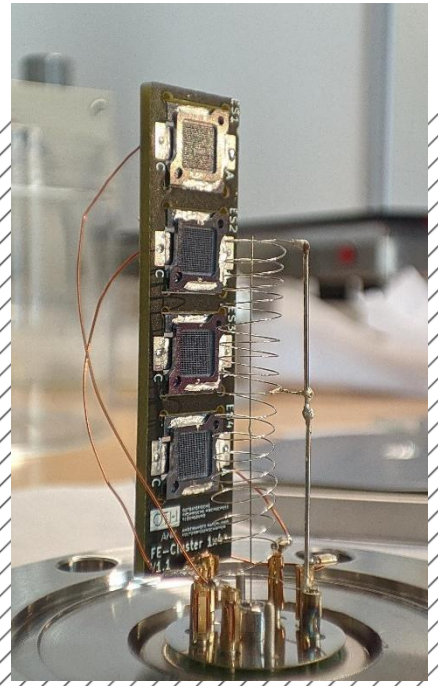

Concept of Maximizing the FE-eGun Lifetime of an Ionization Vacuum Gauge

Markus Langmantel[1], Matthias Hausladen[1], Stefan Weber[2], Peter Gerlesberger[2], Heinz Plöchinger[2], Joachim Wolf[3], Rupert Schreiner[1]

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Introduction, Motivation

Introduction

- Pressure readings are necessary in variety of vacuum applications
- Ionization vacuum gauges are commonly used
- commonly used electron source in ionization vacuum gauges is the hot cathode
  - Known
  - Reliably
- Hot cathodes are not usable in every environment
- Cold Cathodes
  → Silicon based field emission sources (FES)

Hot cathode B_IG19BA Ion Gauge Sensor, Thyracont: https://thyracont-vacuum.com/en/product/b_ig19ba-ion-gauge-sensor-type-bayard-alpert-for-pvc-controller/

Introduction, Motivation

Motivation

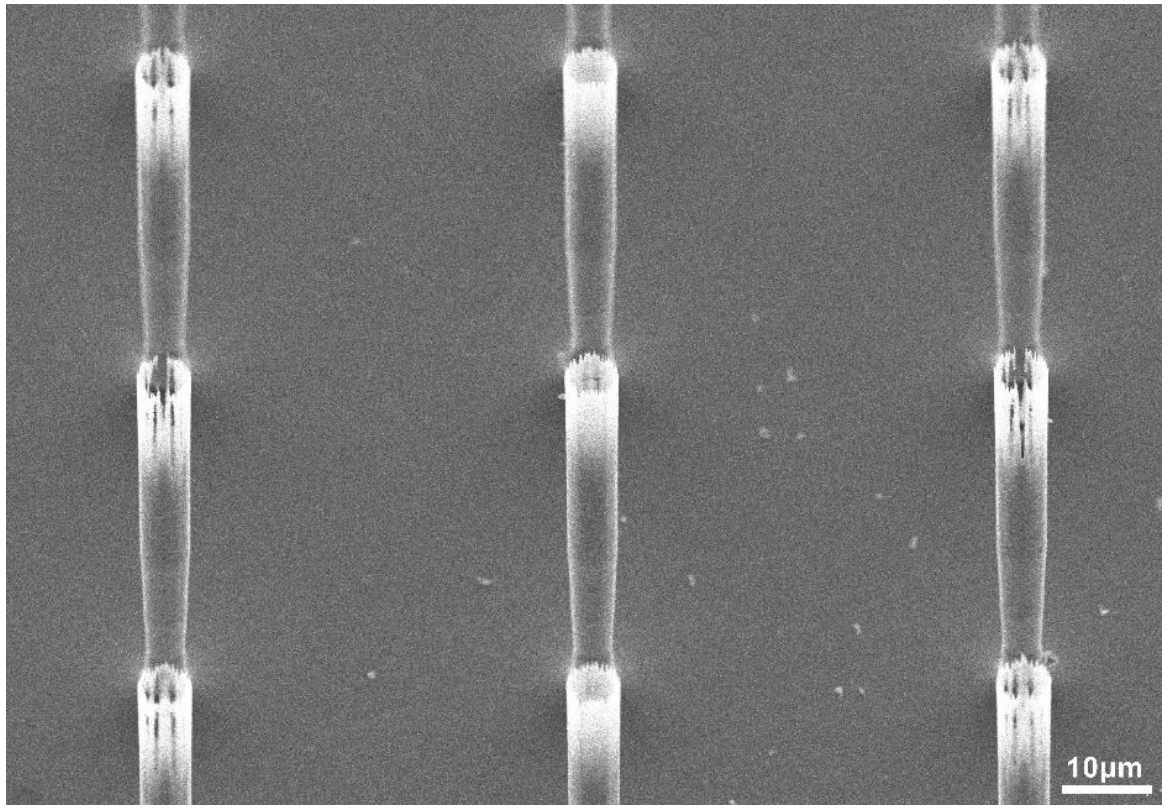
Problems with the silicon based FES due to

- Degradation → short Lifetime
- Reliability
- repeatability

→ Extension of lifetime of FE-eGuns

Approach:

Distribution of emission current



→ Testing distribution design featuring a multiple field-emission arrays (FEAs) for ionization vacuum gauge

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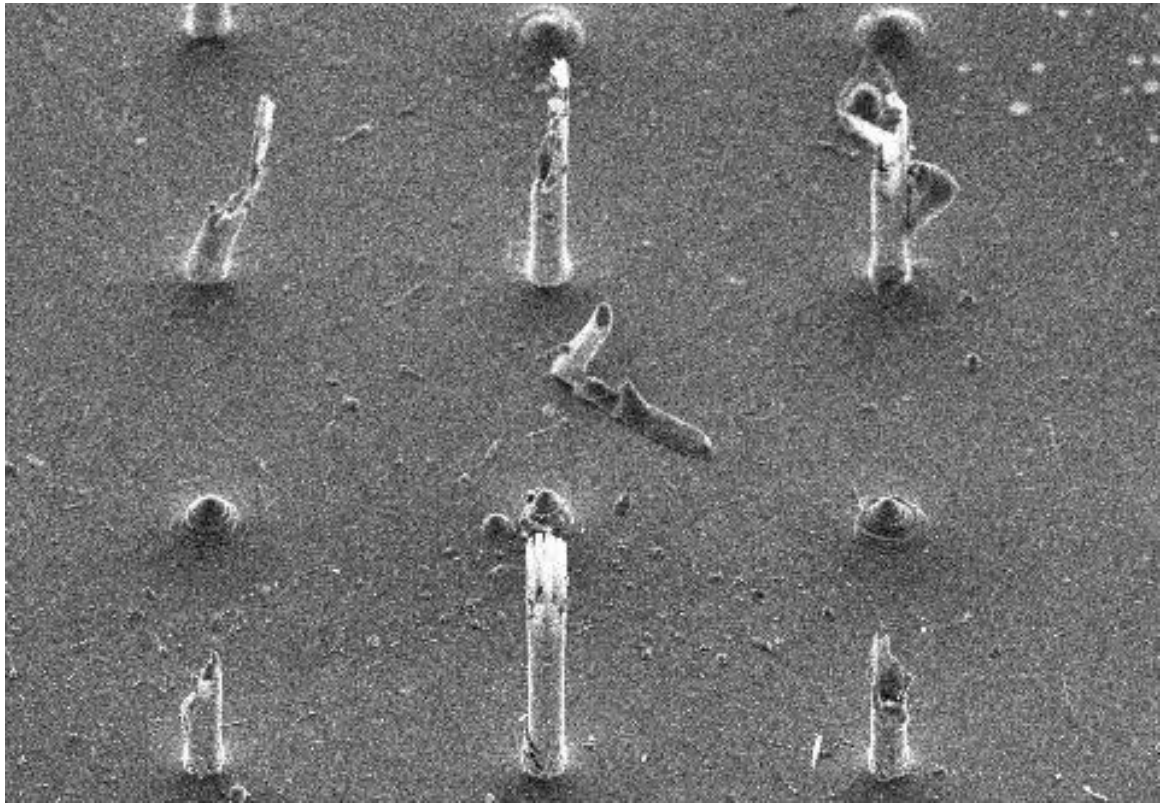
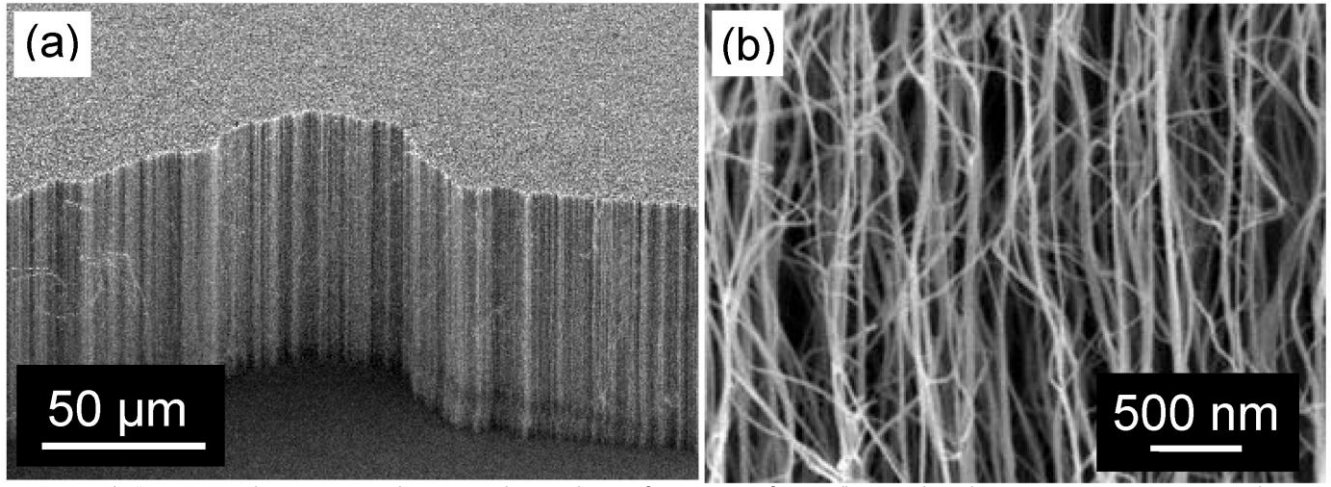


→ Testing distribution design featuring a multiple field-emission arrays (FEAs) for ionization vacuum gauge

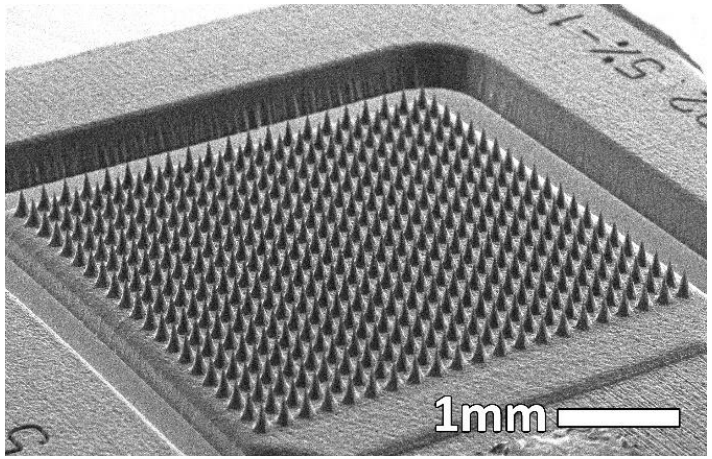
Essentials

Field emitters

- field emitters
  - Work with the principal of extraction of electrons via high electrical fields
  - Use of quantum mechanical tunnelling effect
- types of cold-cathodes / field emitters
  - Silicon based
  - Carbon based
  - Metallic emitters



M. Yu et al., "Recent Developments in Carbon Nanotube Membranes for Water Purification," Materials, vol. 3, no. 1, pp. 127-149, 2010, doi: https://doi.org/10.3390/ma3010127



M. Hausladen, P. Buchner, M. Bartl, M. Bachmann and R. Schreiner, "Silicon field emission electron source with individual control of single emitters," Journal of Vacuum Science & Technology B, vol. 42, no. 2, 2024, doi: https://doi.org/10.1116/6.0003233.

Essentials

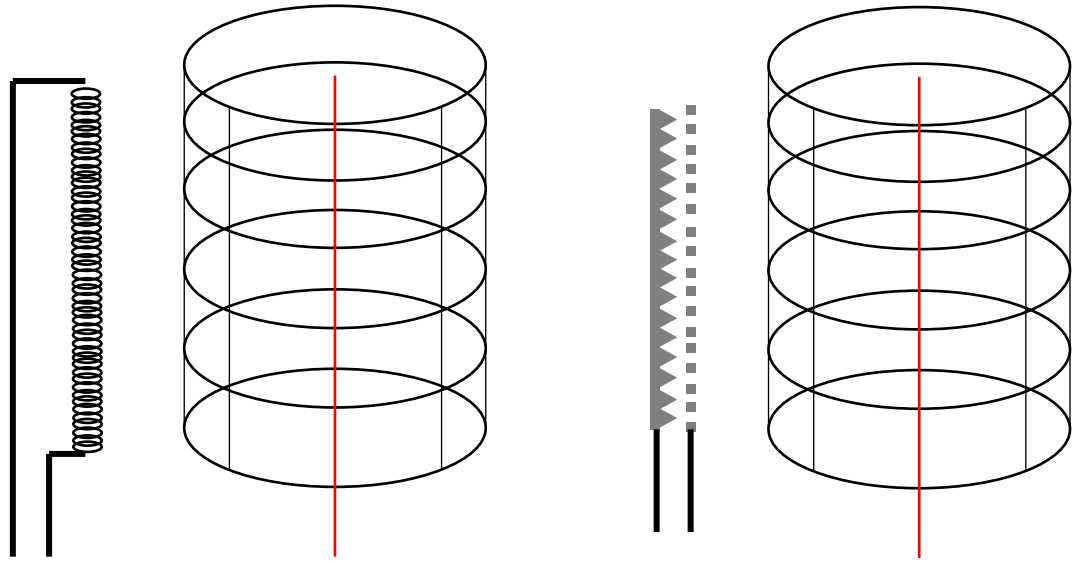
Bayard Alpert

- With hot cathodes: the source for the emitted electrons is a heated filament working via thermionic emission
- With field emitters: extraction of electrons via high electrical fields

The state of field emission sources (FES) in Ionization Vacuum Gauges

Currently two Approaches

- Investigation of CNT based cathodes
- Research of silicon-field-emitter arrays



Essentials

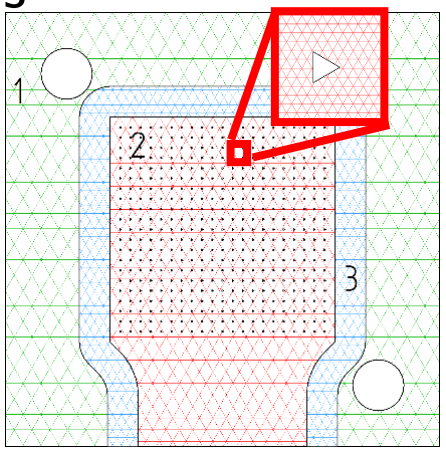
Manufacturing of Fieldemitters

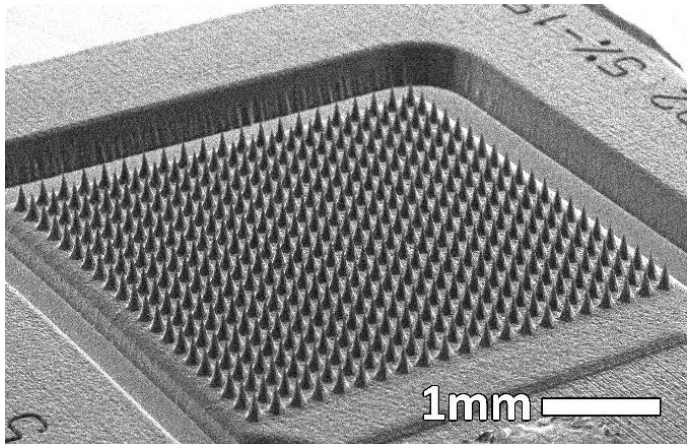
Manufacture of silicon-based field emitters

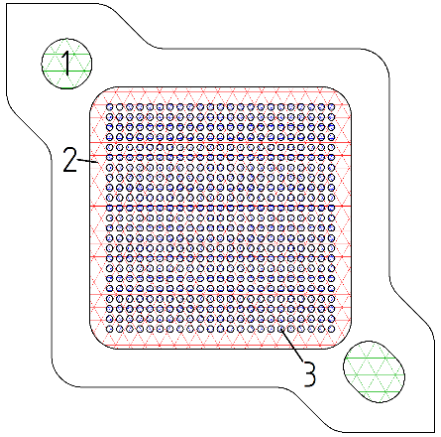
Via laser ablation

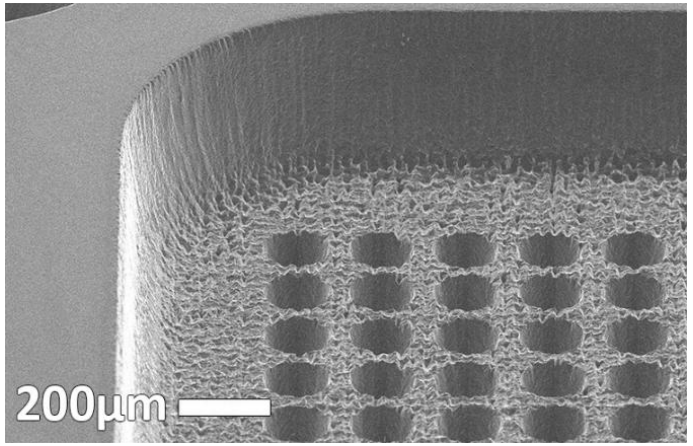
- Emitter:
  - Bonding of Si wafer on glass-substrate
  - Laser ablation of emitter
  - Etching of Oxid with HF and TMAH

- Grid:
  - Laser ablation of grid
  - Etching of Oxid with HF and TMAH









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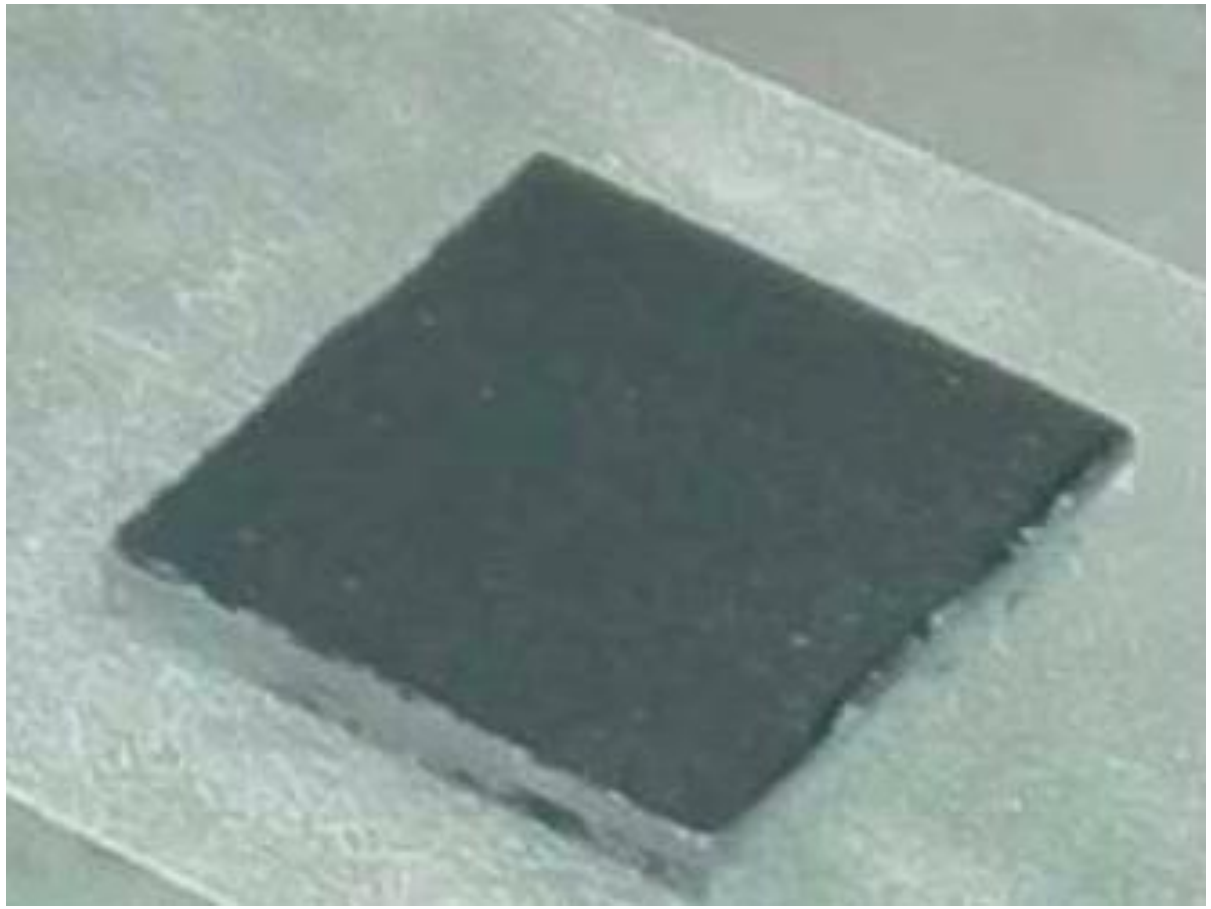

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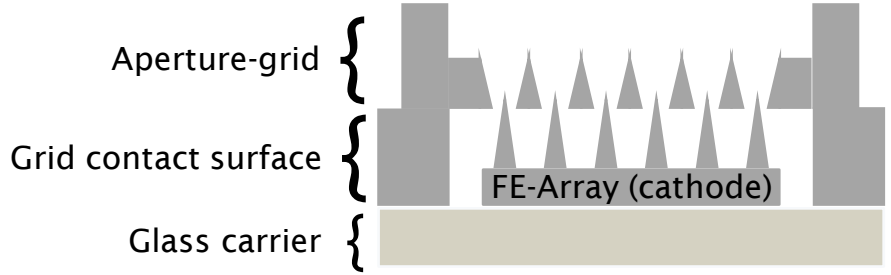
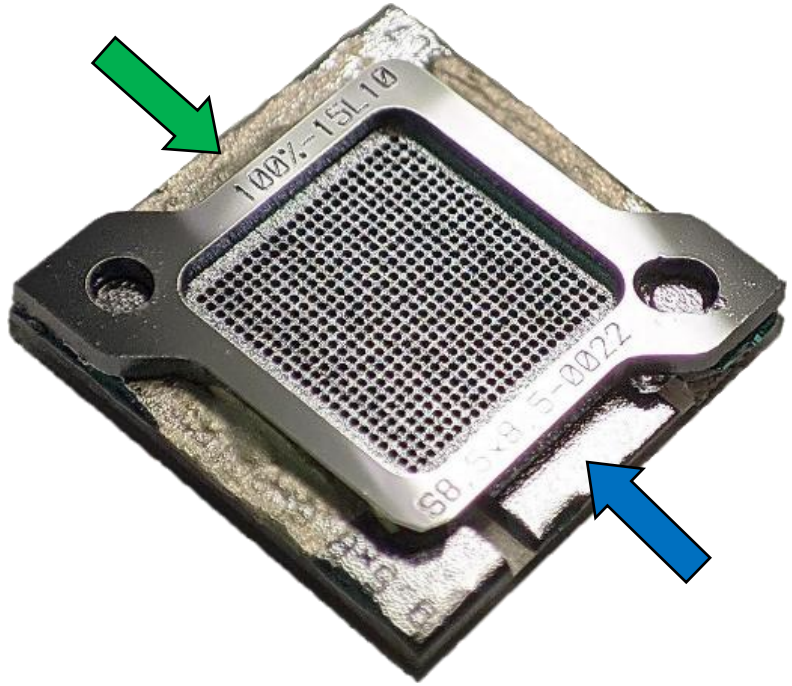
Essentials

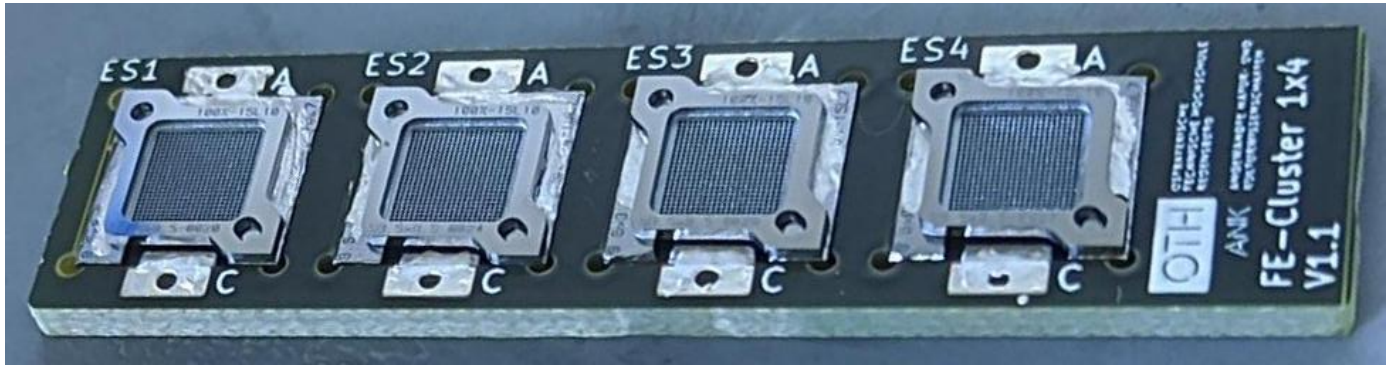
Manufacturing of fieldemitter-arrays

- Assembly of the emitter array with grid
  - Electrical contact of grid with silver-epoxy-glue
  - Extra contact for emitter array





- Assembly of a cluster with 4 arrays on PCB board



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Equipment and setup

Control circuit board

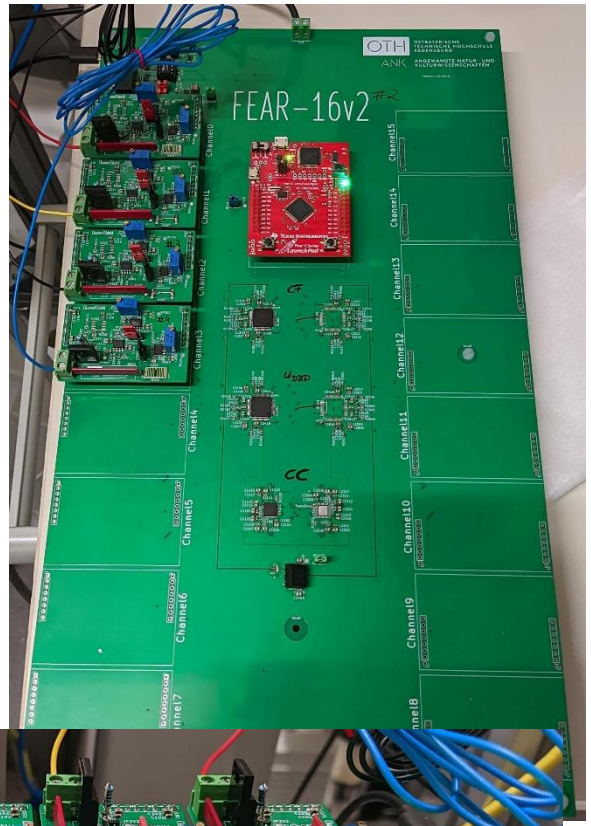
Mainboard FEAR 16v2, „Field Emission Array Regulation“

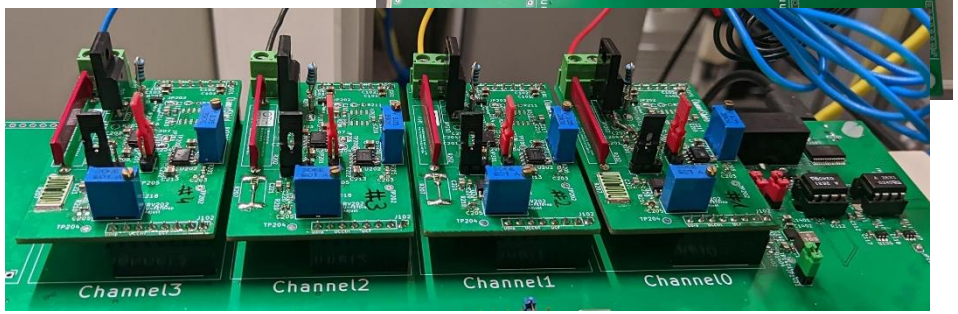
Potential difference up to 1500V between Logic- and HV-Side

External power supply (HV)

- Logic-Side
  Communication as a virtual Com-Port and Power-Supply via USB-C

- HV-Side
  - With up to 16 channels/shields
  - Shields: Circuit-design defines the functionality
  - Example: Cathode-Regulation

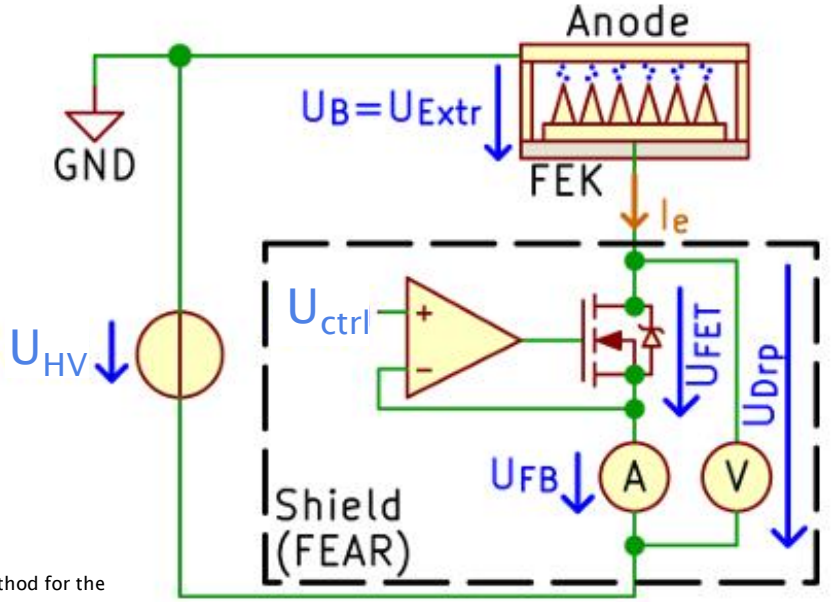




Equipment and setup

Cathode regulation

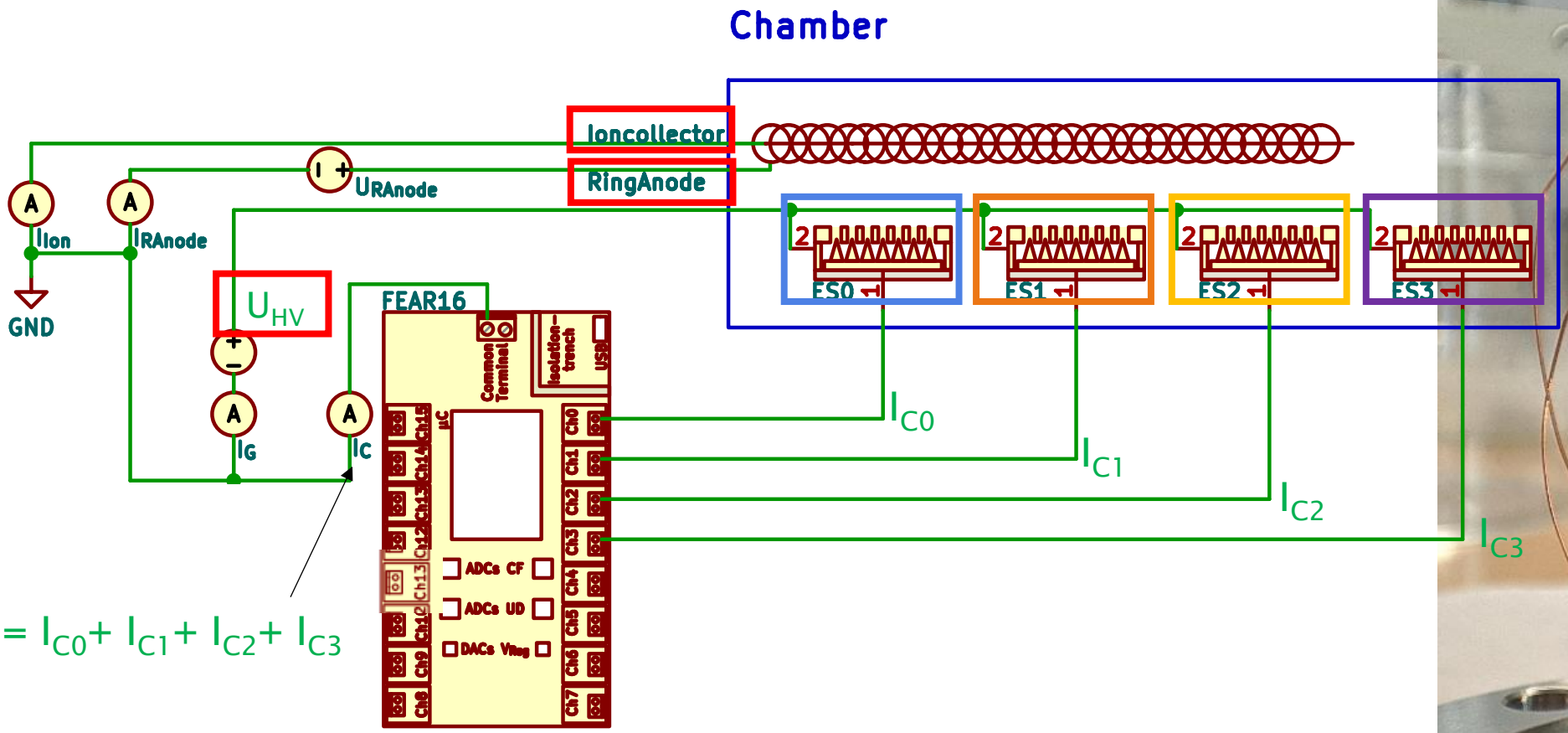
- First concept: constant field emission current by regulating the cathode potential
- the OpAmp (yellow) compares the given voltage (U_{ctrl}) with the measured one (U_{FB})
- Regulates the MOSFET as variable resistor
- Desired extraction voltage (U_{Extr}) is set for the optimal current as given due to U_{ctrl}
- Const. cathode-current at expense of varying electron energy

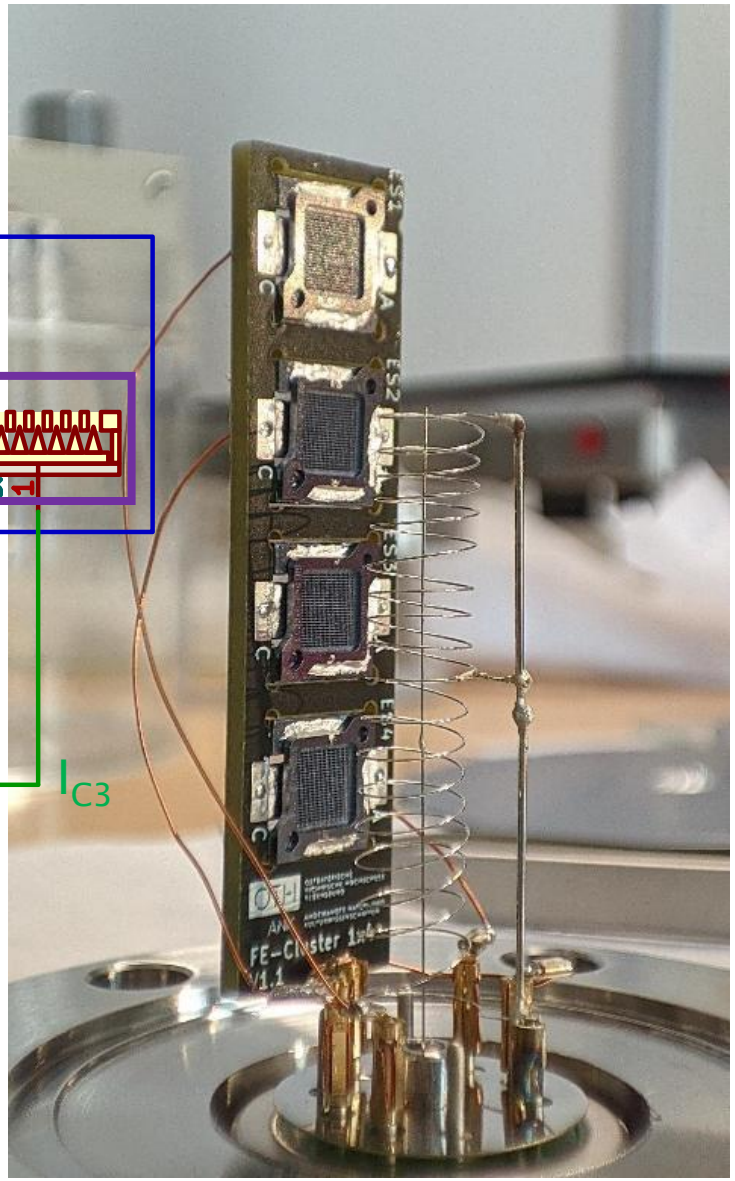


M. Hausladen, "Development, Analysis and Application of a Spatially and Temporally Resolved Measurement Method for the Quantitative Characterization of Field Emission Cathodes," Dissertation, OTH Regensburg, publication process.

Equipment and setup

Measurement setup



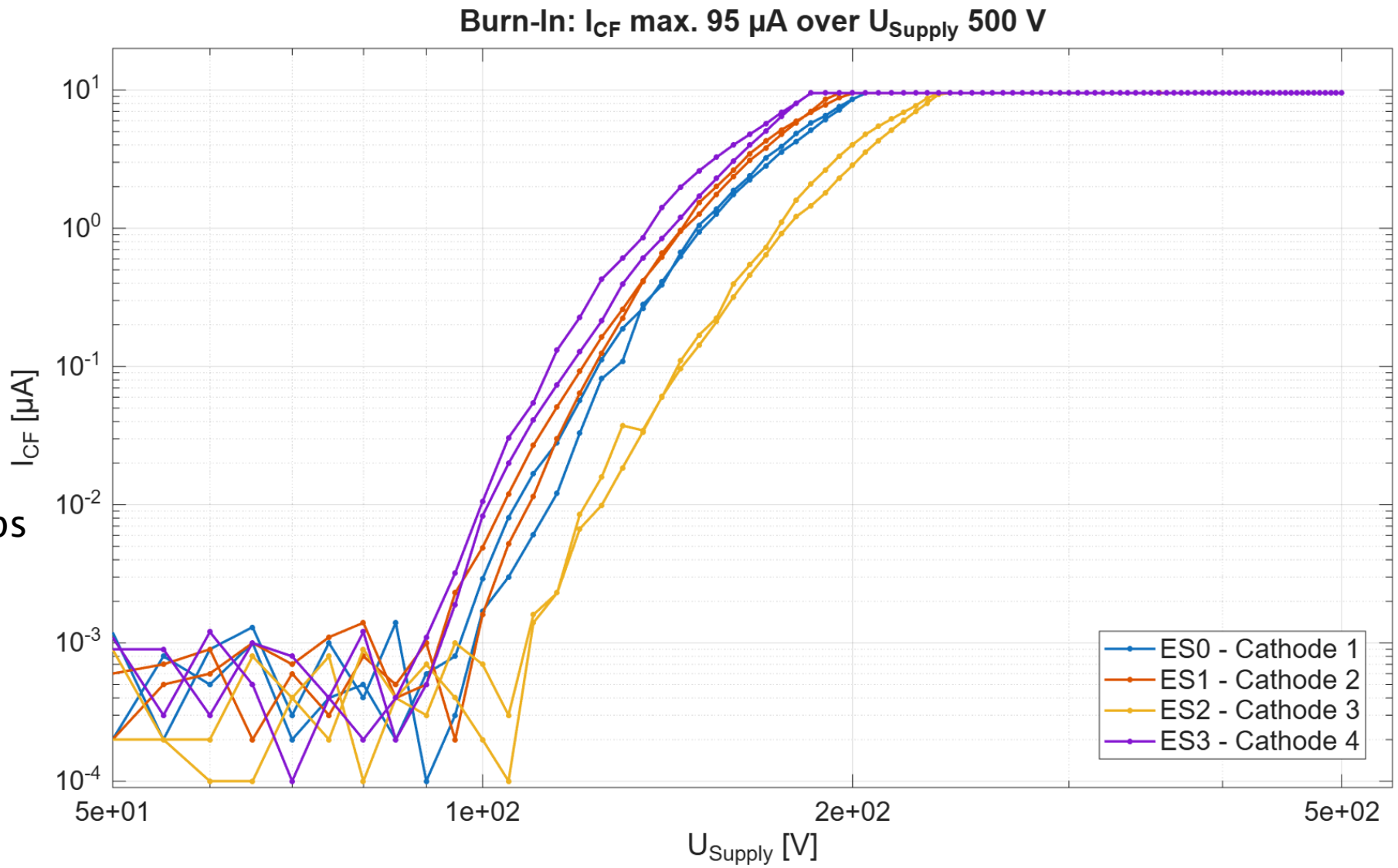


Measurement

Conditioning of the tips

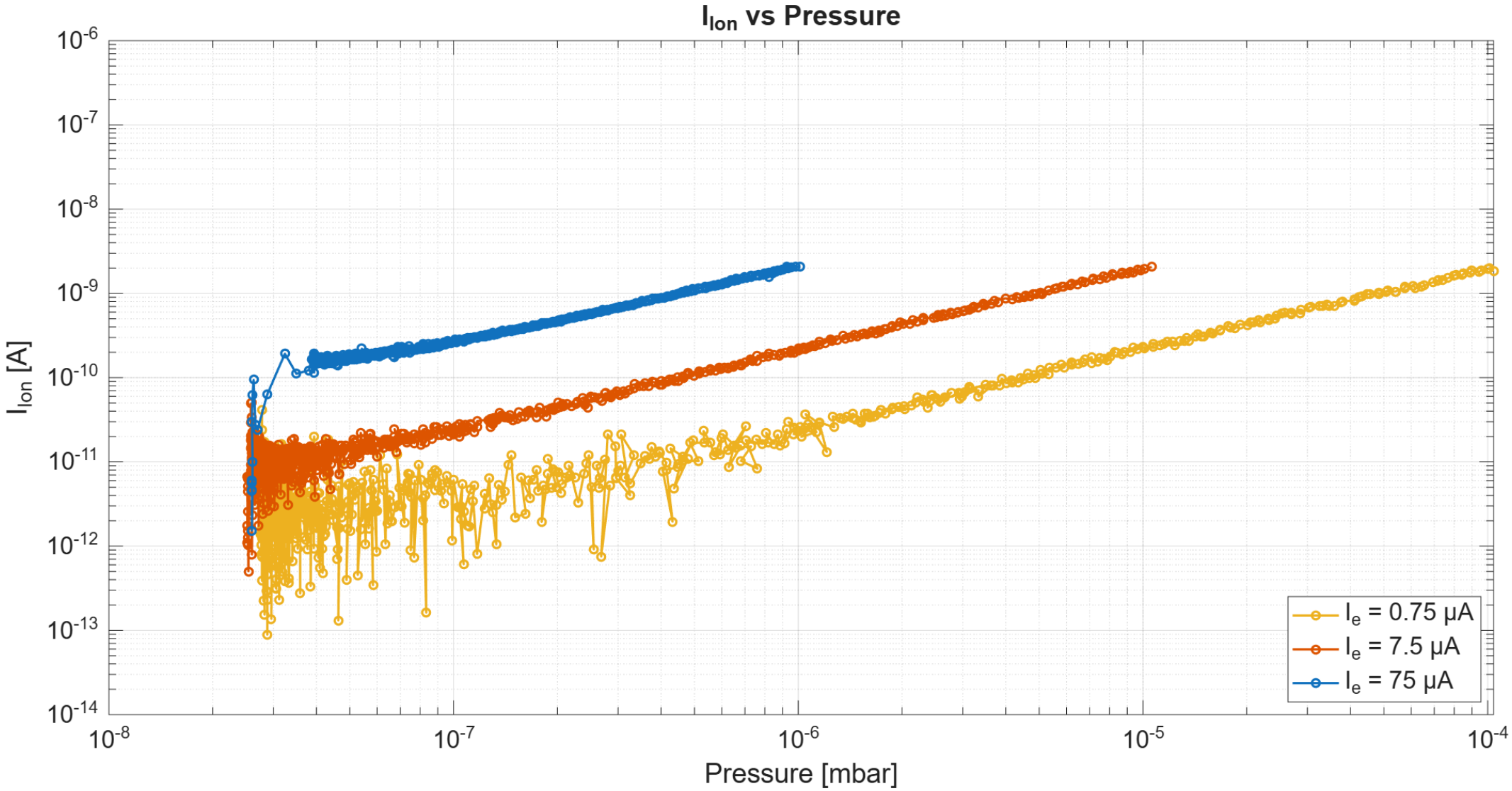
1. Test for shorts
   - Reversed potential
   - Any current?
2. Activation

   Consecutive steps to search for emitting-Voltage
3. Burn-In
   - repetition of sweeps
   - Eliminate oxide, absorbates
   - Elimination of hysteresis



Measurement

Pressure sweep, proof of concept BA



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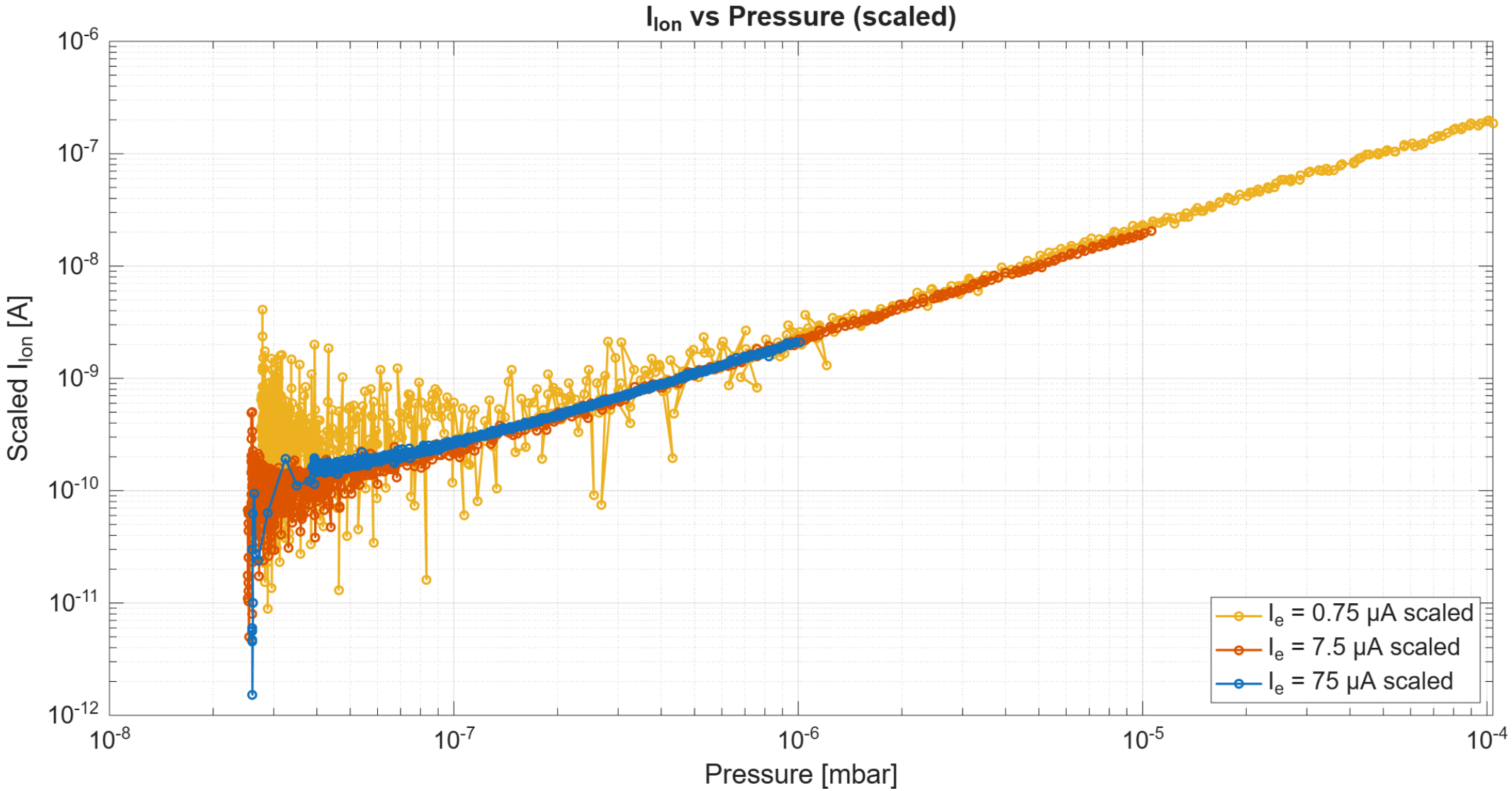
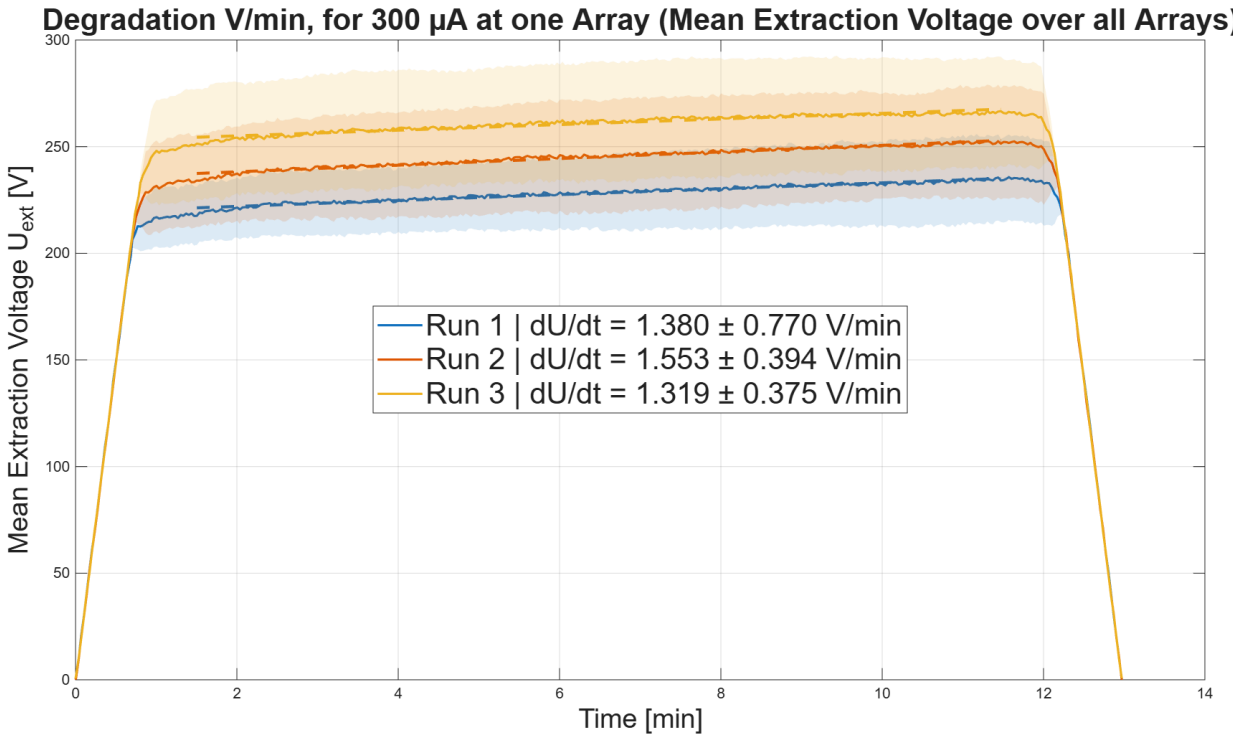
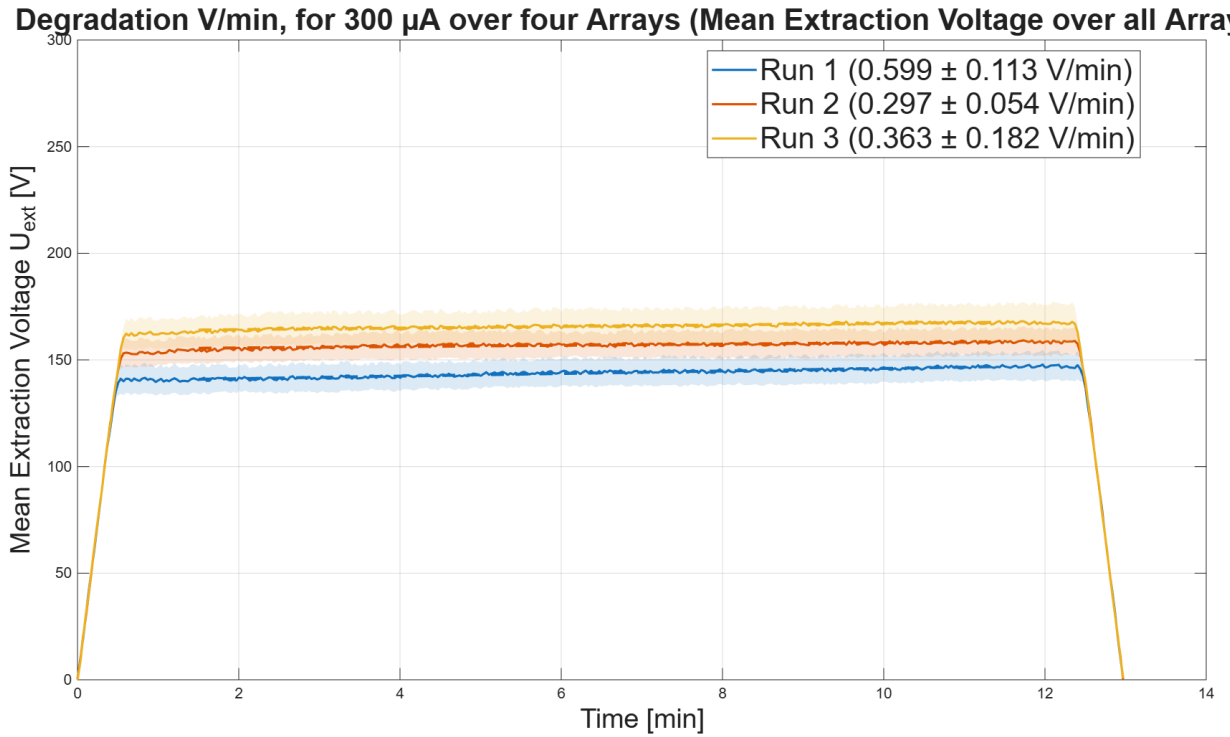


Measurement

Degradation measured via increase in voltage per minute of U_{ext}

if max. current of 300 µA at one Array vs. distrubuted over four





Conclusion and Outlook

Conclusion

- Working cathode-regulation-setup
- Proof of functionality of this setup for use as Bayard Alpert ionisation vacuum gauge with multiple arrays of FE
- Proof of concept of reducing degradation of FE with distributing emission current works also for Bayard Alpert vacuum gauge

Outlook

- Test of other regulation-modes possible, Extraction-grid Potential regulation to achieve fixed acceleration voltage, const. electron energy
- Improvement in homogeneity of field-emission arrays to achieve longer lifetimes
- Verification of usage in other environments like cryogenic environments
- Integration into commercially available systems

Thank you for your attention!

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