

# **XFEL Accelerator R&D Status**

## **Nanostructured and other metal photocathodes**

### **RP-218**

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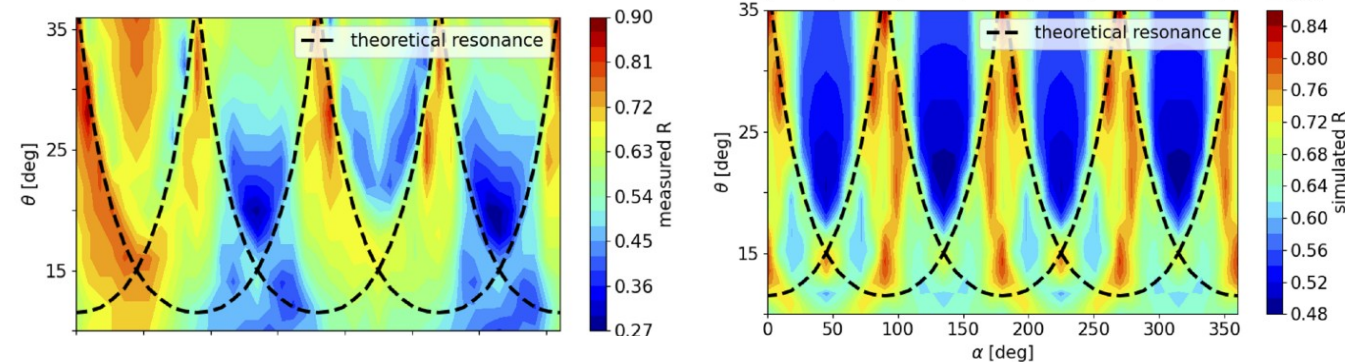
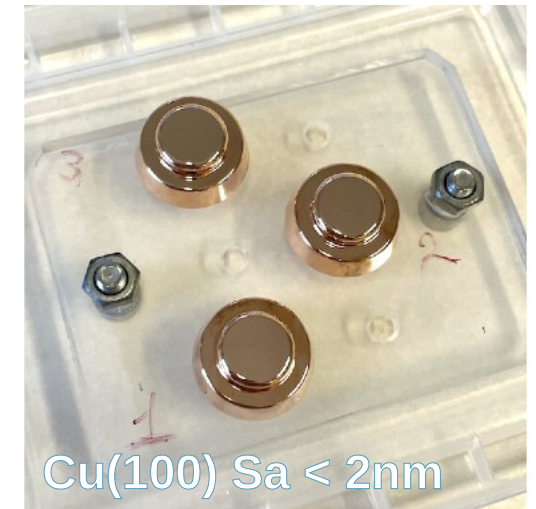
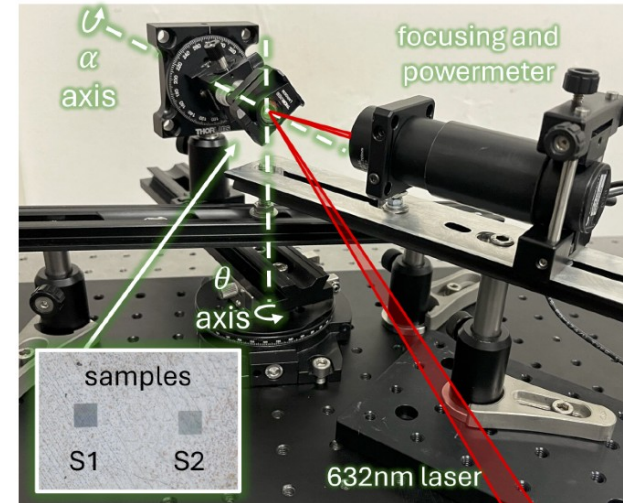
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## Scope of the R&D activity

- Prepare experimental infrastructure for metal cathode preparation and characterization
- Produce nanostructured photocathodes on single-crystal Cu substrates
- Develop low-field quantum-efficiency studies of metal photocathodes
- Create proof-of-principle tests for nanostructured photocathodes
- Install and test photocathodes at REGAE
  
- This project is linked to RP-212: SRF CW Gun

## Achievements in the past year

- Established infrastructure: dedicated test chamber and refurbished SAFEM system for quantum-efficiency studies
- Advanced activation procedures: BPS172 treatment achieved two-order-of-magnitude QE increase
- Produced three single-crystal copper cathodes with ultra-high optical precision ( $S_a < 2$  nm)
- Assembled optical characterization setup and confirmed surface-plasmon resonance excitation
- Developed numerical framework with TU Darmstadt



## Deviations from plan

- Leaving of Sven Lederer from MVS caused months of delay (ca. 1 year) in progress
- Structured cathode tests at low fields
  - Extended optical alignment work shifted first quantitative tests to late 2025
  - Confirmed feasibility of focusing excitation laser down to 50 um (Aug 2025)
- Laser issues at REGAE impacting project timeline
- Nanostructuring scale-up slower than planned due to technical constraints
  - Required patterning confirmed later than expected (early 2025 vs 22 Aug 2025)
  - Difficultues in scaling patterned areas to 50 um using focused ion beam

## Timeline of this R&D activity

Date / Period	Milestone Description	New Date/ Period
Q3/2022	purchase of single crystal sample material and first nanostructuring	done
Q4/2022	first characterization of nanostructured samples in the lab	done
Q4/2022	initiate the purchase of a vacuum chamber for photoemission studies	done
Q4/2022	kick off meeting with colleagues from Hamburg University	done
Q4/2022	hiring a PhD student	done
Q1/2023	planning the demonstration of the principle at an NC gun like REGEAE	done
Q2/2023	first characterization of photoemitted electrons - delayed	<b>Q4/2025</b>
Q3/2023	start purchase of first single crystal SRF cavity cathode plug -delayed (ts4i delay)	2026
Q4/2023	nanostructuring of first single crystal SRF cavity cathode plug – delayed (ts4i delay)	2026
Q1/2024	potential demonstration of the principle at an NC gun like REGEAE – delayed	<b>Q4/2025</b>
Q4/2025	potential first test in SRF gun at SRF photoinjector test stand - (ts4i delay)	<b>Q4/2027</b>
Q2/2026	if the concept of these cathodes turns out being successful, setup of a concept for a dedicated laboratory for the preparation of nanostructured cathodes	

## Risks to R&D Project

- Beam time availability at REGAE
- Nanostructuring capabilities on campus

## Outlook / Summary

### ■ Planned Activities for This Year (2025):

- Nanostructuring of three single-crystal copper cathodes (early September)
- Quantitative low-field QE measurements (Q4 2025)
- Proof-of-principle tests at REGAE (Q4 2025)

### ■ Risks Challenging These Plans:

- Ongoing laser issues at REGAE may further delay testing schedule
- Technical constraints in nanostructuring could affect cathode production timeline
- Dependency on external facility availability (REGAE)

### ■ Publicaitons:

- M. Bulgacheva et. al., „Simulation study of nanostructured copper photocathodes“ at FEL'24
- C. Banjare et. al., „Surface plasmon enhanced photocathode R&D at DESY for CW photoinjector for future CW and high-duty-cycle European XFEL“ at FEL'24
- D.Bazyl et., al. „OVERVIEW OF METAL CATHODE R&D FOR THE CW L-BAND SRPHOTOINJECTOR AT DESY“ at SRF'25

## Outlook / Summary

- In addition to novel research, this RnD creates foundation for metal cathode expertise at DESY: production, surface finish, cathode preparation and tests with 24 colleagues ( 19 DESY internal) actively contribute to this progress

### OVERVIEW OF METAL CATHODE R&D FOR THE CW L-BAND SRF PHOTOINJECTOR AT DESY\*

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