AWA Test Gun for Novel Superconducting Photocathode Research

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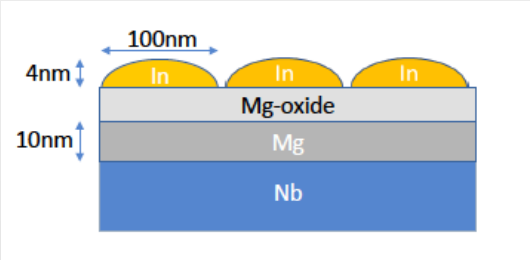
Basic Idea – Ultra thin-film coatings to increase QE of Nb but minimize additional RF losses

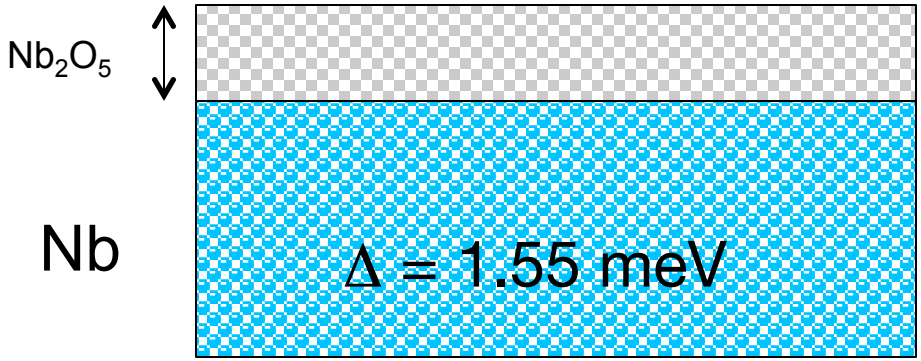
1. Superconductor/Semiconductor
   - Nb/Cs_2Te *AWA/Argonne* *Yusof et al, PHYSICAL REVIEW ACCELERATORS AND BEAMS 20, 123401 (2017)*

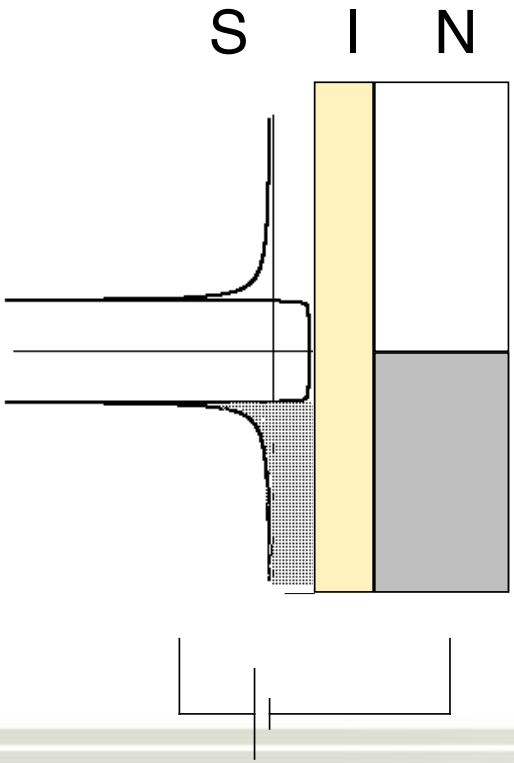
2. Superconductor/Metal Nb/Mg
   - Exploit Proximity Effect
   - Lower work function of Mg (3.66 eV)
   - Plasmonic Enhancement
   - >400 X increase in QE
   - Robust in air!

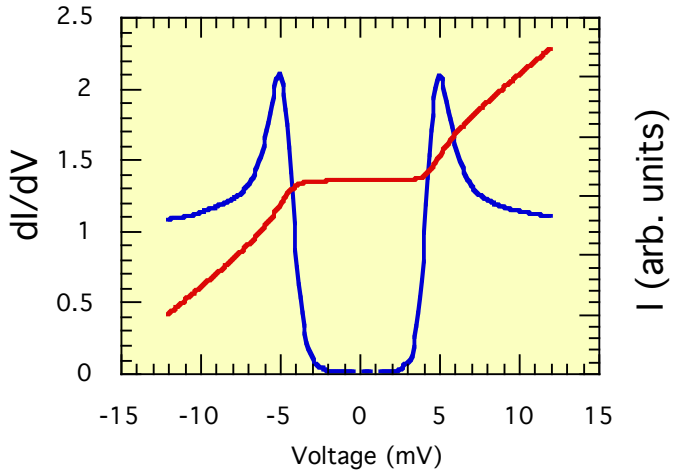


Superconducting RF Impedance

$$R_s \propto \lambda_L^3 \, \omega^2 \, l \exp\left[-\frac{\Delta(T)}{kT}\right]$$







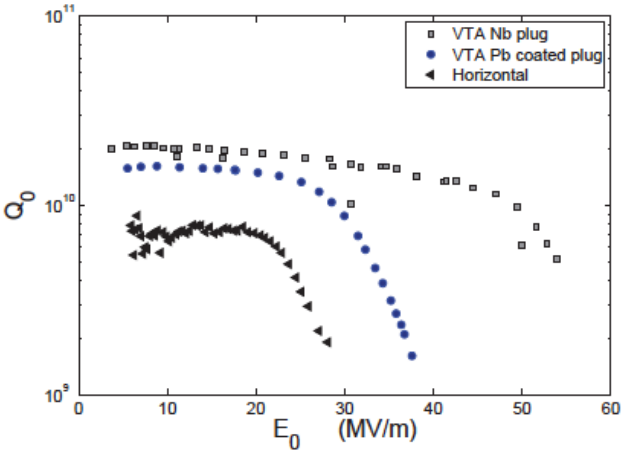
SRF Linac and Photoinjector

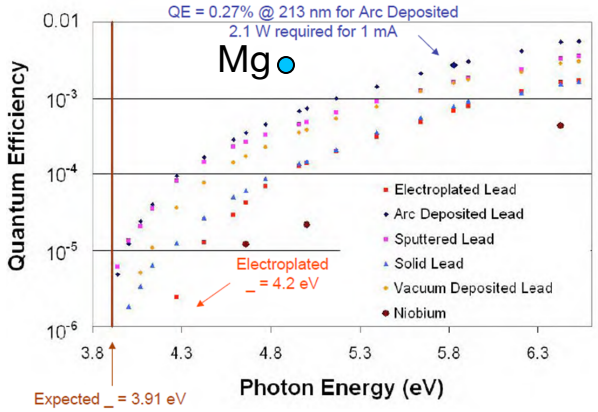
MOIOB02 Proceedings of SRF2013, Paris, France

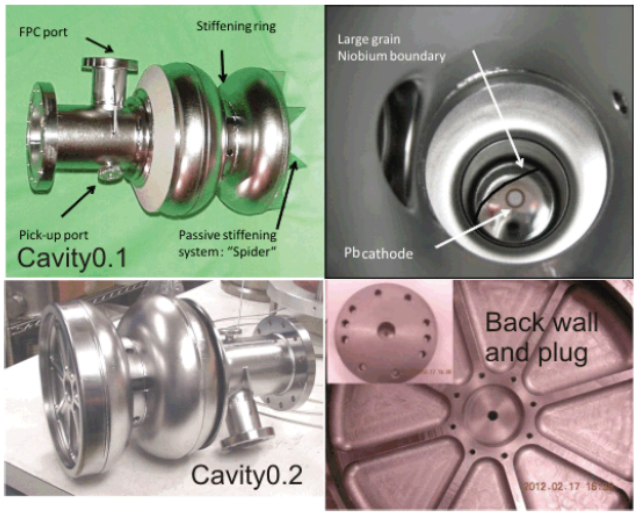
TOWARDS A 100mA SUPERCONDUCTING RF PHOTOINJECTOR FOR BERLinPro *

Neumann et al, HZB Berlin

Superconducting Pb Cathodes



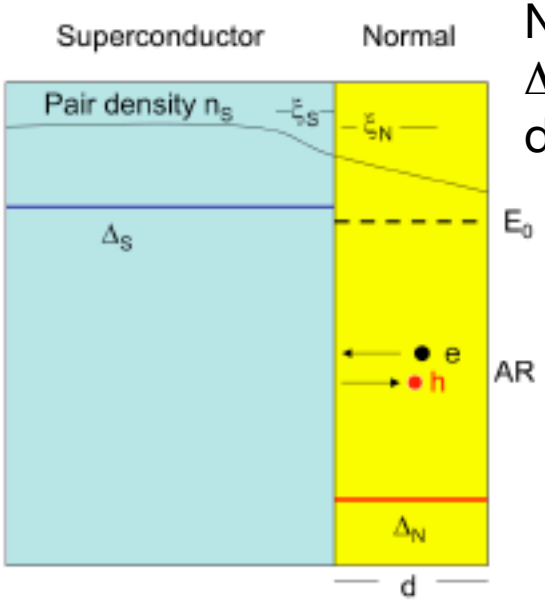




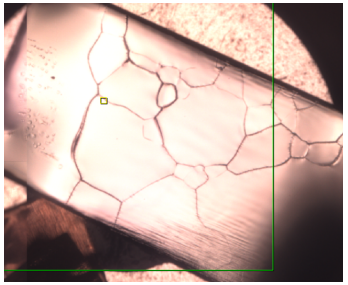
Nb/Mg Proximity Bilayers

D.M. Burnell, E.L. Wolf (JLTP 58, 61 (1984)

E.L. Wolf, J. Zasadzinski, J.W. Osmun and G.B. Arnold, "Proximity Electron Tunneling Spectroscopy I. Experiments on Nb", Journal of Low Temp. Physics, 40, 19 (1979)



Nb gap observed
Δ = 1.55 meV
d_{Mg} = 125 Å



Recrystallized Nb Foil

Mg QE ~ 0.2%

Nb/Mg/MgO/Ag

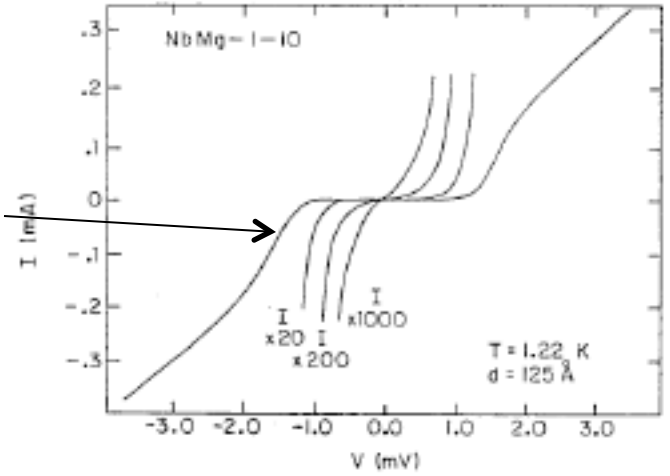
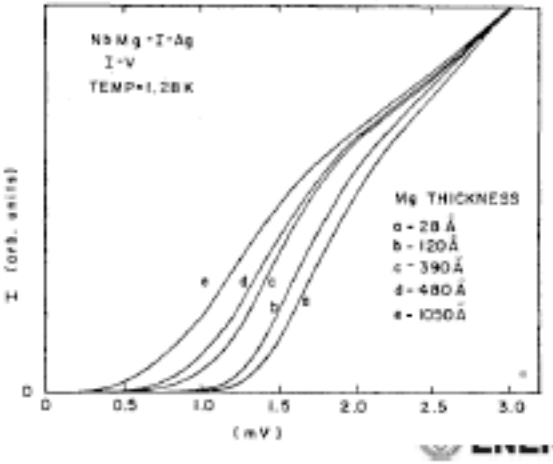
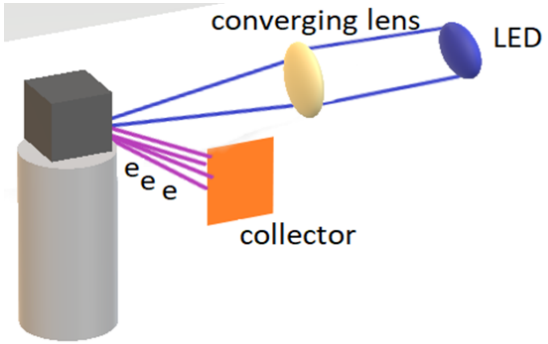


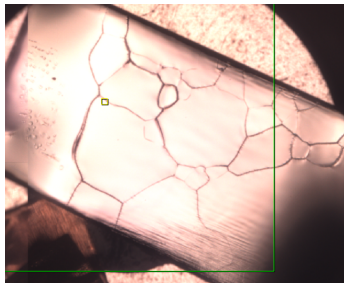
Fig. 1. Representative gap region I–V characteristic for Ag–Mg–Nb junction of Mg thickness 125 Å measured at 1.2 K. Expanded traces indicate that the current leakage is less than 1/1000.

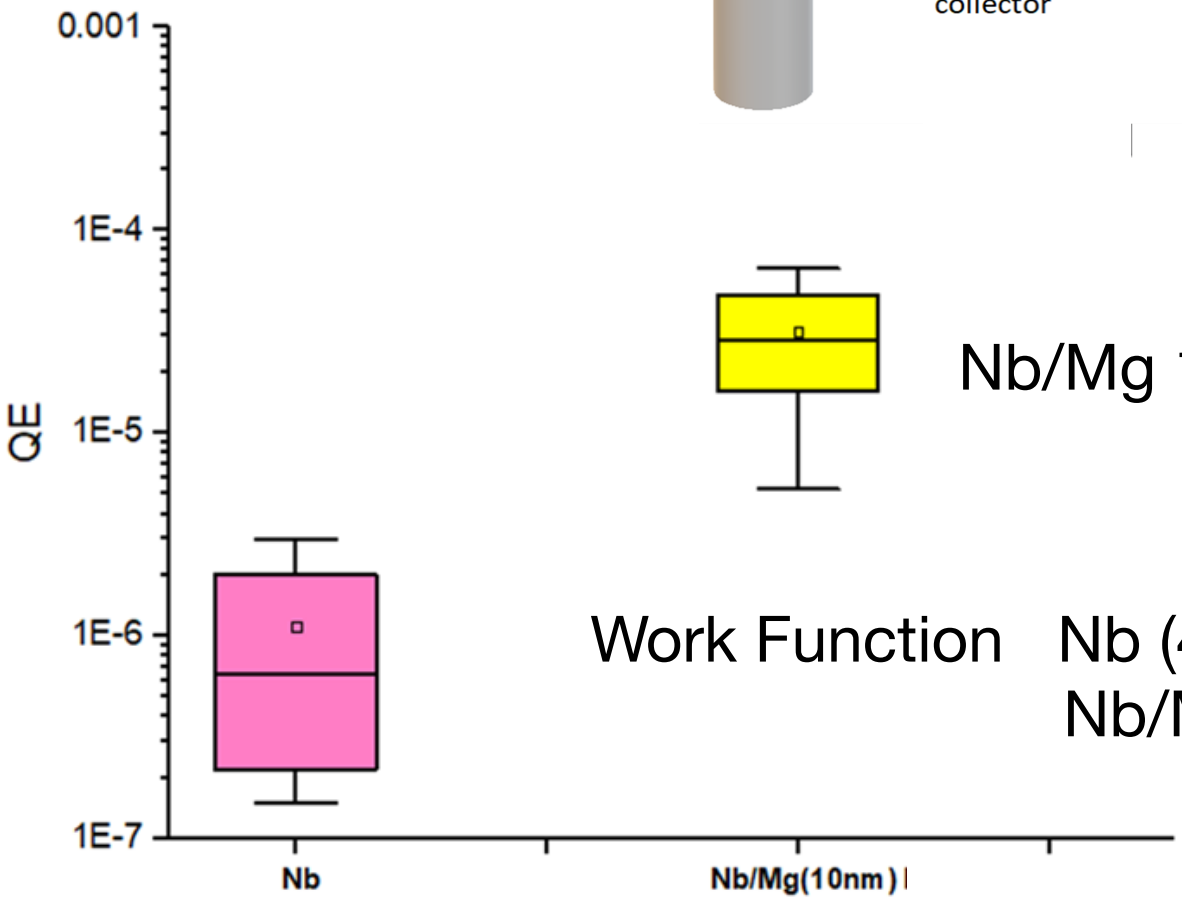


Nb Foil Results

LED 248 nm 1mW



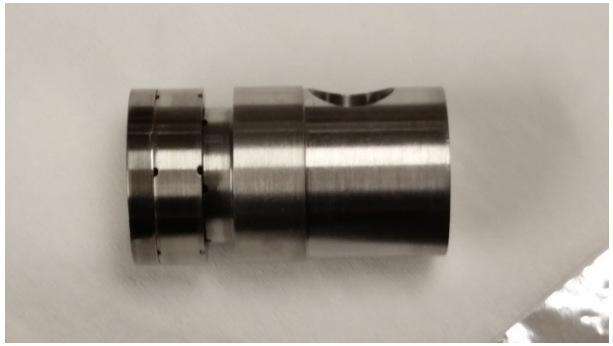


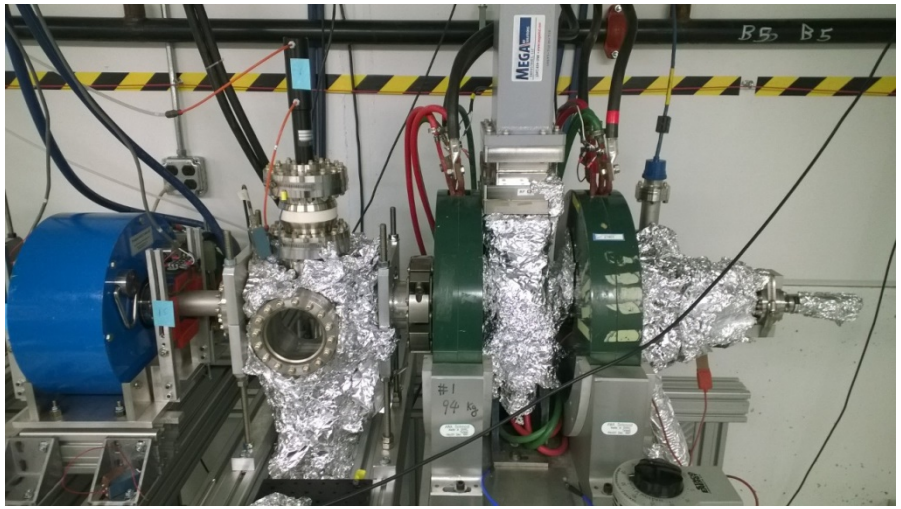


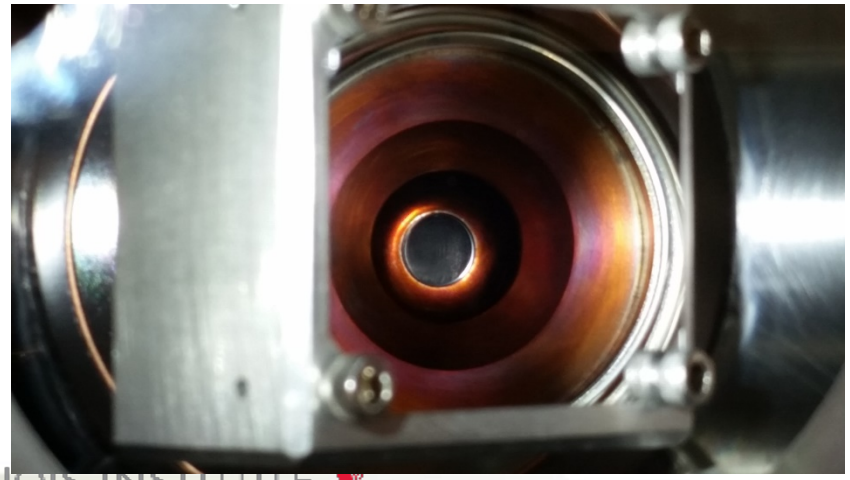
Nb/Mg 10nm

Work Function Nb (4.1 – 4.6 eV)
Nb/Mg (3.8 – 3.86 eV)

Nb Cathode Insertion into AWA test stand (12/7/2015) (M. Warren IIT PhD Thesis, SCGSR)

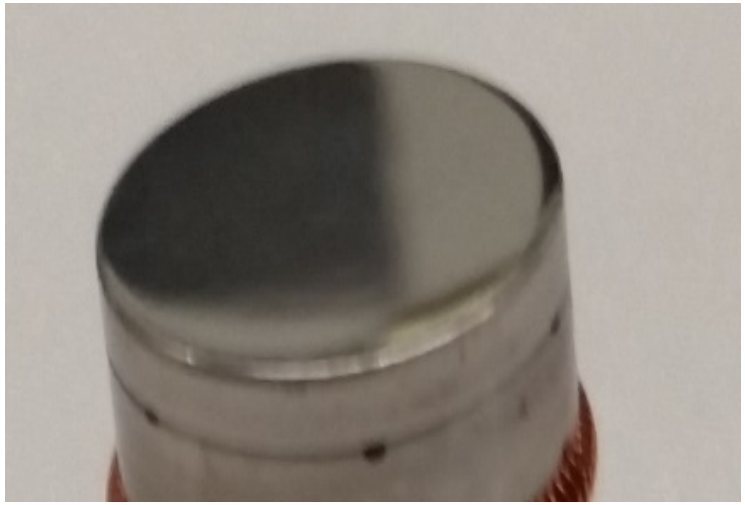






Bulk Nb Plug (mechanical polish, 600C anneal UHV)

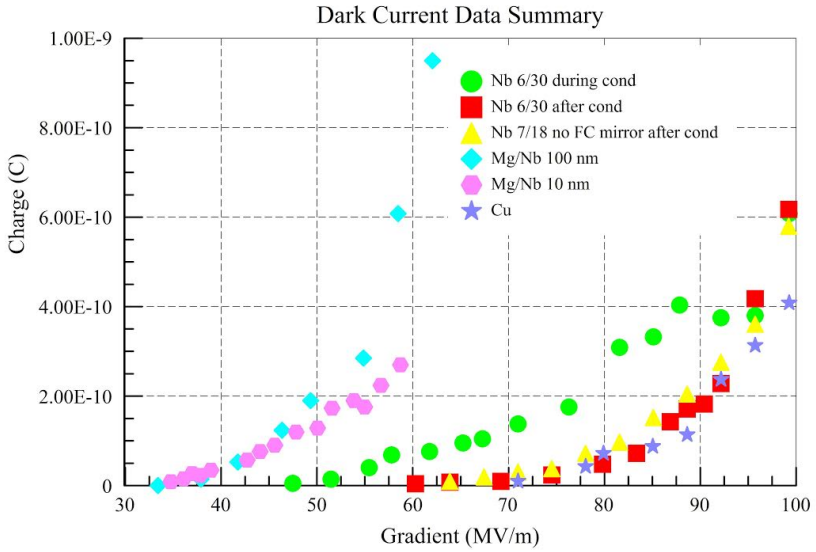
100 nm Mg Before/After

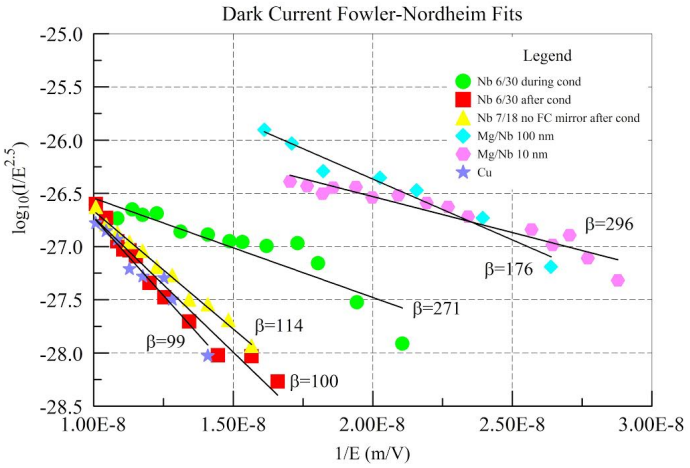


RF Test Gun

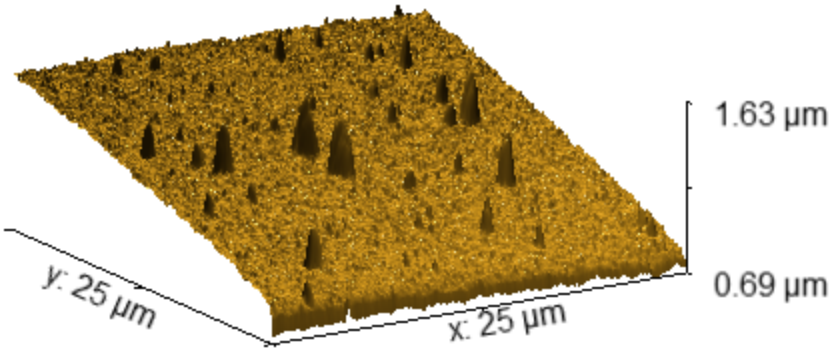
Dark Current Results for Nb and Nb/Mg

Two thicknesses (10 nm, 100 nm)





AFM Topography of Nb/Mg (10 nm)

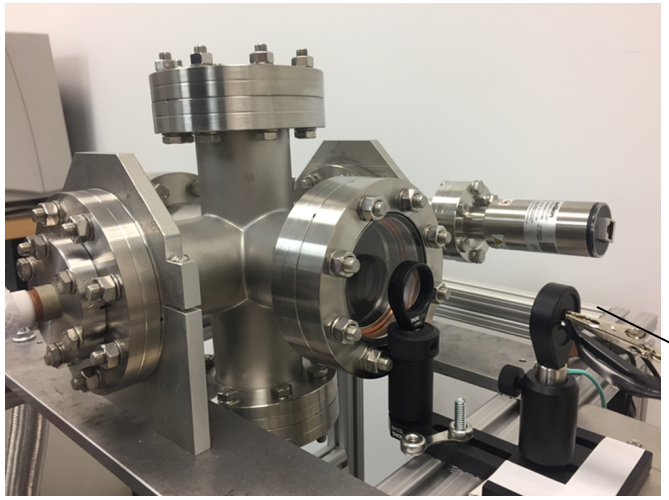


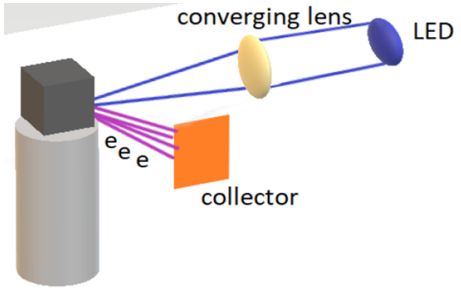
High Field enhacement, β, likely due to surface roughness (field emiiters)

Plasmonic Enhancement of QE of Niobium

(Shokoufeh Asalzadeh)

- Ag, Au, In thin films (PVD) on Glass, Sapphire
- Controllable Island formation
- Islands measured by SEM, AFM, STM
- Plasmon resonances in Transmittance, Reflectance
- Strong enhancement of QE at 250 nm using In films





UV LED 248nm

In on Sapphire: Nano Island Growth

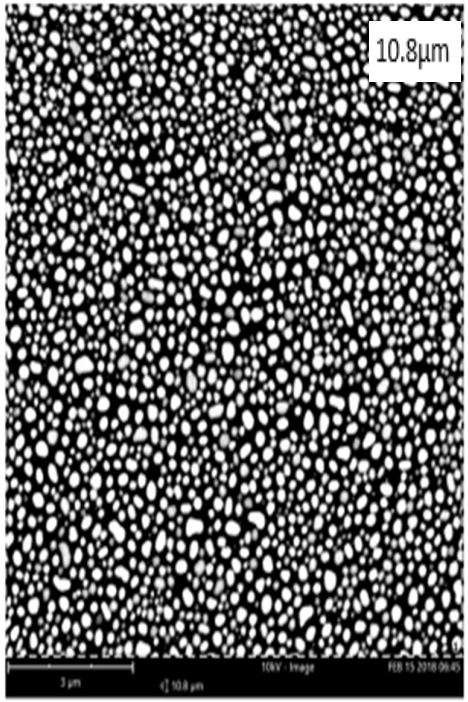
SEM

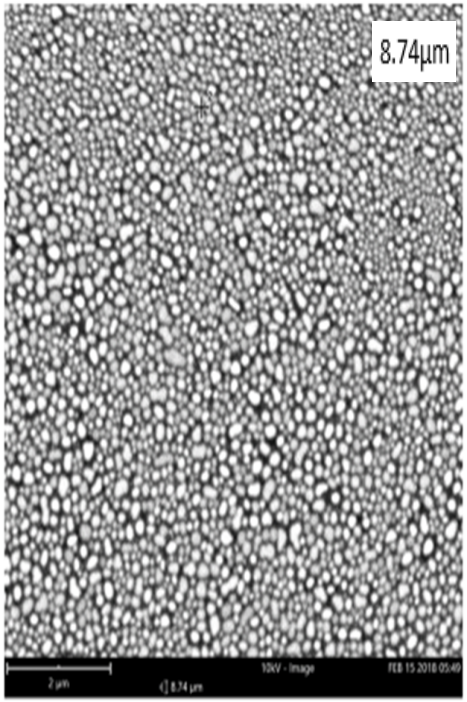
AFM

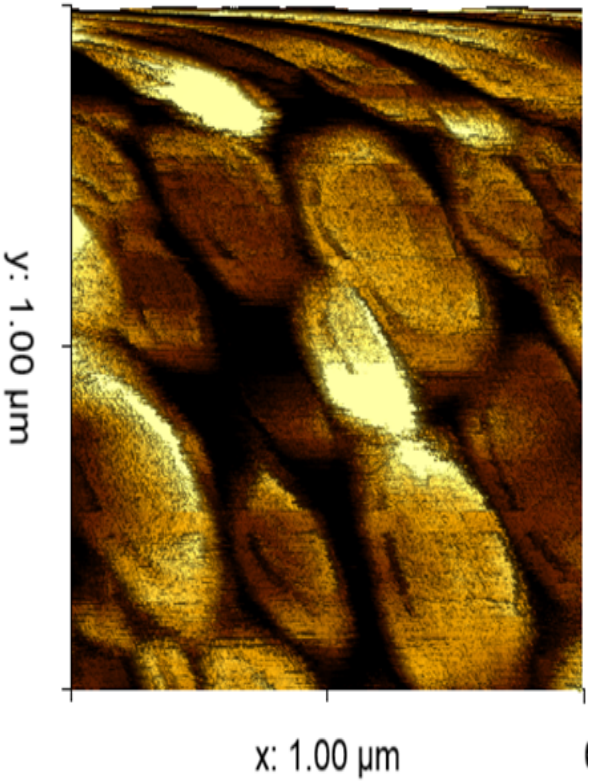
Thickness 200 A

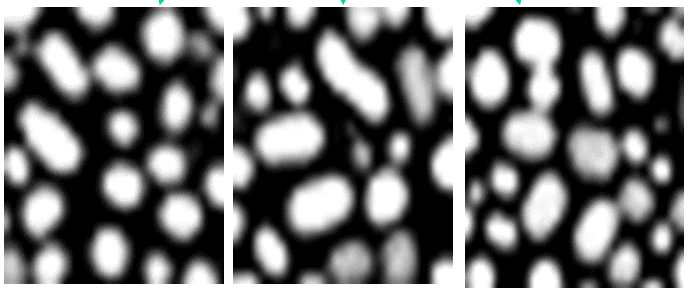
150 A

200 A





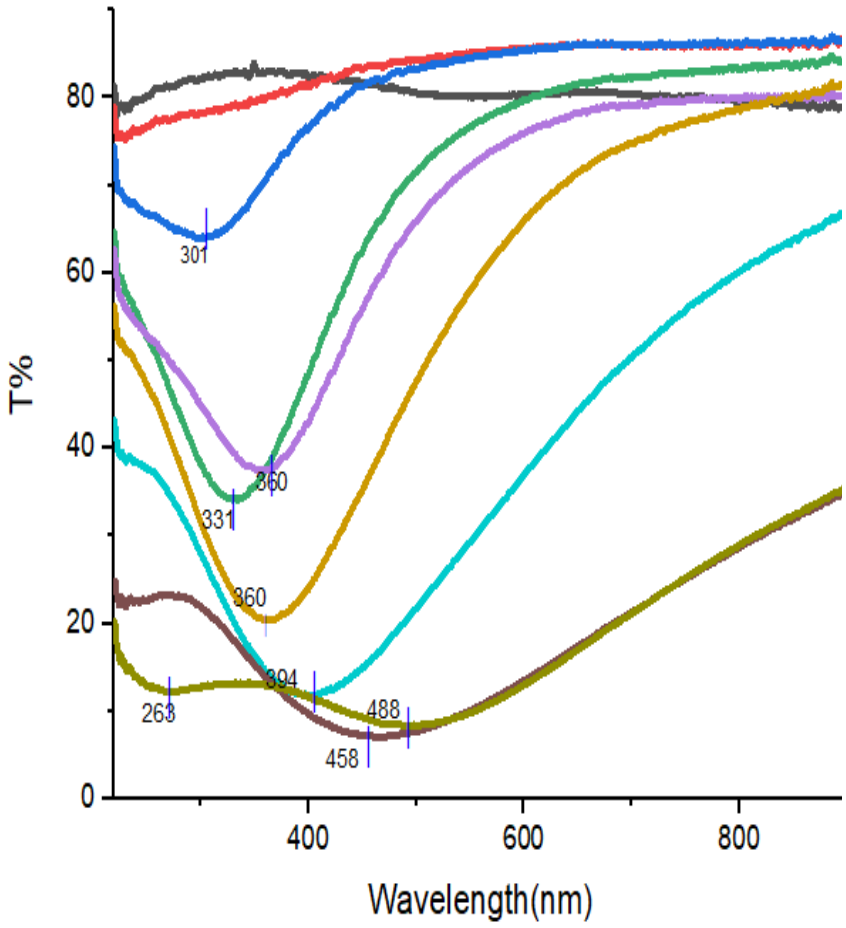


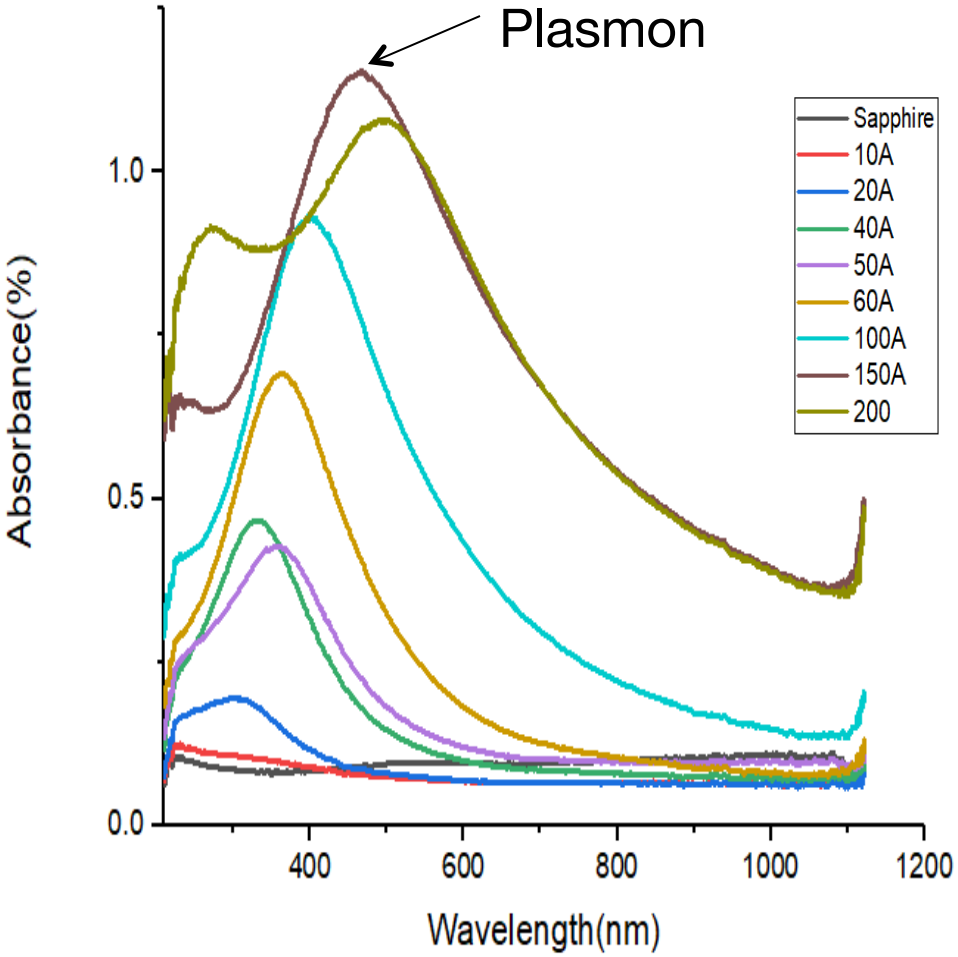


Island Diameter >> Thickness

Optical Transmittance/Absorbance of In/Sapphire

Surface Plasmon Mode Tunable with Nominal Indium Thickness

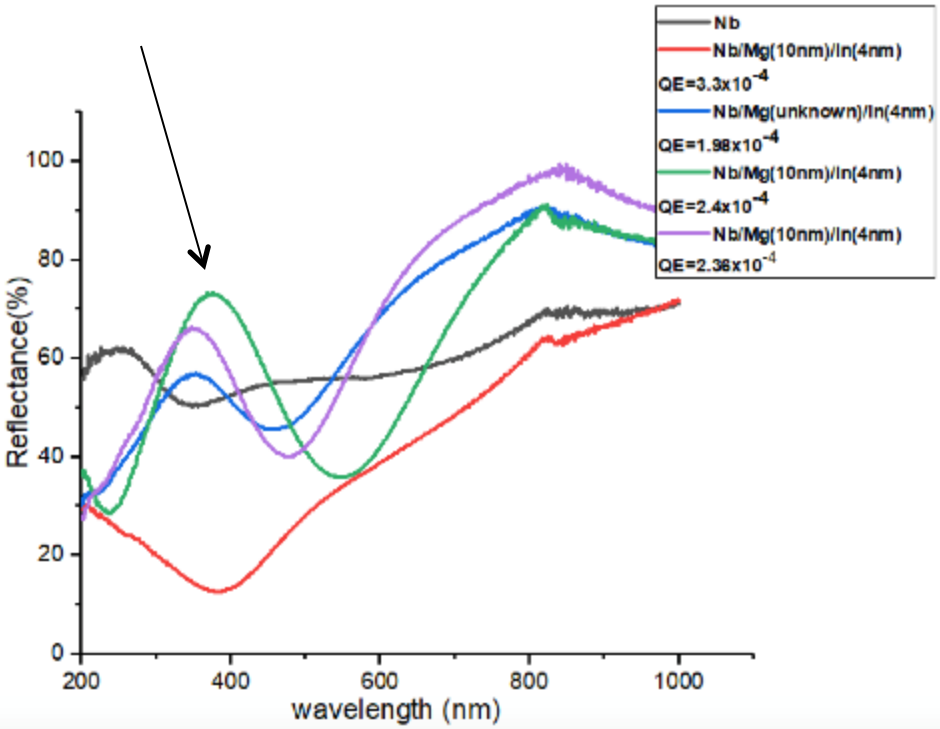




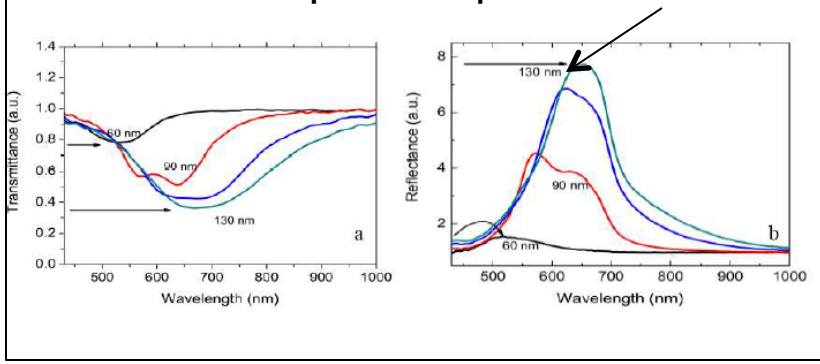
Reflectance

Nb/Mg(10nm)/MgO/In(4nm)

Reproducible Plasmon Mode

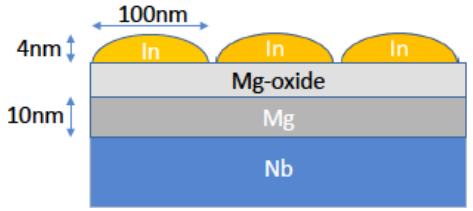


Ag nanoparticles on glass
Reflectance peak is plasmon

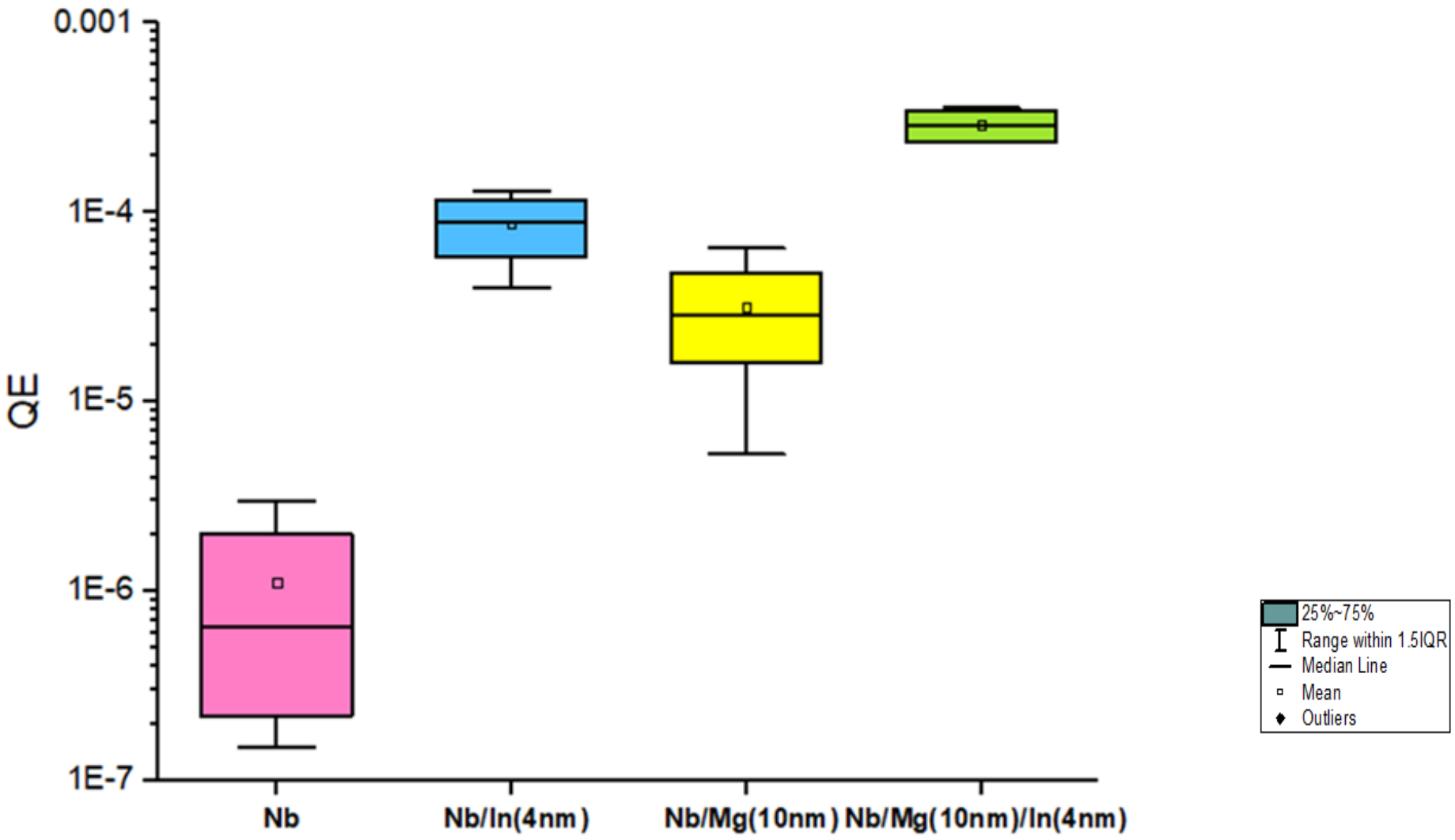


Article *in* Optics Express · August 2010

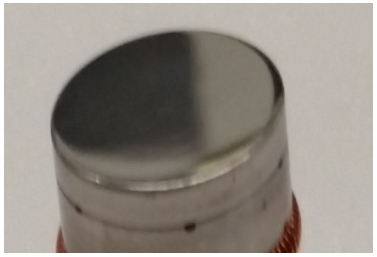
DOI: 10.1364/OE.18.017322 · Source: PubMed



QE results


0.001
1E-4
1E-5
1E-6
1E-7
QE
Nb
Nb/In(4nm)
Nb/Mg(10nm)
Nb/Mg(10nm)/In(4nm)
25%~75%
Range within 1.5IQR
Median Line
Mean
Outliers

Summary/Future Work



- Nb/Mg Single Crystal
- Polished ~25 nm RMS roughness
- QE high fields ~ 50 MV/m
- Emittance

Mg Crystal
QE ~ 0.3% after laser Cleaning. Remove MgO

MOPIK003 Proceedings of IPAC2017, Copenhagen, Denmark

IMPROVEMENT OF PHOTOEMISSION EFFICIENCY OF MAGNESIUM PHOTOCATHODES

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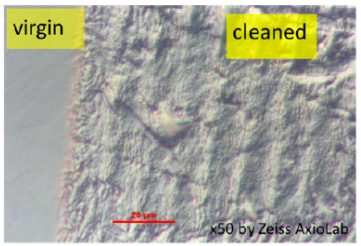
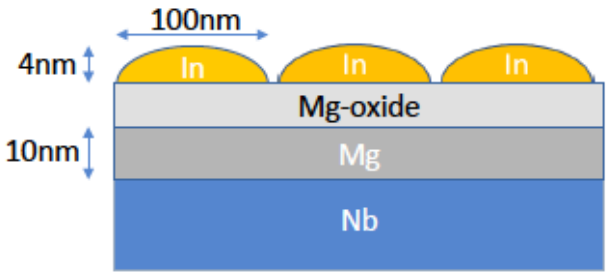


Figure 5: Surface structure changes after cleaned with high intensity laser.

Plasmonic Enhancement



Resilience of In Islands
QE at high fields
Explore tailored plasmonic structures, e.g.uniform disks