HZB Helmholtz Zentrum Berlin

First beam commissioning of the HZB SRF photoelectron gun

T. Kamps (HZB/HU Berlin)

presented at ARD ST3 Annual Workshop, Zeuthen, Germany

27.06.2025, 09:20 to 09:40

更亮
更快
更智能

Thanks and acknowledgements

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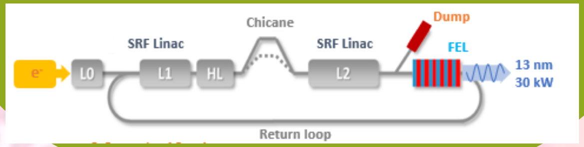
KEK HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION
UKRI Science and Technology Facilities Council ASTeC

Helmholtz-Zentrum Berlin, Adlershof campus

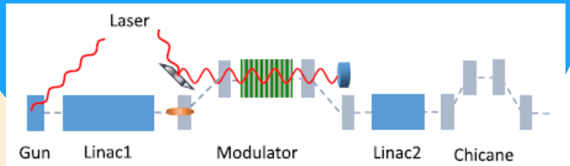
Why high brightness, high average current electron beam sources?

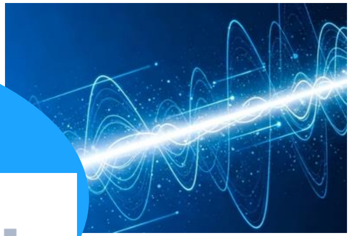
Ballpark e- source
1 to 5 MeV
10 to 100s pC
0.1 to 10s ps
0.1 to 10 um emittance
1 MHz to 1 GHz
0.1 to 10s mA

ERL EUV FEL lithography [1]



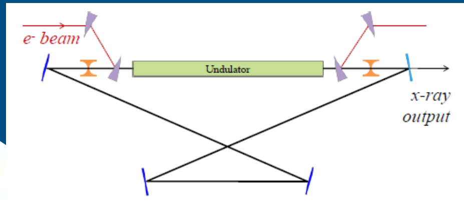
THz FEL Source [3]



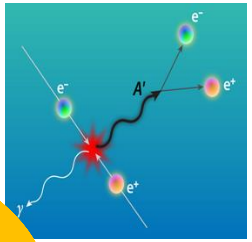


Courtesy THz Young Scientists Meeting 2025

XFEL Oscillator [2]

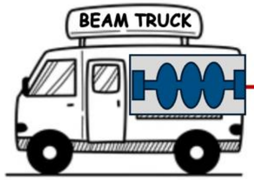


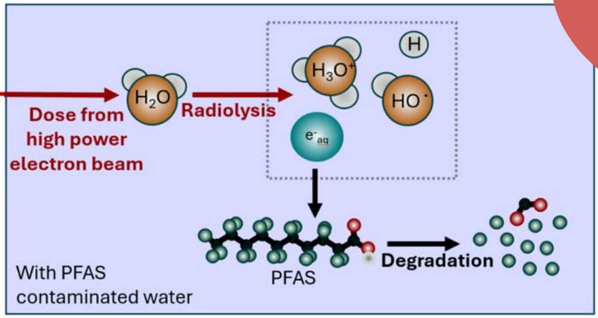
HEP and NP applications [4]: electron cooling and electron-ion collider [5]



Courtesy APS

Compact sources for UED [6] and EBWT [7]





T. Kamps, T. Spohr

UED – Ultrafast electron scattering
EBWT – Electron beam water treatment

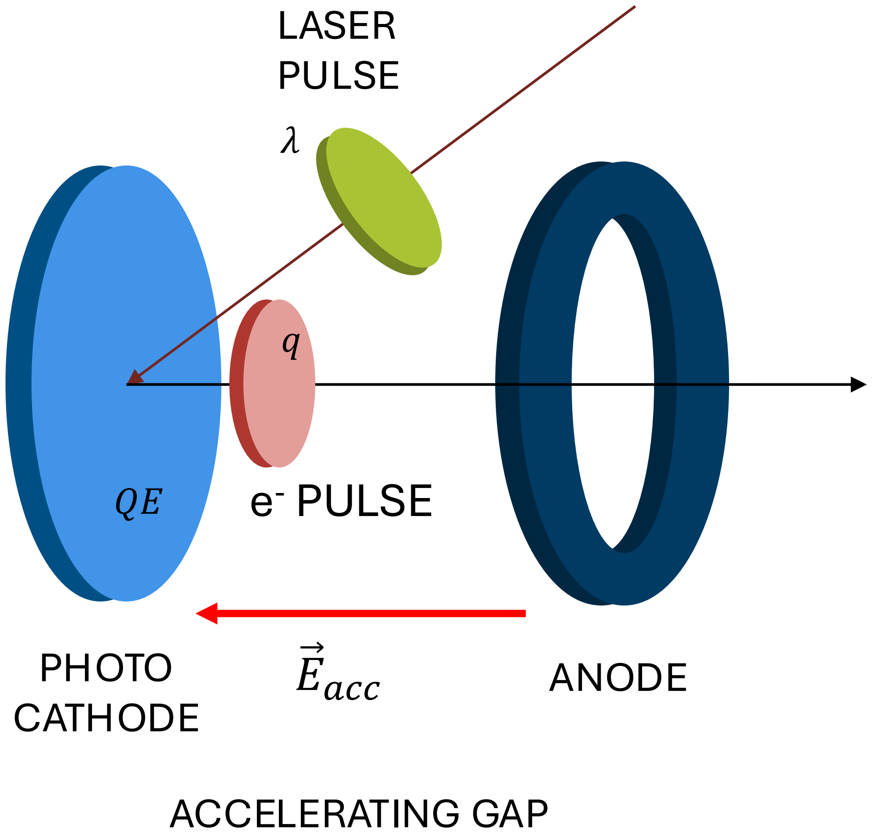
[1] M. Venturini, G. Penn, NIM A 795 (2015) 219-227
[2] for example K.J. Kim, et al., XFELO at LCLS-II
[3] Z. Zhang, et al., PRAB 20, 050701 (2017)
[4] European Strategy for HEP – Accelerator R&D Roadmap, 2022
[5] V. Litvinenko, ERL 2024 and IPAC 2025
[6] B. Alberdi, Thesis HU Berlin, 2024
[7] T. Spohr, submitted, 2025

How do you get bright electron beam at high average current?

Stick a photoemission source in an accelerating gap

Photoemission source: photocathode illuminated by a continuous wave of laser pulses

Accelerating gap: Supply high voltage during emission and quickly accelerate to relativistic beam energies

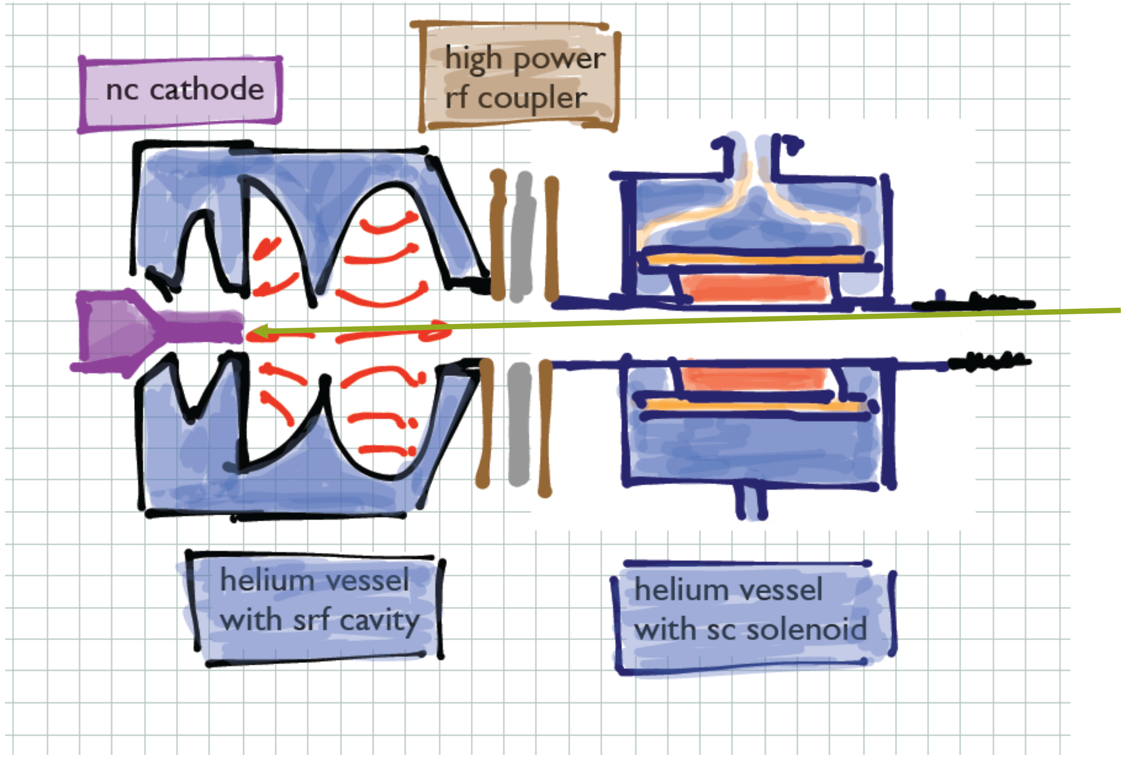


How do you get bright electron beam at high average current? An SRF gun!

Stick a photoemission source in an accelerating gap

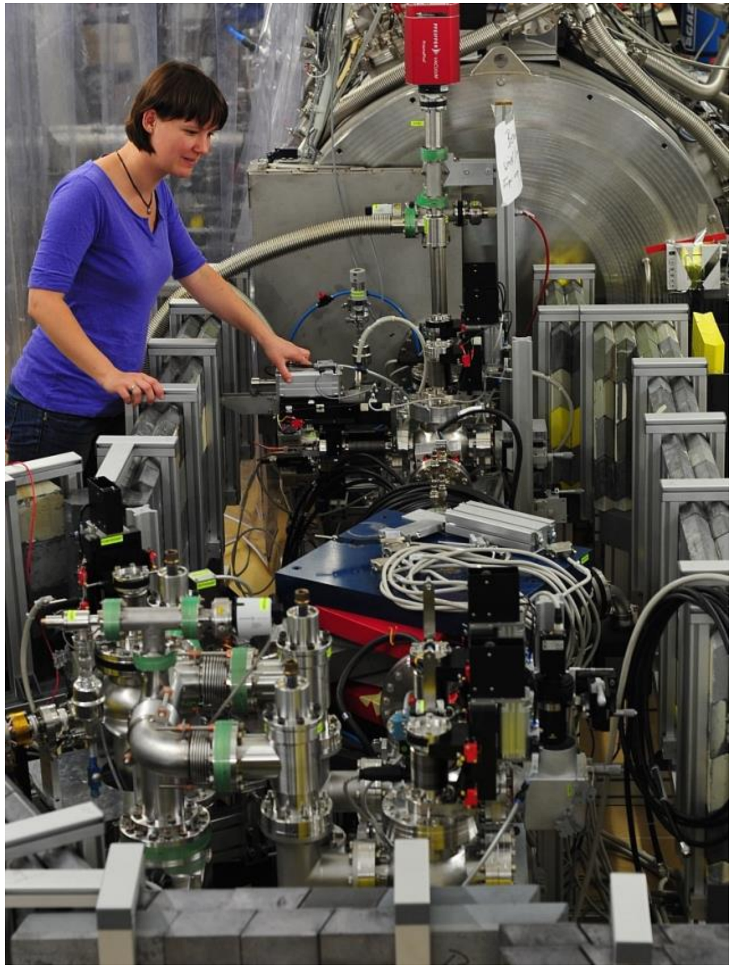
Photoemission source: photocathode illuminated by a continuous wave of laser pulses

Accelerating gap: Supply high voltage during emission and quickly accelerate to relativistic beam energies



SRF gun development at HZB

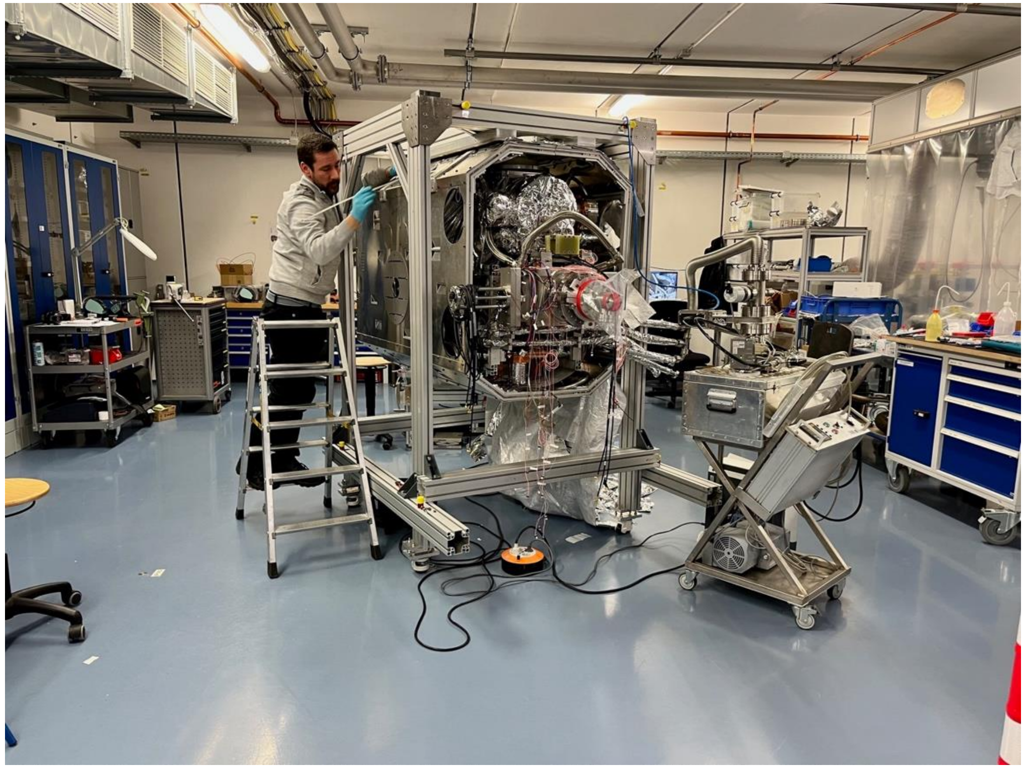
GUN0 HOBICAT (2011)

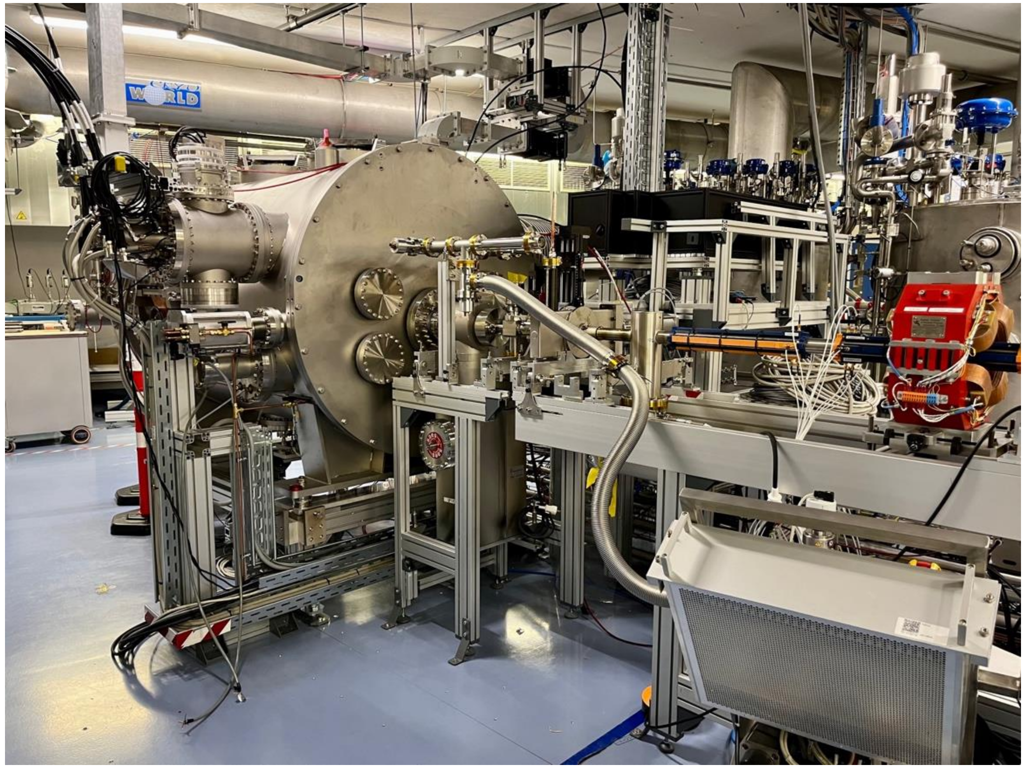


GUN1.0 GUNLAB (2018)

for references see T. Kamps, IPAC 2025-WECN2, IPAC 2023-TUPL160

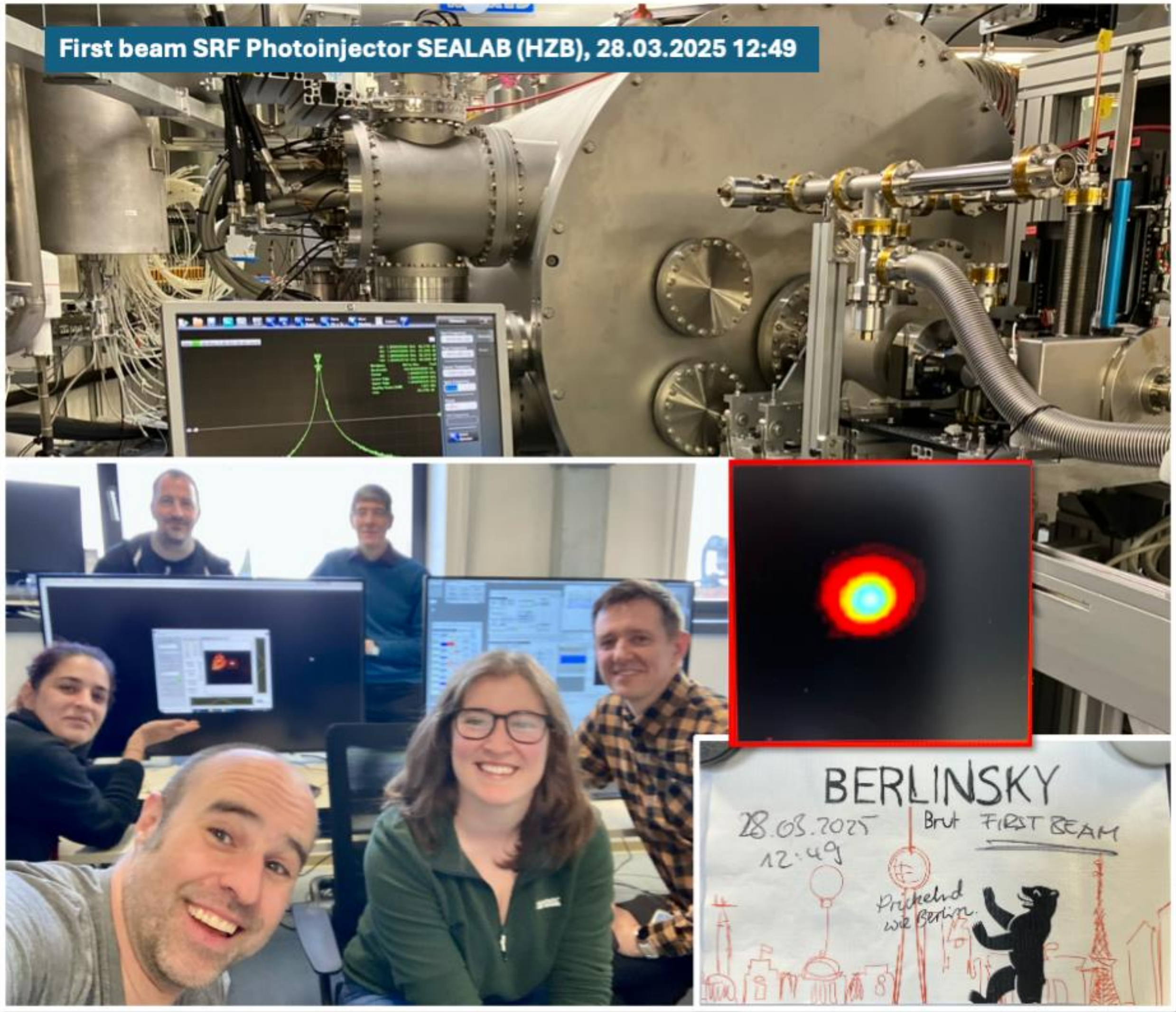
Setup of the SRF gun (mark 1.1) in the SEALAB accelerator hall (2019 - now)



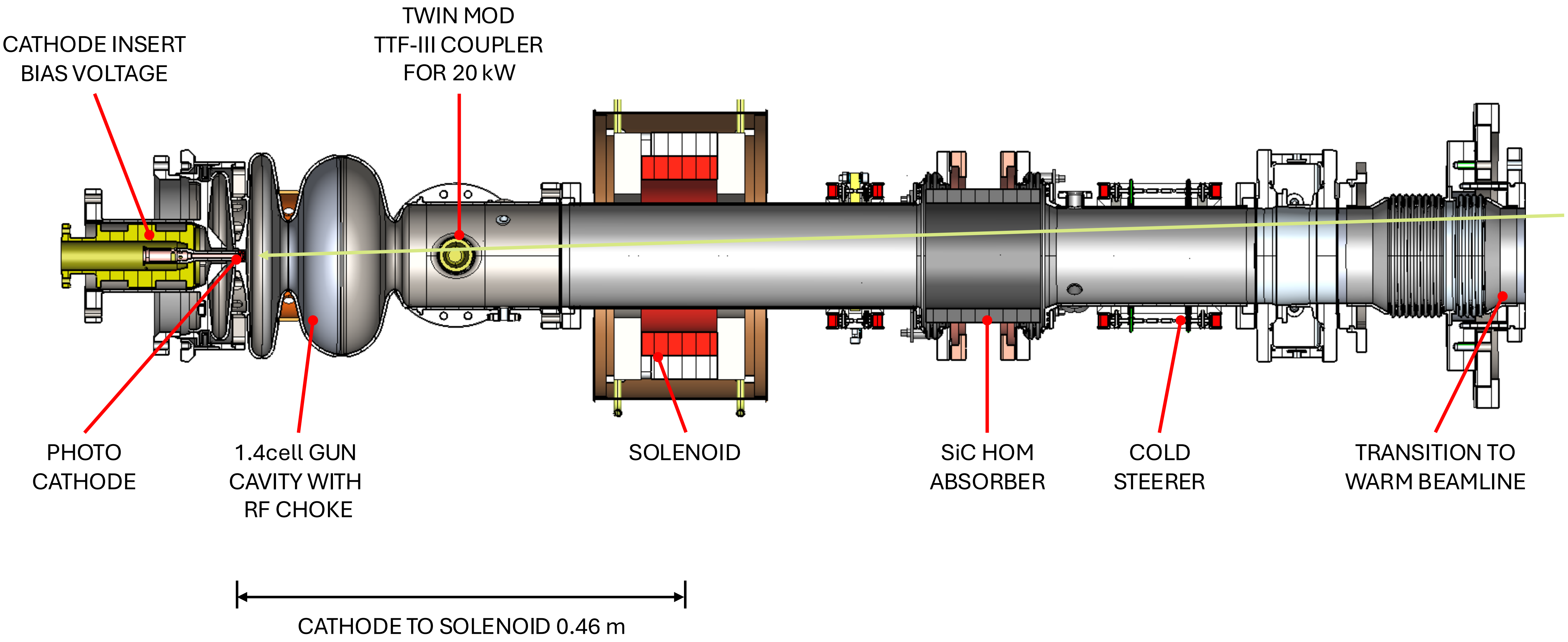


First cooldown of module in Oct 2023
Setup of beamline, then RF operation in Sep 2024
After repair of warm coupler, first beam in Mar 2025
Beamtime until the end of 2025, beginning of 2026

First beam from the present SRF gun March 2025

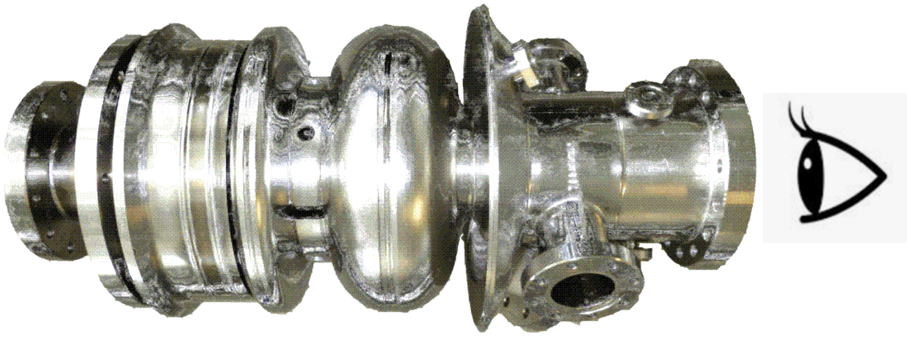


How did we make this? Start with the cold string for the SRF photoinjector

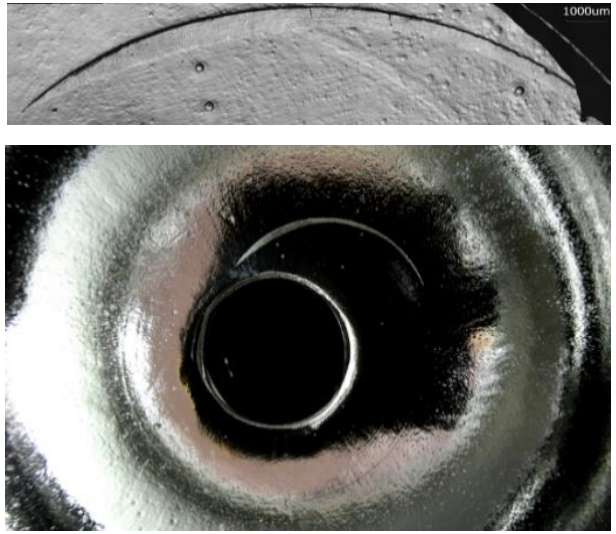


A. Neumann, ERL 2019, SRF 2021
J. Völker, SRF 2021

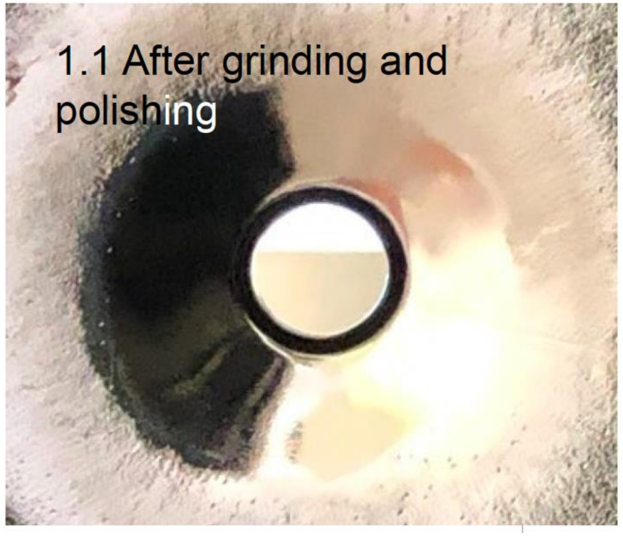
Processing the SRF gun cavity (mark 1.1) for beam operation



SRF gun cavity 1.1 got damaged during production → showed excessive field emission at low gradients



Scratch on backwall from high-pressure rinsing nozzle



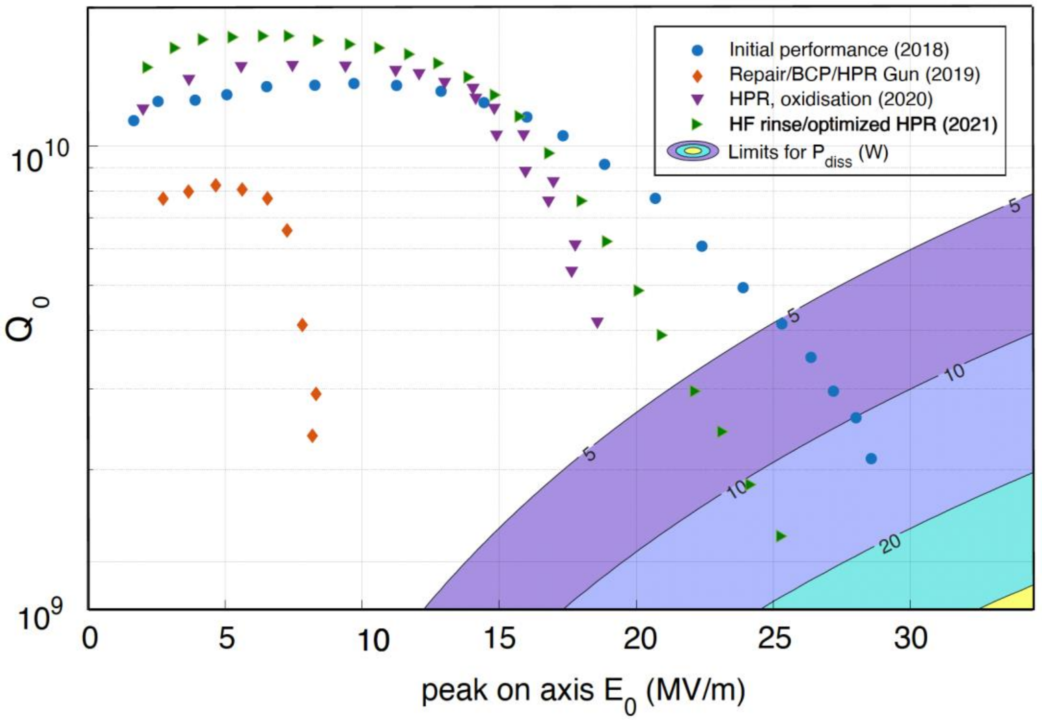
Developed repair strategy, with grinding, HF rinsing and polishing to recover initial performance

Jefferson Lab Thomas Jefferson National Accelerator Facility | HZDR | Fraunhofer IIS

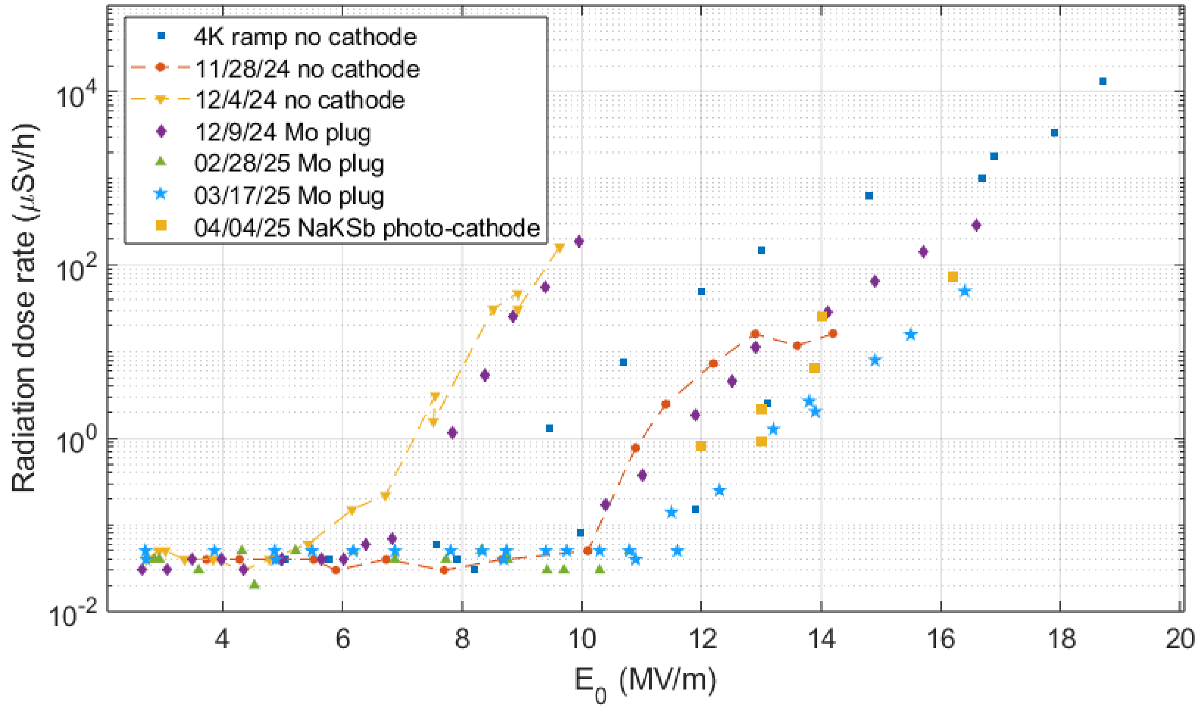
A. Neumann, Y. Tamashevich, SRF 2021

In-situ SRF cavity RF processing

Q vs E DEVELOPMENT OVER TIME



IN-SITU PULSED RF PROCESSING

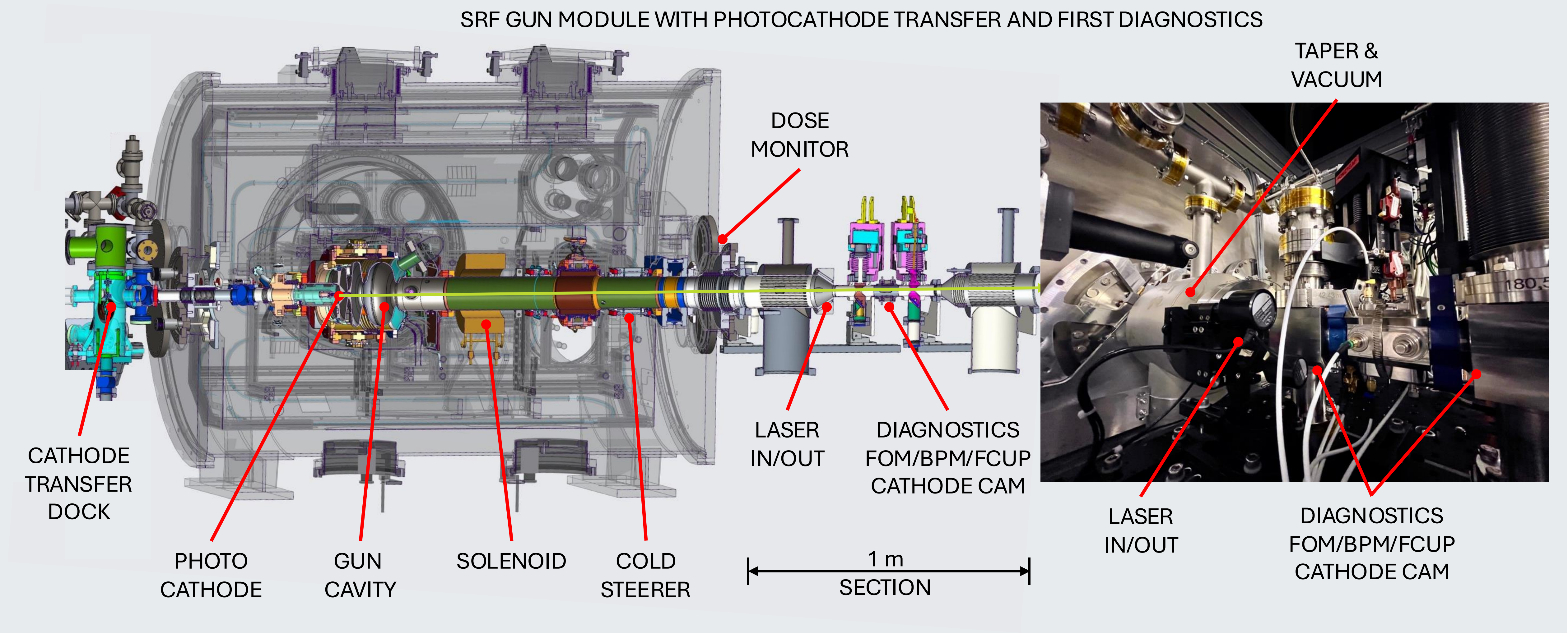


Successful in-situ processing to reach 10 MV/m w/o background, 20 MV/m in CW operation and 25 MV/m pulsed.

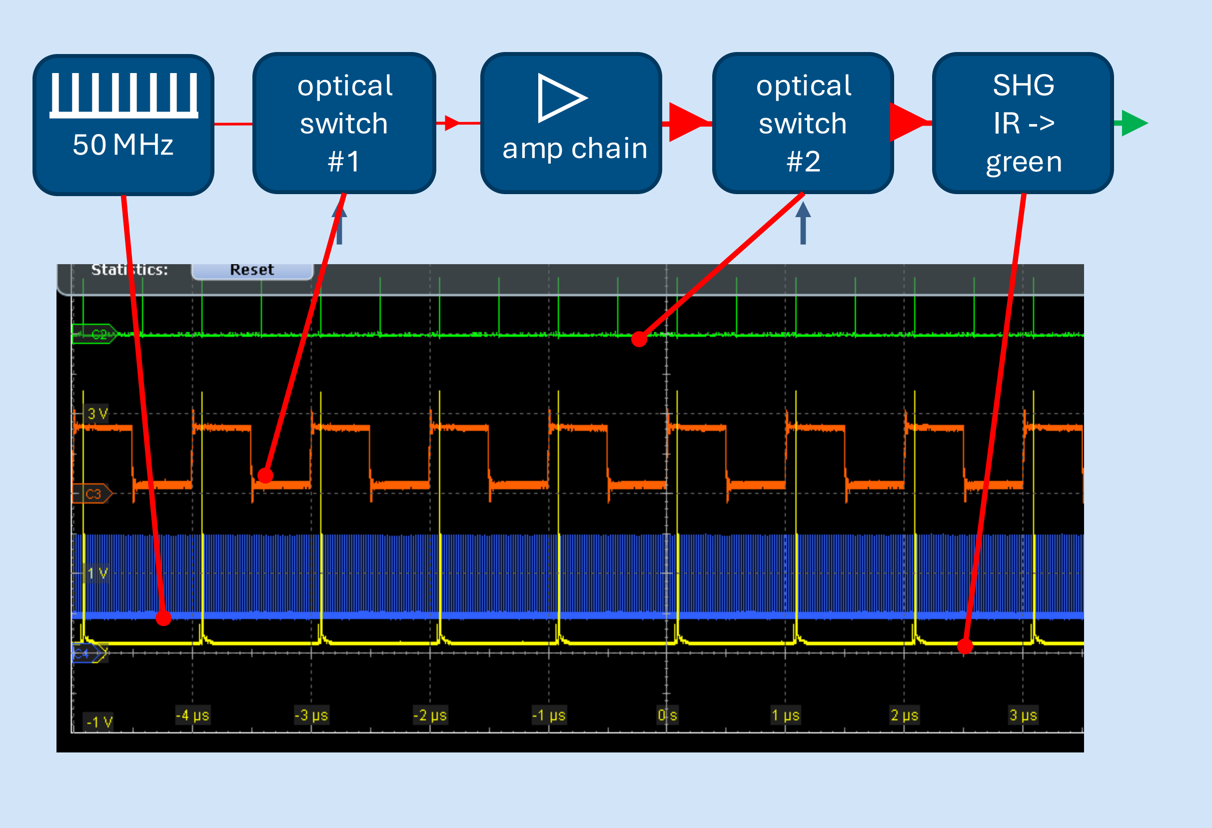
Similar performance with coated and uncoated Mo cathode plug

No multipacting with Na-K-Sb and 3 kV cathode bias

What else do you need to make beam?



Drive Laser provides stable, several-ps-long, visible laser pulses to the cathode



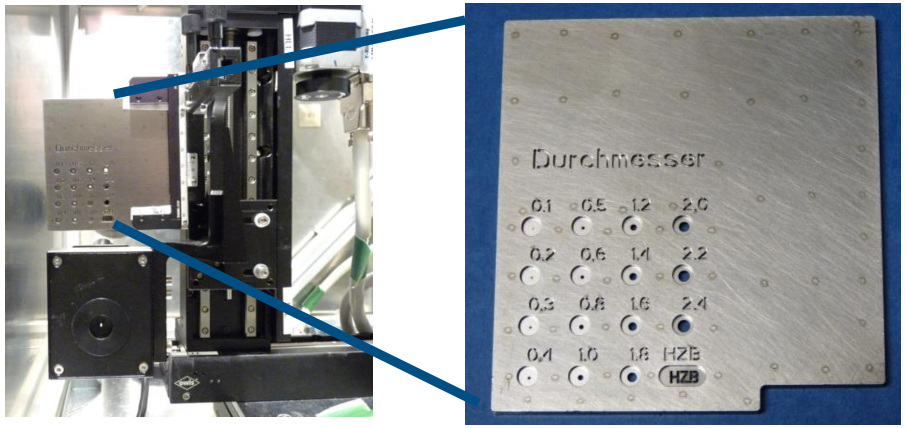
Developed by Max-Born-Institut (I. Will).

Laser power 2 W at 522 nm at laser exit

During commissioning 1 MHz

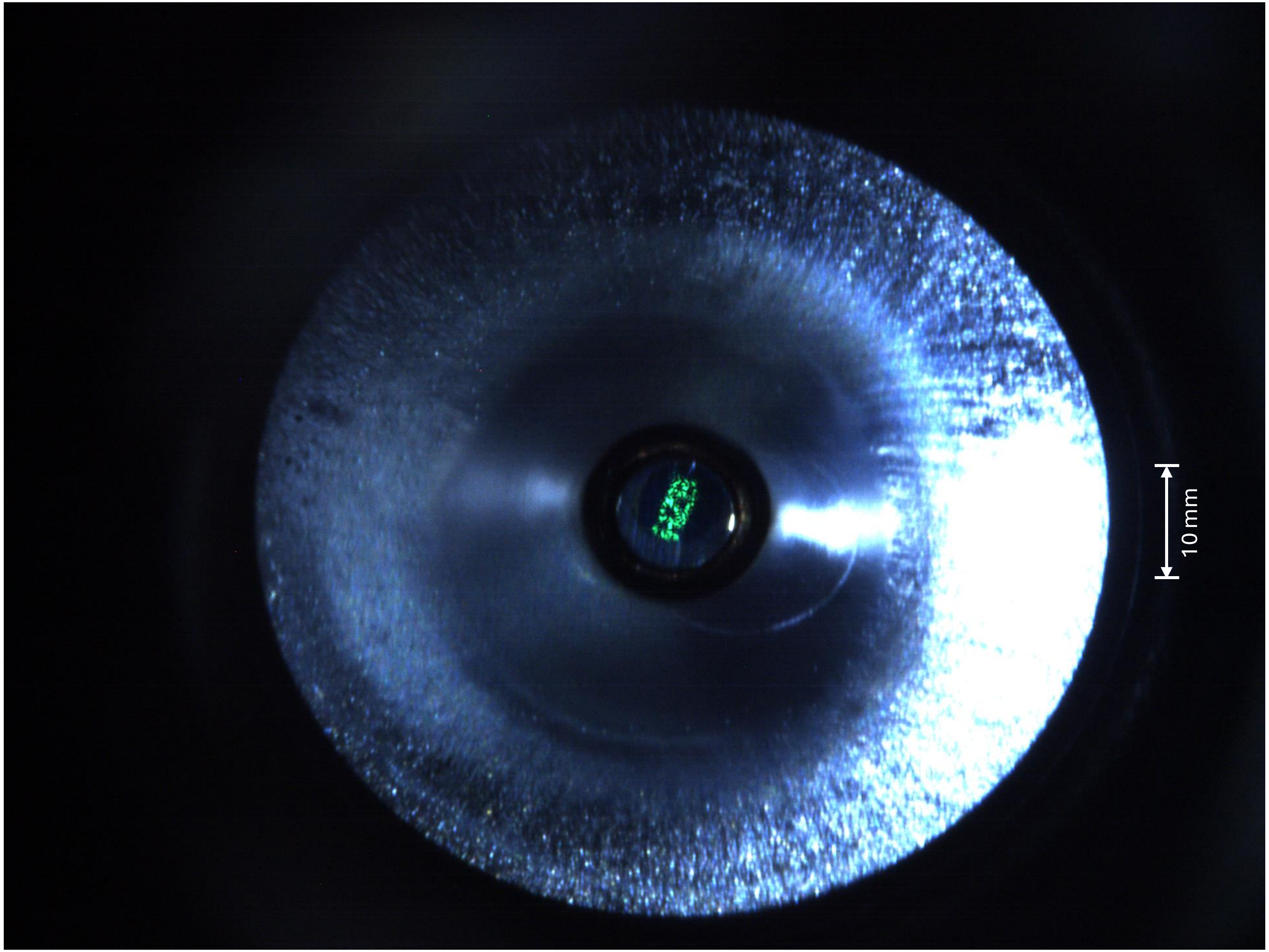
Laser transport from laser to aperture plate in accelerator hall: relay imaging of laser rod to aperture over 36 m with six mirrors and lenses. Transmission efficiency of 85%.

Aperture plate



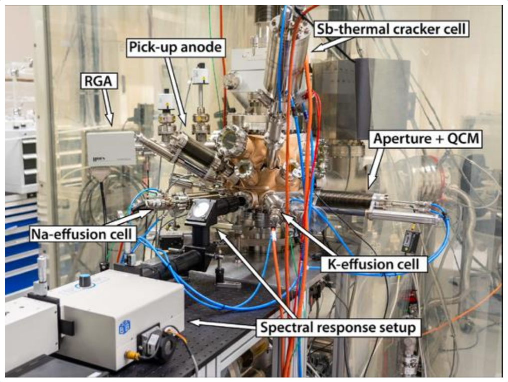
Further 1:1 relay imaging. Transmission efficiency aperture to cathode 1% to 10%.

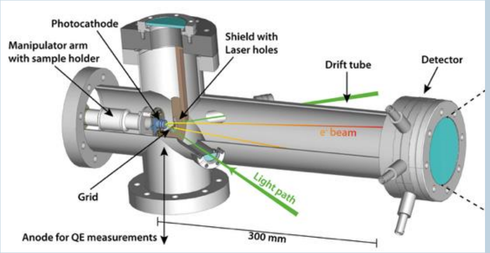
Power stability on cathode 1%, pointing stability on cathode < 0.1 mm.

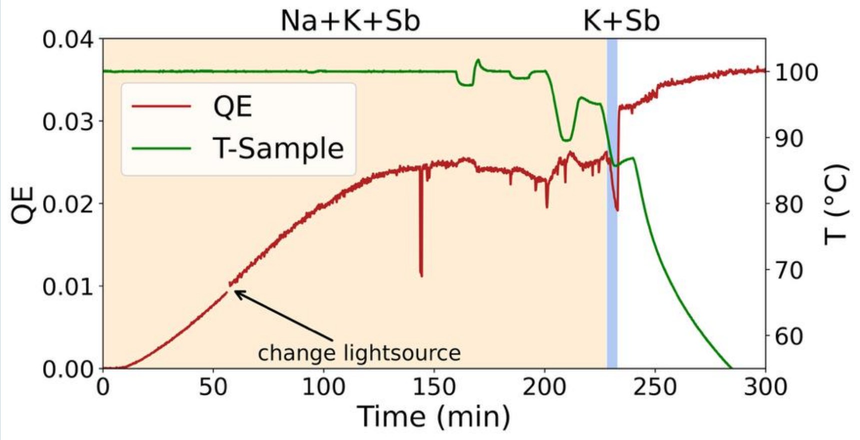


optical relay imaging of HZB logo from aperture plate to cathode

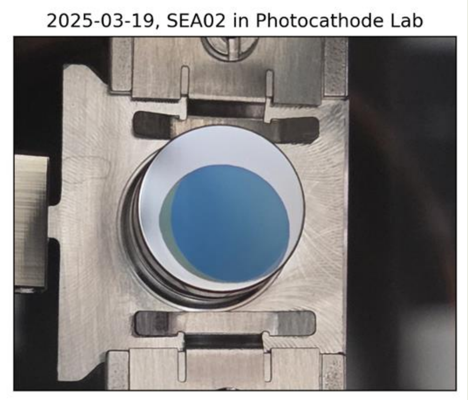
Development of high-brightness electron sources based on multi-alkali metals

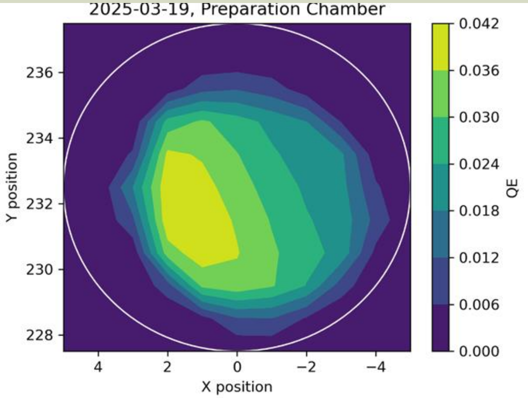


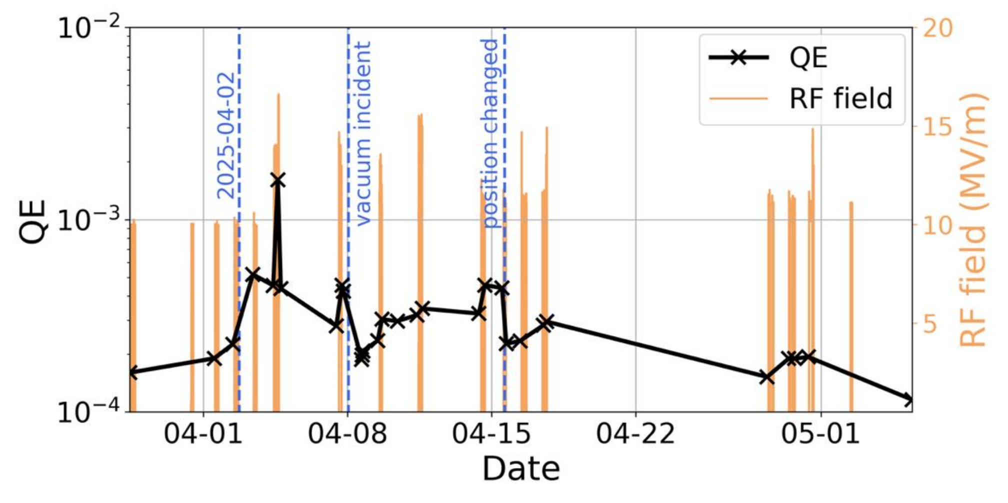




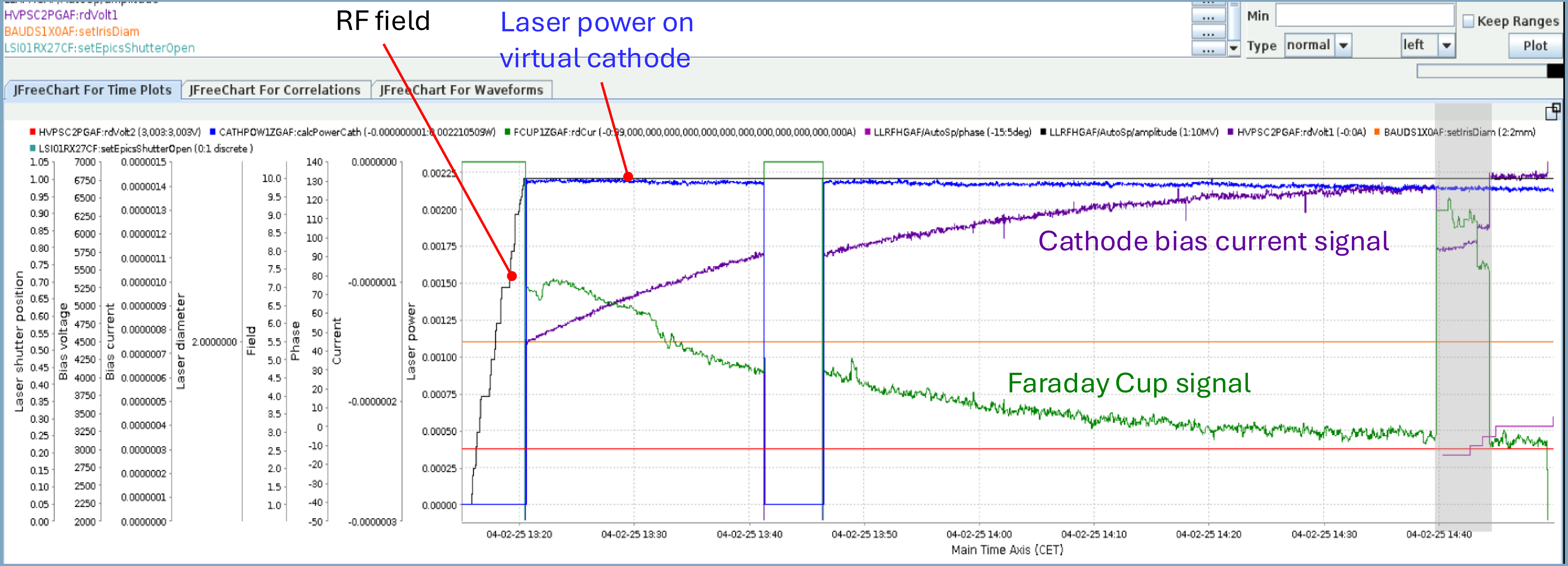
C. Wang, Thesis U Siegen, 2025
J. Dube, arXiv:2503.03573, 2025

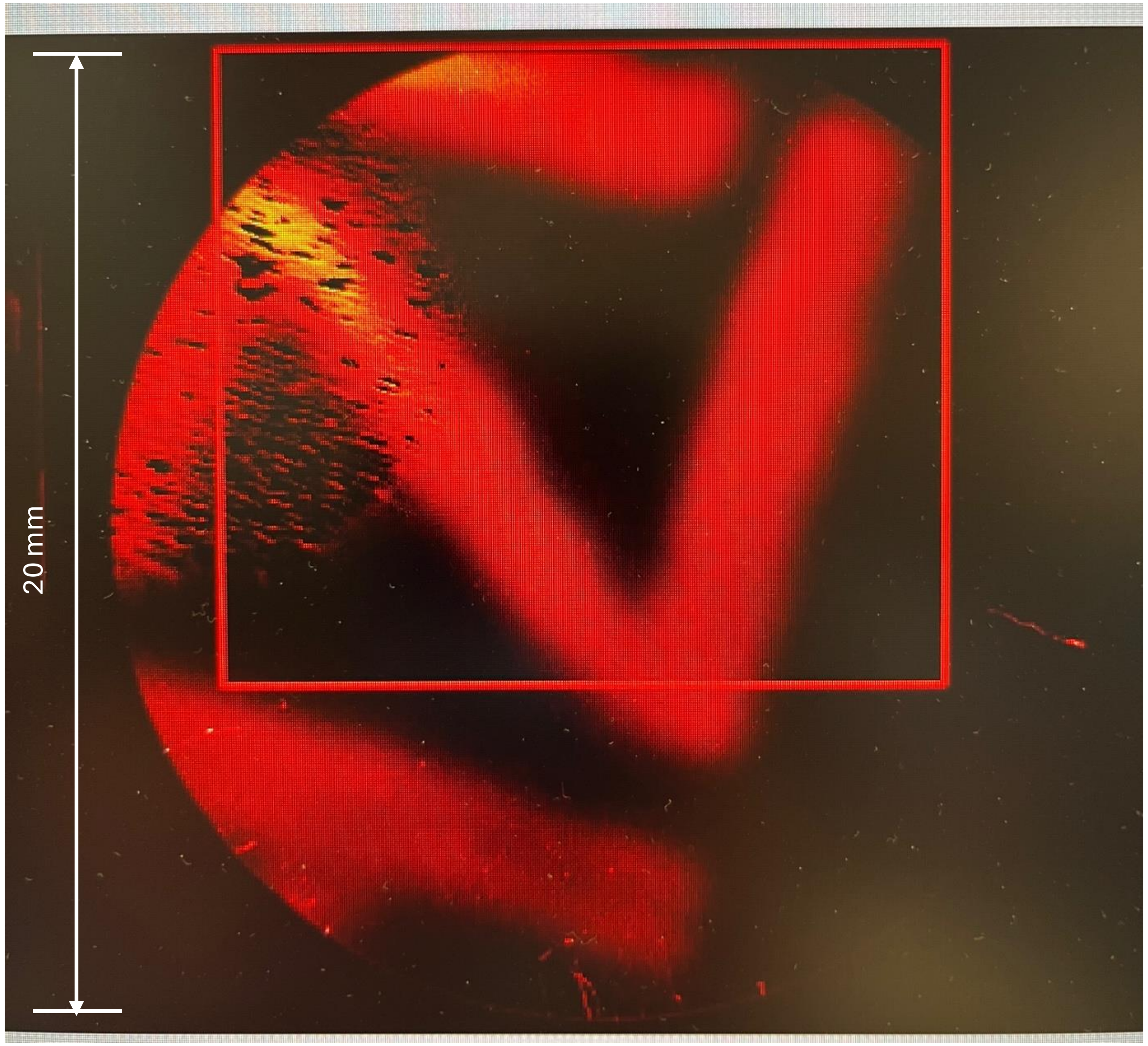






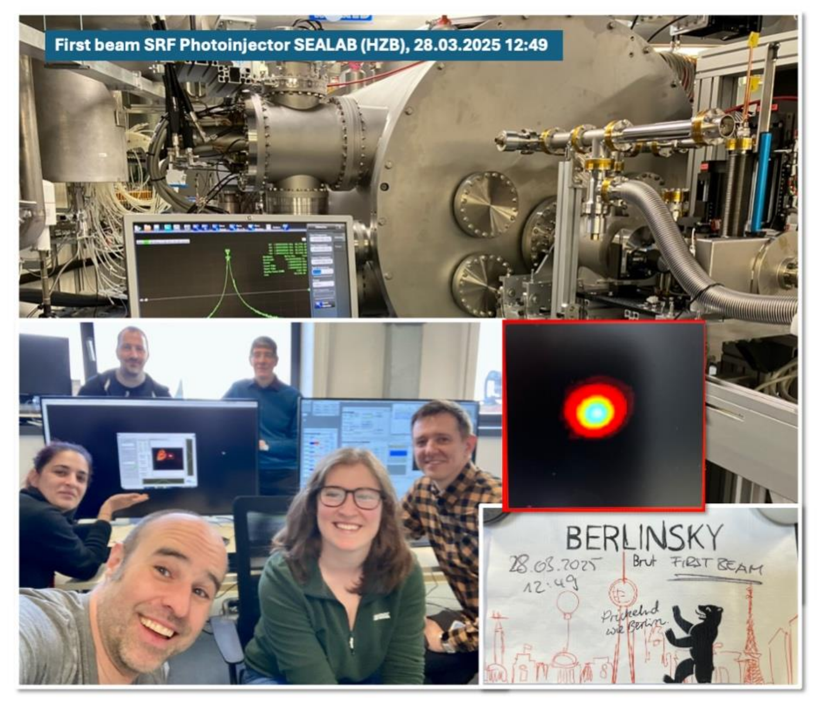
Observation of QE rejuvenation under RF field exposure – RF processing





electron-optical imaging of HZB logo from cathode to first viewscreen/FOM with RF fields of gun cavity. Solenoid is off

Summary



We have finally produced the first beam from a Na-K-Sb photocathode embedded within an SRF gun.

Initial results indicate tremendous potential for the SRF photoinjector across a variety of applications.

There are many open questions: why does the QE rejuvenate with RF processing, how can we improve transmission through the SRF gun, and what are the current/emittance/energy limits we can achieve with our system? Stay tuned for more results coming in 2025

In the meantime, check out E. J. Brookes at IPAC 2025-WEPS043 and B. Alberdi at IPAC 2025-TUPM007