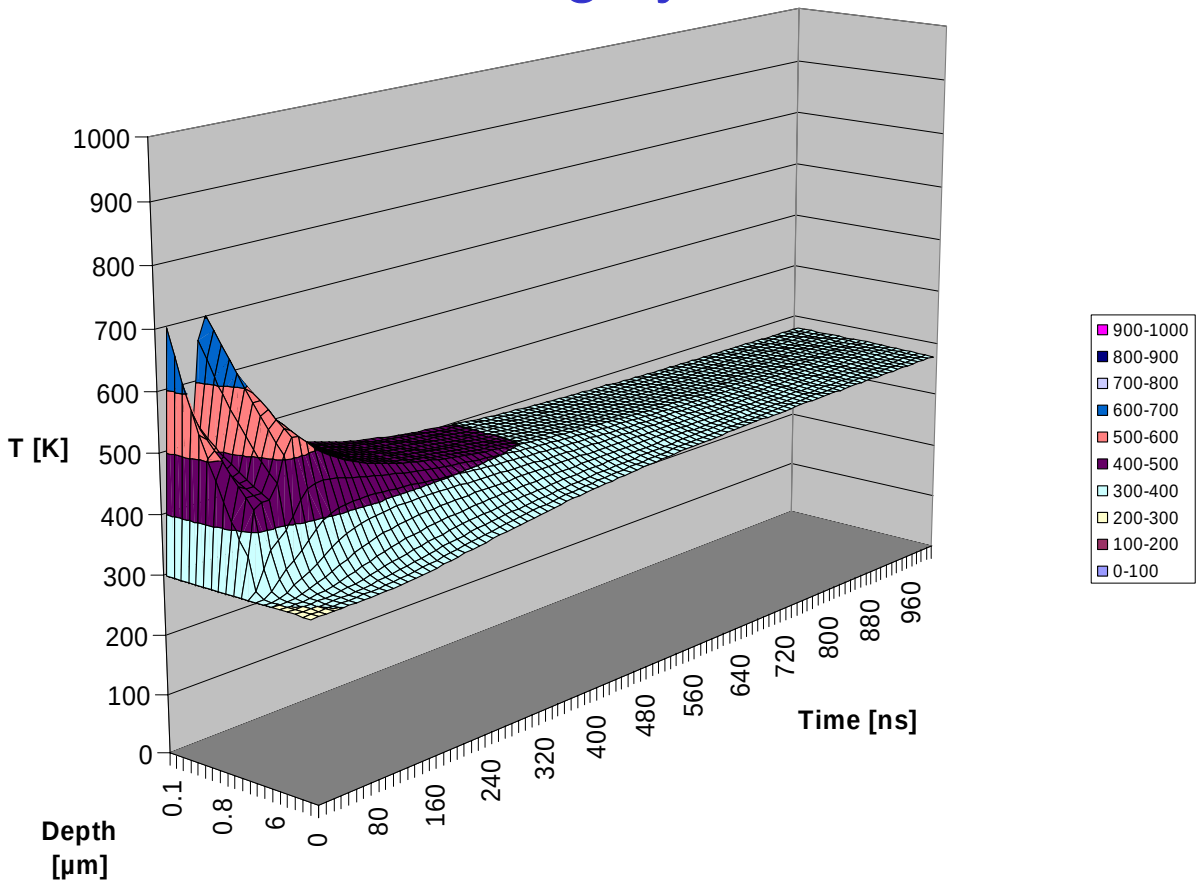
Time profile and spatial energy distribution of the laser beam

Laser pulsed heating – first experiments

Excimer laser 308 nm

Laser pulsed heating – first experiments

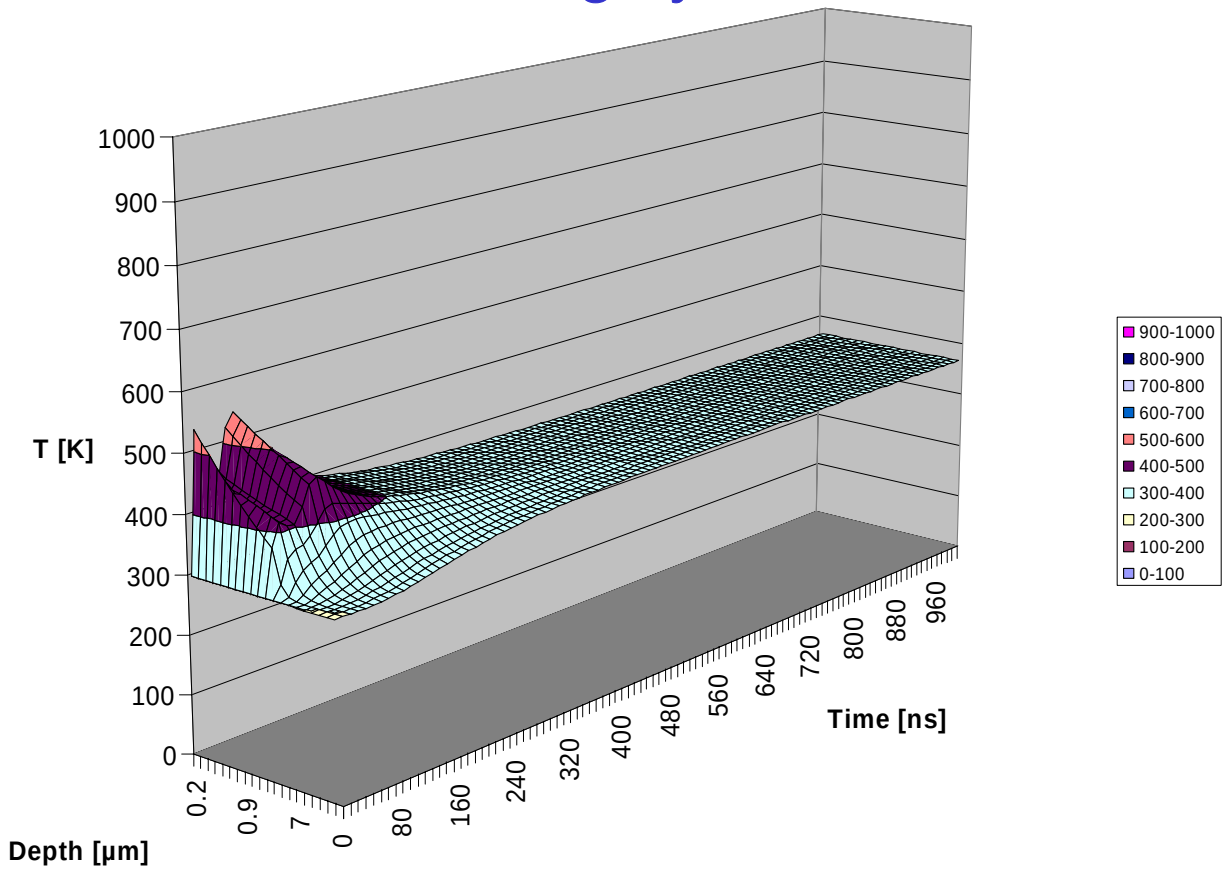
Simulation of surface heating by laser irradiation - W



Calculated temperature profile of tungsten (1 µm + 10 µm) at 0.5 J/cm^2

Laser pulsed heating – first experiments

Simulation of surface heating by laser irradiation - Cu



Calculated temperature profile of copper (1 µm + 10 µm) at 0.5 J/cm^2

Laser pulsed heating – first experiments

Experiments on W and Cu

Tungsten

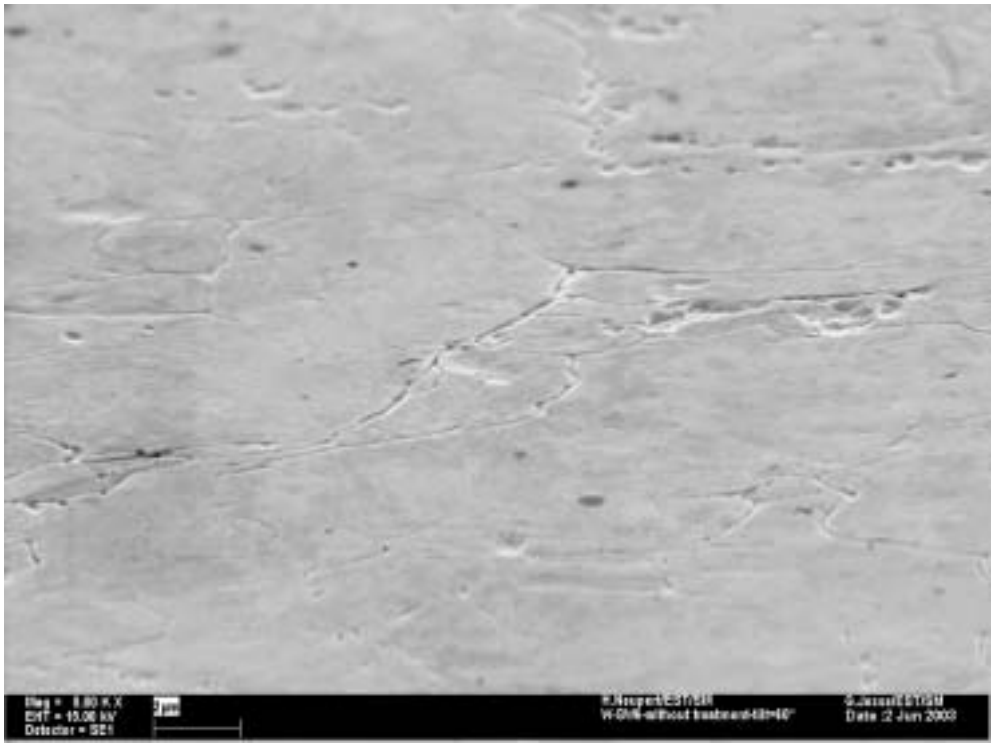
- Goodfellow 0.5 mm sheet treated at 0.5 J/cm^2 for 1200, 12000, 36000 and 120000 shots in air
- Plansee ground iris treated at 0.5 J/cm^2 for 120, 1200, 12000, 120000 shots in argon

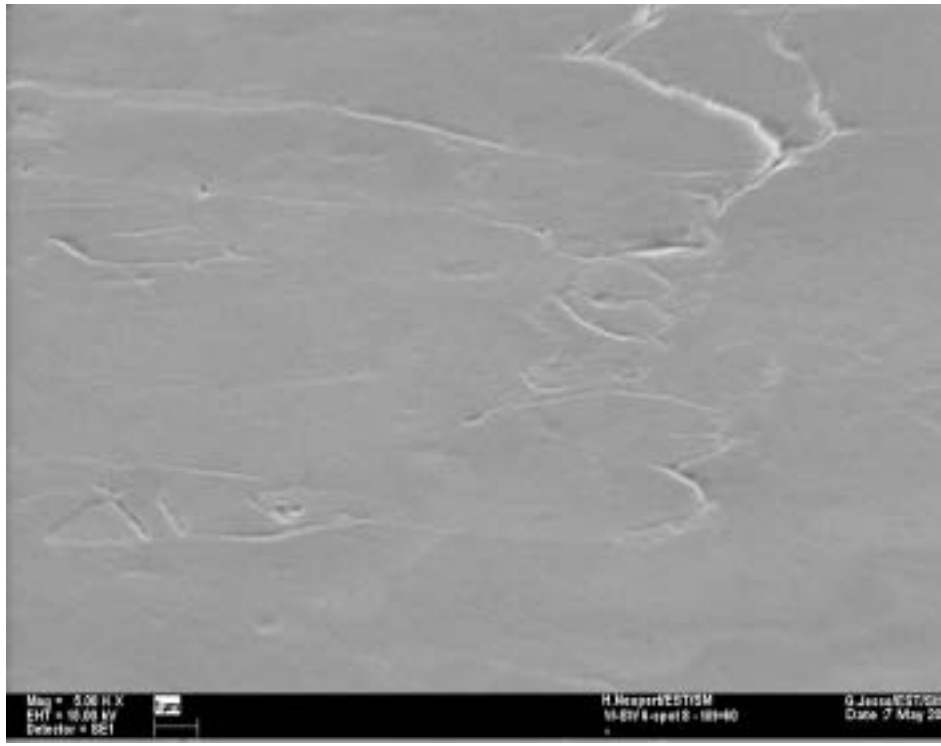
Copper

- Diamond turned iris treated at 0.5, 0.2, 0.1 J/cm^2 for 120, 1200, 12000, 120000 shots in argon

Laser pulsed heating – first experiments

W sheet at 0.5 J/cm^2 ≈ 700 K



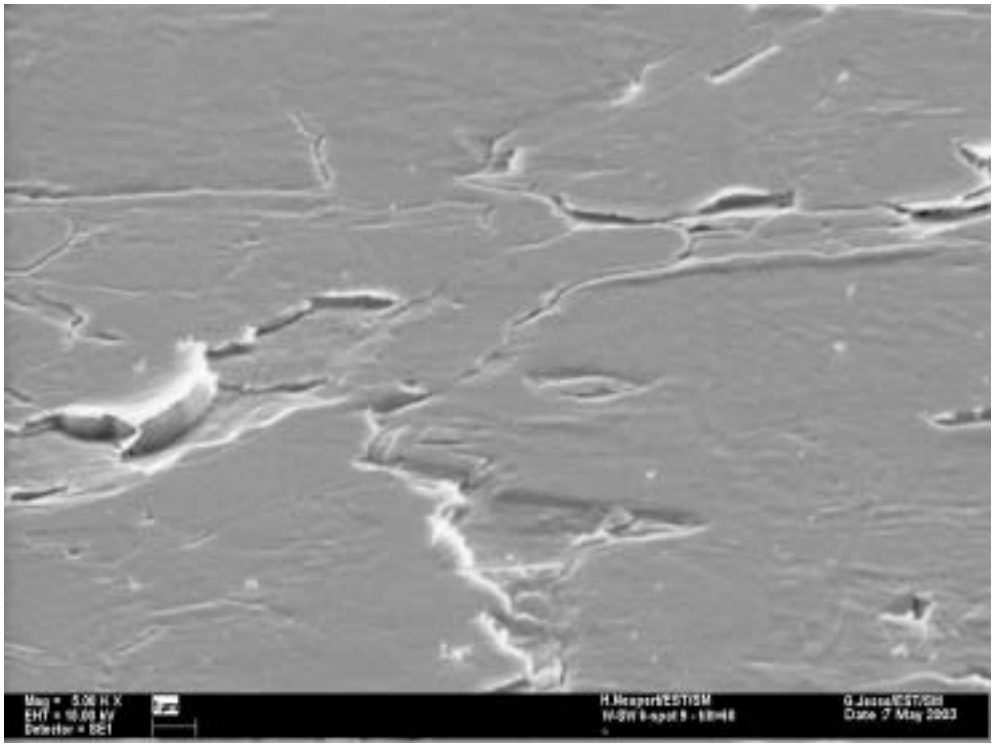


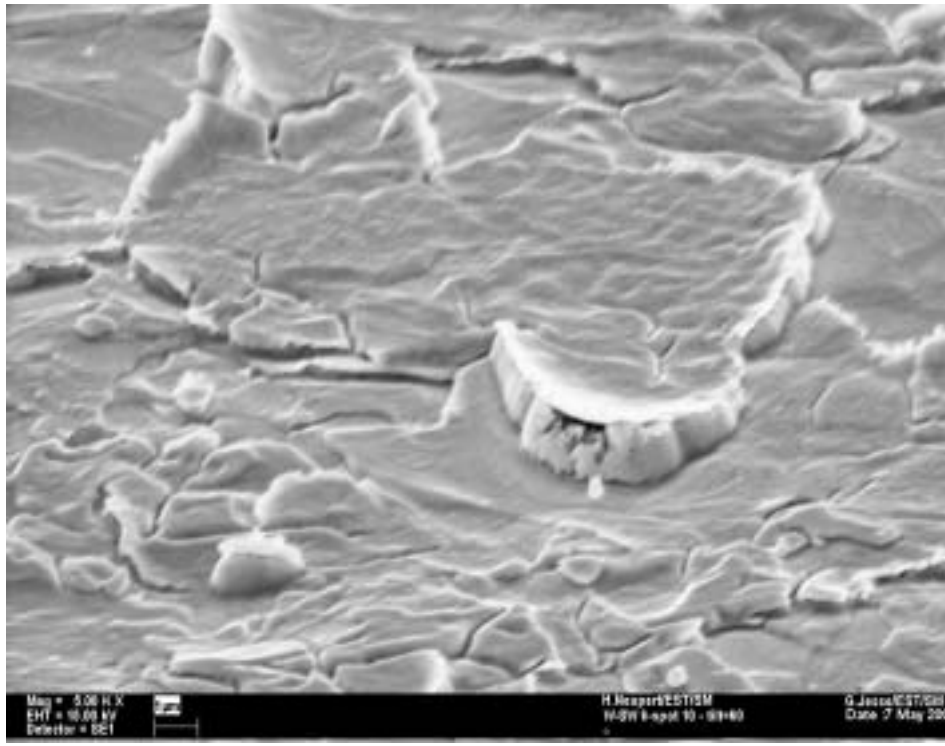
As received

After 12000 shots

Laser pulsed heating – first experiments

W sheet at 0.5 J/cm^2 ≈ 700 K



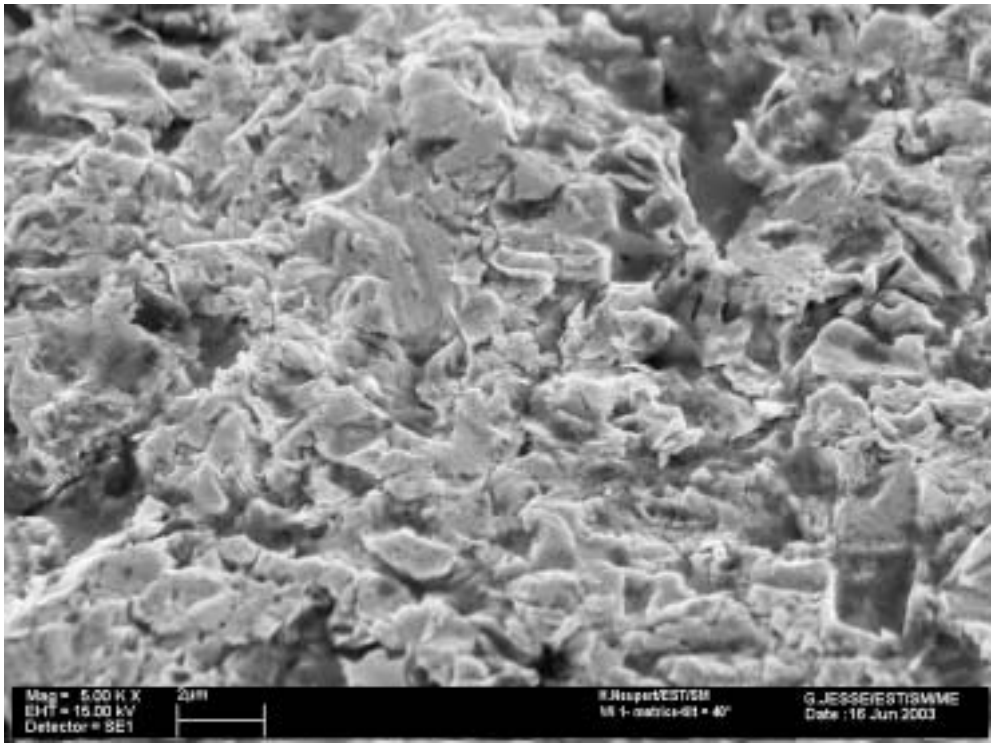


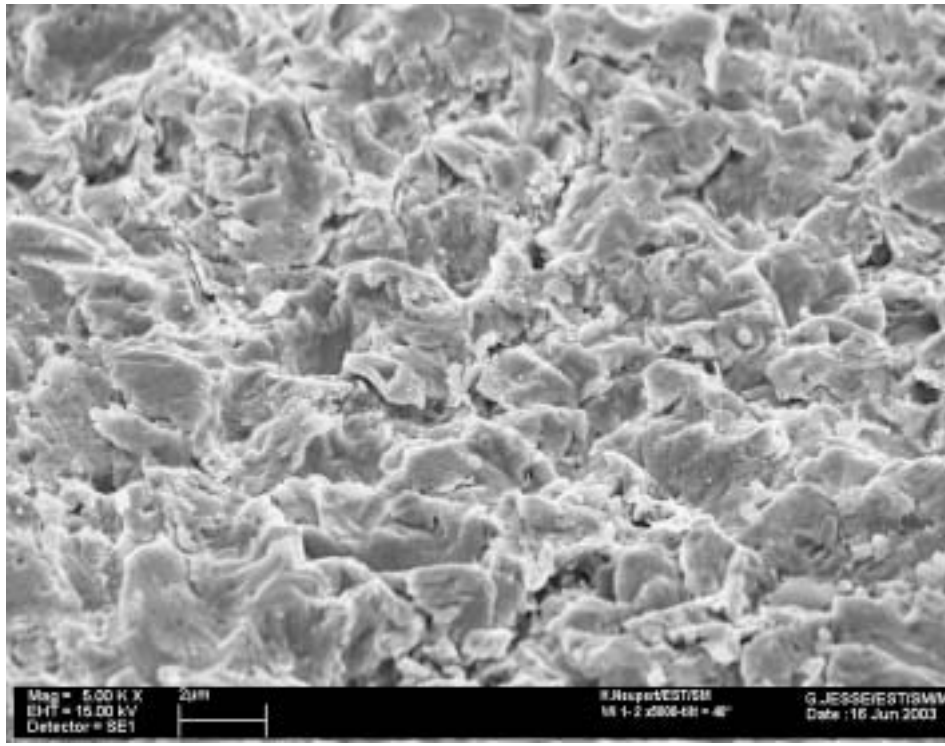
After 36000 shots

After 120000 shots

Laser pulsed heating – first experiments

W iris at 0.5 J/cm^2 ≈ 700 K



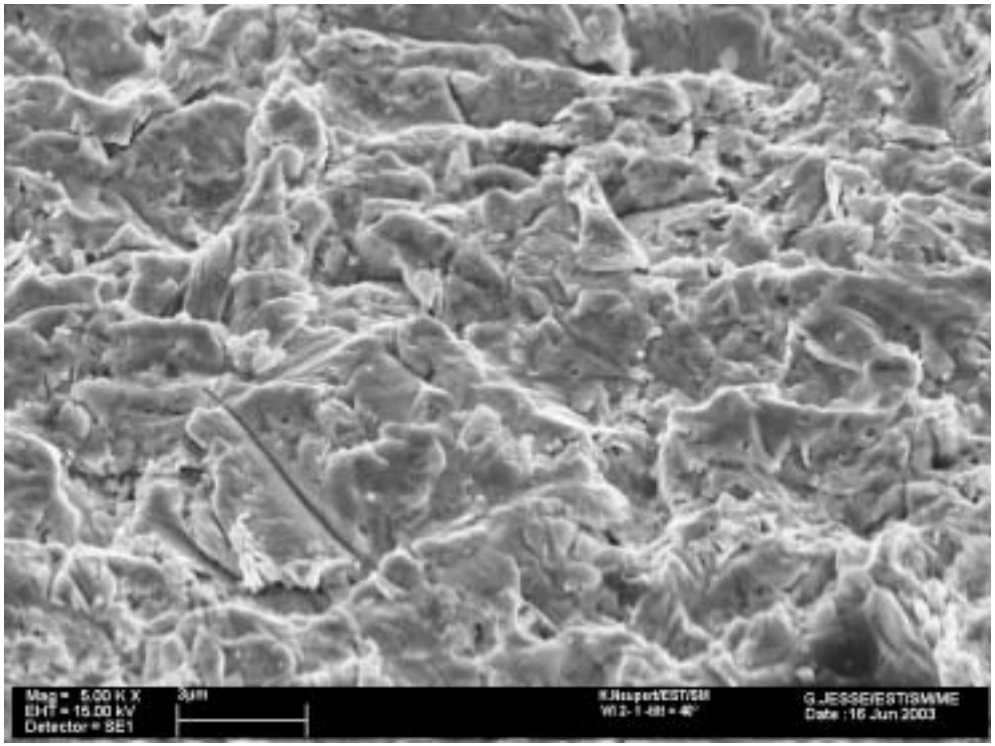


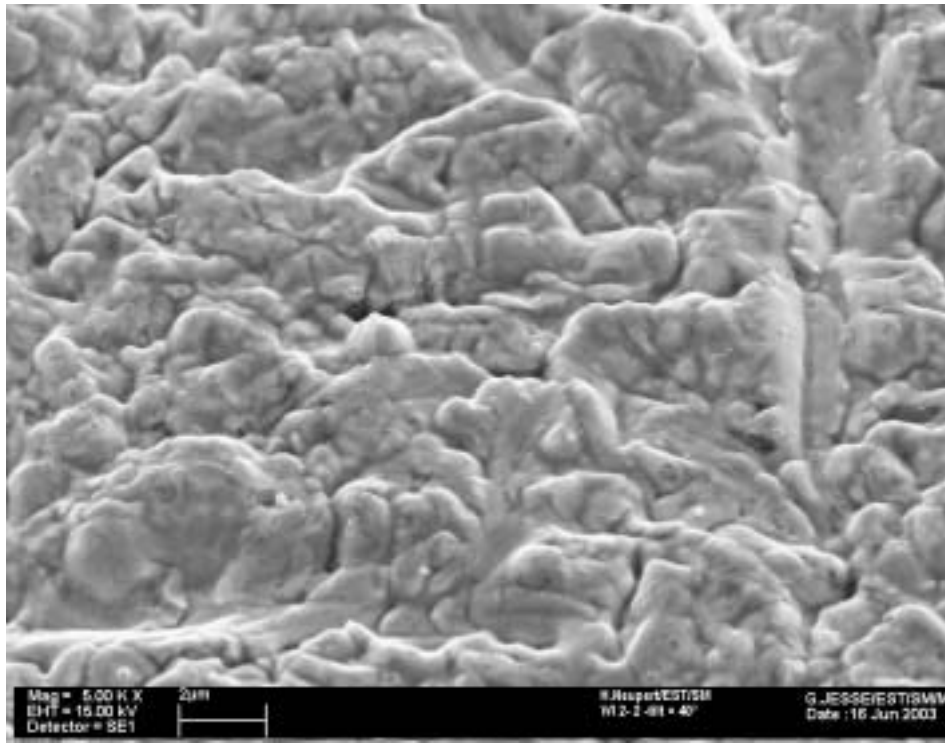
As received

After 1200 shots

Laser pulsed heating – first experiments

W iris at 0.5 J/cm^2 ≈ 700 K



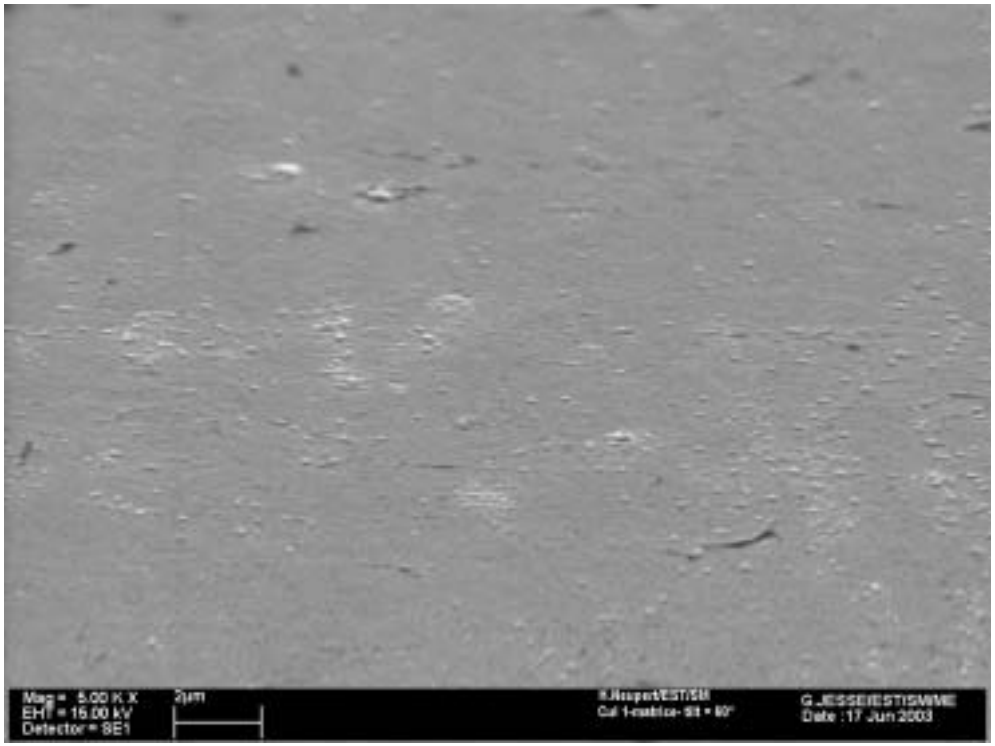


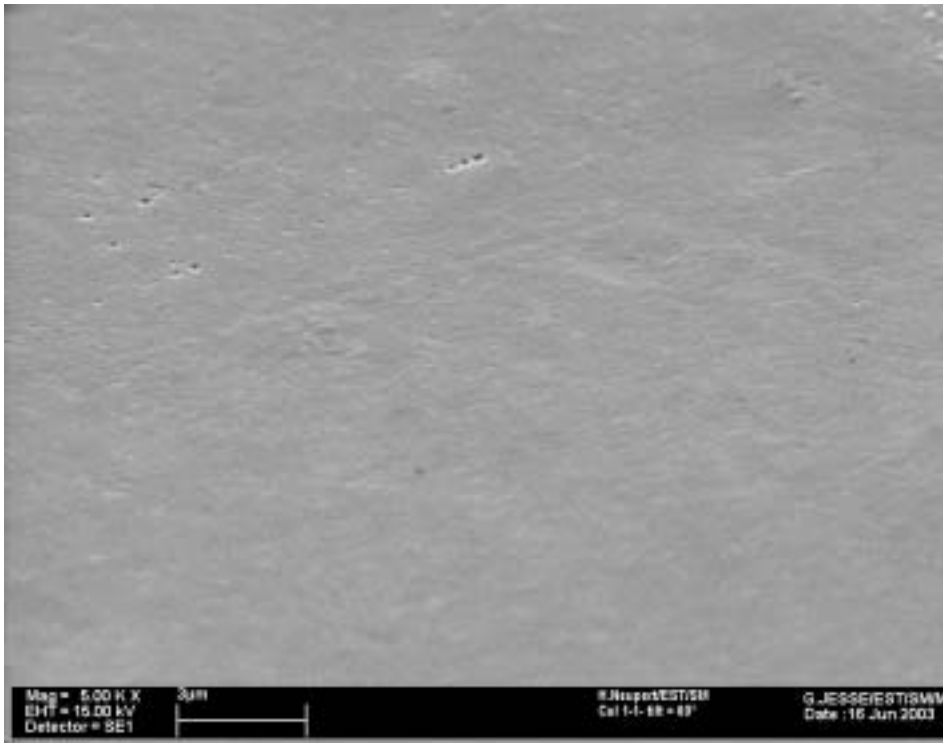
After 12000 shots

After 120000 shots

Laser pulsed heating – first experiments

Cu iris at 0.5 J/cm^2 ≈ 500 K



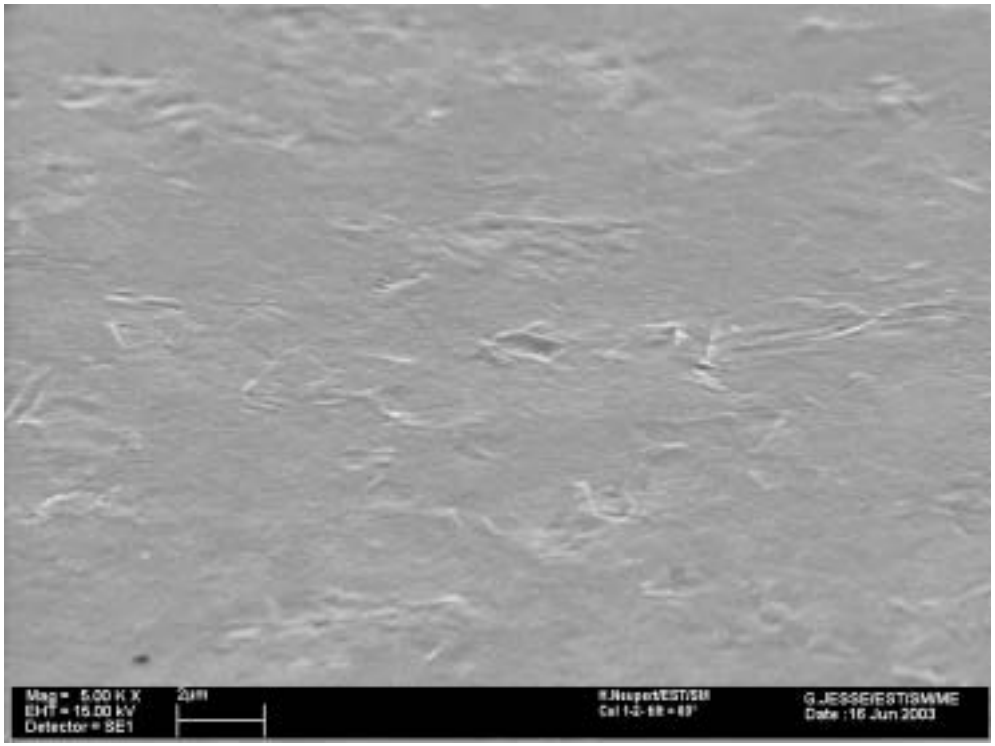


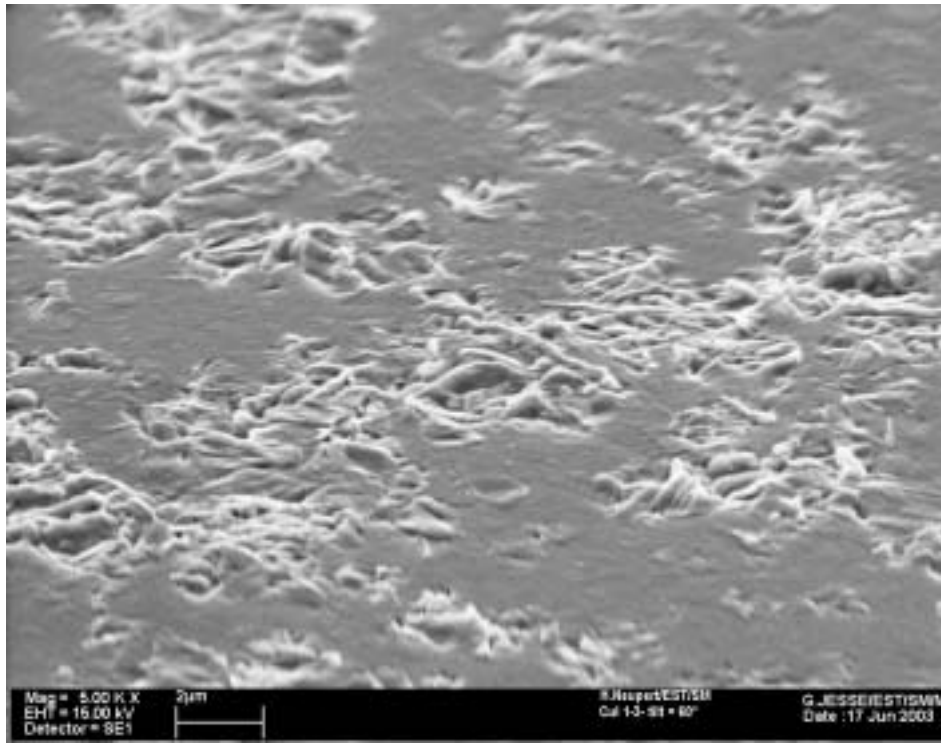
As received

After 120 shots

Laser pulsed heating – first experiments

Cu iris at 0.5 J/cm^2 ≈ 500 K



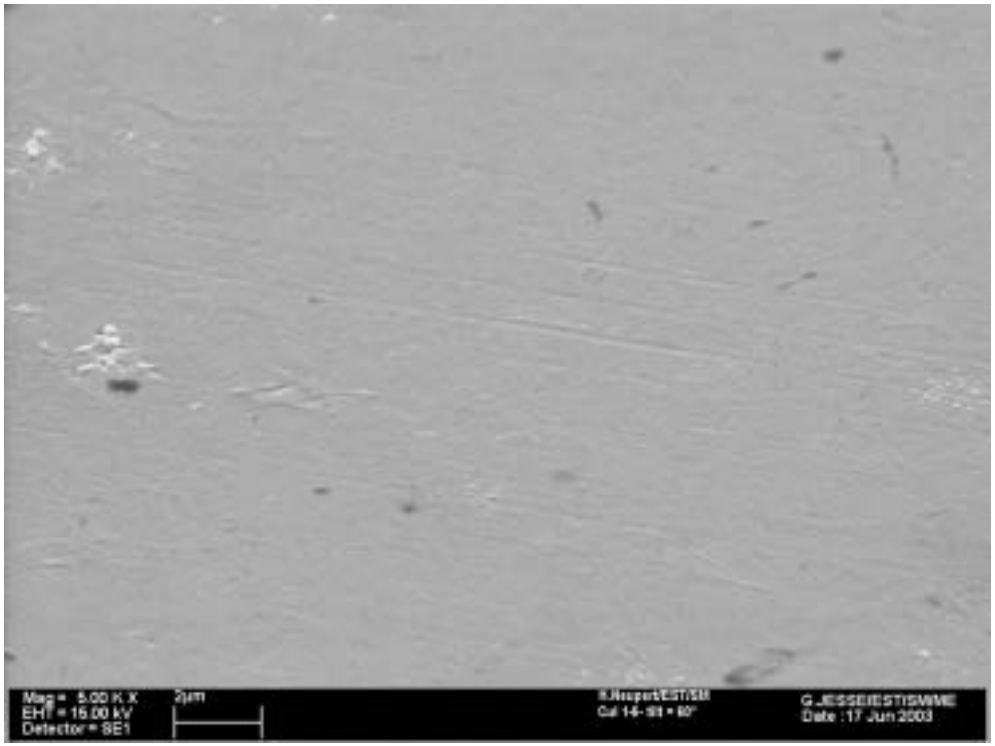


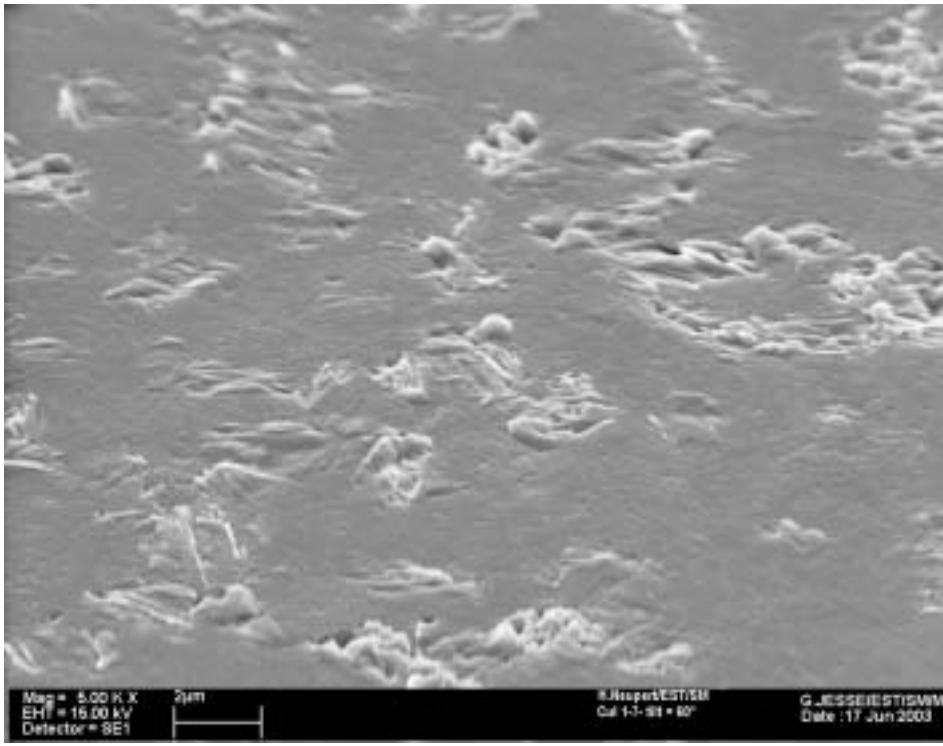
After 1200 shots

After 12000 shots

Laser pulsed heating – first experiments

Cu iris at 0.2 J/cm^2 ≈ 400 K





After 12000 shots

After 120000 shots

Laser pulsed heating – first experiments

Conclusions

Tungsten

- Exfoliation of the sheet after 36000 shots at 0.5 J/cm^2
- Ground iris too rough to draw any conclusion

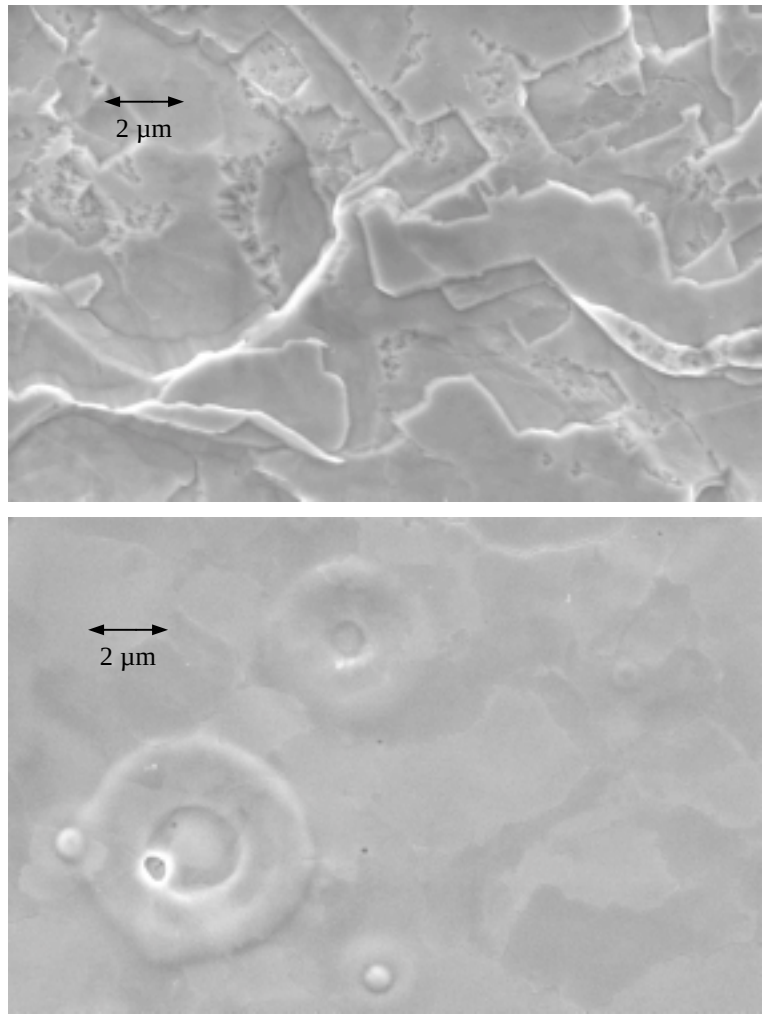
Copper

- Surface break-up “in agreement” with Kovalenko’s model
- Further experiments are needed, in order to make a prediction for the 3x10^{10} pluses foreseen for the CLIC lifetime
- Is it possible to “cure” the vacancies created?

Laser pulsed heating – first experiments

Projet CLIC: traitements laser

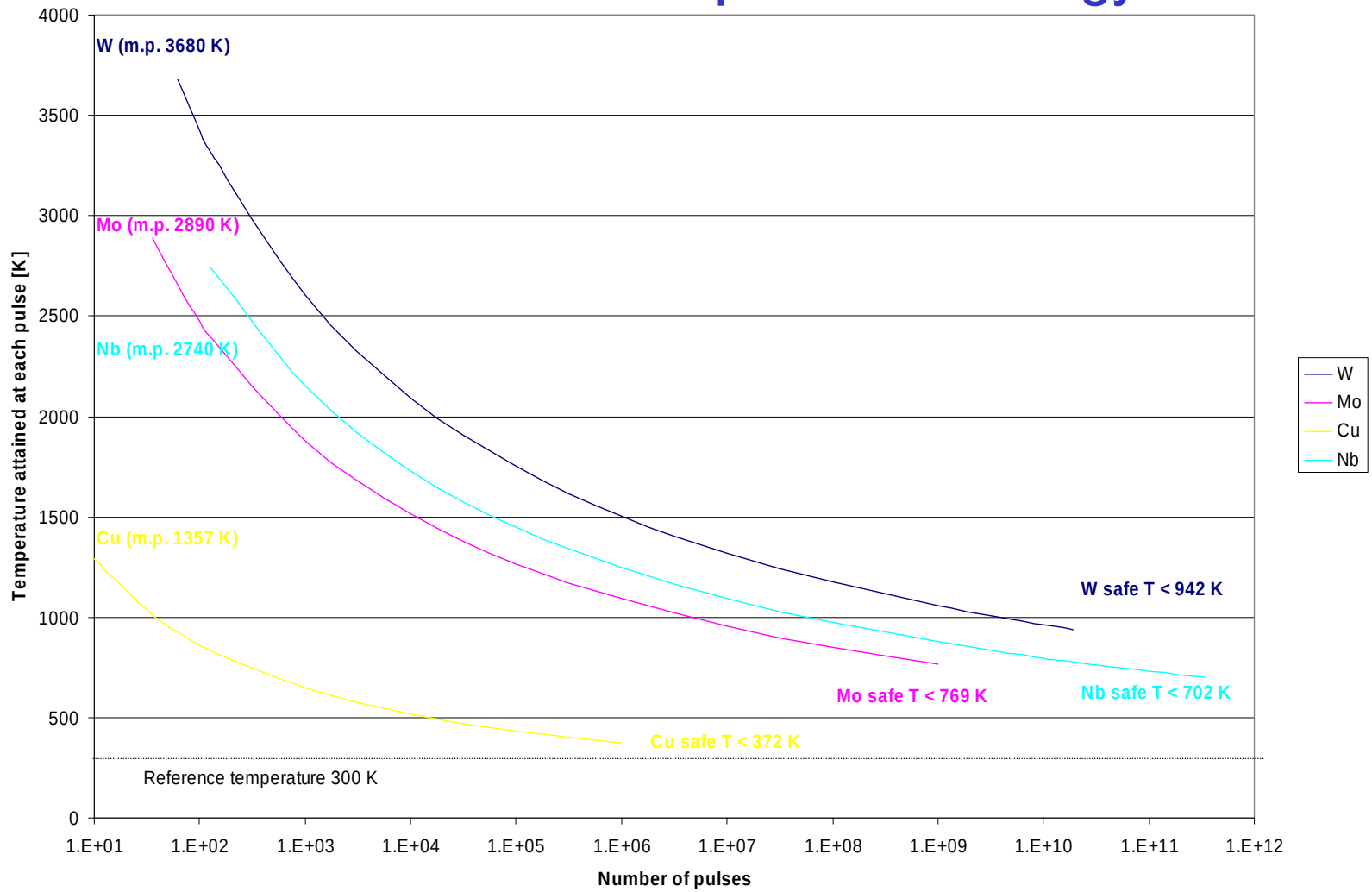
- La surface peut être amenée bien au delà du point de fusion par l'énergie de la lumière UV (308 nm) d'un laser excimère
- Lissage testé
- Résistance aux chocs thermo-mécaniques répétés testée courant 2003



Lissage par laser (2 J/cm^2) du tungstène (faisceau non uniforme)

Laser pulsed heating – first experiments

Calculations with vaporisation energy



Laser pulsed heating – first experiments

Calculations from data tables