Advances in thin film lead photocathodes

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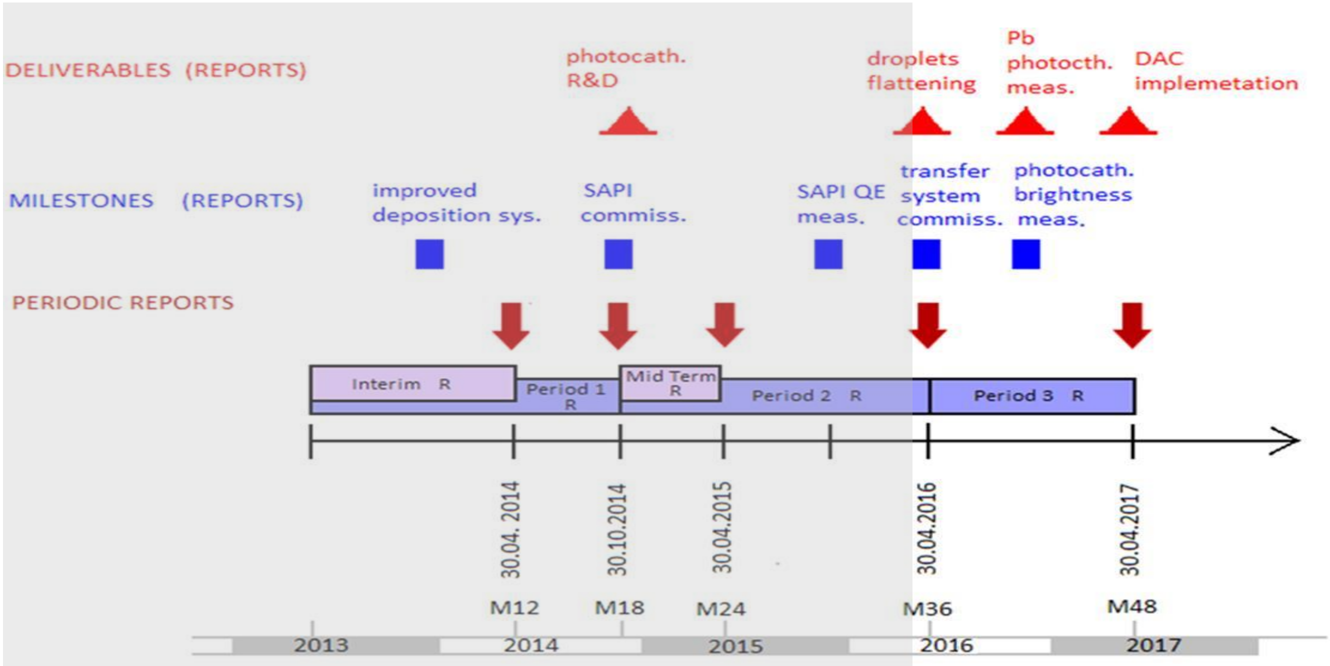
DESY



Milestones

Number	achievment	Performer	Deadline	Product
MS80	Demonstrated operation of improved deposition system, Pb layers of 1 μm in thickness	NCBJ	M30	Report on sample characterisation
MS73	Commissioning of the SAPI for operation with metal photocathodes	STFC	M8	Publication report
MS75	Investigation of quantum yield and energy spectrum of the electrons, emitted from the metal photocathode surface in SAPI	STFC	M18	Intermediate scientific report
MS83	Manufacturing and commissioning of the photocathode transport system	STFC	M36	Technical design report
MS85	Investigation of the brightness of different metal photocathodes in a S-band NCRF gun	STFC	M42	Scientific report

Deliverables

Number	achievment	Performer	Deadline	Product
D12.4	Scientific report on photocathode R&D	STFC	M18	Report
D12.8	Optimised procedure of preparation flat and adherent Pb/Nb layers	NCBJ	M36	Report
D12.9	Pb/Nb plug photocathodes measurements and characterization.	HZDR	M42	Report
D12.13	Results of DAC implementation in SRF guns.	HZB	M48	Report

Eucard2 obligations

Change the Deliverable

D. 12.8.

Optimised procedure for microdroplets flattening with an UV laser

↓

Optimised procedure for preparation of flat, clean and adherent Pb/Nb films

Reason

We found that plasma pulsed irradiation is more effective that the laser one. Basically we learned how thick layer must be deposited to undergo a right change caused by energy deposition.

Delay

The all superconducting SRF-injector program at DESY is motivated by perspective of an increased flexibility in the time structure of the FLASH/EXFEL photon beams by enabling cw/lp operation.

Present parameters of the DESY injector

	Unit	Spec 2014
Cathode	-	Pb
Bunch charge	pC	100-300
Bunch length	ps	3
Bunch rep. rate	kHz	100-33
Trans. slice emittance	µrad	< 0.7@100pC
Energy	MeV	3.7
Beam current	µA	10
QE	%	0.015@260nm
Max. E on cathode	MV/m	40
Eγ on cathode	µJ	2.4-7.2
Laser P at cathode	W	0.24
Laser P at 1032	W	24

Challenging parameter is marked in yellow

R&D at DESY

The 1.5-cell gun cavity prototype was built at TJNAF. The present plug version has very effective cooling of the cathode.

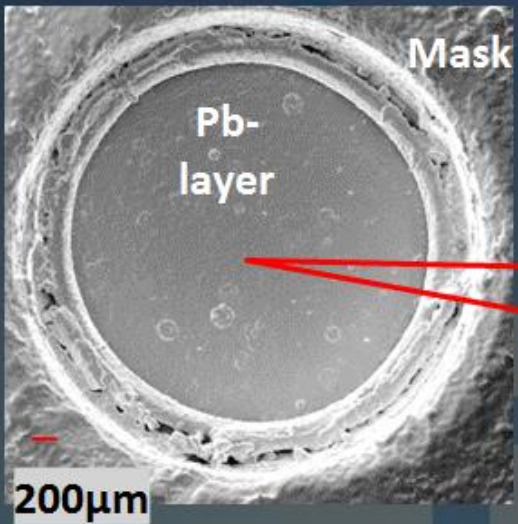
1.5-cell , 1.3 GHz gun cavity

New plug with LHe channels

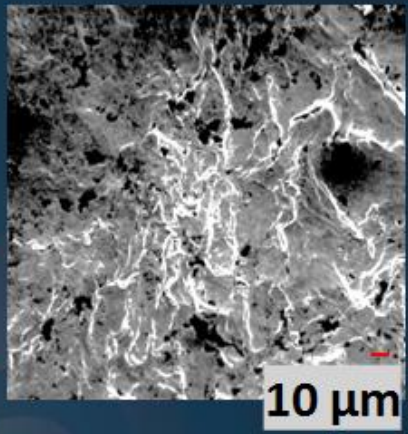
Nb/Pb cathode

Roughness of the Pb coating (arc-deposition) on new plug

Courtesy NCBJ



Pb-layer after the plasma treatment
Droplets ϕ ca. 100µm, elevation few µm



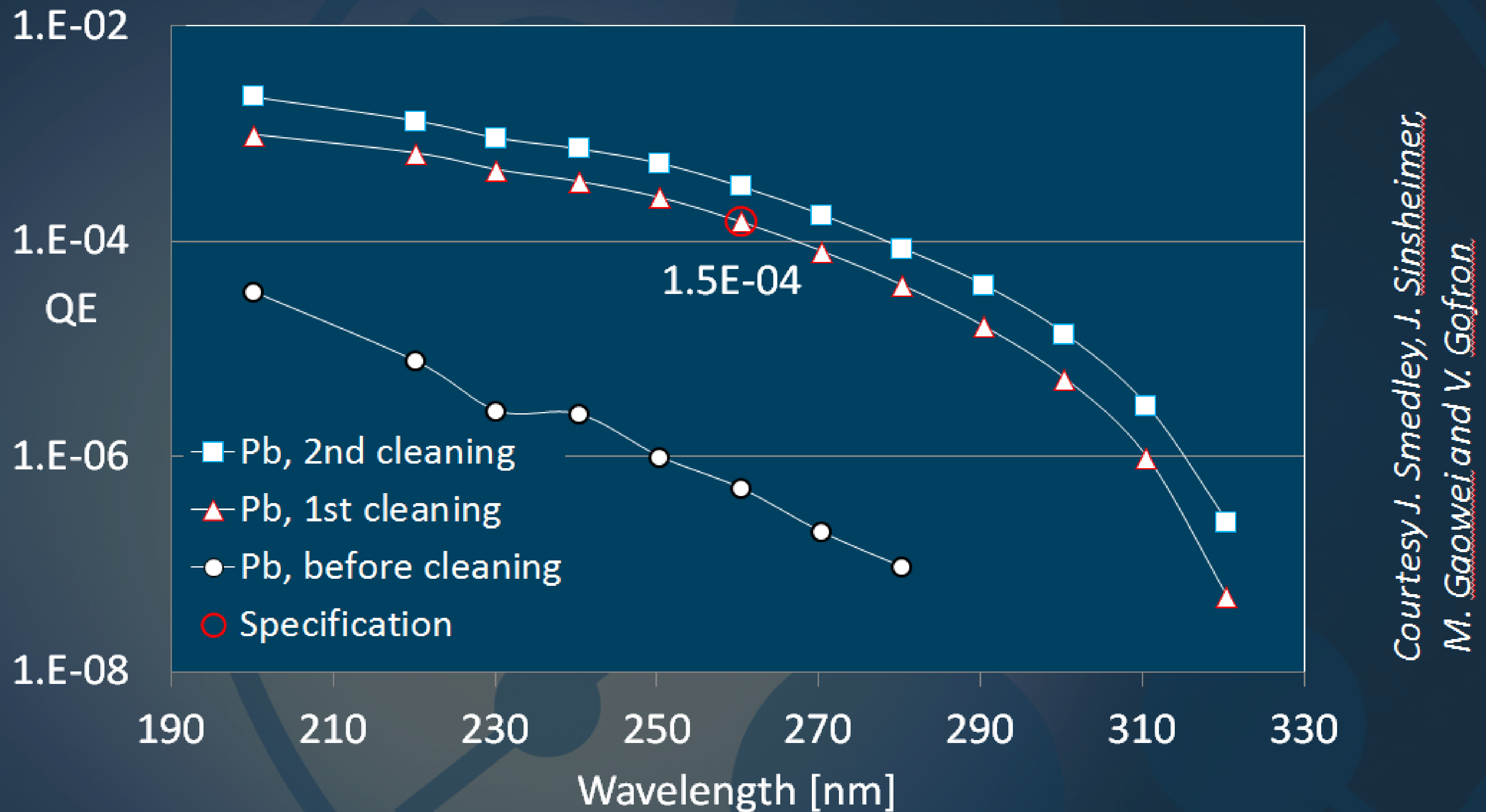
Courtesy BNL

Pb-layer after the 2nd laser cleaning

Next

- Surface is too rough. Pb-layer is 15µm thick. It will be molt by laser irradiation and then QE test will be repeated.
- The Pb-coated plug will be then installed in 1.5-cell at DESY for the SRF-test.

Recent QE test at BNL of the Pb coating on new plug



Laser cleaning: 1^{st} 1000 shots with 0.06 mJ/mm^2,

2^{nd} 10000 shots with 0.06 mJ/mm^2, all at 248nm

Further steps…

… towards *D12.9 Pb/Nb plug photocathodes measurements and characterization* at HZDR

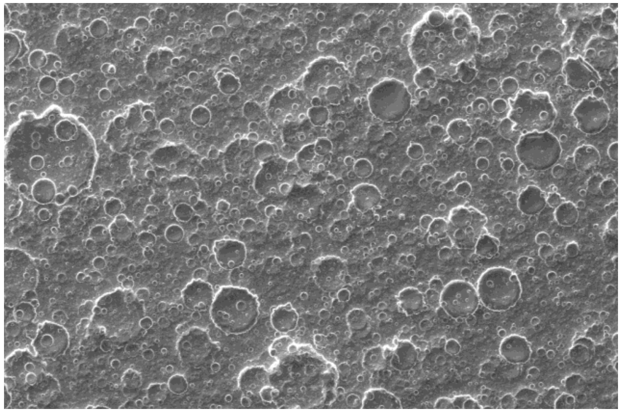
The maximum program for the experiment would be:

1. assembling the Pb-coated plug in the vacuum chamber,
2. laser- cleaning accordingly to John's recipe,
3. measure QE at ca. 260 nm ,
4. irradiate the cathode for several weeks in total (can be done in many shorter periods) with your laser: 0,5 W, 500 kHz, 10 ps , 260 nm
5. measure QE again.

Pb/Nb until April 2015

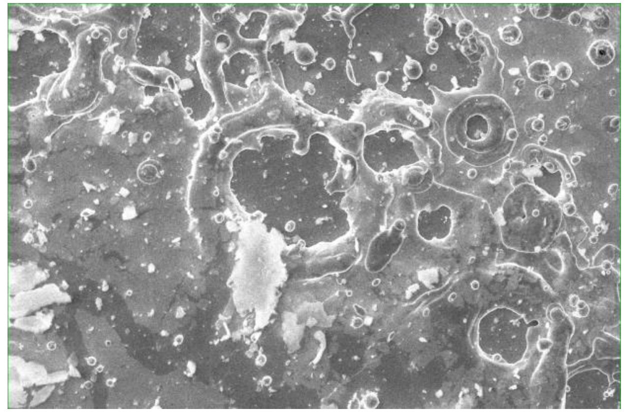
8 µm Pb

20 µm X 500



UHV arc deposition

X 1000



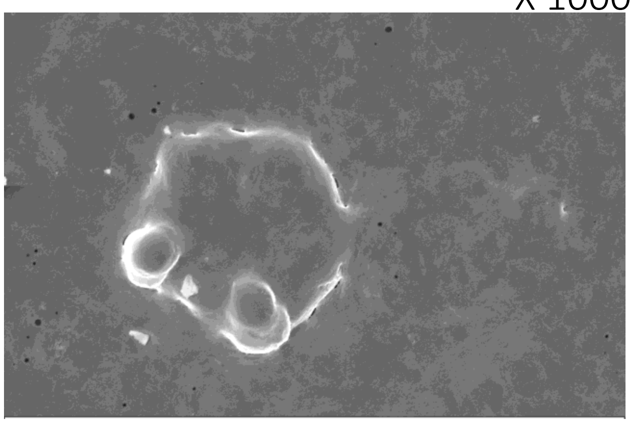
1 plasma pulse of 1.8 J/cm^2

Too thin and thus perforated

- Distinct areas of perforations size of which did not exceed 10 µm
- non-coated area amounting to 3-5% of the total layer surface.

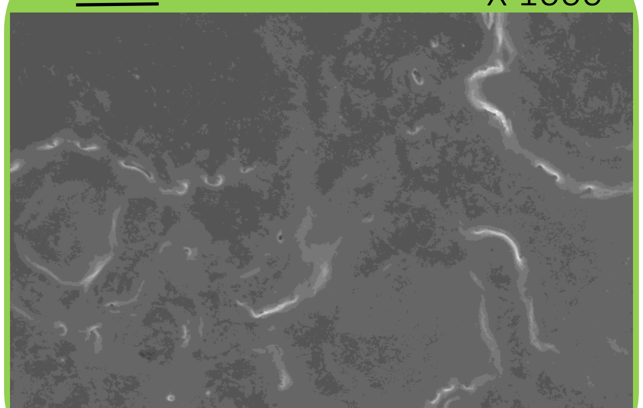
12 µm Pb

X 1000



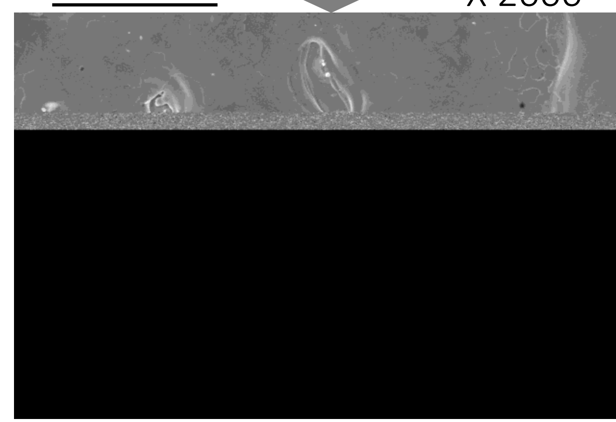
1 plasma pulse of 1.5 J/cm^2

20 µm X 1000



2 pulses of 1.5 J/cm^2

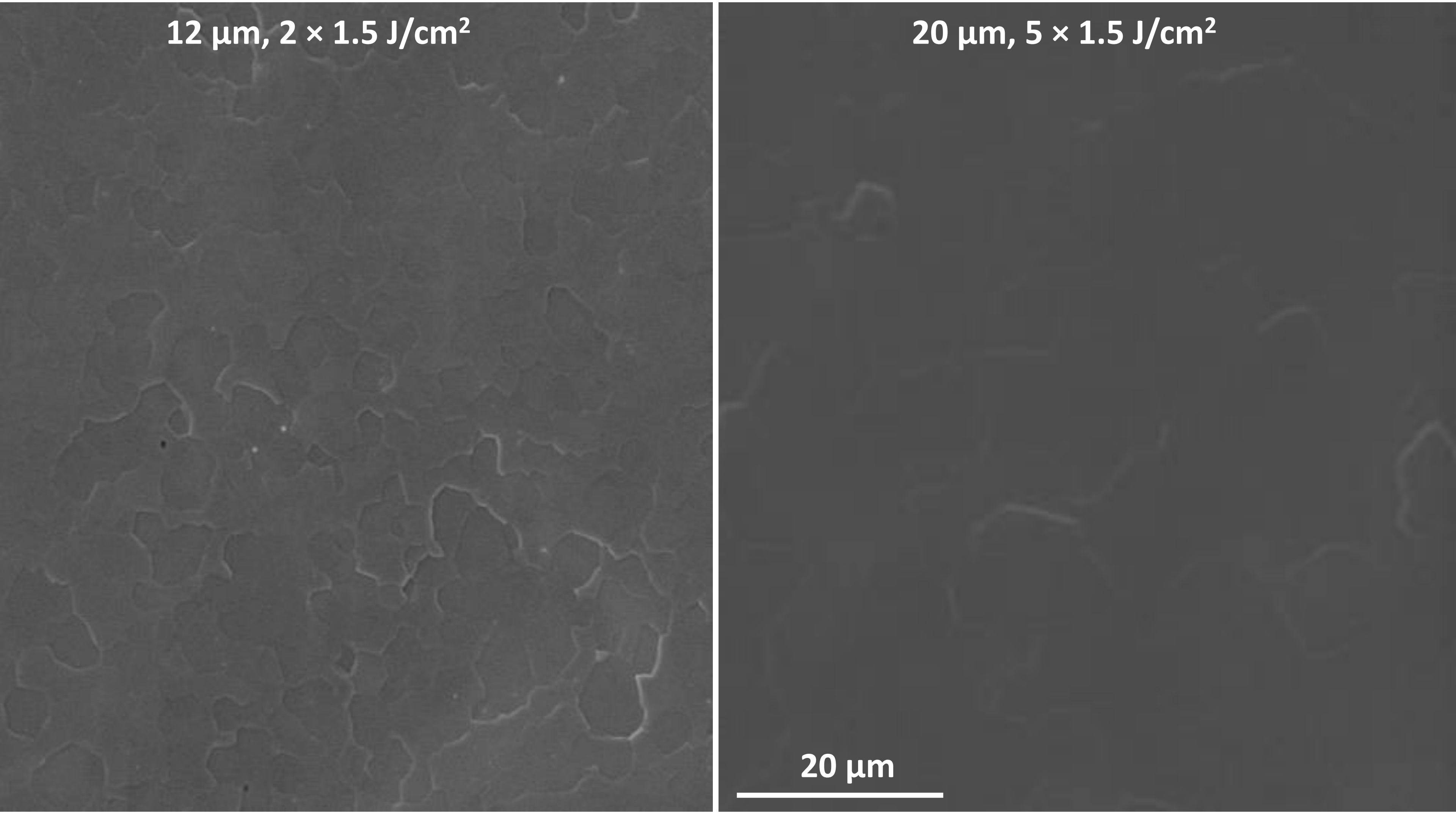
20 µm X 2000



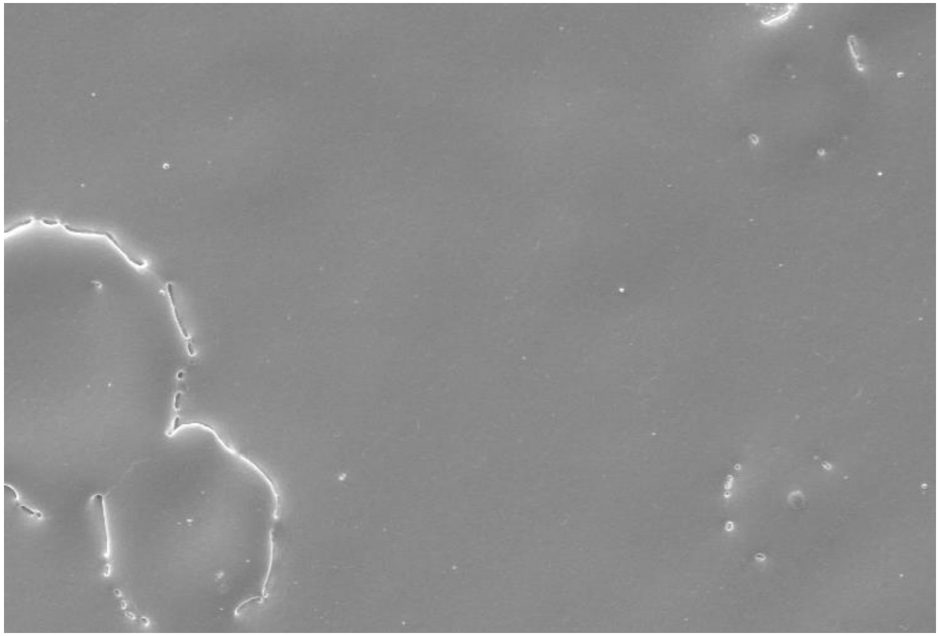
3 pulses of 1.5 J/cm^2

15 µm Pb underway…

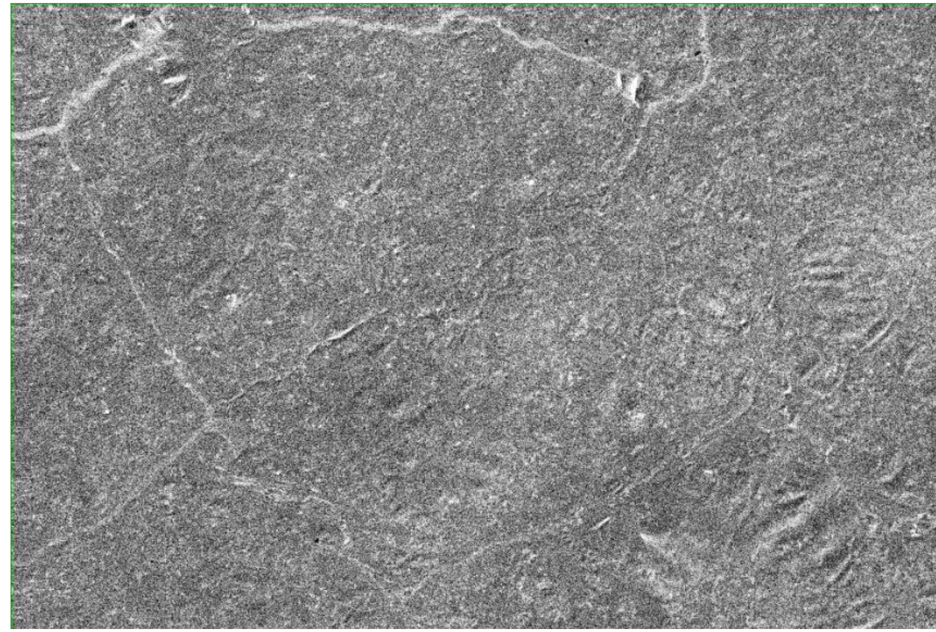
Further flattening



Further flattening

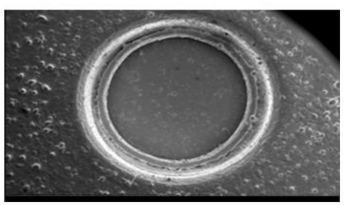


10 μm, 25 × 1 J/cm^2 through a hole in mask



10 μm, 25 × 1 J/cm^2 without shielding

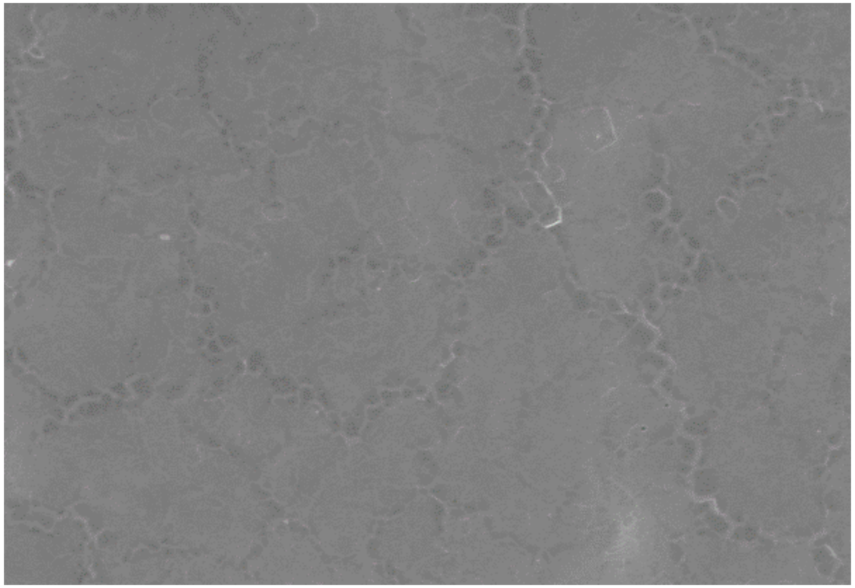
50 μm



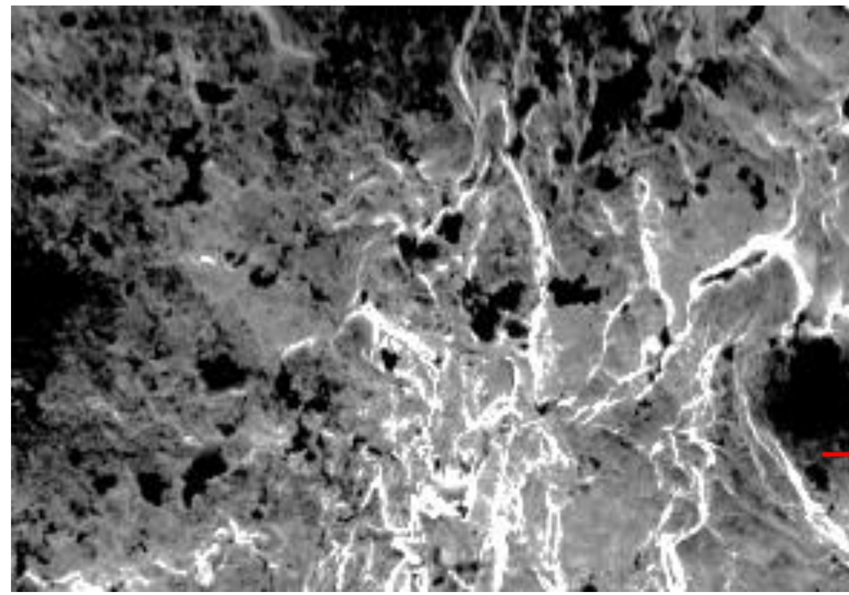
3 mm

We found that surface morphology depends on that whether it was irradiated with a mask or without it. Mask impedes an energy transfer from pulse to layer. It leaves crater and droplets remnants

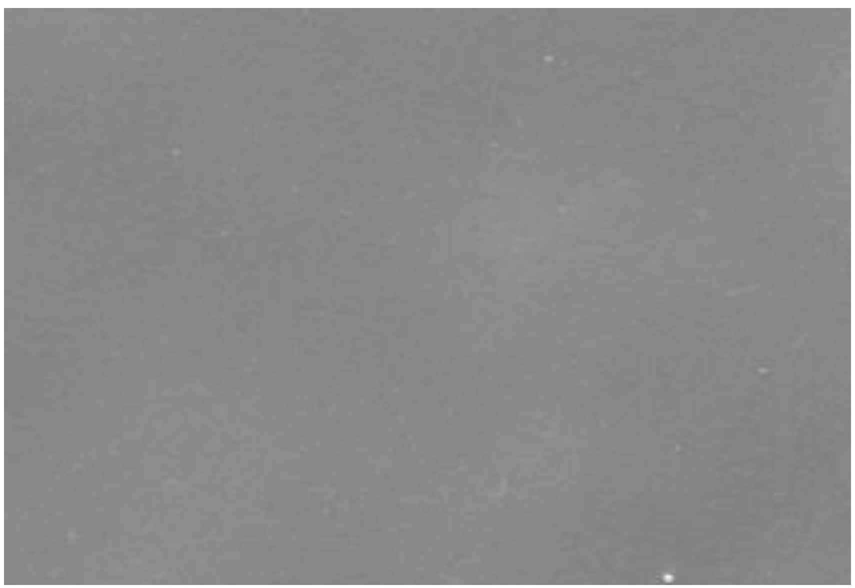
Laser cleaning



Plasma irradiation leaves surface smooth Laser treatment increases the QE a lot. This is accompanied with the roughenieng the surface



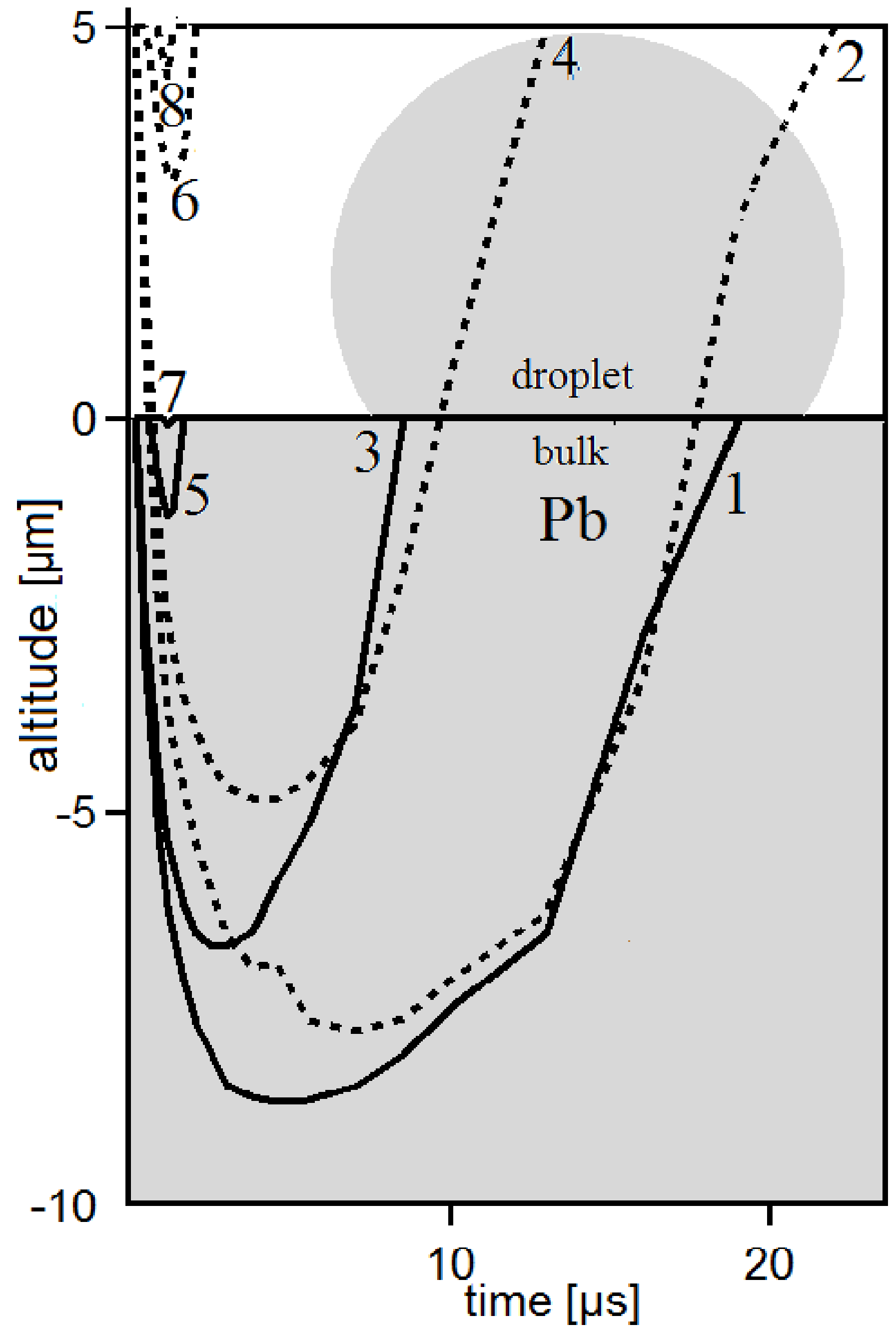
20 μm



20 μm 17 μm, 5 × 1.5 J/cm^2 through a hole in mask

Calculations for 1 J/cm²

We managed to decrease the plasma pulse energy to get the fluency of 1 J/cm^2 . This reduces the samples thickness needed to survive. Corresponding heat transfer calculations have been performed

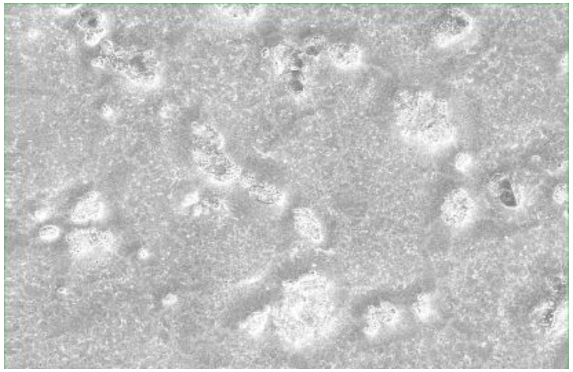


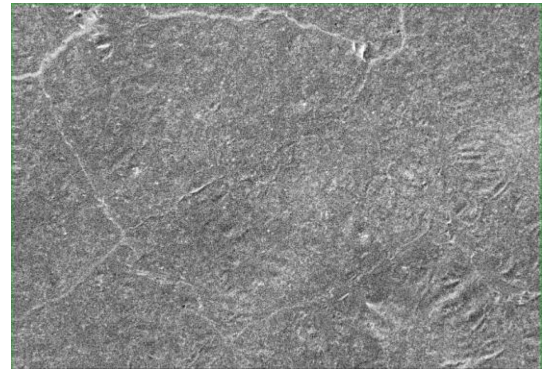
In depth propagation of melting and evaporation fronts. 1. – bulk melting, 1.5 J/cm^2; 2. – droplets melting 1.5 J/cm^2; 3. – bulk melting, 1 J/cm^2; 4. – droplets melting 1 J/cm^2; 5. – bulk evaporation, 1.5 J/cm^2; 6. – droplets evaporation, 1.5 J/cm^2; 7. – bulk evaporation, 1 J/cm^2; 8. – droplets evaporation, 1 J/cm^2

X-ray diffraction

Measured with Cu $K_{\alpha 1,2}$ with a laboratory diffractometer in θ-2θ geometry

5 µm, 10 × 1 J/cm^2
no shielding
filtering

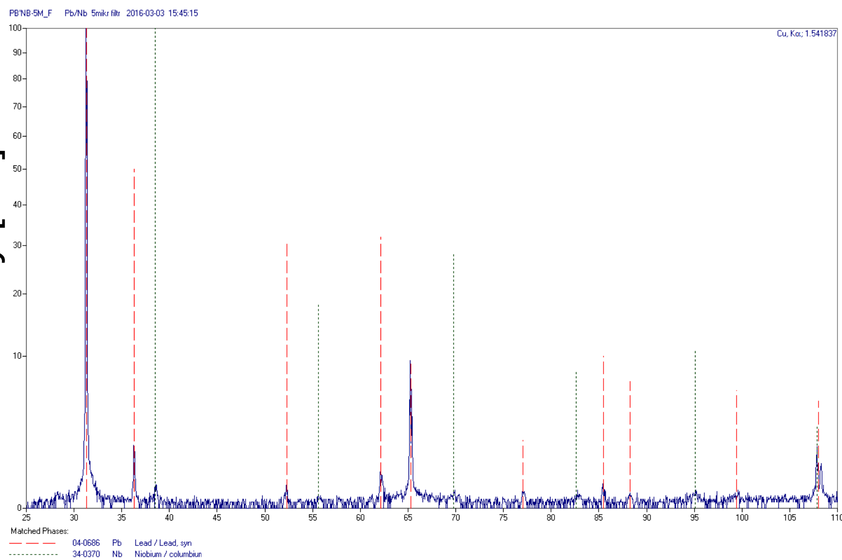




10 µm, 25 × 1 J/cm^2
no shielding
no filtering

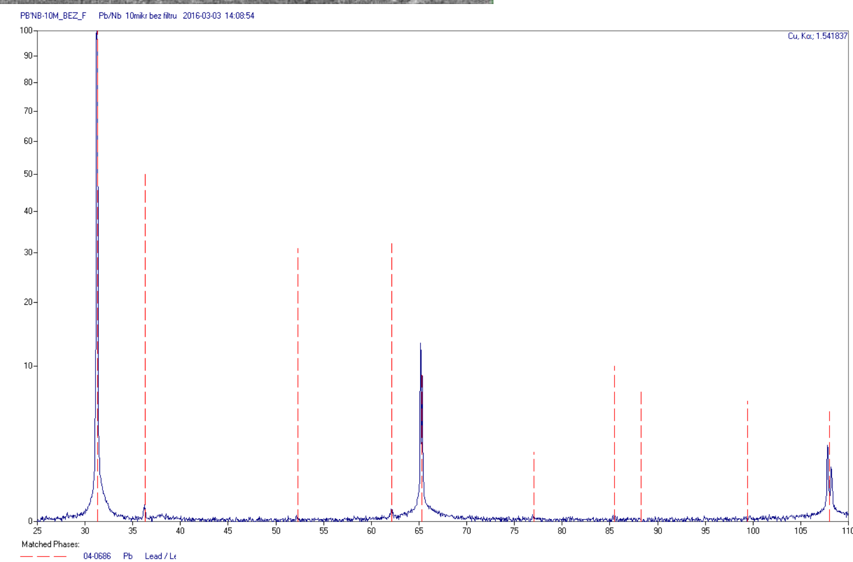
50 µm

Intensity [a.u]



2 θ [deg]

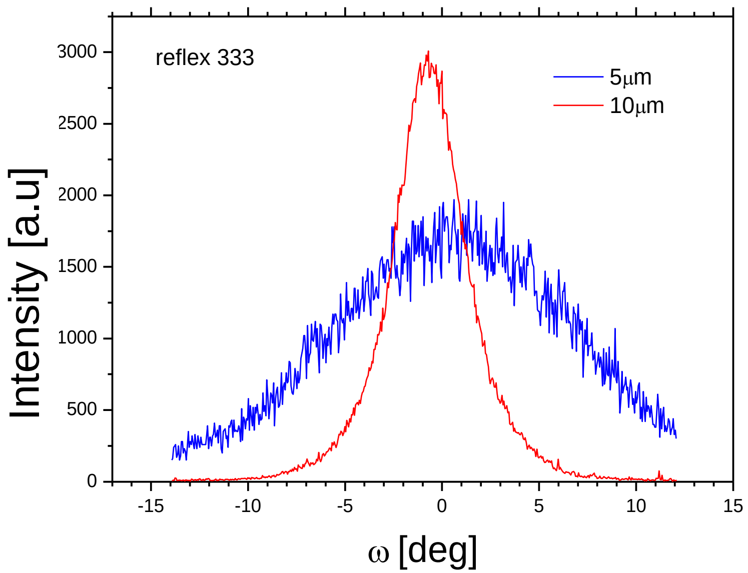
Intensity [a.u]



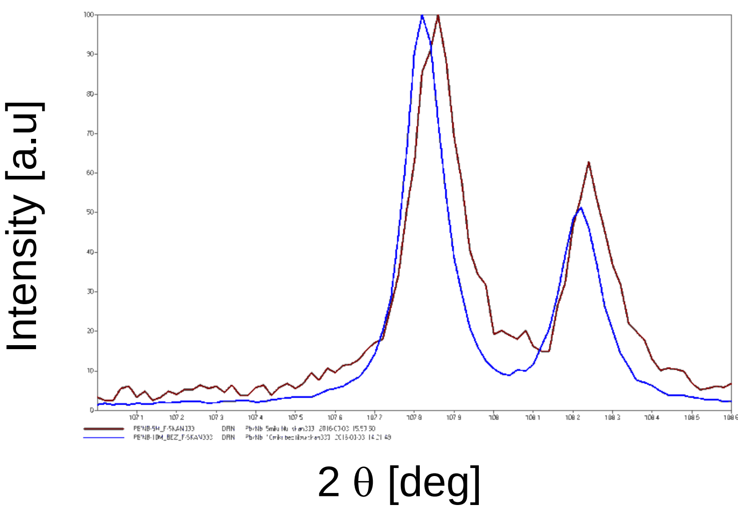
2 θ [deg]

[111] texture occurs for both layers, for thicker layer however no other orientation can be seen.
Does it come from thickness or from irradiation?
Photoemission dependence on surface orientation will be studied by calculations

X-ray diffraction



Rocking curve around reflex 333. It gives the distribution of [111] crystalline plane orientations relative to sample surface
Spread of crystallite orientation in thocer layer is smaller



Fine scan of 333 reflections. Lattice constants and crystallites in-depth dimension [111] evaluated with Scherrer formula:

5 µm filtered	D_{111}=115nm	a= 4.9519 Å
10 µm unfiltered	D_{111}=141nm	a=4.9529 Å

QE measurement setup

Xe lamp 150 W $\Rightarrow$ 0.5 W in 200 – 210 nm

Czerny-Terner monochromator,

Optical fiber

picoamperometer, measures above 10 pA

Nd:YAG laser, 2nd harmonic: 25 mJ/pulse, 20 Hz, 10 ns

Turbo- and scroll- pumps give 10^{-7} mbar

QE measurement setup

Anode holder with an optical fiber and mirror

sample

Optical fiber

Faraday cup for breakdown

Sample holder rotates to enable laser cleaning

For breakdown measuremes, the distance between sample and anode can be adjusted with accuracy of 0.25 mm
HV pulse is 12.5 kV during 1ms
$\Rightarrow$ 50 MV/m

QE measurements

Mesurements

We need

- 50 pA at 200 nm while QE-10 $^{-5}$ → 30 μW of light on the sample
- 50 pA at 250 nm while QE-10 $^{-6}$ → 250 μW of light on the sample

We measured 20 pA (10 pA above the noise) while using white light and dirty sample

Next Steps:
clean the sample with laser
or with glow discharge
improve the transmission, mostly mirror reflection

Cleaning

- YAG harmonic 532 nm 5 mJ/ ($mm^2 \cdot$pulse) , 10 Hz ⇒ 0.05 W
- Excimer Kr 190 nm 10 μJ/ ($mm^2 \cdot$pulse) , 300 Hz ⇒ 0.003 W 2010
- 240 nm, 60 μJ/($mm^2 \cdot$pulse), 10^5 pulses 2015 (DESY& BNL)

Delivery D12.8

Optimised procedure for preparation of flat, clean and adherent Pb/Nb films

Delay

We are going to produce a number of Pb/Nb samples

- flattened down to roughness < 1 μm
- with QE measured higher than $1.5 \cdot 10^{-4}$ at 260 nm

For that we need to prepare cleaning with excimer laser. Unfortunately it will not be possible this year, so we will try to substitute it with Nd:YAG 2nd harmonics and look for other cleaning methodes

We expect to be ready about November 2016

Summary

- We reached the satisfactory flatness
- XRD studies
- QE measurements will be launched

  → cleaning capabilities
- QE measurements vs laser irradiation time (DESY, HZDR)