Novel UHV scanning anode field emission microscope (SAFEM) for dark current investigations on photocathodes

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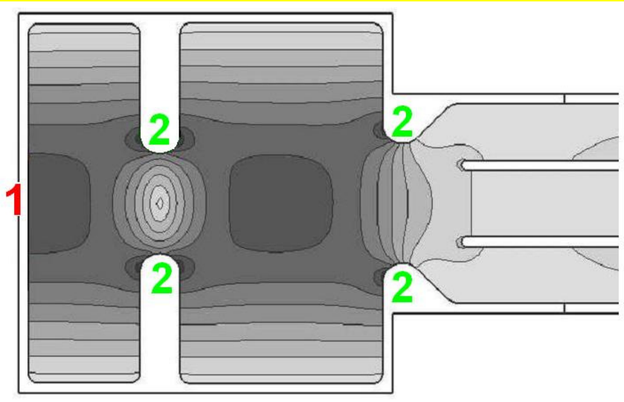
Motivation

One major issue of operating laser driven rf guns with high gradients and high duty cycles as electron sources for free electron lasers like FLASH or the future European XFEL is a dark current emitted from the gun body and the photocathode. It is lost at various places along the beam line and part of it even reaches the undulator. When dark current is lost electromagnetic radiation and neutrons are created and may damage diagnostic components and electronic devices close to the beam line. Imperfect photocathode regions with enhanced field emission and their contact area to the rf cavity are considered as main dark current sources at typical electric surface fields of about 40-60 MV/m.

In order to ensure low field emission photocathodes, investigate dark current sources in detail and improve cathode handling technique a novel UHV scanning anode field emission microscope (SAFEM) has been developed as part of the systematic quality control of freshly prepared photocathodes at DESY. In this contribution we report on completed construction and actual status of the SAFEM.

Microwave Studio simulation [1] of rf field distribution in the gun cavity:

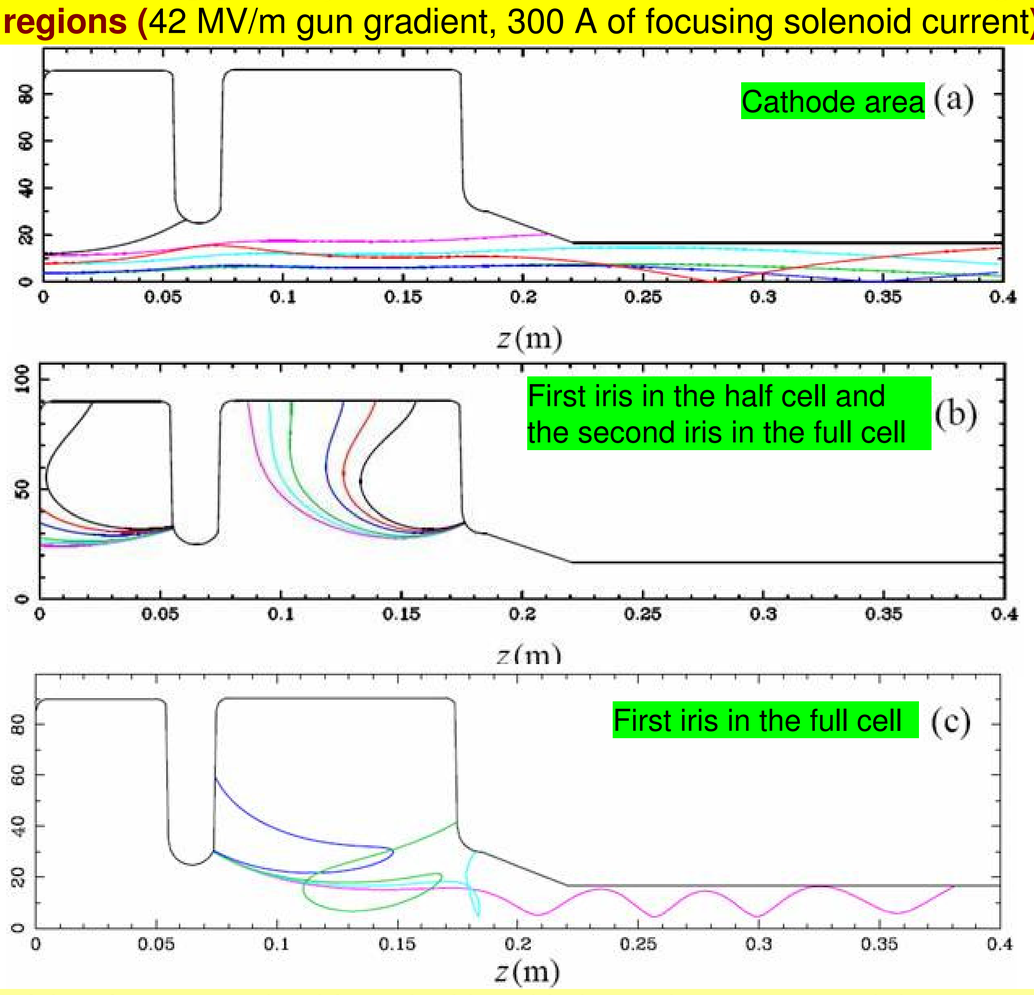


Regions of high surface electric field and likely sources of strong field emission:

⇒ cathode and rf contact area **(1)**

⇒around two irises **(2)**

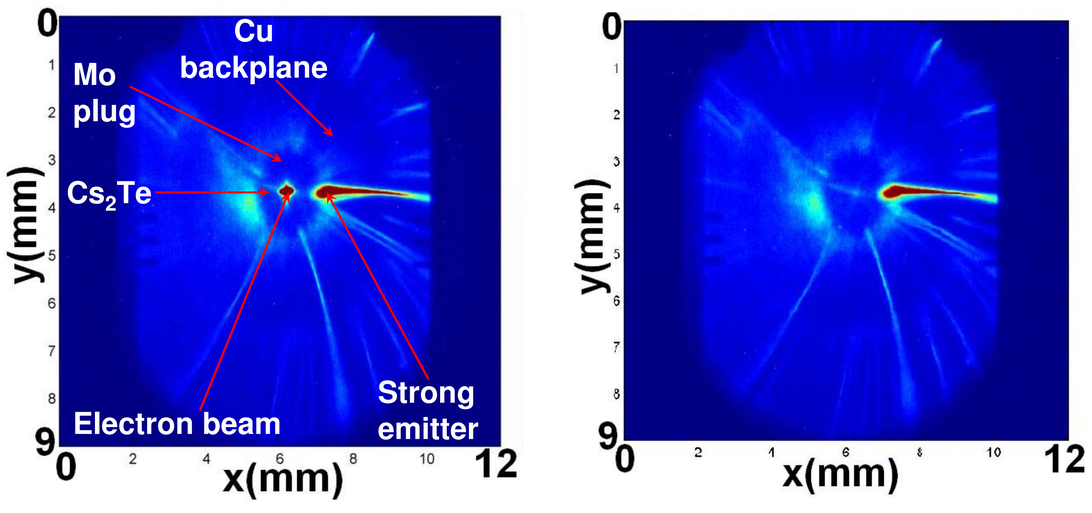
Astra simulation [2] of trajectories of electrons emitted from the high rf field regions (42 MV/m gun gradient, 300 A of focusing solenoid current):



⇒ most of the electrons emitted from the irises hit the cavity aperture and do not escape from the cavity.

⇒ field-emitted electrons from the cathode region can be accelerated downstream, depending on both starting location and the starting rf phase.

Dark current investigations of the gun cavity with beam monitor[3]:



⇒ Image shows dark current coming from photocathode area or rf contact area

References and Acknowledgements
[1] Jang-Hui Han et al, Physical Review Special Topics – AB, 11, 013501 (2008).
[2] Jang-Hui Han, Dissertation, University of Hamburg (2005).
[3] S.Schreiber et al, Proceedings of FEL08, p.552.

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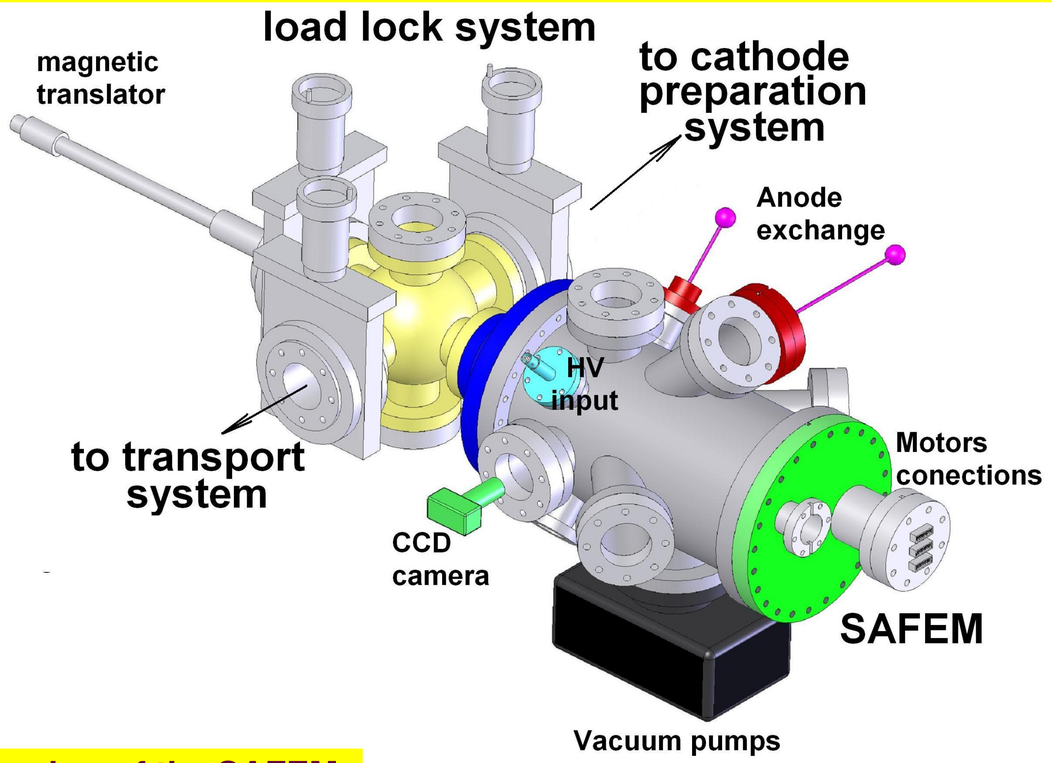
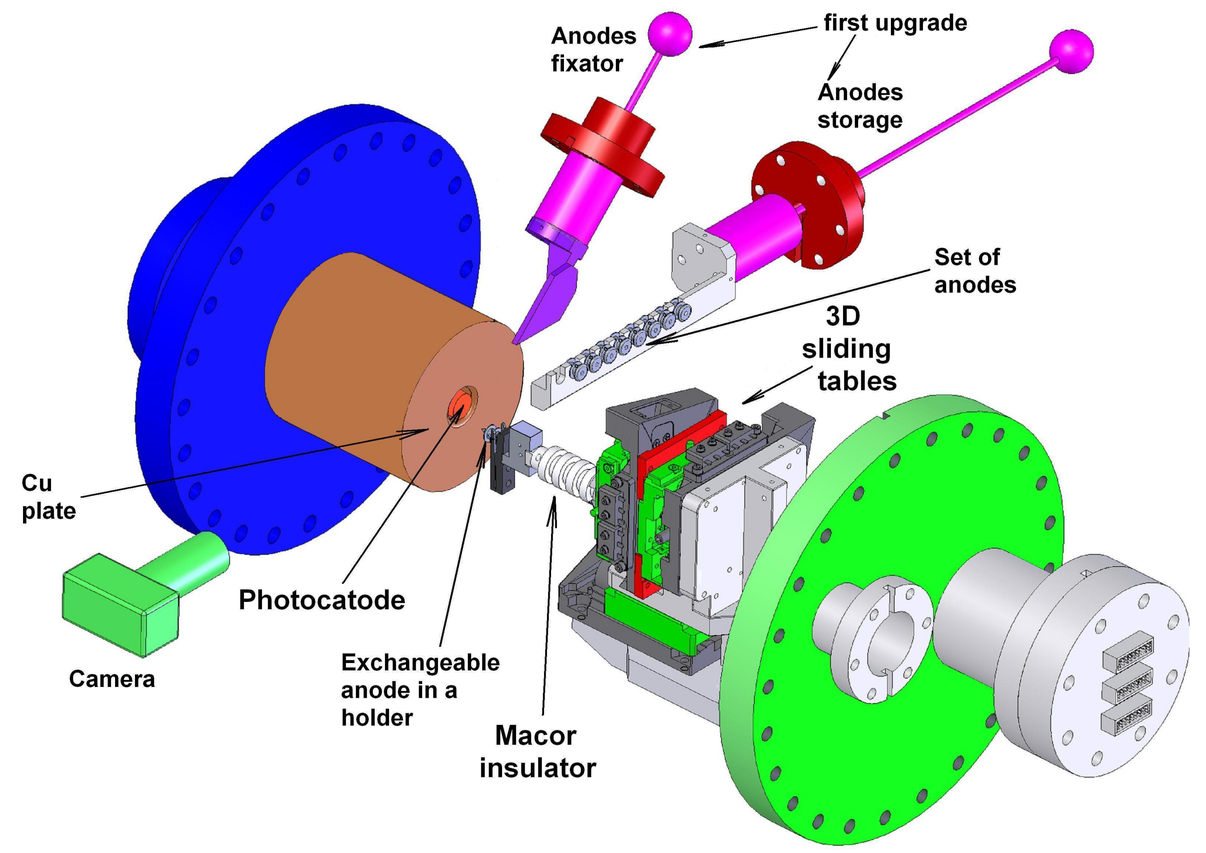
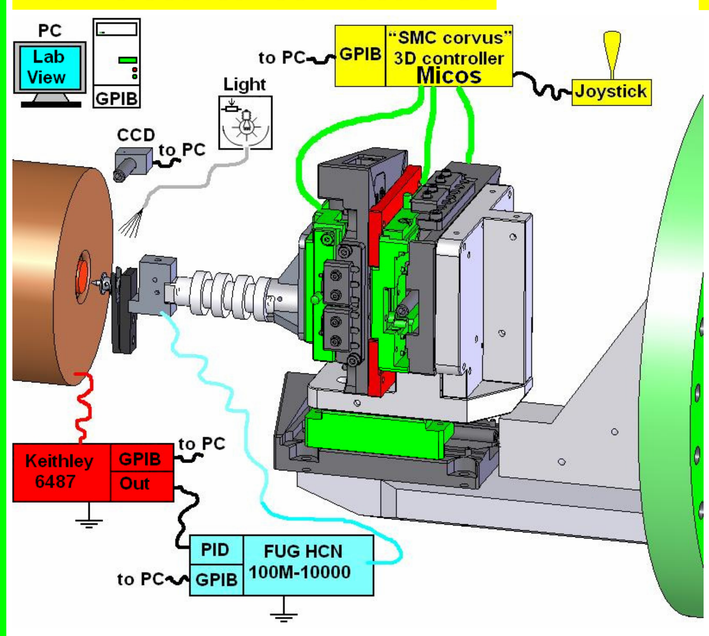
Overview of the SAFEM with a part of UHV cathode transport system:



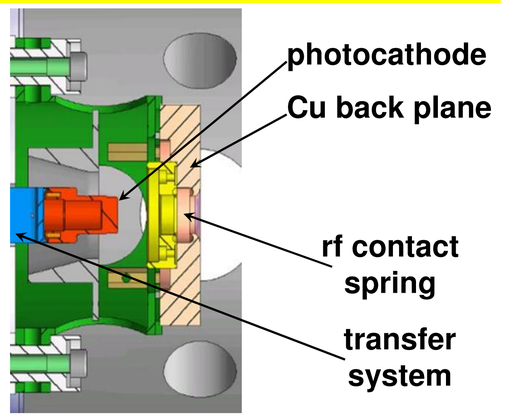
Inner view of the SAFEM:



Main electrical connections:



Cathode holder in the SAFEM:



▪ transfer and holder of cathodes are compatible with actual injector
⇒ simulations of cathode handling and creation of field emitters in the rf contact area is also possible

Final properties of the SAFEM will be:

- ✓ direct transfer of freshly prepared photocathodes between preparation chamber, SAFEM and transport chamber using load lock and magnetic translator
- ✓ 10^{-10} mbar working pressure
- ✓ optical electrode gap control down to 5 µm resolution
- ✓ imaging of potential emitter distribution over photocathode surface and back plane
- ✓ 25 x 25 mm² maximum scanning range, 1 µm maximum scanning resolution
- ✓ 0-10 kV, ± 0.1 V applied voltage (with fast PID regulation) → 0-200 MV/m at 50 µm gap
- ✓ ± 1 fA current resolution
- ✓ fully automated measurement control based on PC/LabView

Actual status and outlook

1. All constructions are ready
2. LabView programming is ready
3. After first comissioning of the SAFEM it will be finally included into the preparation and quality control set-up.
4. In an already planned upgrade stage the SAFEM will be equipped with an anode exchange system. This will give opportunity to choose between 9 anode of different radius without breaking the vacuum.