Interaction of TTF FEL Radiation with Solids

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Outline:

- Motivation
- Experimental
- Damage threshold and surface modification
- Plasma results
- Conlusions

FELIS

Free Electron Laser - Interaction with Solids

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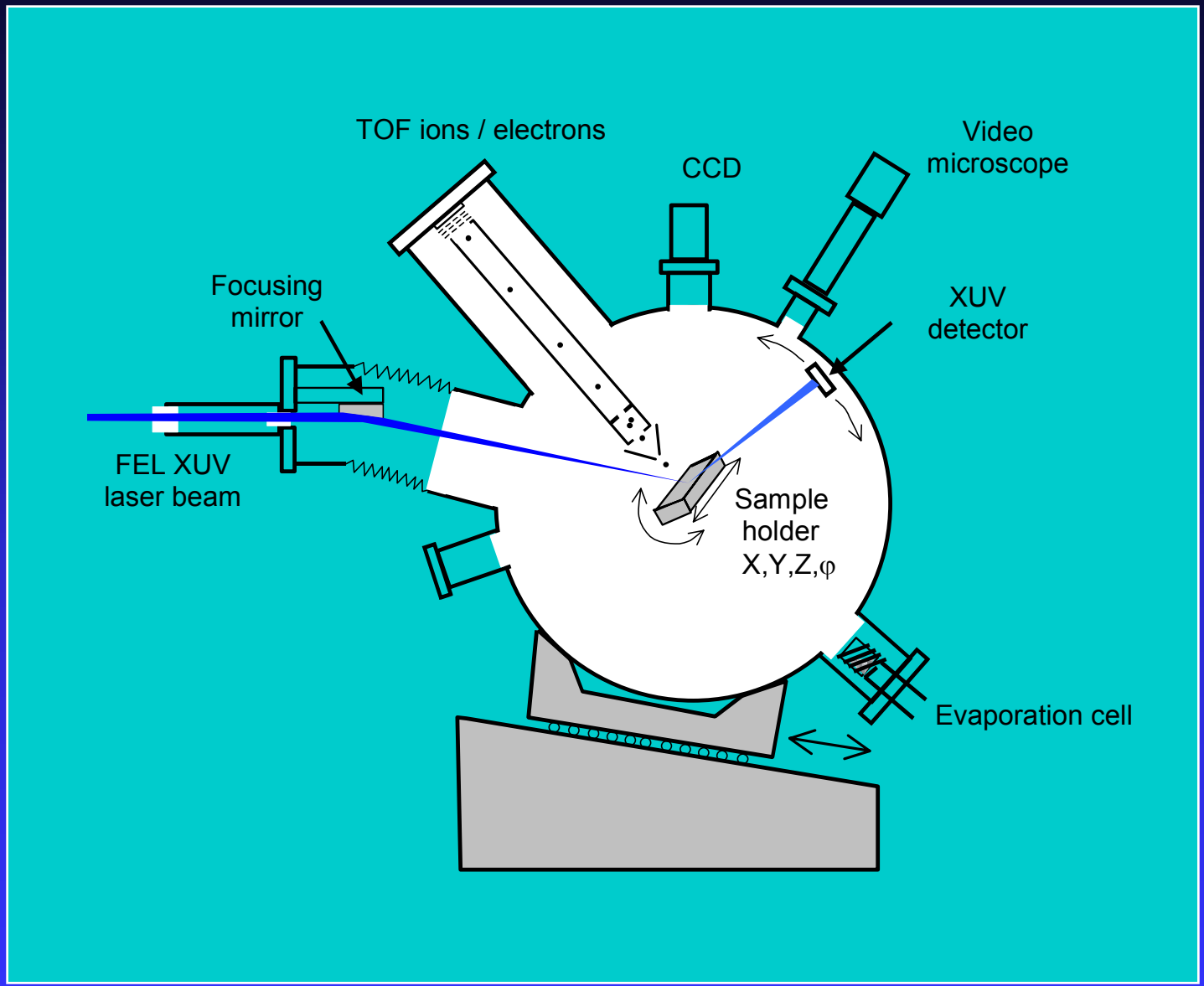
Motivation

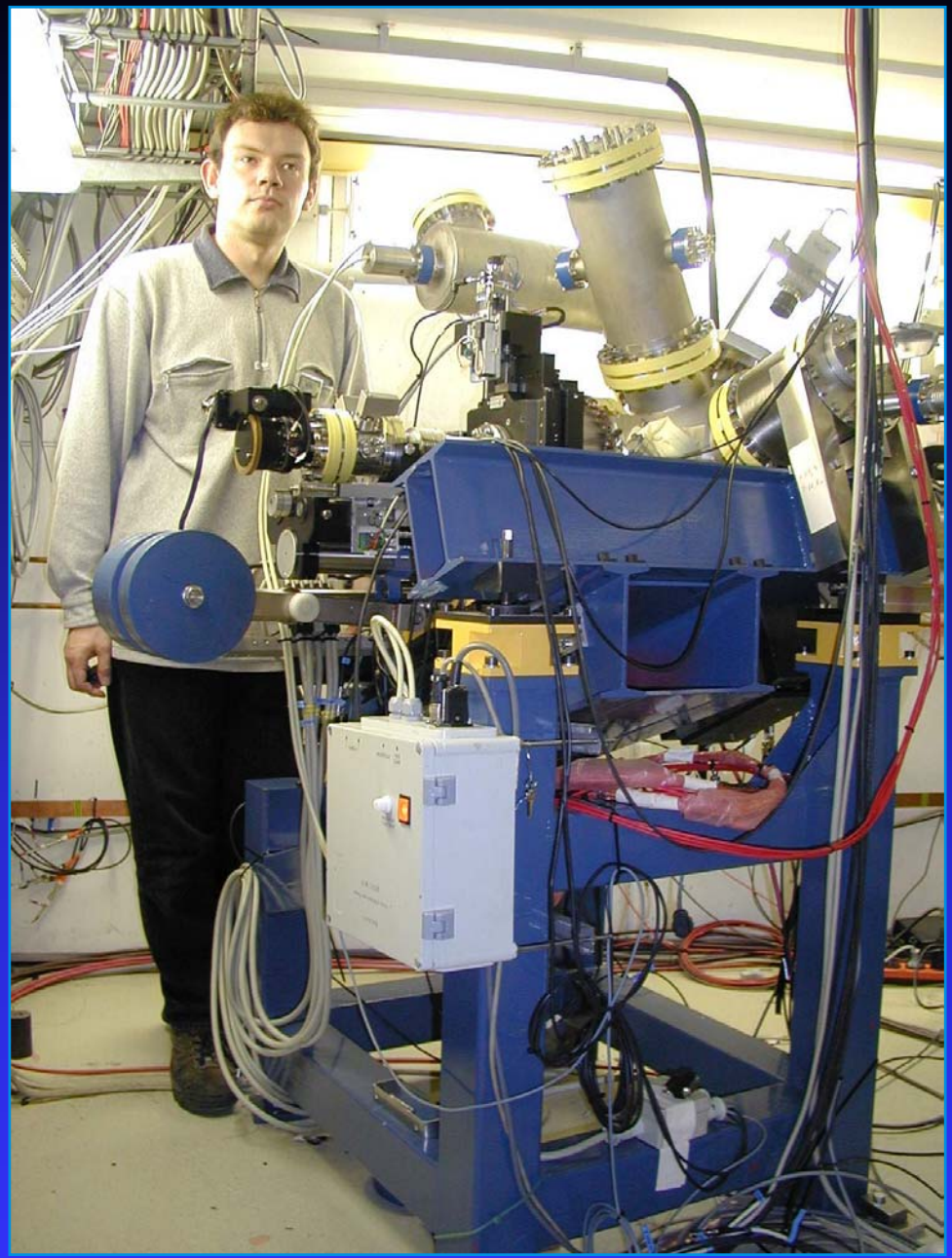
- Nowbody was there yet !
  - Strong VUV femtosecond pulses
- Damage of optics for short-wave sources
- Damage of samples
- Nanotechnology
- First plasma physics data

Experiment

- Layout
- Photon beam parameters
- Samples

Layout of the experiment

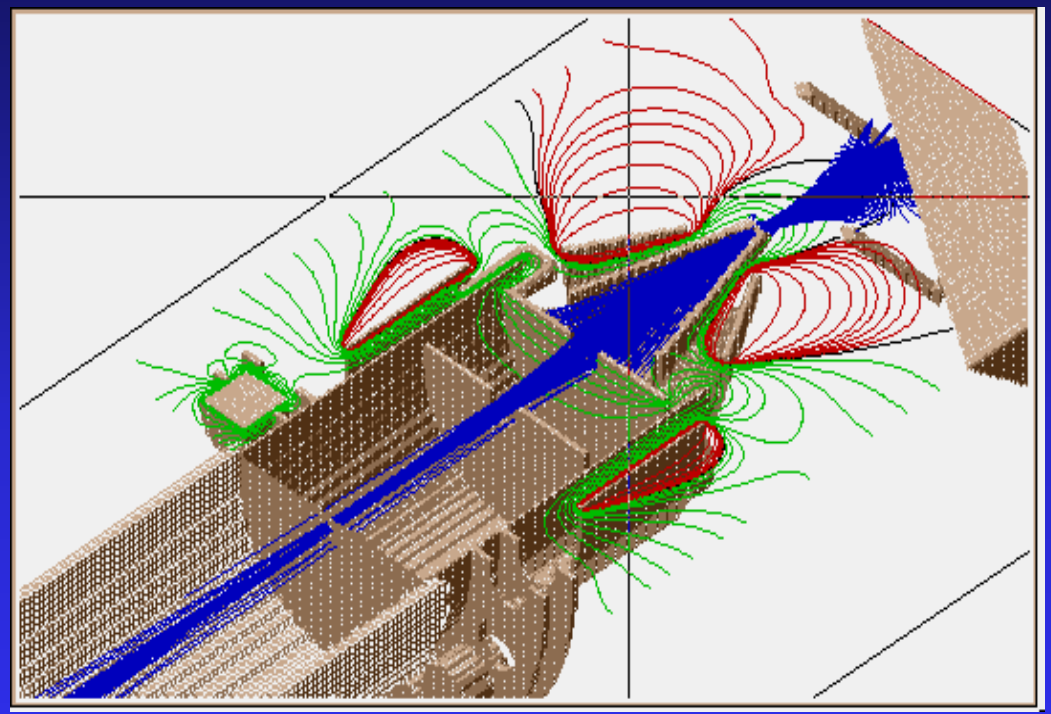




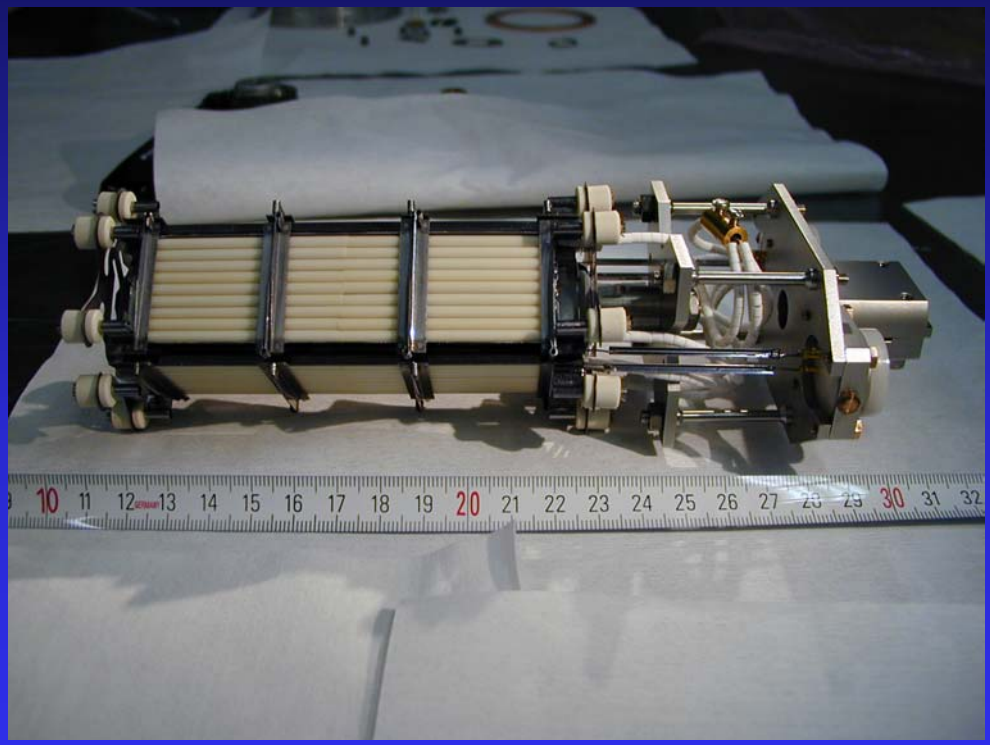
Photon Beam Parameters

Wavelength	80-98 nm
Pulse length	50 fs
Pulse energy	1-10 uJ
Min. Spot size	10 um
Max. Intensity	$\sim 10^{14}$ W/cm^2

TOF Spectrometer



Samples



Metals:

Au, Al, Cu

Semiconductors

Si, Graphite

Insulators

Al_2O_3 SiO_2 YAG

MgF_2 BaF_2

Organic compounds

PMMA, PTFE

Damage Threshold Questions:

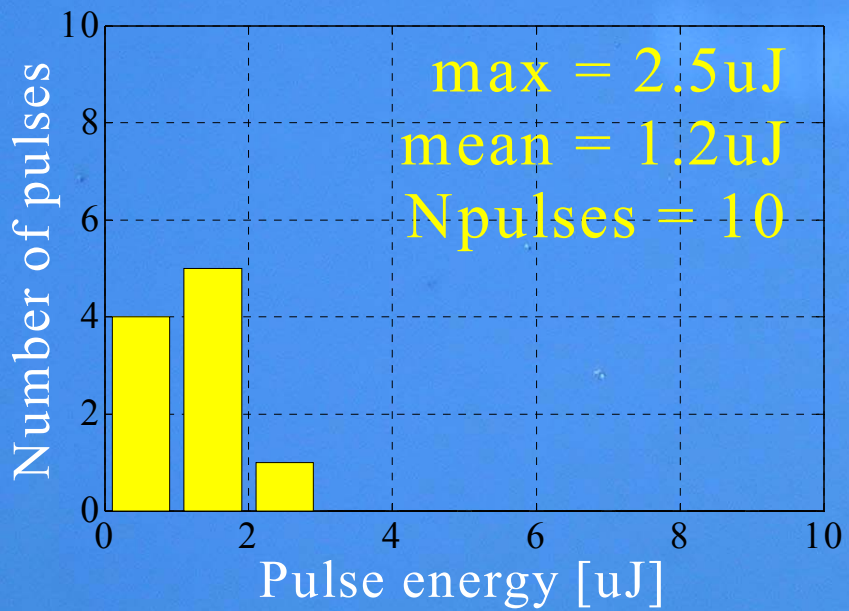
- What are damage threshold for ultra-short VUV pulses
- Can we predict damage thresholds ?
- How does it relates to Quantum Lasers?

Phase contrast microscopy

Peak fluence ~ 0.15 J/cm^2

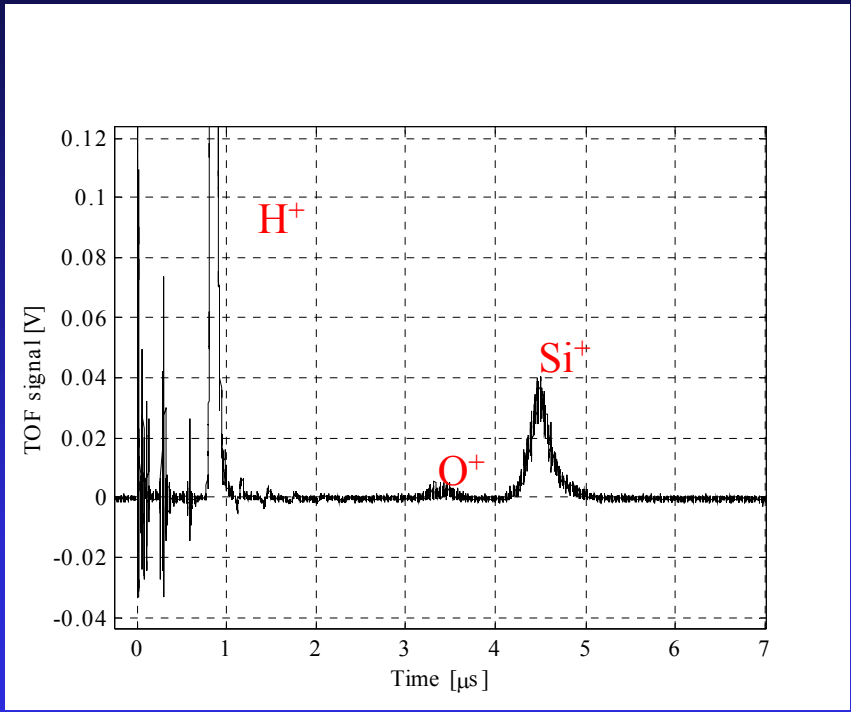
Raman spectra show amorphous phase here

fluence ~ 0.02 J/cm^2

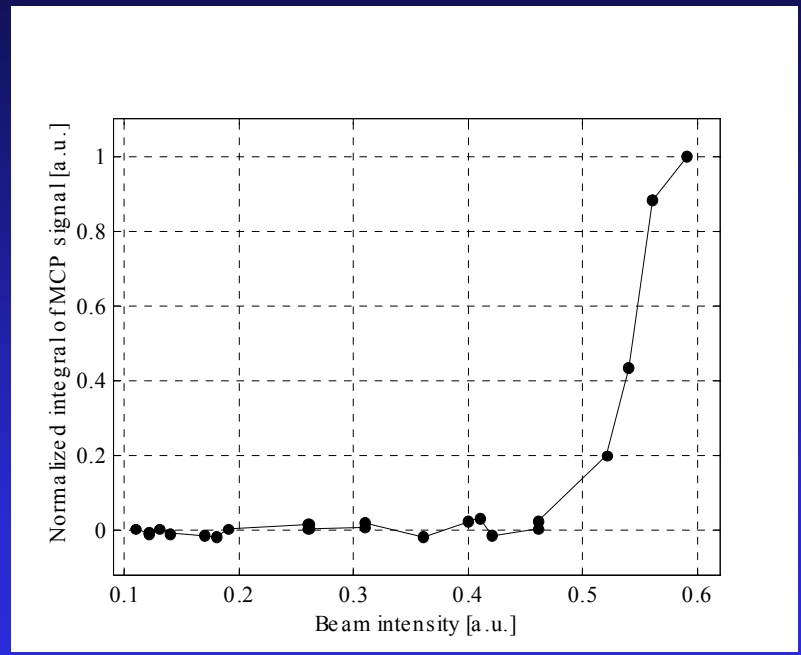


50 um

Example of TOF mass spectrum, Ions emitted from silicon sample



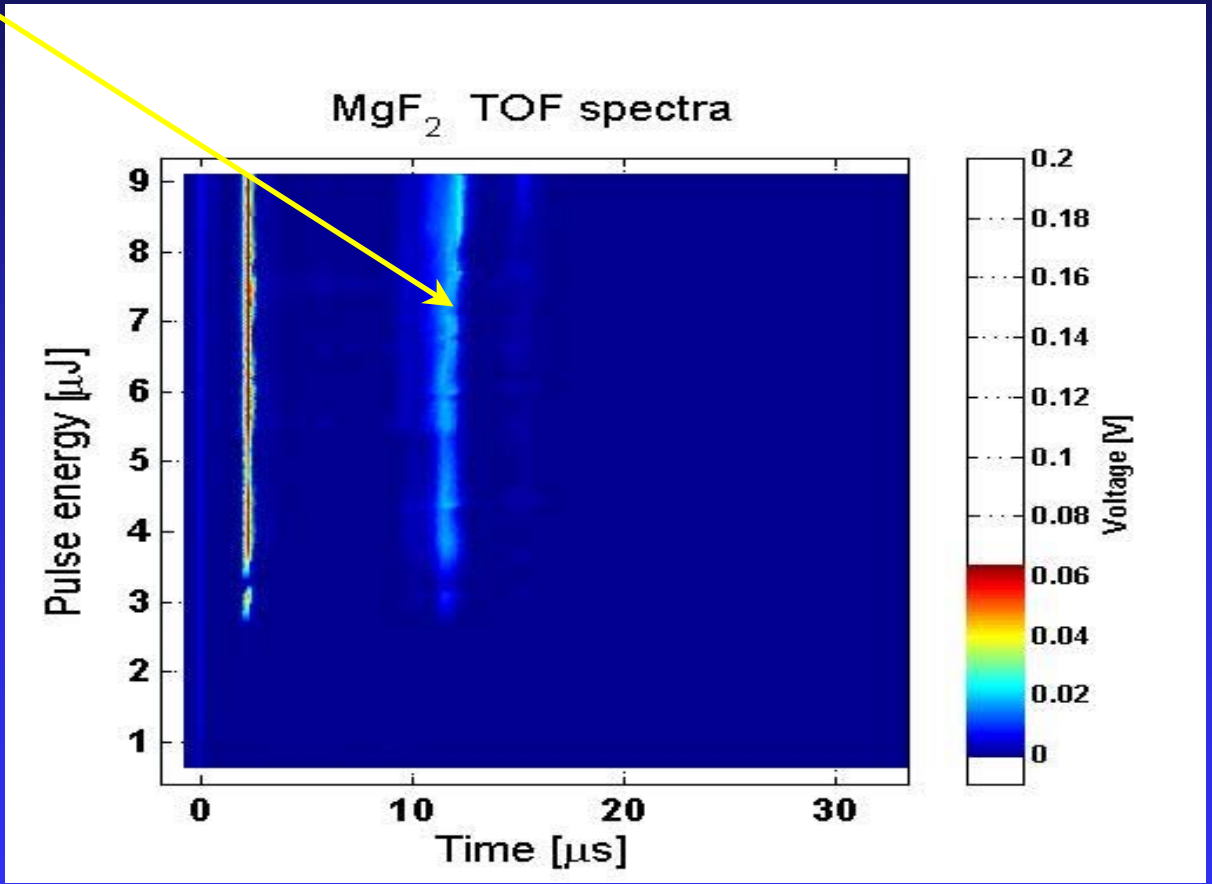
TOF mass spectrum



Threshold of Si^+ ion emission

MgF emission

MgF_2 spectra



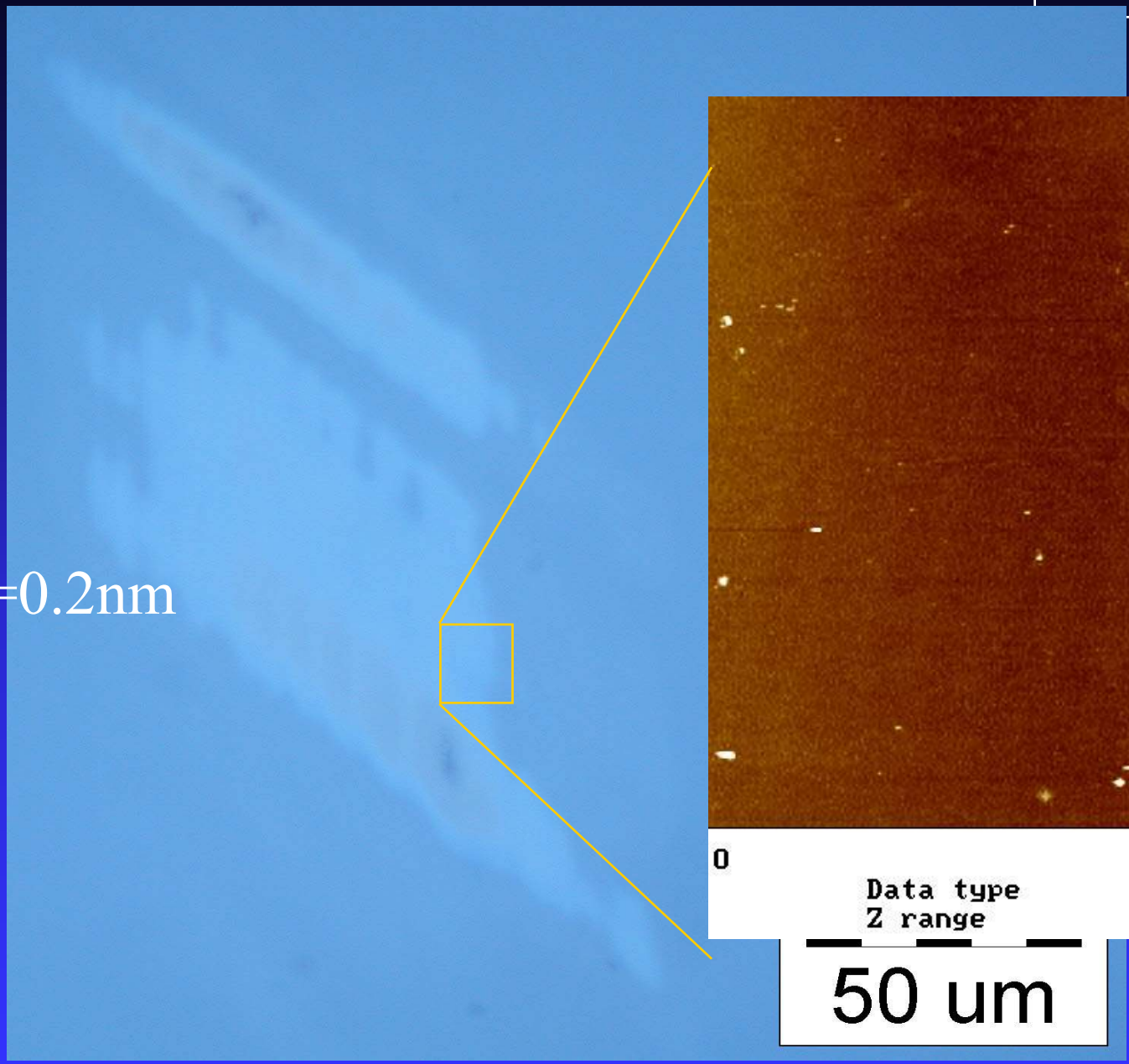
Estimated ion emission thresholds:

Sample	thickness	damage threshold [J/ cm^2]
Cu	bulk	0.5
Au	10 nm	0.05
Si	bulk	0.1
C	40 nm	0.07
YAG	bulk	0.07

Morphology of silicon surface as a function of radiation intensity

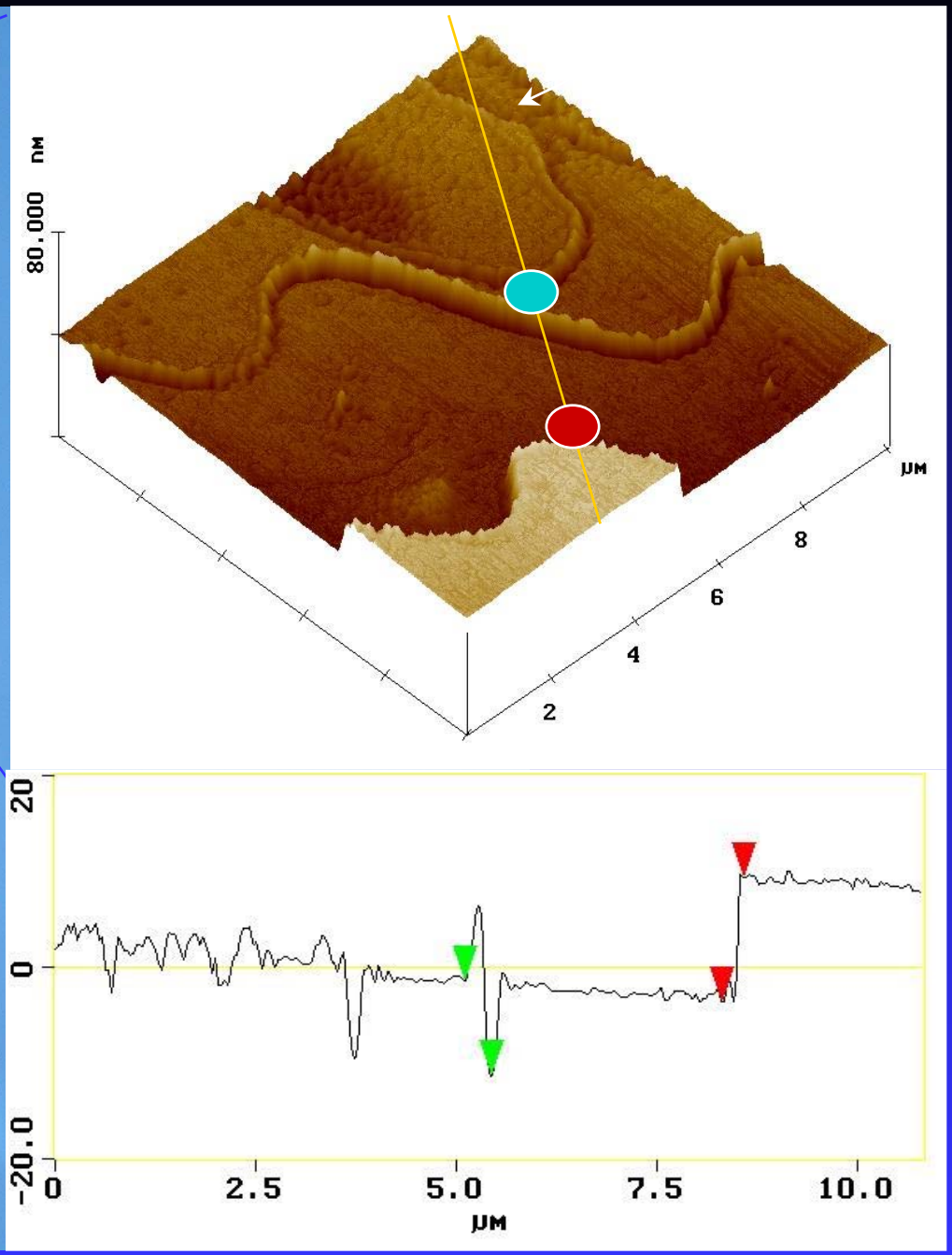
C film

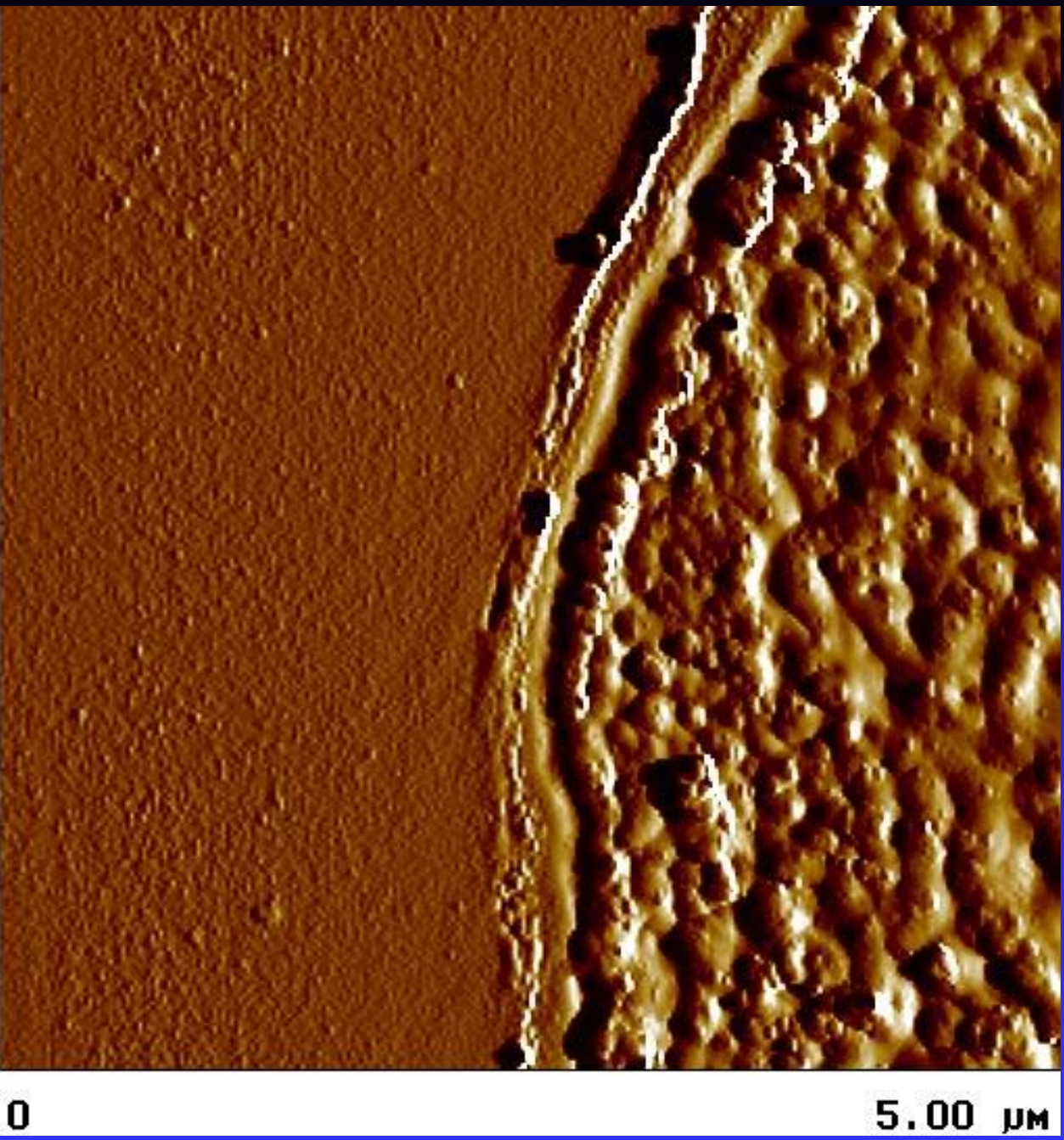
Δ=4.5mm


RMS=0.2nm
RMS=0.3nm
0
10.0 µm
Data type
Height
Z range
10.00 nm
50 um

C film on Si substrate

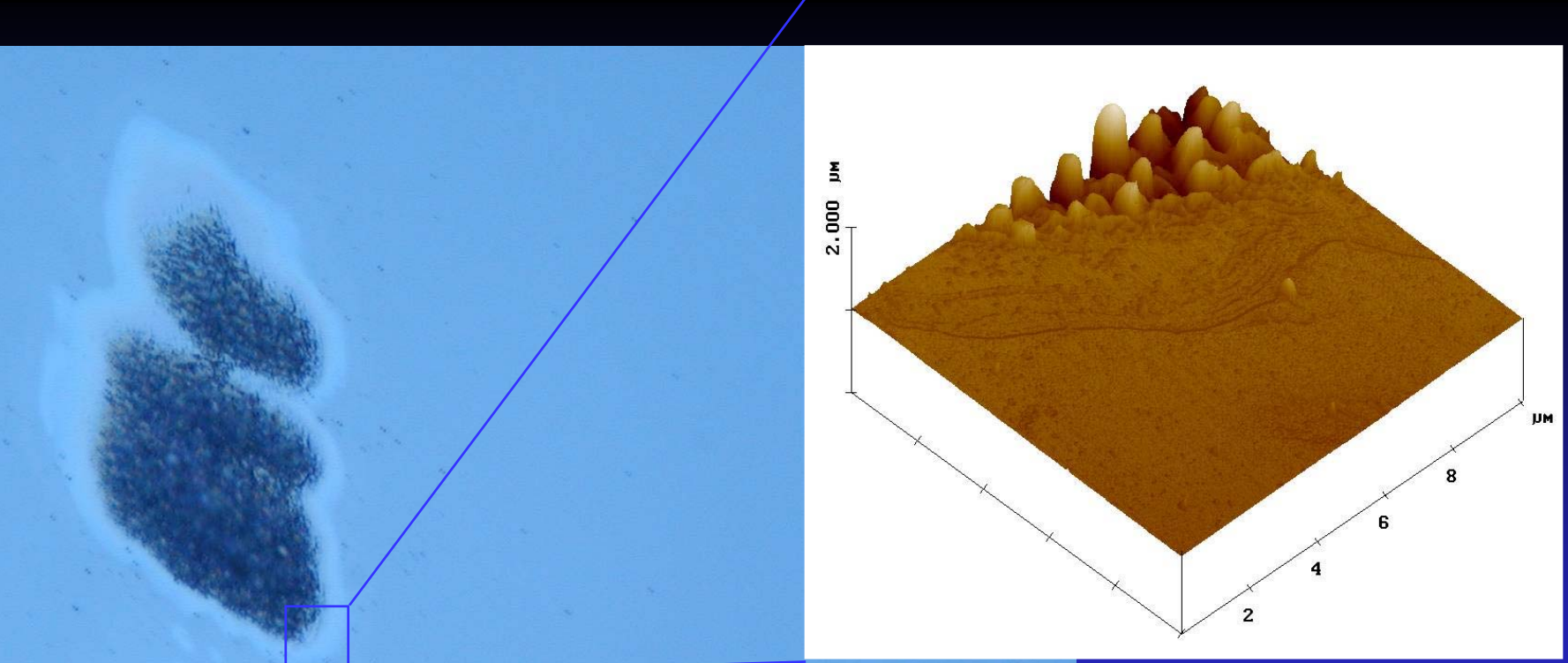
fluence ~ 0.1 J/cm^2





C film on Si

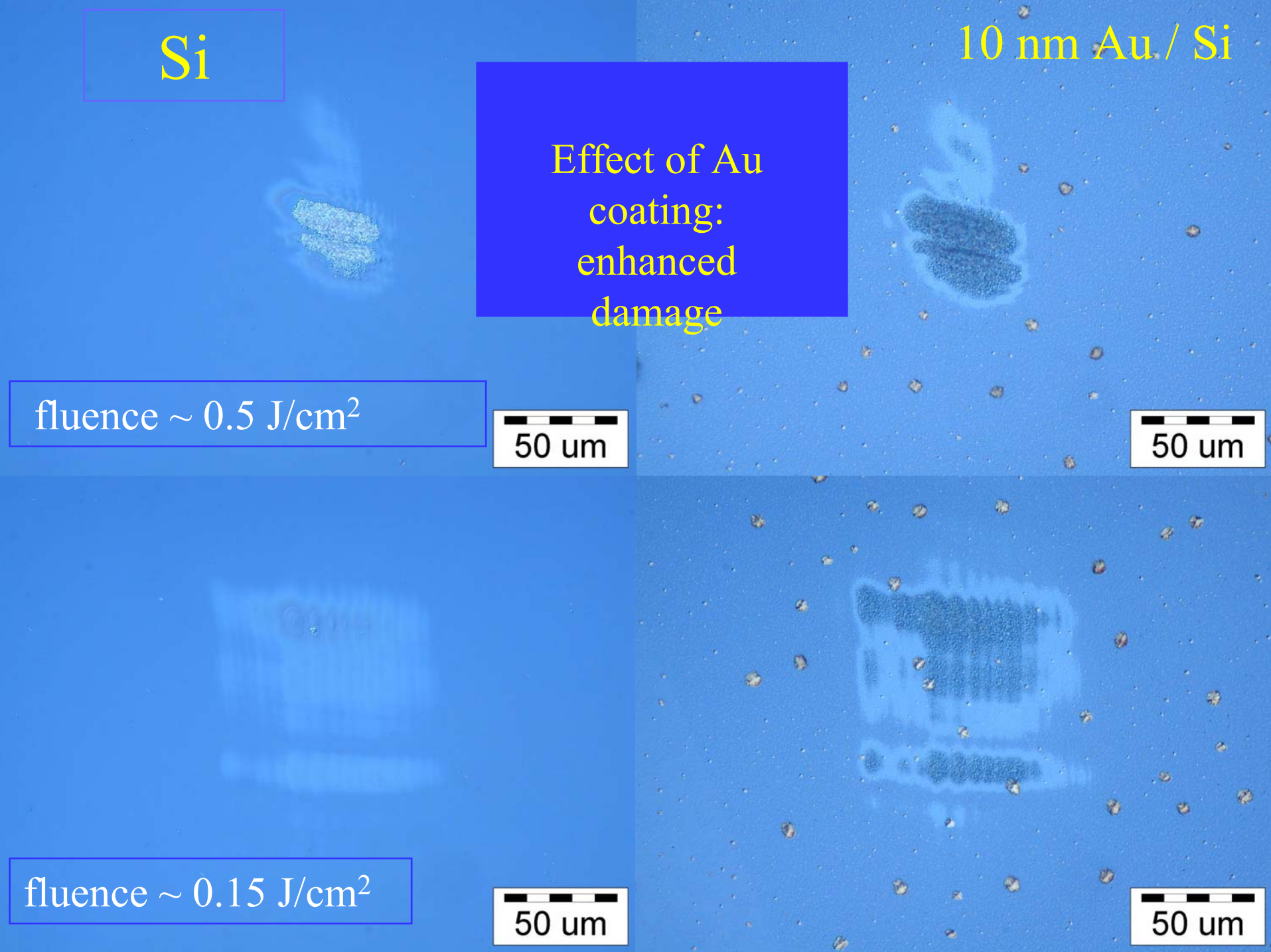
fluence ~ 0.3 J/cm^2



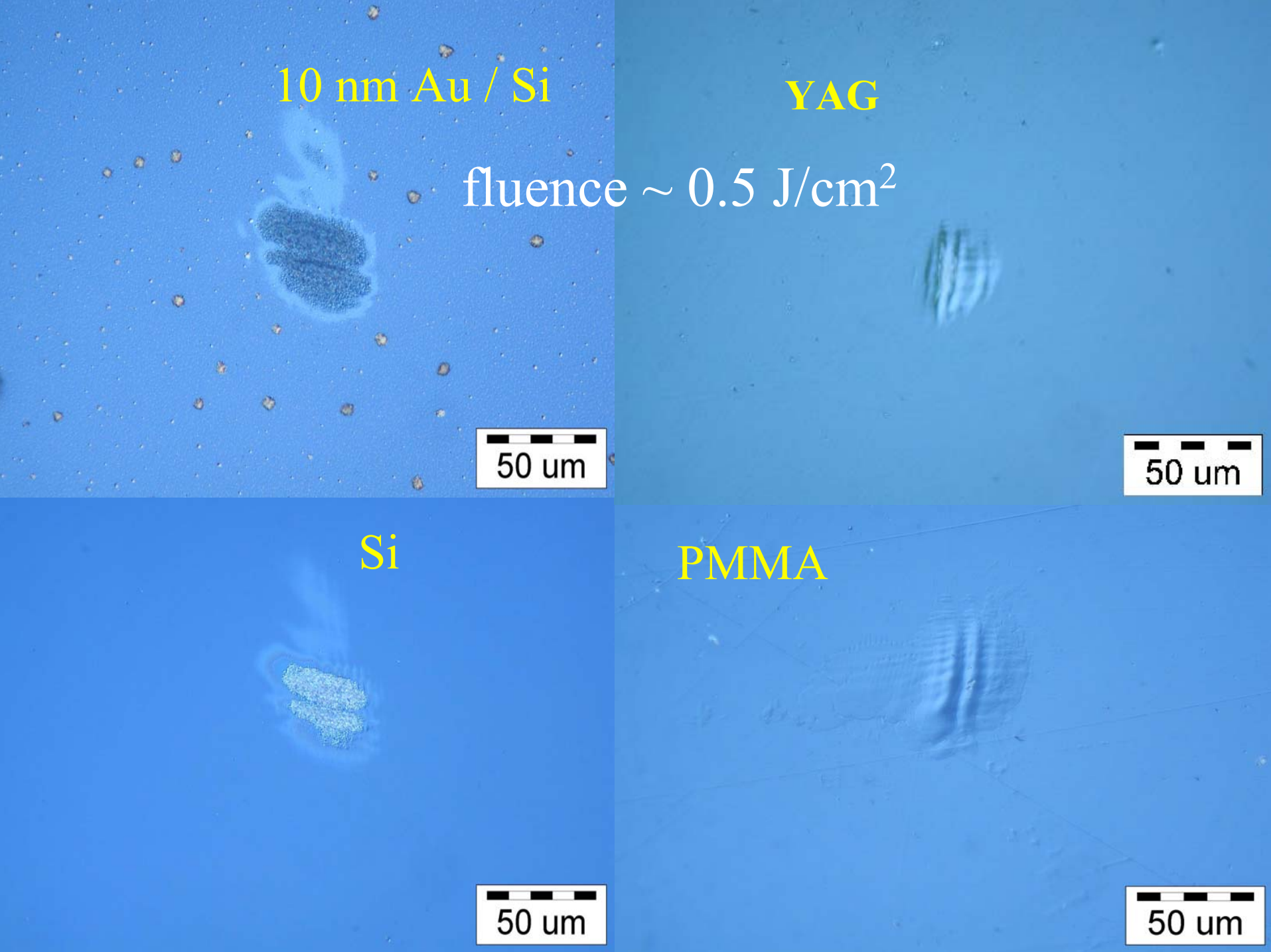
C film on Si

50 um

fluence ~ 3 J/cm^2

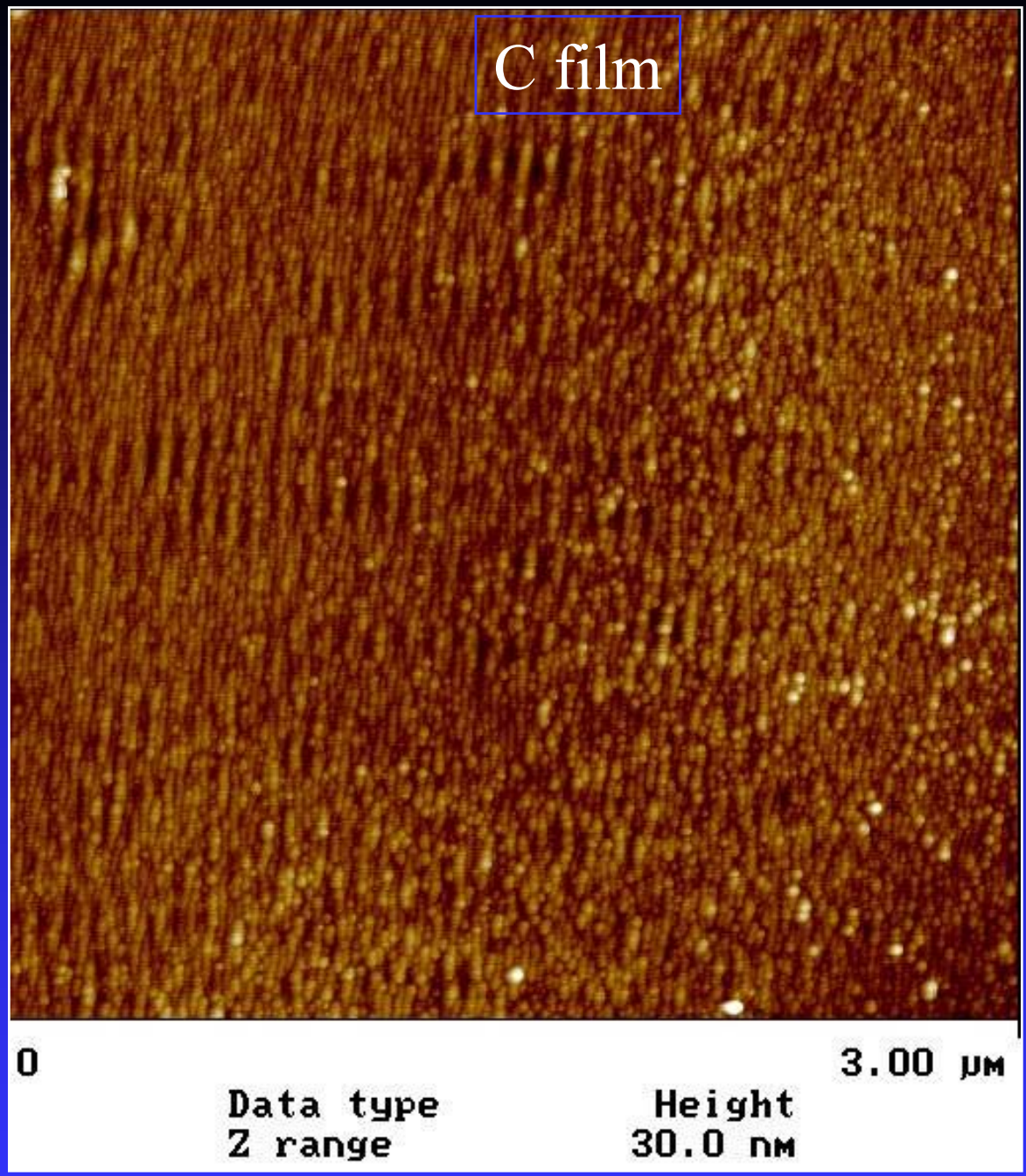

Si
10 nm Au / Si
Effect of Au coating: enhanced damage
fluence ~ 0.5 J/cm²
50 um
50 um
fluence ~ 0.15 J/cm²
50 um
50 um

ionic crystals and organic compounds exhibit very sharp ablation threshold with no modification of surrounding material


10 nm Au / Si
YAG
fluence ~ 0.5 J/cm2
50 um
50 um
Si
PMMA
50 um
50 um

LIPS - Ligth Induced Periodic Structure

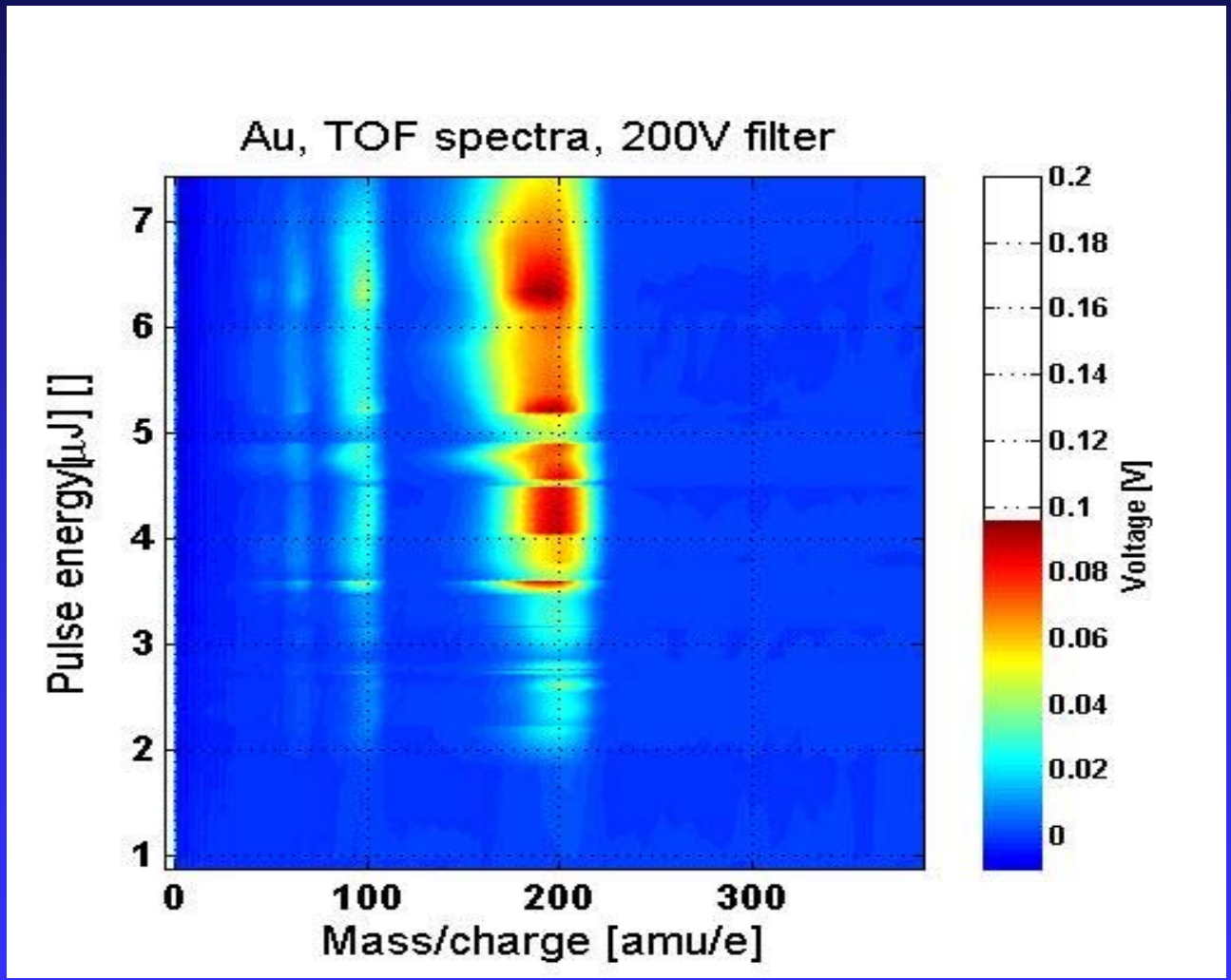
period ~ 78 nm



Summary:

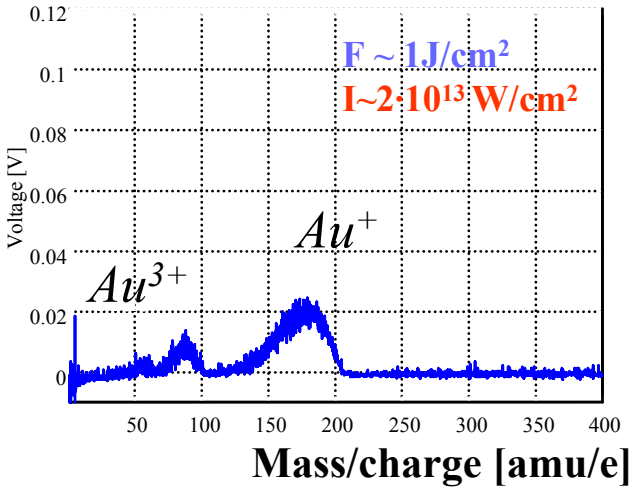
- Measured thresholds can be estimated from optical constants measured at low intensities (which is not true in the case of quantum lasers)
- Short VUV pulses are suitable for nano - processing of ionic crystals and organic compounds

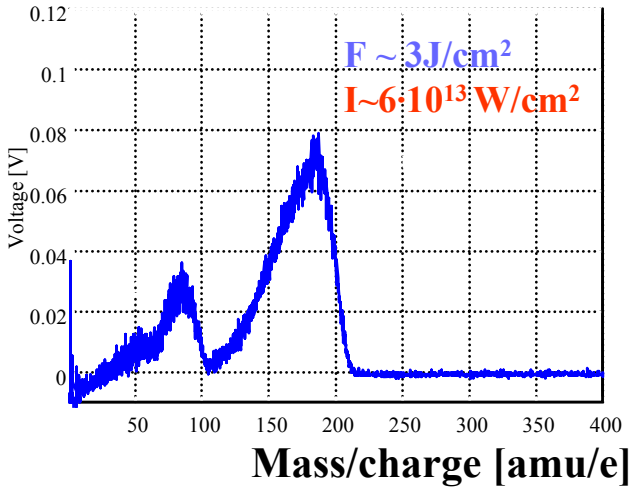
Plasma formation

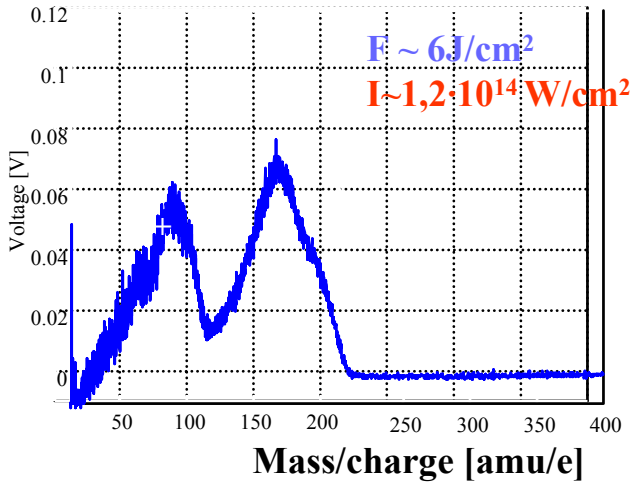


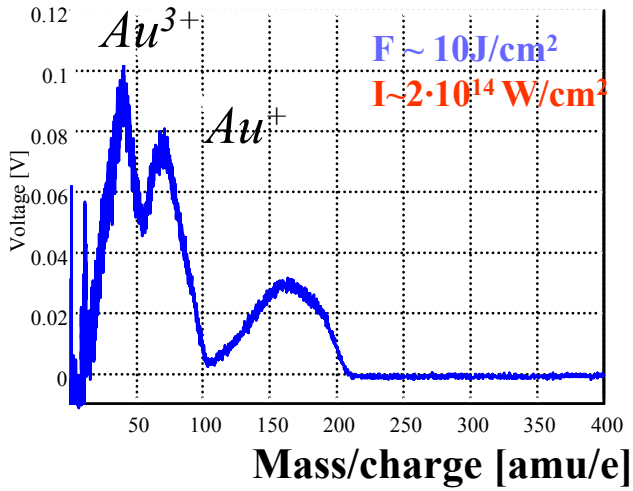
Au

High pass filter 200 V

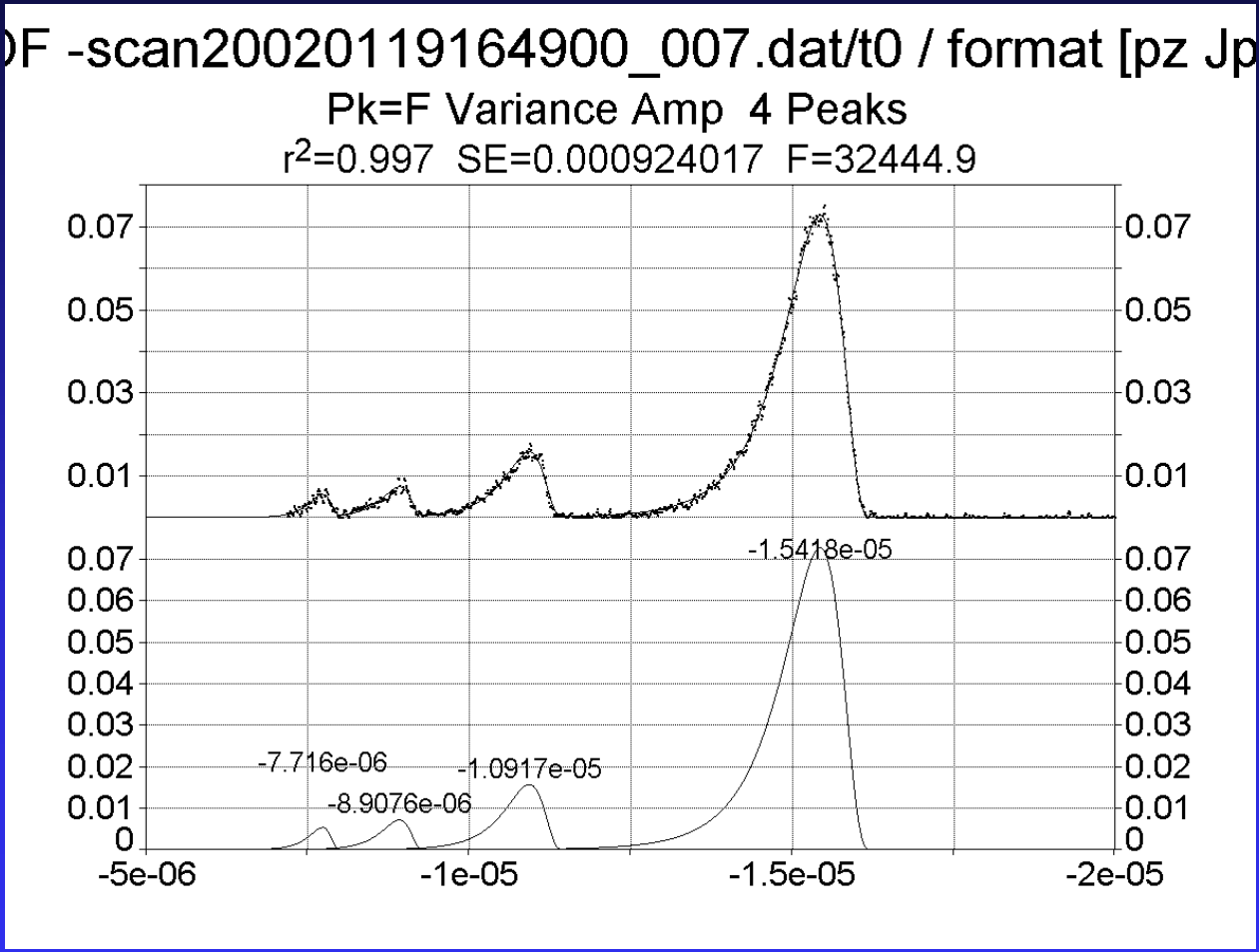




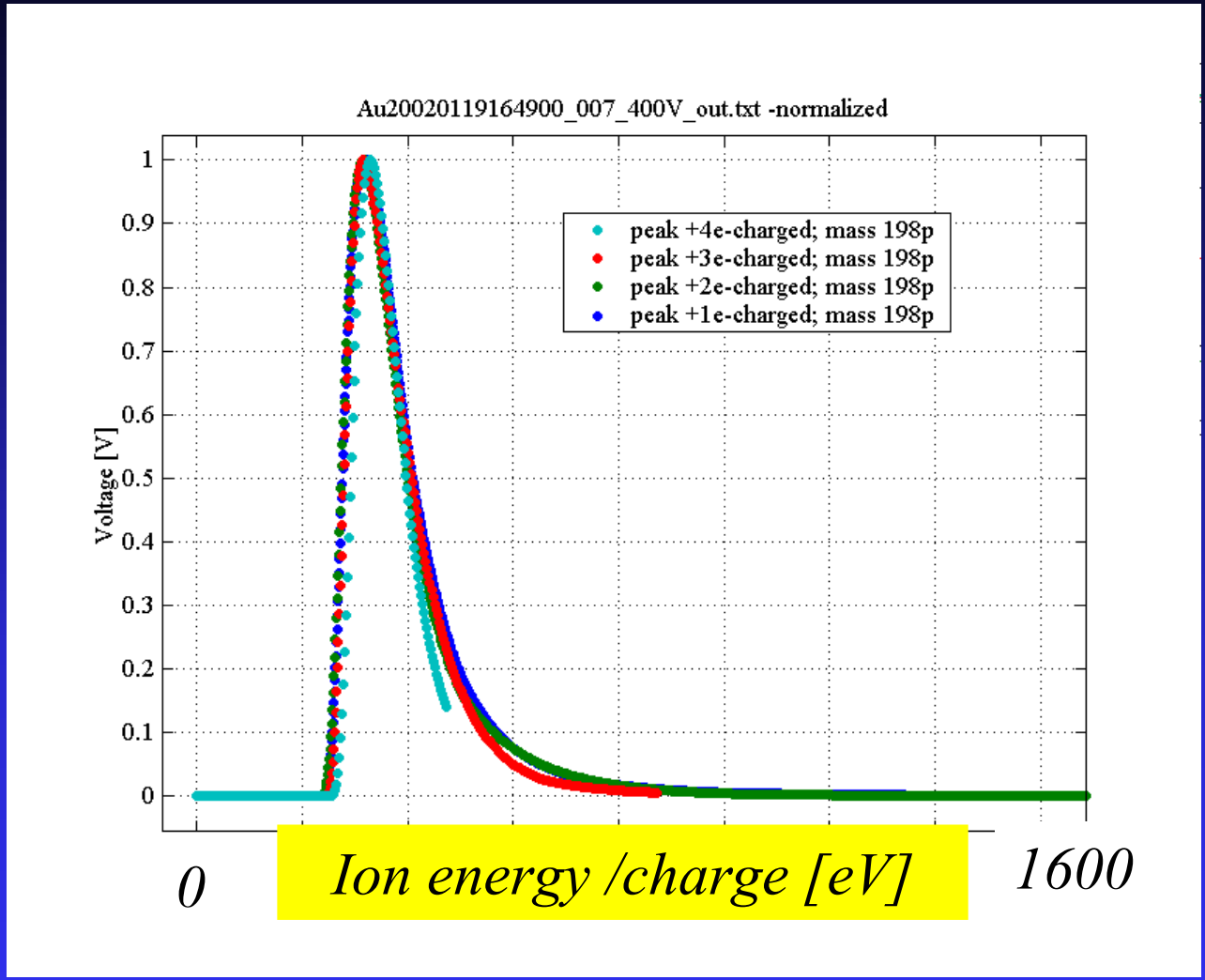




Measurements of ion energy distribution



Energy distributions for different charge states scale with a charge



Similar scaling has been observed for Cu and Si

Energy distributions for different charge states scale with a charge

What This Means

- Ions are emited by electric field

Summary of plasma results

- Energetic ions up to several keV
- Energy distributions scale with charge -> filed emision
- at fluencies 10 J/cm^2 higher charge states (2+, 3+) dominate distribution

Conlusions:

- Damage thresholds can be predicted from optical constants measured at low intensities (which is not always true in the case of quantum lasers and insulators)
- Short VUV pulses are suitable for nano -processing of ionic crystals and organic compounds
- Plasma results show that ions energy distributions scale with charge. That suggests field emision mechanism