EUCARD^2 ; Sub-task 12.5.1 Pb photocathode deposition for improved performance of SRF guns

status in April 2014

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for NCBJ (in Świerk) group collaboration

Contents:

- Obligations: sub-task12.5.1
- Methods of upgrading thin-layer phtotocathode morphology
    - Non-filtered deposition + remelting
    - Filtered deposition
- Diagnostic stand
- Vacuum annealing

Obligation

Workpackage: WP12 Innovative RF technologies

Task: WP12.5 Photocathodes

Pb photocathode deposition for improved performance of SRF guns

deposition improvement, post-deposition treatment, Q and QE measurements

Milestone

MS80 Demonstrated operation of improved deposition system, Pb layers of 1-2 μm in thickness

M30

Report on samples characterisation NCBJ

Deliverables

D12.8 Optimised procedure for microdorplets flattening with an UV laser

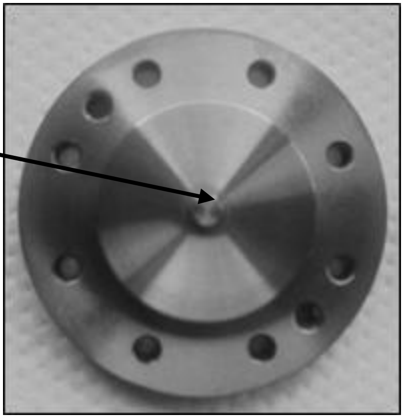
M36

Report NCBJ

D12.9 Pb/Nb plug photocathodes measurements and characterization.

M42

Report HZDR (+DESY + NCBJ)



Approach to Eucard 2

To improve Pb photocathode preparation

pre – deposition substrate preparation

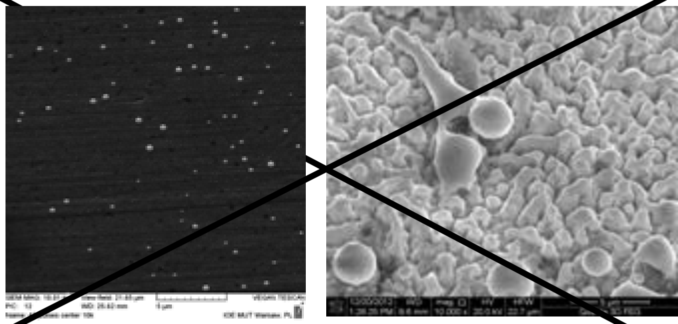
Deposition system reconstruction to find better compromise between thickness and low micro-droplets population

micro-droplets filter developement

MS 80

Post–deposition flattening:

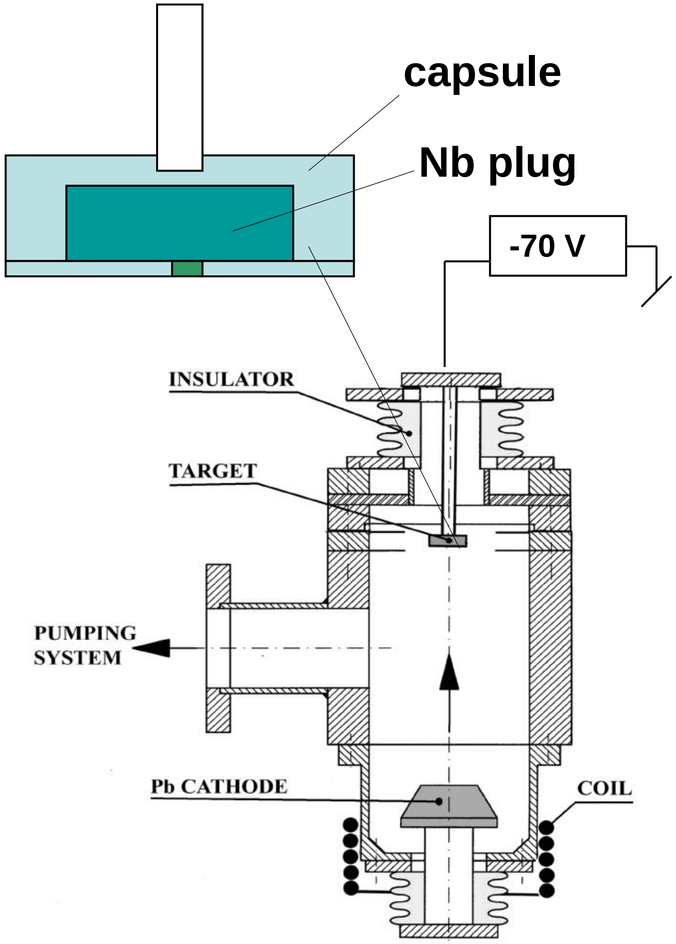
EUV irradiation- REJECTED

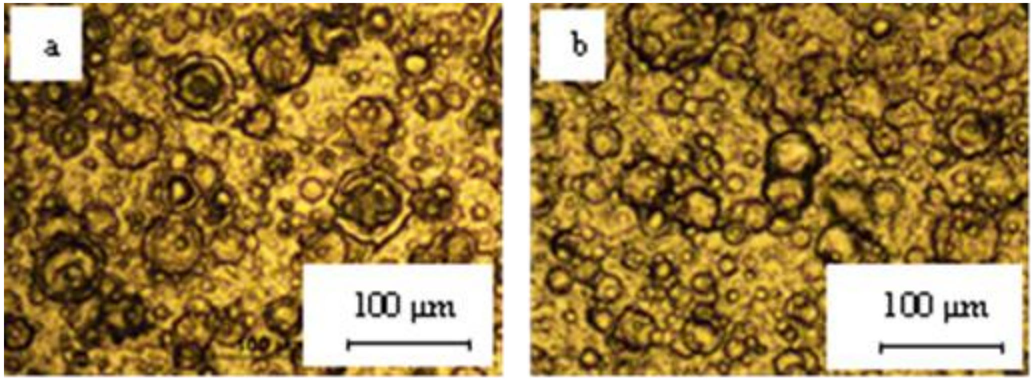


laser irradiation
plasma ion pulses irradiation
annealing

D12.8

First approach: lead deposition in a short non-filtered arc

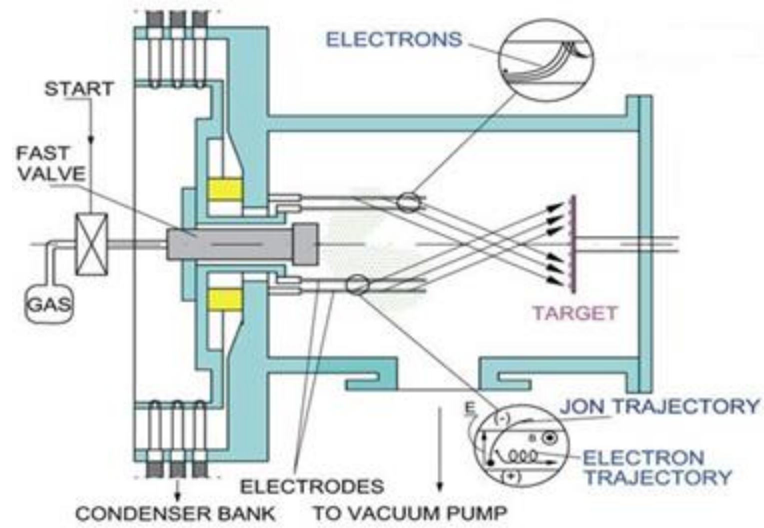


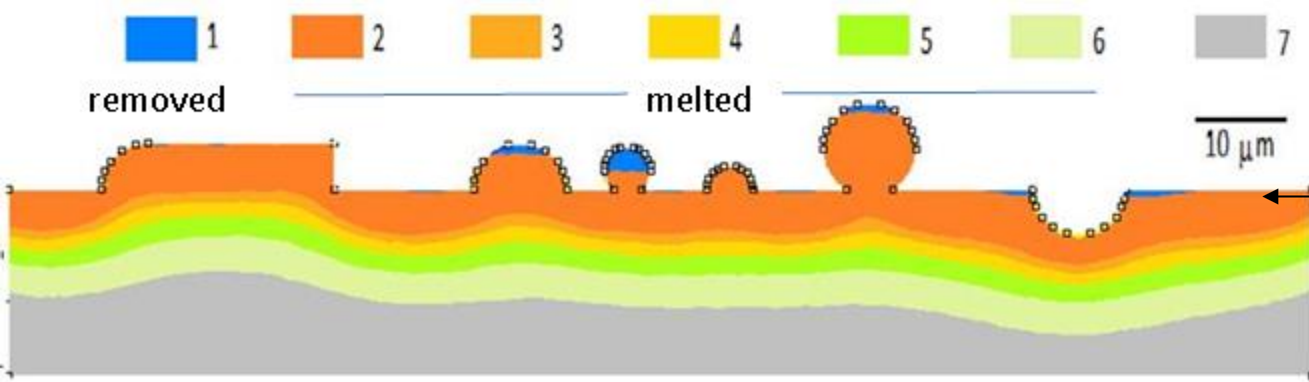


arc current 25 A, (pulse length 5-20 s.)
cathode-target distance 10 cm
substrate bias -70 v – energetic deposition
current to the target dens. ≈ 42 mA/cm^2
Pb deposition rate ≈ 3 μm/min
substrate: Nb, Pb sapphire samples
no droplets filtering – droplets density

First approach: melting and recrystalization with ion pulses

Plasma source: Rod Plasma Injector IBIS
The RPI-IBIS device was equipped with two coaxial electrodes composed of 32 thin metallic rods placed inside a vacuum chamber, which was pumped out to the background pressure equal to about 10^{-6} Pa. Before each discharge the inter-electrode gap was filled up with some amount of Ar injected by a fast acting valve. with a chosen delay advance to the discharge. During the discharge the working gas, after its ionization, was accelerated in the injector and emitted along the z-axis towards Pb/Nb target in a form of an intense plasma-ion stream.



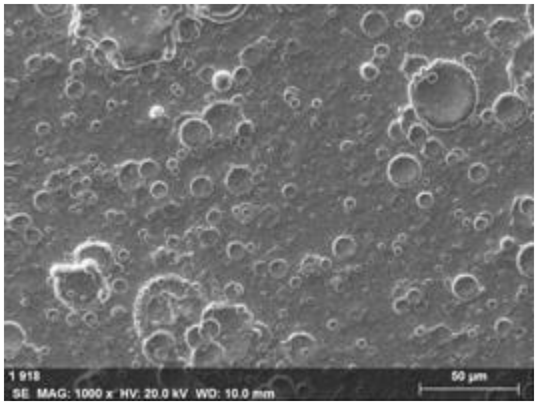


Heat transfer evaluation by FEM for typical arc deposited film surface morphology:
- **single 3 J/cm² pulse removes lead from droplets but not from the flat surface**
- **melts c.a 10µm in depth**

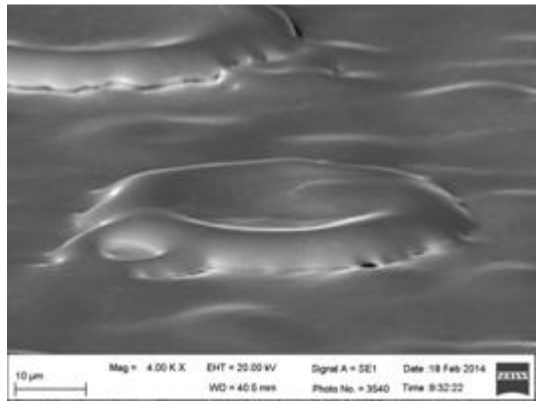
First approach: melting and recrystalization with ion pulses in practice

UHV arc deposited 2 µm thick Pb layer on EP niobium substrate (RRR>300):

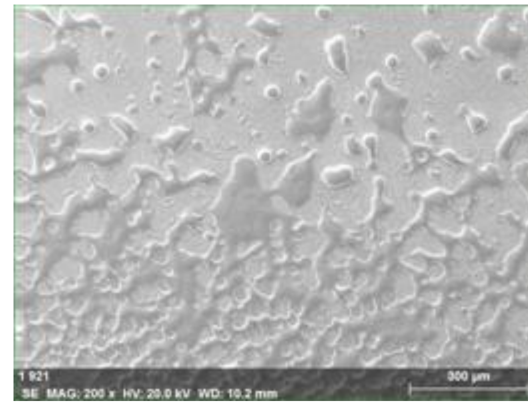
deposition



exposed to 6 Ar^{+}pulses 1.5J/cm^2



exp. to 3 pulses 2.5 J/cm^2



Remelting and flattening of extrusions on the surface of a Pb layer with low-fluency 1.5 J/cm^2 ion pulses is effective only for extrusion smaller than ≈ 20 µm. After applying ion pulses of 2.5 – 3 J/cm^2 fluency the layer is melted completely forming a non-uniformly spread „labirynth" with most of the Nb surface deprived of lead. It results from poor niobium wettability with molten Pb.

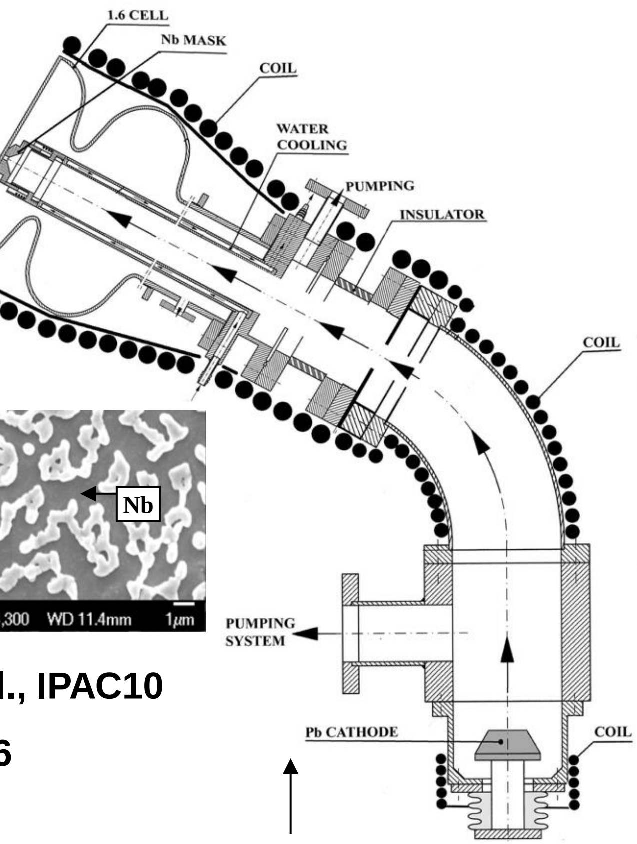
Considered remedies - improving Pb to Nb adhesion by preliminary treatment in the IBIS RPI:

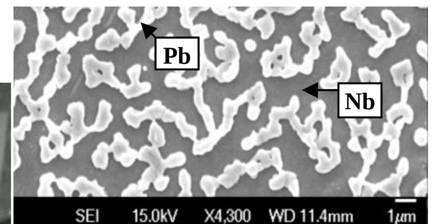
- introducing Pb ions from rod electrodes into Nb substrate and remelting

- Pb ions implantation into a Nb substratr, creating an intermediate layer

Second approach: Pb deposition in UHV arc with droplets filtering

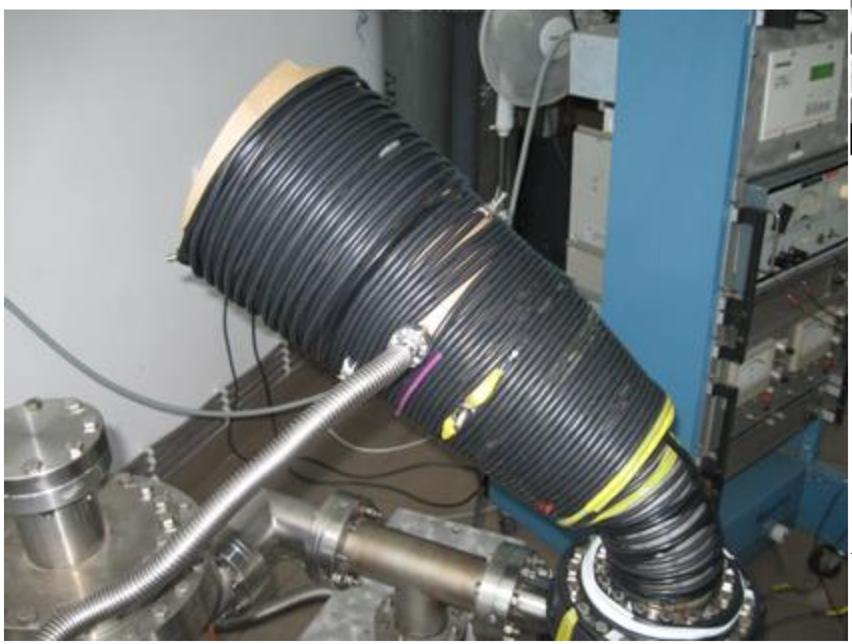
Angular magnetic filters designed to remove droplets from plasma stream before deposition. Metal plasma is guided by axial magnetic field along a curved plasma duct. Most of the droplets strike the duct wall due to high mass-to-charge ratio. Some of them are dissipated and reach the target.





Rao T. et al., IPAC10

(2010) 4086



Example: UCARD 2009:

filtered UHV arc system used for Pb photocathode deposition directly on the back wall of a 1.6 Nb cell It resulted in thin (100 nm) layer of poor adhesion (no energetic deposition possible, no neg. bias of target).

Second approach: Pb deposition in UHV arc with droplets filtering

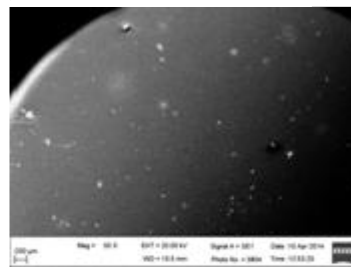
Using UHV arc lead deposition with 30^0 angular filter, extended plasma duct and movable, negatively biased target. Optimization of target position to reach flat layer at sufficient deposition rate.

SEM images of Pb/Nb layer coated at different target positions

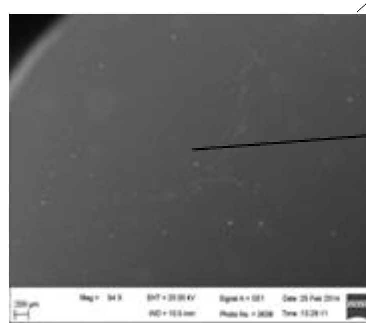
Arc current: 15 A
Arc pulses: 20 s
Layer thickness: 2 µm

Dep. time 1000 s., ≈ 5 prticles/mm^2,
Peeling products up to 120 µm

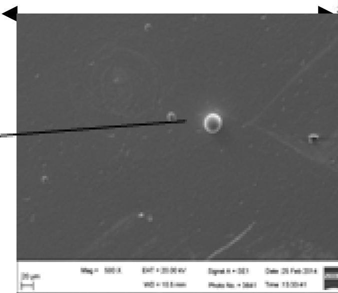
6 mm



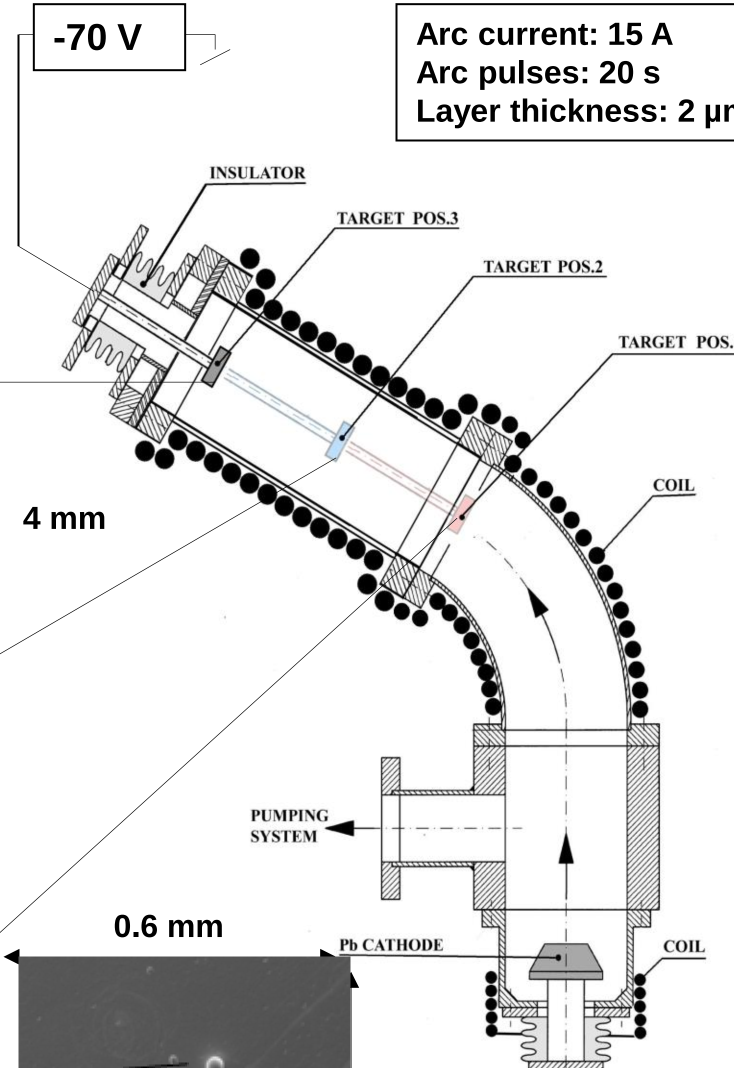
4 mm



0.6 mm



0.4 mm



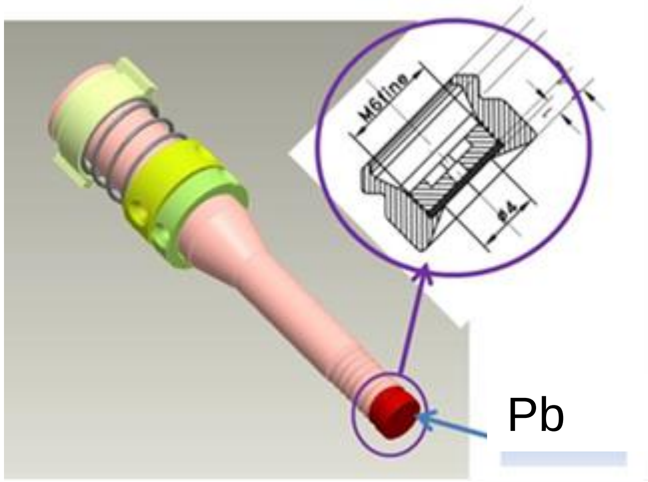
20 keV EDS results (SEM):

Pb:	92.9 wt %
Nb:	4.4 wt %
C:	1.8 wt %
O:	0.9 wt %

Dep. time 800 s.,
5 prticles/mm^2,
10 µm < drop size < 20 µm

Dep. time 660 s.,
8 prticles/mm^2,
10 µm < drop size < 40 µm

Pb/Nb thin layer photocathodes at HZDR



HZDR: four Nb plugs has been
- **fabricated**
- **polished and cleaned**
- **sent to NCBJ Swierk for Pb deposition**

NCBJ: the Nb plugs were Pb UHV arc deposited up to 2 μm using 30^0 angular droplets filter. One of the plugs was additionally treated with three 1.4 J/cm^2 Ar^+ pulses in the IBIS rod plasma injector. The plugs were sent back to HZDR for tests in ELBE SRF gun (black current and QE). The results are not known yet.

Pb/Nb photocathodes diagnostic stand at NCBJ is being developed

Photocathode diagnostic stand (schematic):

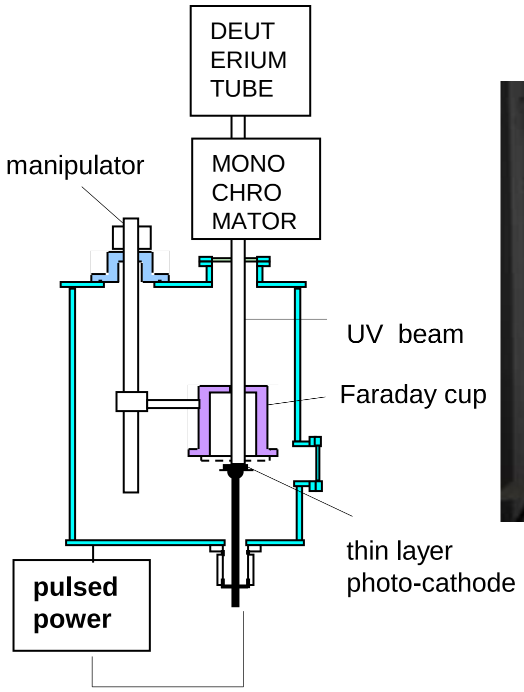
-planned: photocathode, Faraday cup with transparent mesh anode, integrated deuterium tube + monochromator;

-possessed: UHV chamber

- ordered: FC and photocathode manipulators

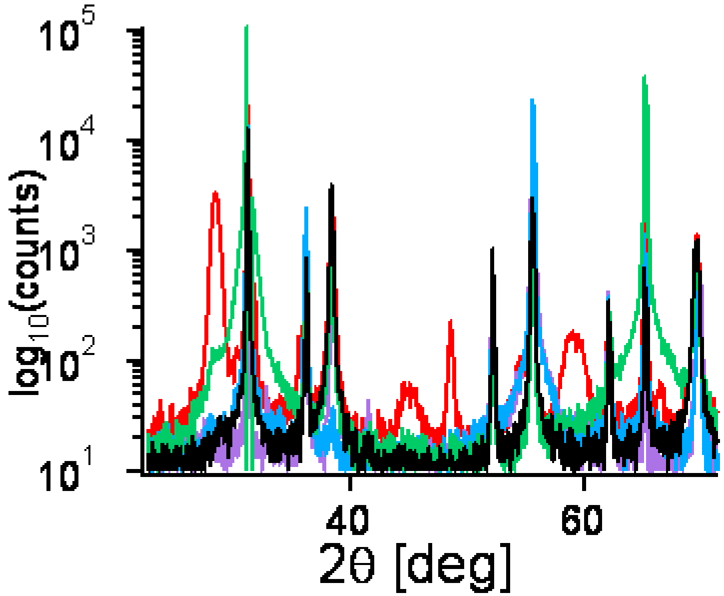
-high voltage pulsed power supply (preliminarily tested);

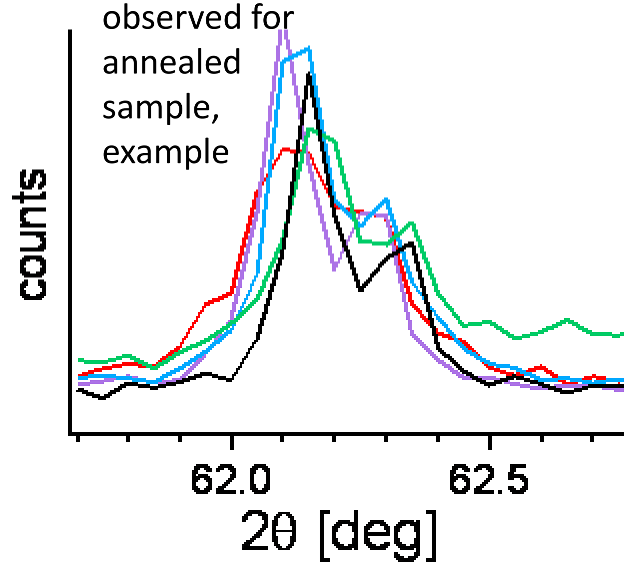
Diagnostic stand schematic



12.5 kV pulsed power supply

Post- deposition treatment – vacuum annealing





X-ray diffraction on Pb/Nb layers treated with various plasma pulses and with long time annealing (black curve):

- strain relaxation with annealing only,
- various surface orientations preffered

It comes from XRD measurements and heat calculs that pulse melting and recrystallization do not remove the strains induced during an arc deposition, this can be done by long time annealing.

Publications 3013

1. R. Nietubyć, J. Lorkiewicz, R. Mirowski, M. Barlak, J. Witkowski, J. Sekutowicz
Recent development in optimization of superconducting thin film lead photocathodes at NCBJ Świerk
Proc. SPIE 8903 (2013) 89032B

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2. J. Lorkiewicz, R. Nietubyć, M. Barlak, R. Mirowski, A. Bartnik, J. Kostecki, J. Sekutowicz, A. Malinowska, P. Kneisel, J. Witkowski
Deposition and optimization of thin lead layers for superconducting accelerator photocathodes
Physica Scripta T (in press)

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Thank you !