EuroFEL: Workshop on Photocathodes for RF guns – SUMMARY

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Talks (1)

- F. Hannon: A Summary of the 2010 Photocathode Physics for Photoinjector Workshop (was 1st)
  - Goals: Share documentation; learn from predecessors
  - Participants mostly from North America and Europe – non from China (Omittance, because of strong developments in photomultiplier etc. business there)
  - Good PC summary: D. Dowell et al. NIM A622 (2010) pp. 685-697
  - Conference slides: https://indico.bnl.gov/conferenceDisplay.py?confId=290
  - Discrepancy between theory and experiment (up to factor 2) $\rightarrow$ go beyond three step model
  - New ideas:
    - Cathode coating to lower work function and improve laser transmission, e.g. MgF_2 on Cu. Also: K. Nemeth et al. Phys. Rev. Lett. 104, 046801 (2010)
    - Optical enhancement (plasmons, nanostructures …)
- Next workshop: 2012 at Cornell

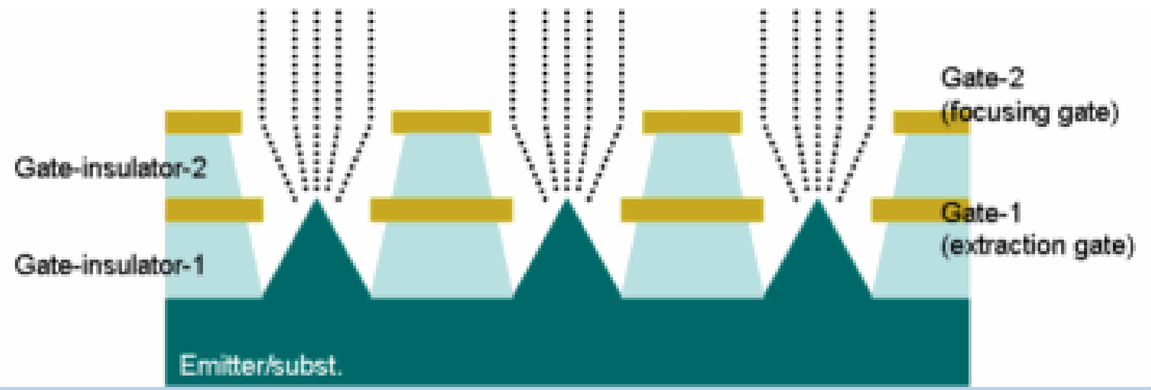
Talks (2)

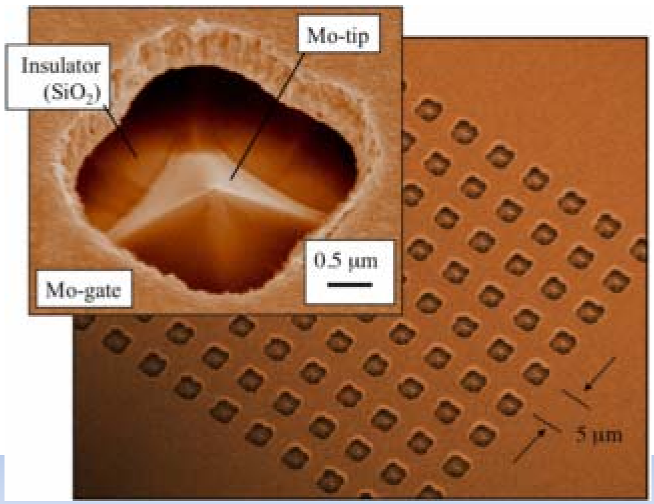
- L. Cultrera: Overview of photocathodes for high brightness beams
  - New idea for high-current sources: Diamond window amplifier – X. Chang et al. Phys. Rev. Lett. 105, 164801 (2010)
  - Metal photocathode: Laser cleaning (focused beam), H-ion bombardment, ozone
  - Coating to increase QE: thin film of wide bandgap semiconductor (transparent) – also lowers dark current; e.g. Cu with CsBr coating $\rightarrow$ 0.3% QE (50x of pure Cu)
  - Also alloys: Mg with 2.1% Ba $\rightarrow$ 2.6% QE
  - Collaborations: http://photocathodes.chess.cornell.edu (photocathodes: domain is work in progress)

- G. Gatti: Cu photocathode operating experience at SPARC.
  - QE map by cathode imaging
- M. Trovo: Cu cathode experience at FERMI and ozone cleaning.
  - NB: Ozone $\rightarrow$ only venting, 1-3 days baking at 120°C

Talks (3)

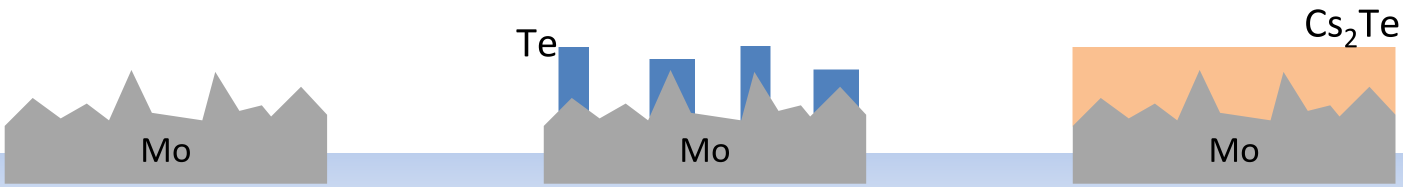
- S. Tsujino: Nano field emitter arrays at PSI
  - Molybdenum molded double gate (Mo tips with two ring electrodes on top of each other): 1st electrode for extraction (positive bias); 2nd electrode on top for collimation (negative bias)
  - Alternative: laser induced field emission → use 1st electrode for positive bias, modulate with laser (max. charge: 0.3 … 5pC for around 1ps pulse length)
  - High brightness: Large array (problem: yield) – Charge: 200pC in 10ps / emittance: 0.4mm mrad
  - QE: $Q_{ext} \approx 10^{-7}$; $Q_{tip} \approx 10^{-2}$





Talks (4)

- D. Sertore: High quantum efficiency Cs_2Te photocathodes at INFN Milano – LASA
  - $K_2CsSb \rightarrow$ QE~10%, but few hours life time
  - Cathode boxes transport to FNAL with NEG pumps (no IGP bec. Plane transportation)
  - Good experience with cathode production – only 3 serious incidents (like bending of the carrier) in more than 10 years
  - Cs_2Te growth:
    - 1) polish molybdenum plug to about 10nm roughness
    - 2) grow Te - pillars on Mo peaks
    - 3) grow Cs – Te dissolves into Cs to form amorphous Cs_2Te with extremely low surface roughness
    - QE depends strongly on Cs/Te ratio
    - Idea: E_g+E_a optimization while cathode film growth
  - Cathode data base: http://wwwlasa.mi.infn.it/ttfcathodes
  - QE over the years: 8.7±2.9% at 254nm
  - Collaboration with LBNL: Tests with Sb photocathodes



Talks (5)

- S. Schreiber: Operation of Cs_2Te photocathodes at FLASH and PITZ
  - FLASH: Change cathode every ≈100 days
  - XFEL specs for the cathode laser: 3/20\3 ps (?)
  - Another XFEL spec → E_{cath}=50MV/m (?)
  - QE maps shown are definitely smeared out by the vacuum mirror (MK)

- D. Dowell: Photocathode properties and requirements for photoinjector
  - Factor of 2 between theory and experiment ($\varepsilon_{exp} \approx 2x\ \varepsilon_{th}$) → surface effects leading to emittance growth:
    - Roughness: transversal field
    - QE modulation: modulation of electron density (shown by simple simulation)
  - Cathode contamination: Breakdown of molecules and deposition of debris takes much too long to be responsible – possible mechanism: deposition of molecules and dissociation at surface. A model proposed to explain cathodes life time
  - Towards cw operation – average cathode laser power <20W
  - Mg cathodes could be interesting candidate from point of view of thermal emittance

Talks (6)

- X. Wang: Efficient low thermal-emittance metal cathode?
  - Low QE cannot just be mitigated by cranking up laser power: breakdown!
  - Mg PC could give ok efficiency, but only at low charge (<250pC)
  - Why Mg? It is a unique metal since its work function (3.6eV) is smaller than its plasmon energy (7.7eV)
  - Photocathode with 200nm laser: 2% QE
  - Thermal emittance vs. laser spot size fit line $\rightarrow$ only slope fitting (not passing through the zero)? (MK)
  - Measured dependence of the QE (Mg cathode) on the laser polarization revealed a factor of ~1.5? – not understood

- A. Lorusso: Thin film metallic photocathodes grown by pulsed laser ablation

Talks (7)

- R. Nietubyc: Pb/Nb thin film photocathodes
  - PC for superconducting ERL at HZ Berlin
  - Highest QE: 0.55% at 200nm

- T. Kamps: Cathode preparation for high average current ERL accelerator
  - Goal for ERL at HZ Berlin: max. current 100mA; max. energy 100MeV; bunch charge 77pC; max rep. rate 1.3GHz; emittance <1mm mrad
  - Want to go to visible light for photo excitation!
  - First normal conducting semiconductor PC, then superconducting PC (Pb/Nb) – start with CsK_2Sb: QE 45% at 400nm / 15% at 532nm – but: need $<10^{-10}$ mbar / low life time
  - Use DC gun
  - Laser from MBI (260nm; 30kHz rep rate; 2…3ps pulse length (Gauss); 0.15µJ/pulse)
  - SC cavity: $Q=10^{10}$ at 40MV/m

- B. Militsyn: The perspective to use GaAs type phocathodes in SRF guns
  - GaAs is expensive, needs XHV, is difficult to activate, has low life time, properties drift: Is worth only if you need polarized electron beams

- F. Le Pimpec: Photocathode experience and development for SwissFEL
  - Use Cu cathode
  - Roughness after operation: Mass movement of Cu due to RF fields (not laser influence)

Workgroups

- Workgroup: Cathodes for SC Machines
  - S. Schreiber: requirements to SC linac based RF injectors: QE>10%, use a fundamental laser wavelength is a challenge for the photocathode laser
  - Jochen Teichert: NC cathode in SC gun, QE~1% for the cooled Cs_2Te, a very fast drop of the QE, it is not clear when it happened – by transport to the SC gun or by the cooling with LN2. Total extracted charge 35C, average current ~1mA, MP in the cathode channel has been detected. 15-15MV/m at the cathode
  - L. Cultrera: K_2CsSb in the DC photo gun - impressive results
  - SRF: Cavity acts as big cryo pump
  - Choke: normal conducting PC would dominate Q of SC cavity: Insulate PC electrically
  - New light sources: Need QE>10% operable in SC environment
  - New materials: Cs_3Sb, CsK_2Sb, NaK_2Sb
  - D. Dowell (on behalf of Maldonaldo, SLAC): CsBr coating on Nb (thickness < Cooper pair coherence length) – promising results on an increase of the QE (>50 times?). Br (passivating) is gas $\rightarrow$ evaporated $\rightarrow$ Cs is activated

- Workgroup: Cathode issues
  - Cathode passivation: Thin ($\approx$1nm) coating of wide bandgap semiconductor – problem: RF influence
  - Coating can increase QE of metal PCs by orders of magnitude
  - A. Clozza (INFN LNF): Ablated Mg films for the photocathode production
  - M. Krasilnikov: possibilities for thermal emittance and emission studies at PITZ.

- S. Schreiber: Summary of workgroups

Summary

- Big problem: Photocathode degradation by surface contamination (both semiconductor and metal) – needs regular exchange/cleaning – possible help: Thin film coating (passivation)
- Thermal emittance: Discrepancy between theory and experiment (Experimental values are 2x of theoretical predictions)