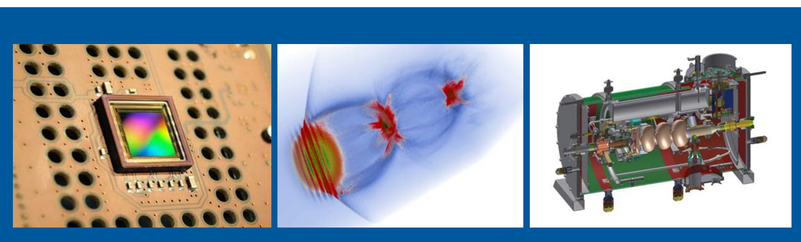
Programme Matter and Technologies

From Alchemy to Understanding – Photocathodes for High Brightness Electron Sources



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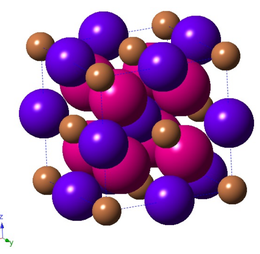
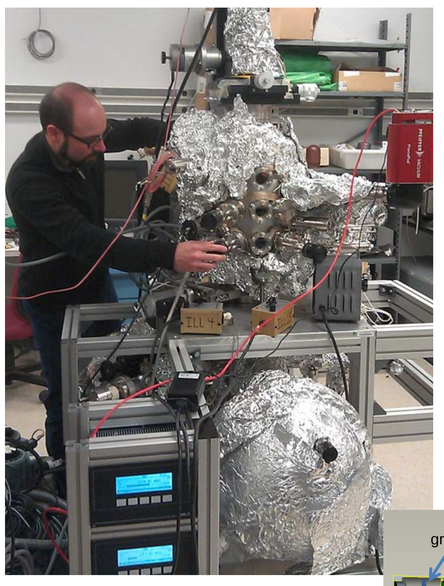
ARD – ST1 Superconducting RF Science and Technology

Photoelectron emission from laser driven photocathode embedded in SRF cavity allows generation and acceleration of high brightness electron bunches.

- Prime candidate materials for photocathodes are multi-alkali antimonides like CsK_2Sb or Na_2KSb.
- By understanding the growth and properties of these materials optimization is possible towards excellent performance in the SRF gun environment.
- Therefore a variety of materials and surface science tools on todays synchrotron light sources are used to enable the next generation particle accelerators.



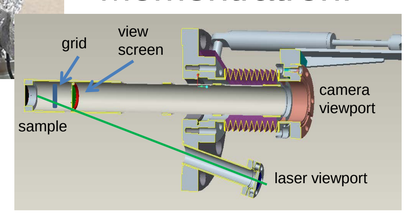
CsK_2Sb structure : brown- Sb, blue – K, purple-Cs.



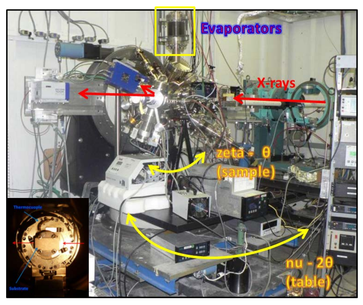
Preparation chamber:
Four evaporation sources, mass spectrometer, two quartz crystal microbalances, photo current meter, and sputter gun for substrate preparation

Analysis chamber:
XPS, LEIS, energy analyzer for chemical composition, depth profiling, surface composition, deposition rate, spectral response.

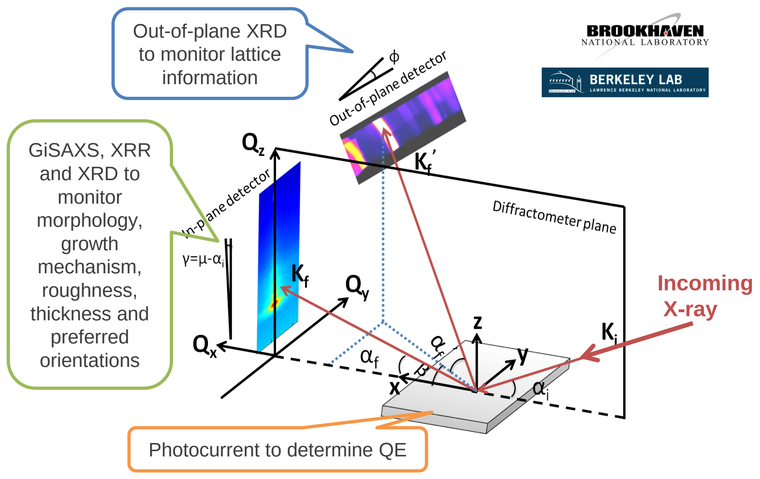
Momentratron: Transverse energy distribution of photoelectrons → intrinsic source emittance.

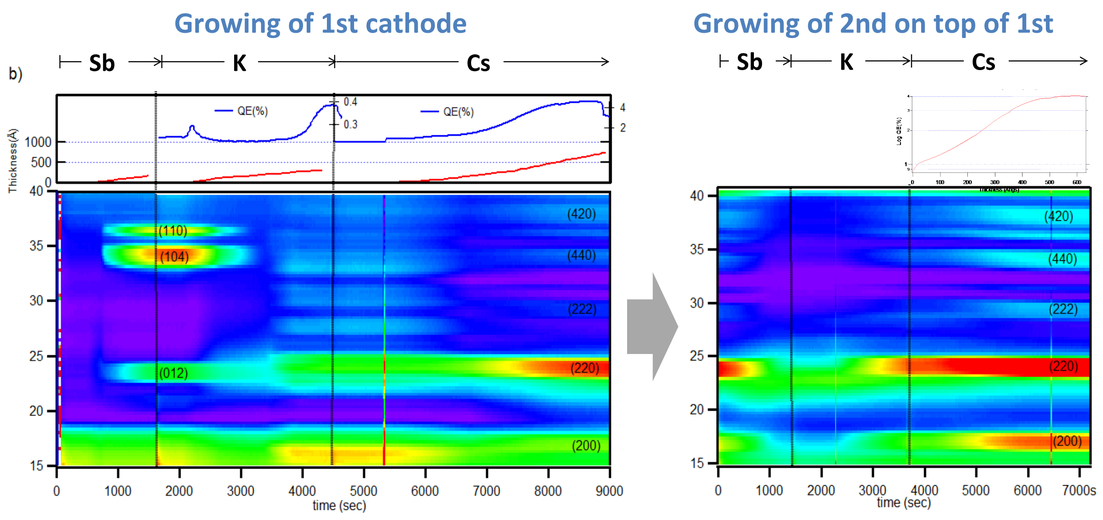


Understanding the growth mechanism, function of the individual materials, and bulk crystal structure with X-Ray Diffraction (XRD) measurements. A collaborative effort with US labs at BNL.



X21 experimental setup at NSLS/BNL and CHESS/Cornell





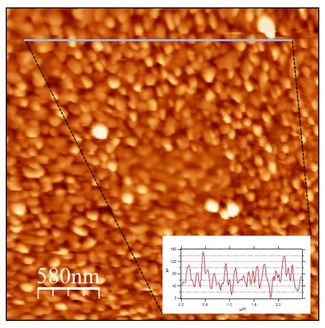
- XPS studies allow to look into the chemical composition of the surface and bulk of the photocathode material → the surface is Cs enriched with a stoichiometry close to Cs_2KSb.
- XRR gives average roughness, measuring the height difference of the particles on the surface, not sensitive to properties of single emitters → field emission measurements.

Goal is to understand correlations between photocathode growth and electron bunch properties after photoemission, and to study limits from unwanted beam generation.

- Setup of UHV photocathode preparation and analysis chamber for high quantum efficiency photocathodes including load-lock for UHV cathode transfer.
- Combined growth and analysis experiments at synchrotron radiation source beamline.
- Beam tests in high brightness SRF gun test facilities at GunLab/BERLinPro (HZB) and ELBE (HZDR).

UHV-AFM:

- Measurement of the film morphology after deposition.
- Surface shows rms roughness of 25 nm.
- ➢ In electron gun with gradients > 3 MV/m this roughness would be the dominate intrinsic source of emittance.



Collaboration with industry (Photonis):

- Multi-alkali antimonide cathodes commonly used in PMTs.
- Photonis interested in XRD analysis and layer-by-layer growth procedure.
- Current Photonis cathode has reliable high QE (4.6% at 532nm) but exhibits rough surface.

New preparation approaches:

- Preparation of sputter targets from powder, prepared from stoichiometric mixture of the elements (yield 96%).
- Sputtered films are expected to show lower surface rougness than evaporated films.

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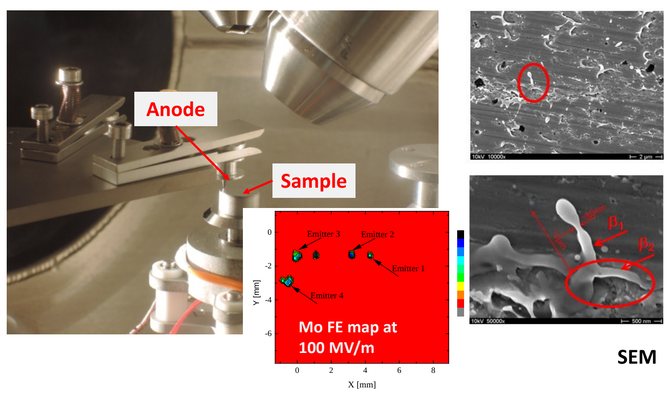
Field emission (generating unwanted beam) from single emitters or surface structure is a fundamental limit for operation of electron gun: dark current, particle losses and multipactoring sources.

- FE setup and field emission scanning microscope experiments to learn about FE sources and strategies to mitigate FE.



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FESM: study surface morphology and chemical composition of emitters with SEM and EDX. Investigate effect of dry-ice cleaning and heat treatment.

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People involved:
S. Schubert, T. Kamps, R. Barday, A. Jankowiak, G. Klemz, J. Knobloch, E. Panofski, M. Schmeißer, J. Völker (HZB), C. Brau, B. Choi (U Vanderbildt), S. Lagotsky, G. Müller (U Wuppertal), M. Ruiz-Oses, J. Smedley (BNL), J. Teichert, R. Xiang (HZDR)

Key publications:

S. Schubert, et al., APL Materials 1, 032119 (2013)
R. Barday, et al., Phys. Rev. ST Accel. Beams 16, 123402
T. Kamps, et al., arXiv:1307.1571 [physics.acc-ph]

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