Friedrich-Alexander-Universität Erlangen-Nürnberg
Chair of Electron Devices

sglux UV SENSORS

Fraunhofer IISB

With funding from the:

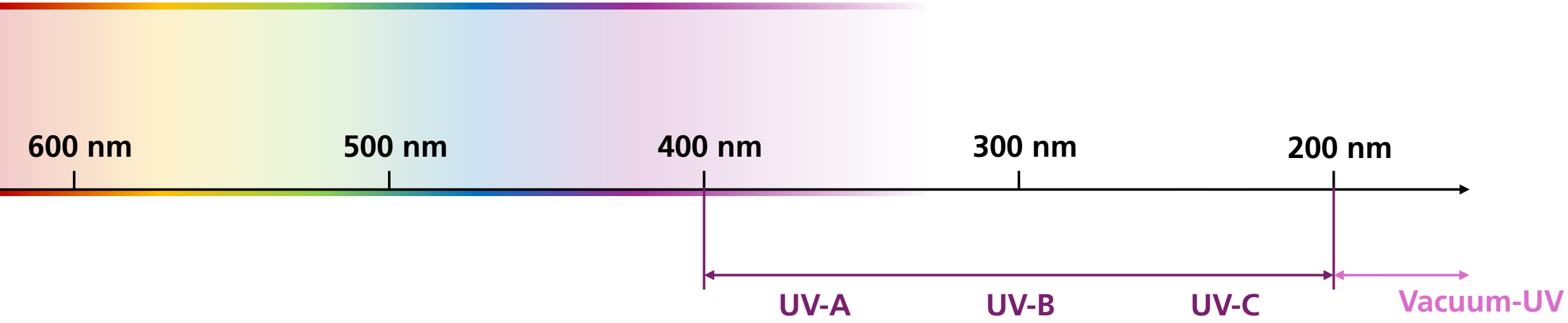
Federal Ministry of Research, Technology and Space

ICSCRM 2025
14-19 September 2025
BEXCO, Busan, Korea

Self-heating in 4H-SiC Avalanche-Photodiodes and its Impact on Spectral Responsivity Measurements

F. Beier, N. Papathanasiou, B. Kallinger, M. Rommel, J. Schulze

Detection of weak UV signals



- State of the art: Photomultiplier tubes
  - Short lifetime
  - High cost
  - High operation voltage

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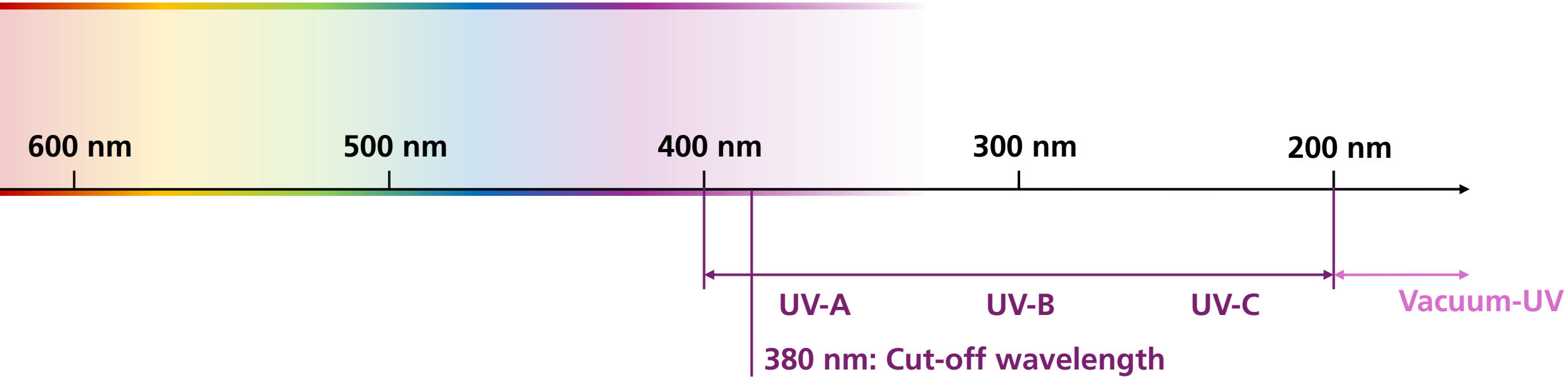

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  - High electrical breakdown field strength
  - Small light absorption coefficient

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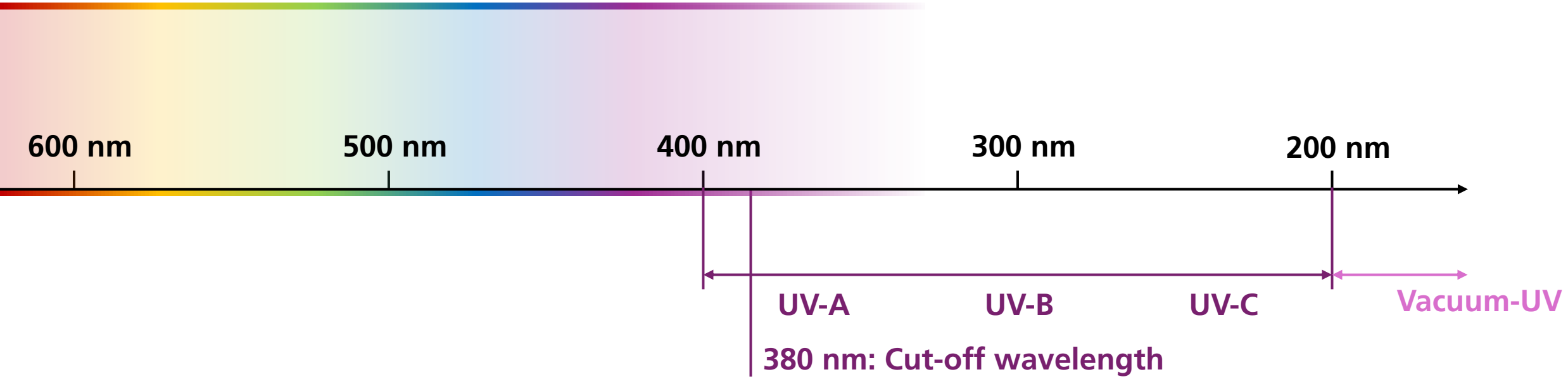

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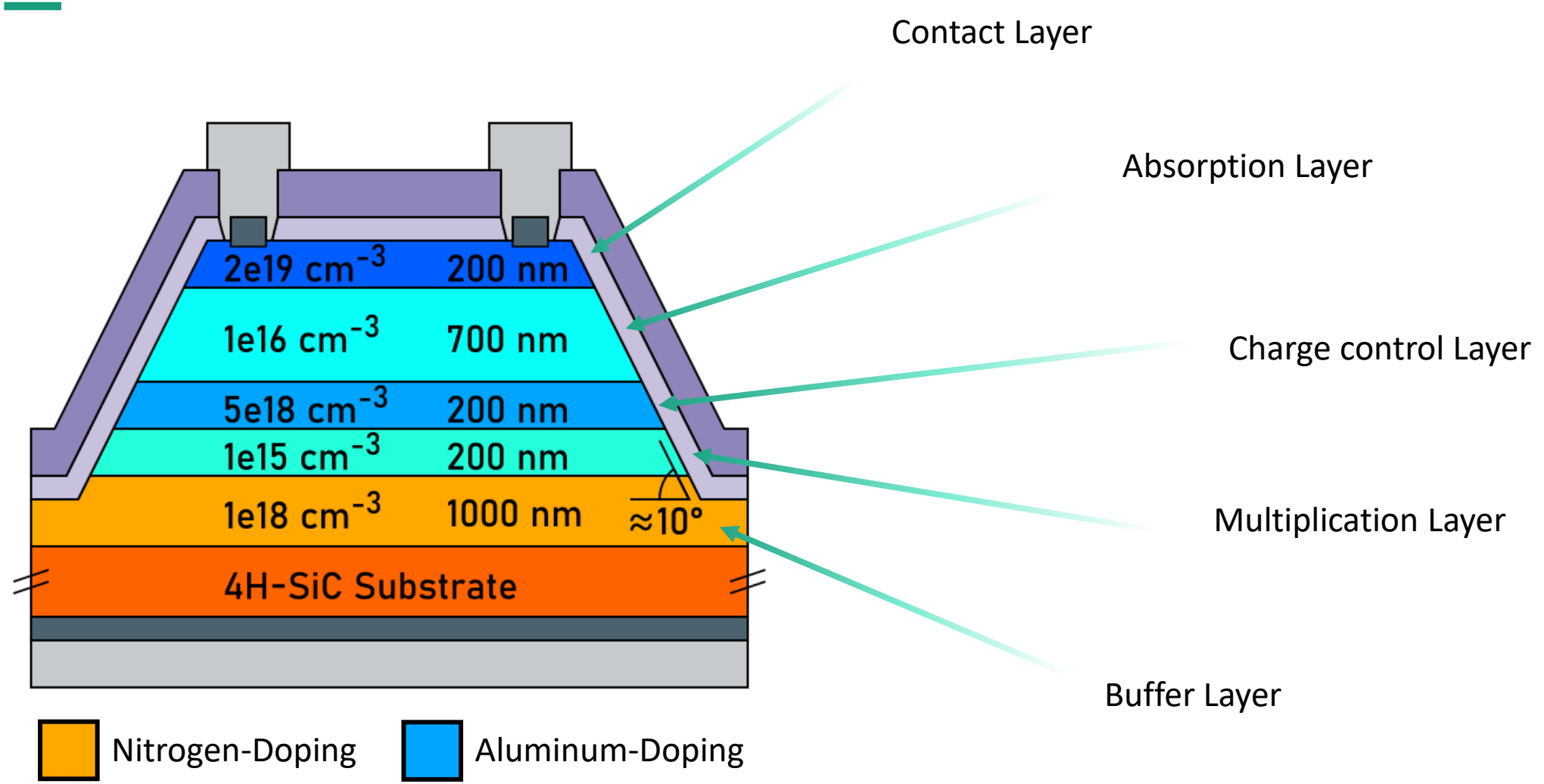
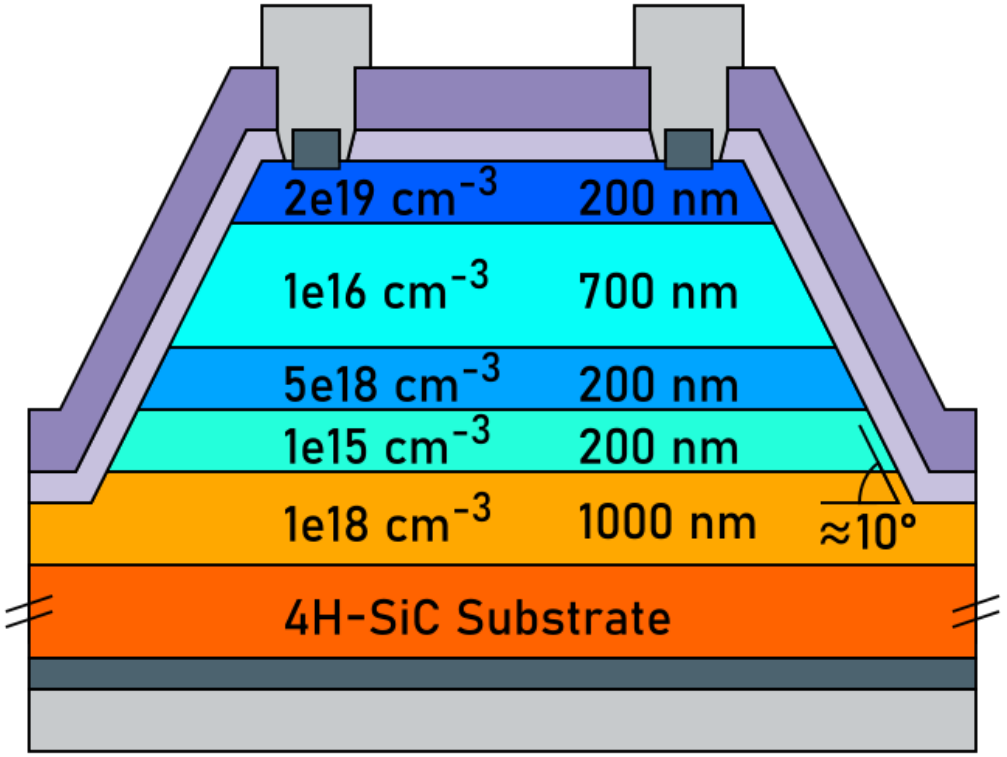
→ SACM-Design (**S**eparate **A**bsorption **C**harge and **M**ultiplication Design)

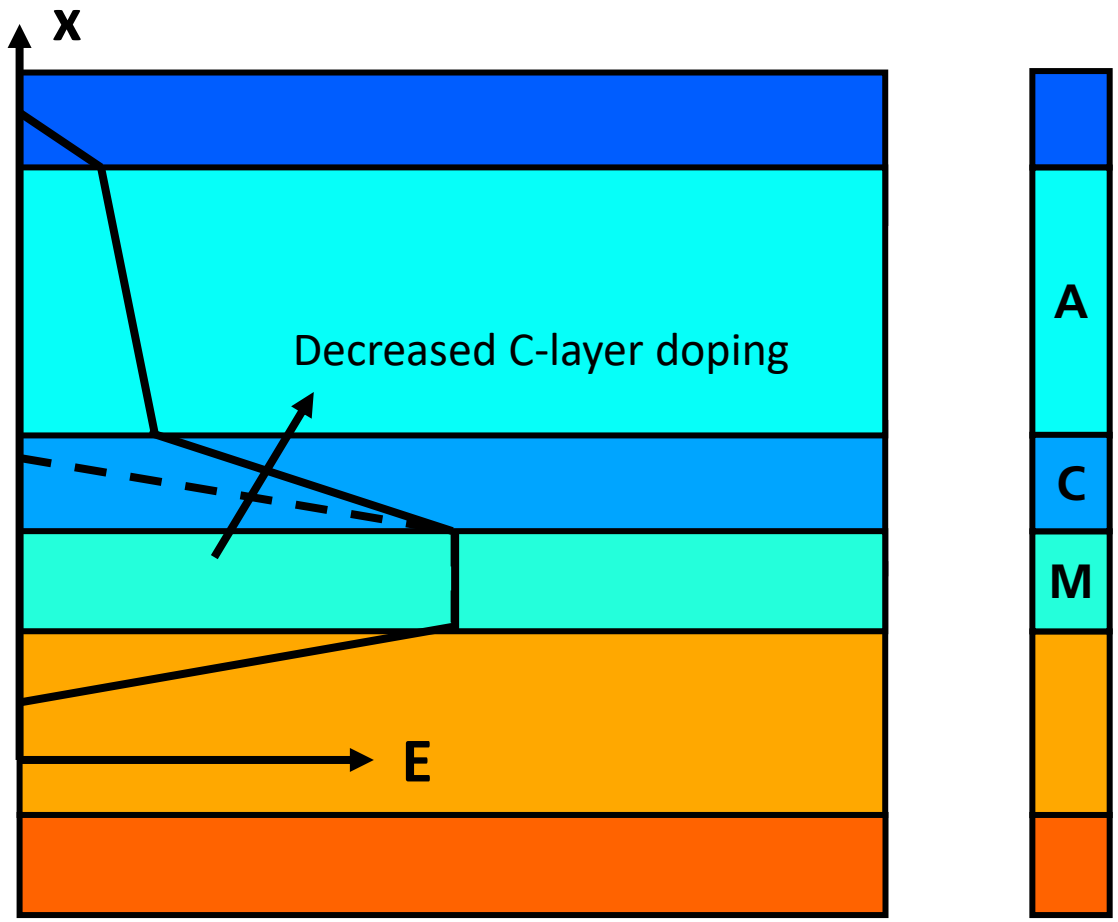
4H-SiC SACM Avalanche Photodiodes



4H-SiC SACM Avalanche Photodiodes



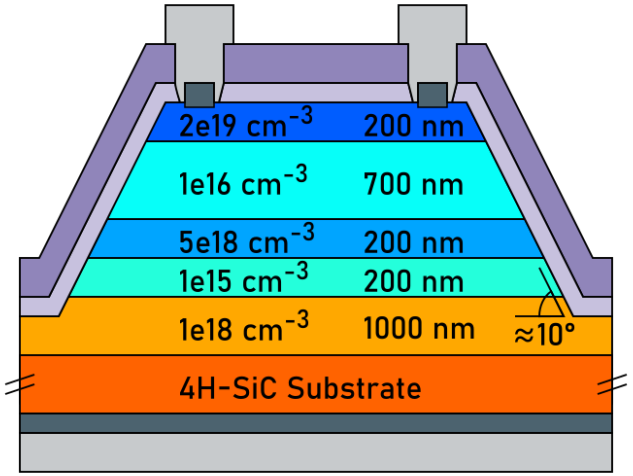
Nitrogen-Doping Aluminum-Doping



Reach-through: Higher spectral responsivity

Non-reach-through: Lower dark current

Sample fabrication

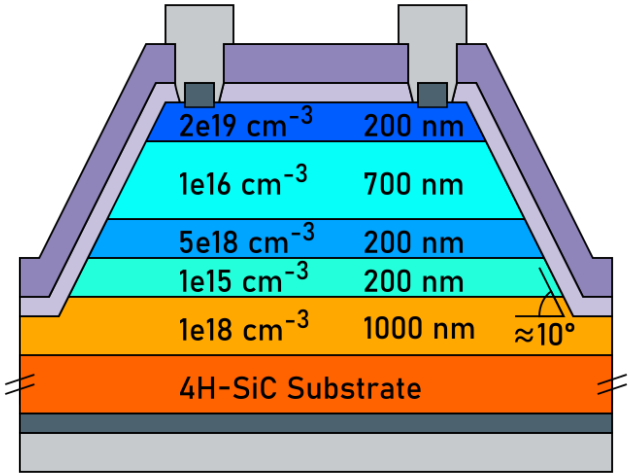


Nitrogen-Doping

Aluminum-Doping

Epitaxial growth

Sample fabrication



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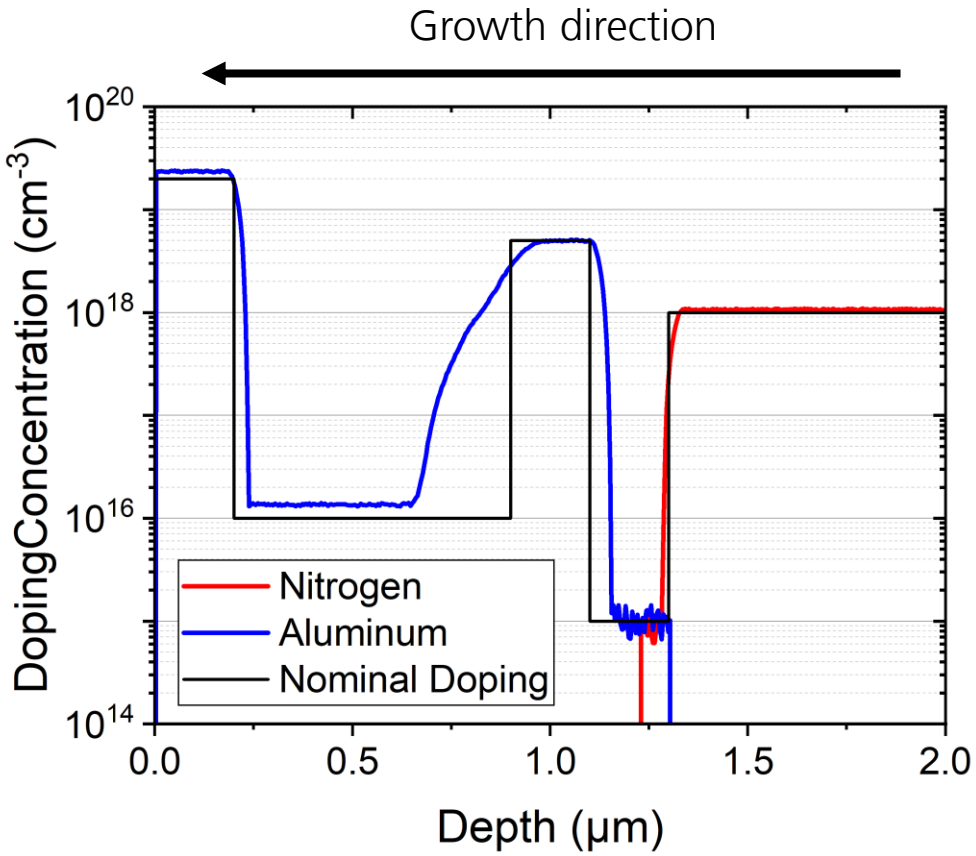

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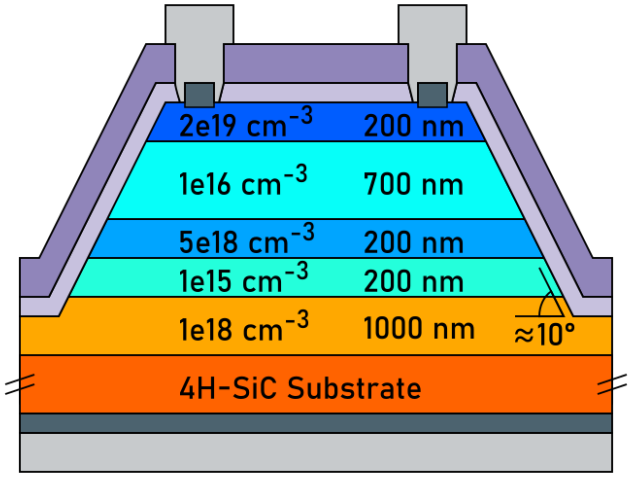
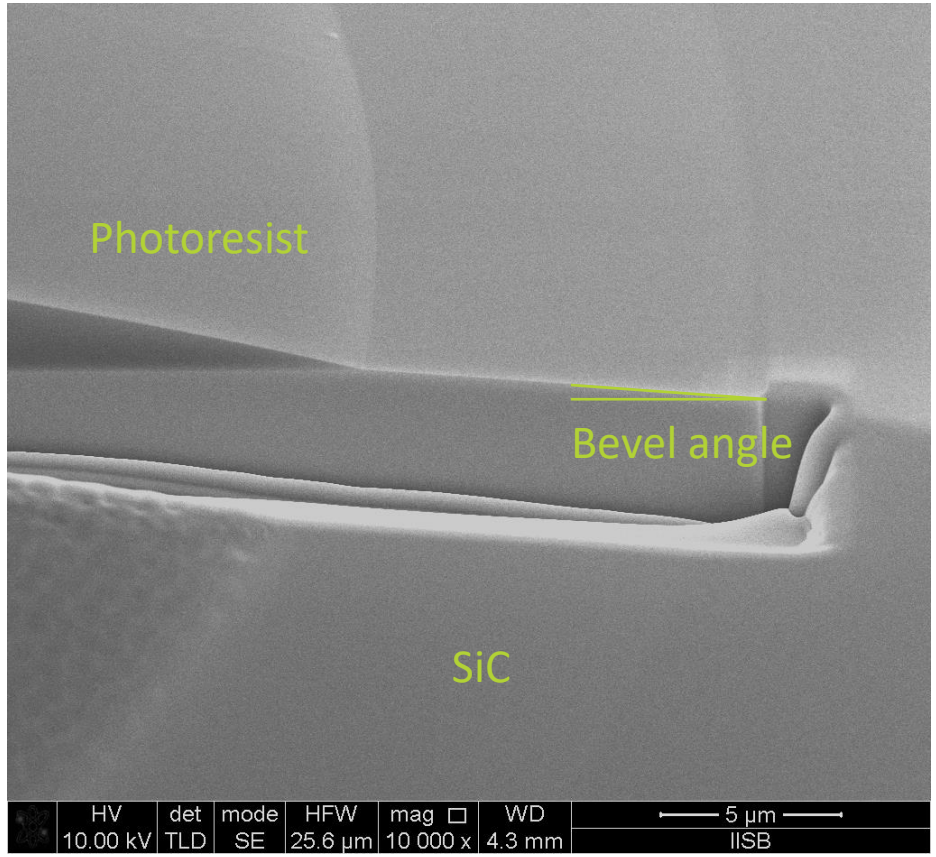


Nitrogen-Doping

Aluminum-Doping

- Epitaxial growth
- Bevel etching via resist reflow technique



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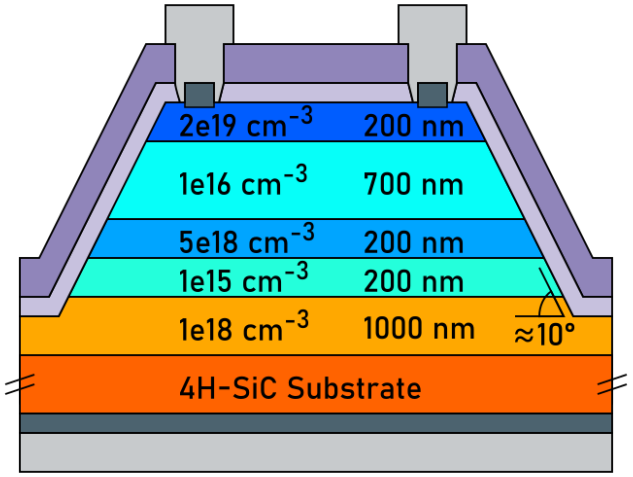
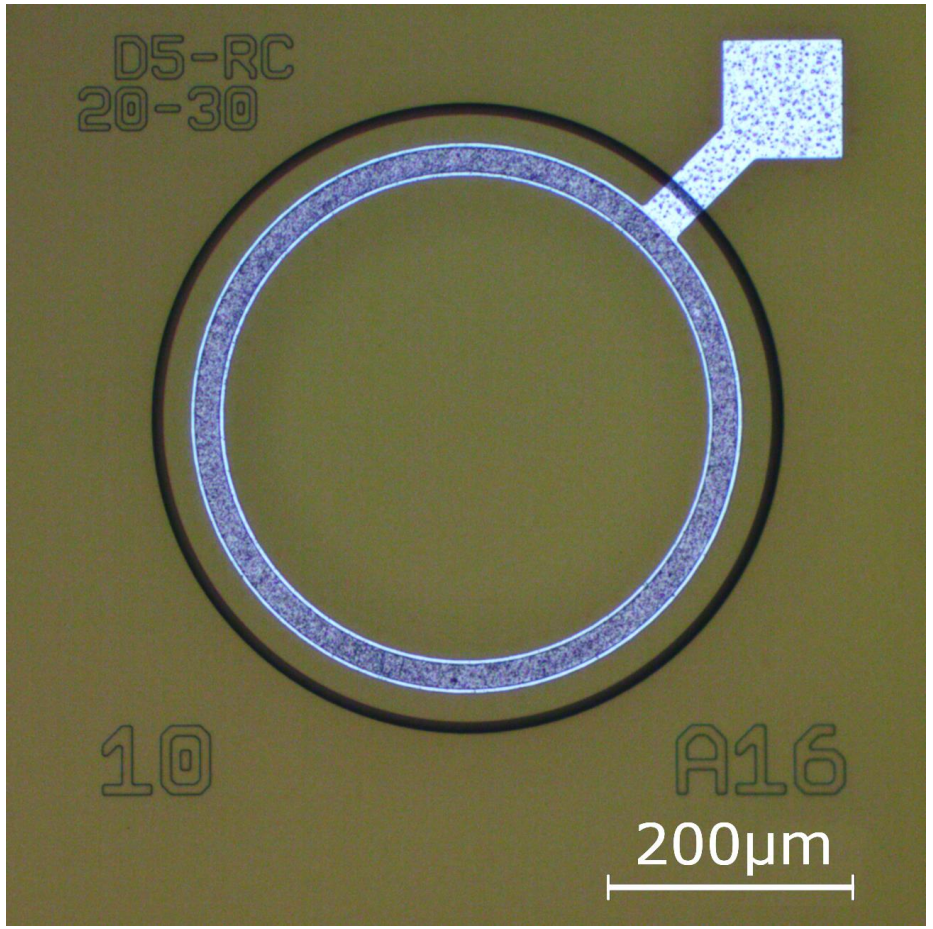


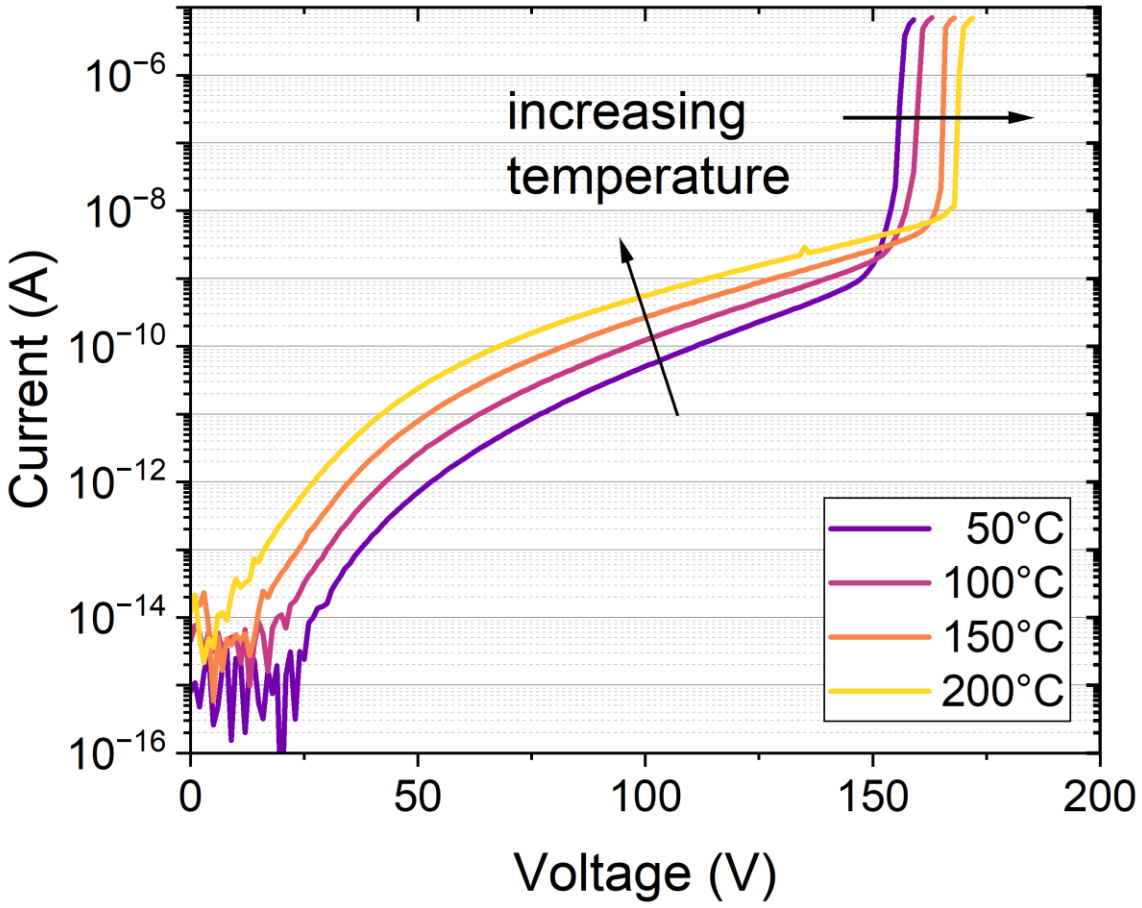
Nitrogen-Doping

Aluminum-Doping

- Epitaxial growth
- Bevel etching via resist reflow technique
- Passivation with thermal oxide and TEOS
- Ohmic contact formation on front- and backside
- Metallization



Temperature dependent IV-Characteristics (Reverse Bias)



- Breakdown voltage: ≈ 150 V
- Dark current: < 100 pA
- Increasing leakage current with temperature

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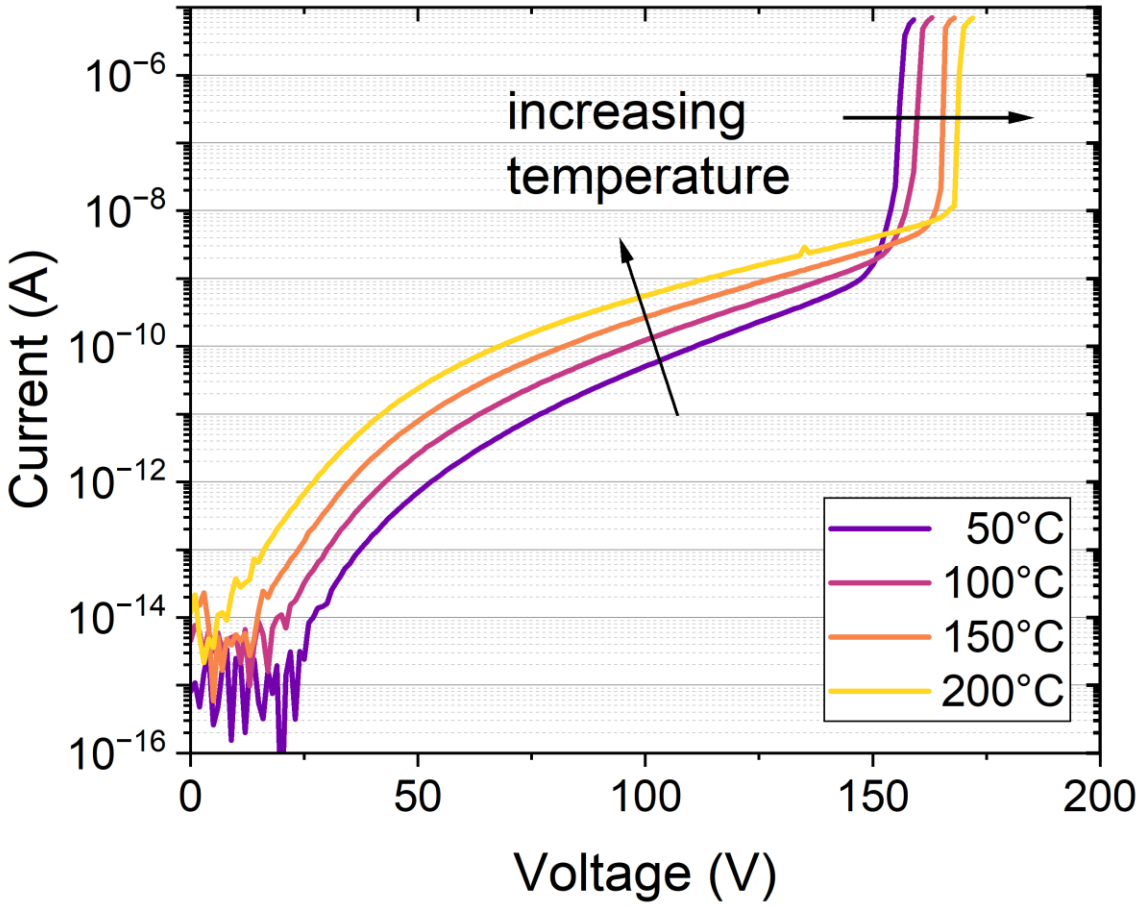

- Breakdown voltage: ≈ 150 V
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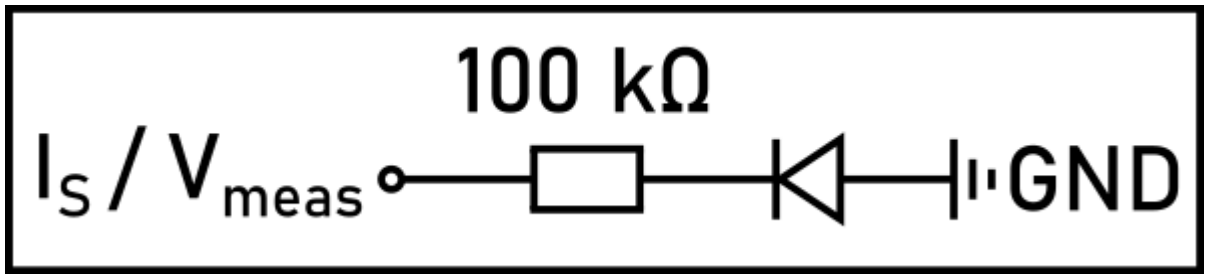
- Increasing leakage current with temperature
- Increasing breakdown voltage with temperature:
  - → Decreased carrier mean free path due to increased phonon-interaction
  - → Higher electrical field needed for avalanche breakdown
  - → Evidence for avalanche breakdown

Temporal behavior under constant current stress



I_S = const. : sourced current

V_{meas} : measured voltage

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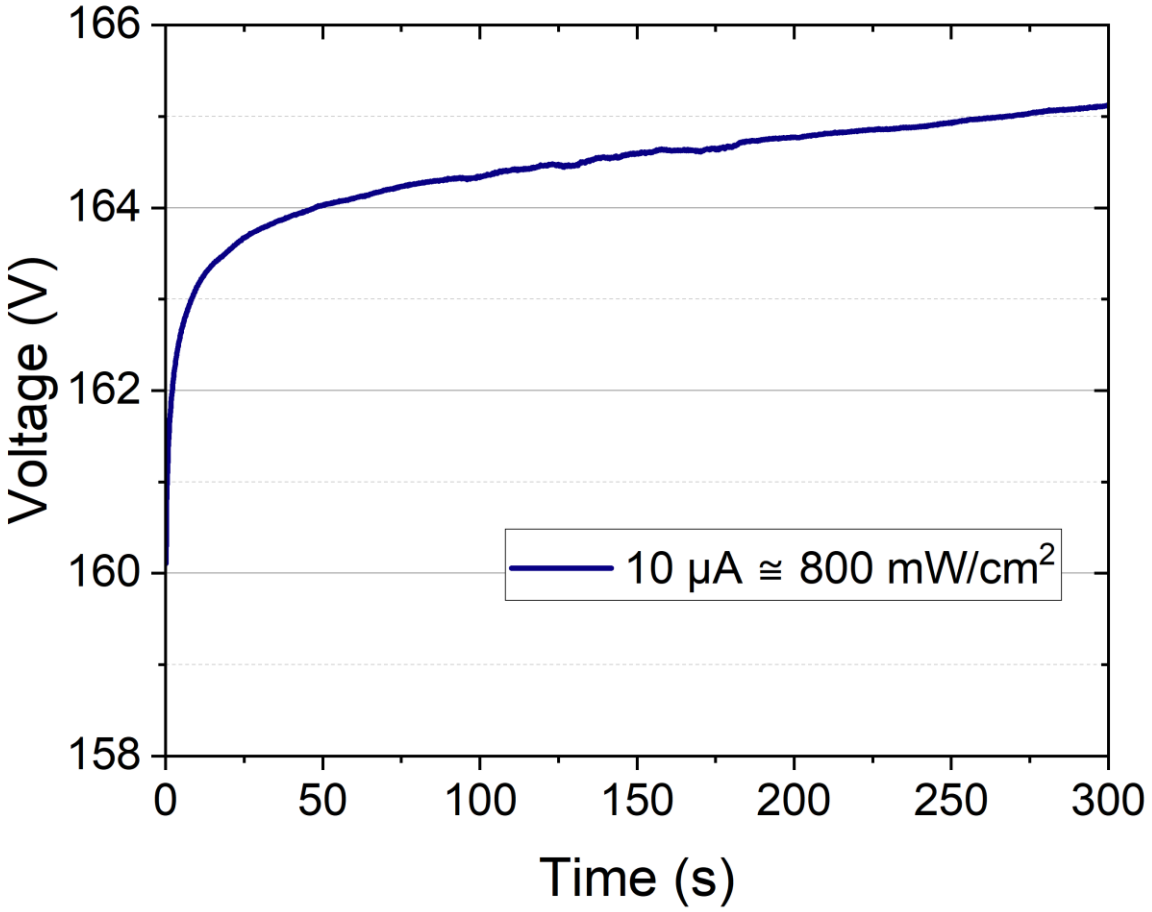

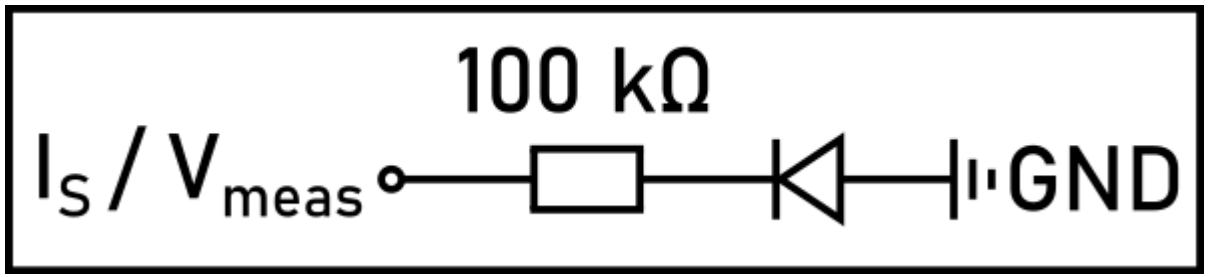

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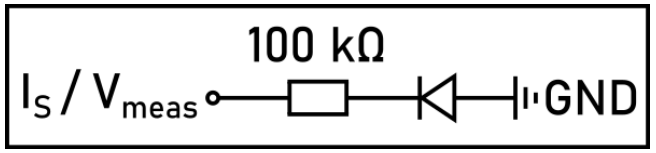

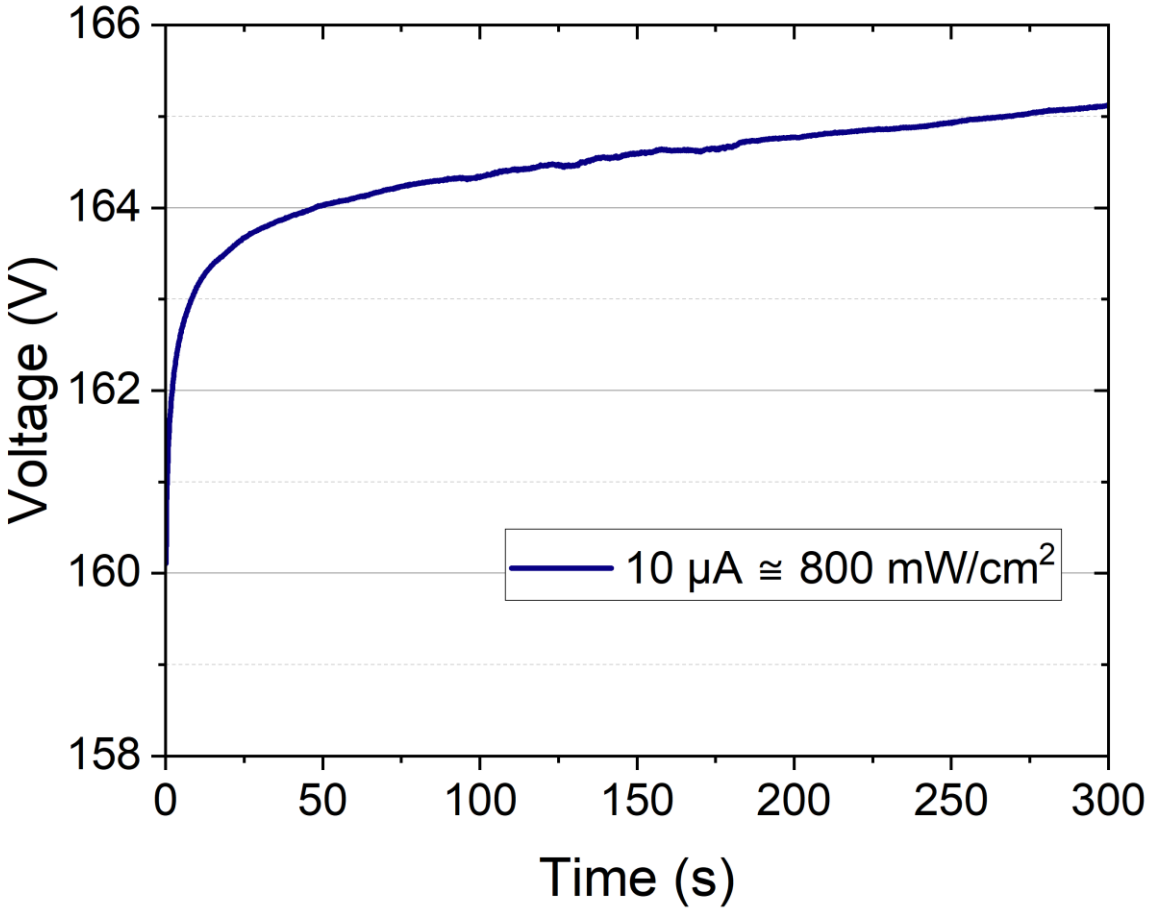

- Voltage needed to maintain current flow increases over time
- Long-lasting temporal effect

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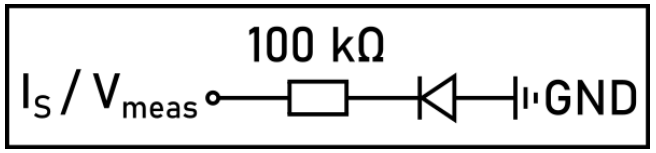
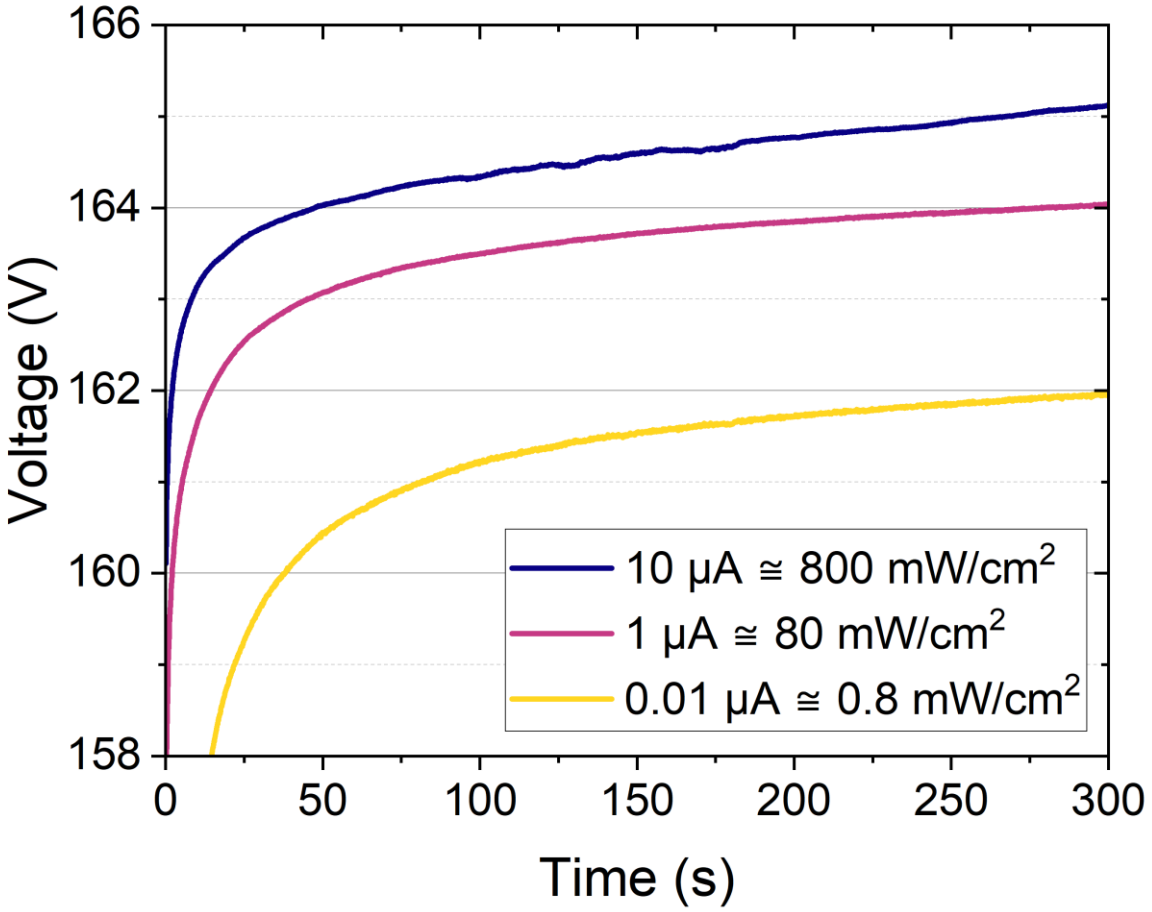
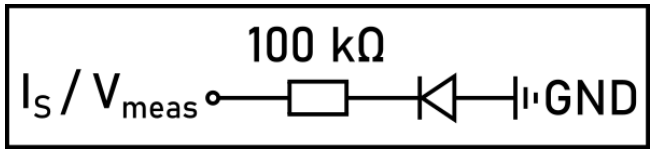


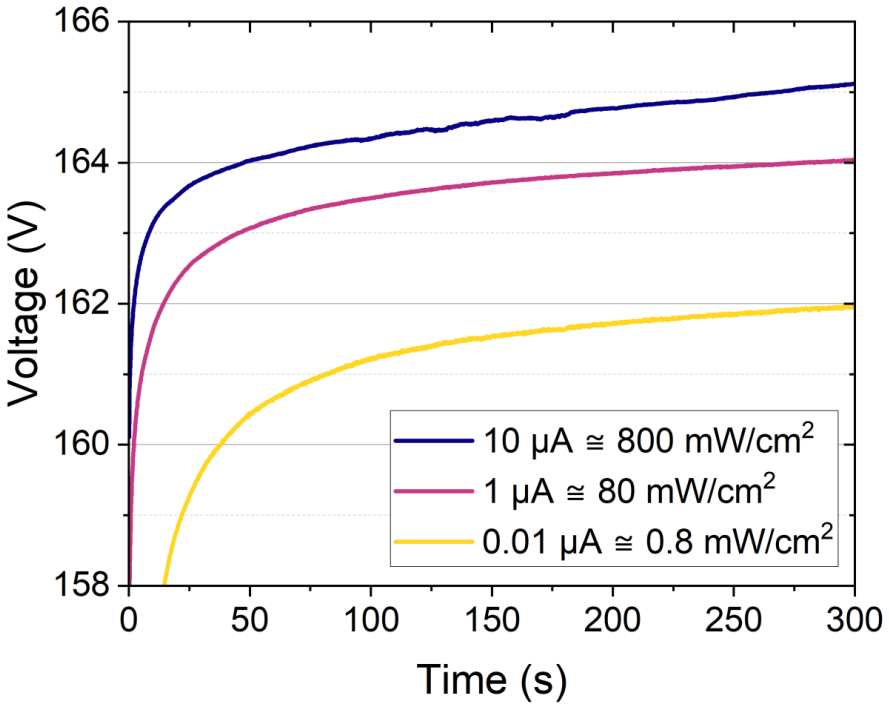


- Voltage needed to maintain current flow increases over time
- Long-lasting temporal effect
- Similar behavior with even smaller currents

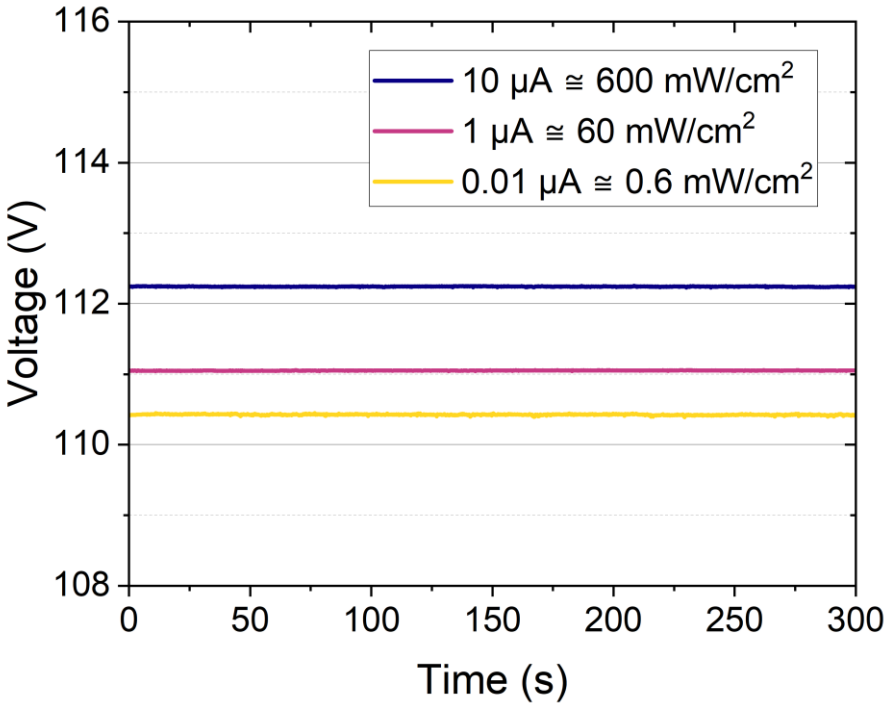
Temporal behavior under constant current stress



Run 1



Run 2



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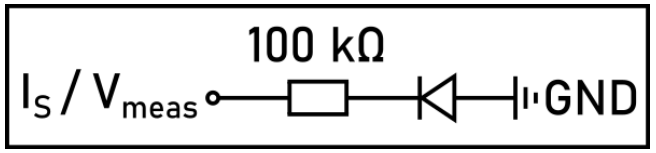

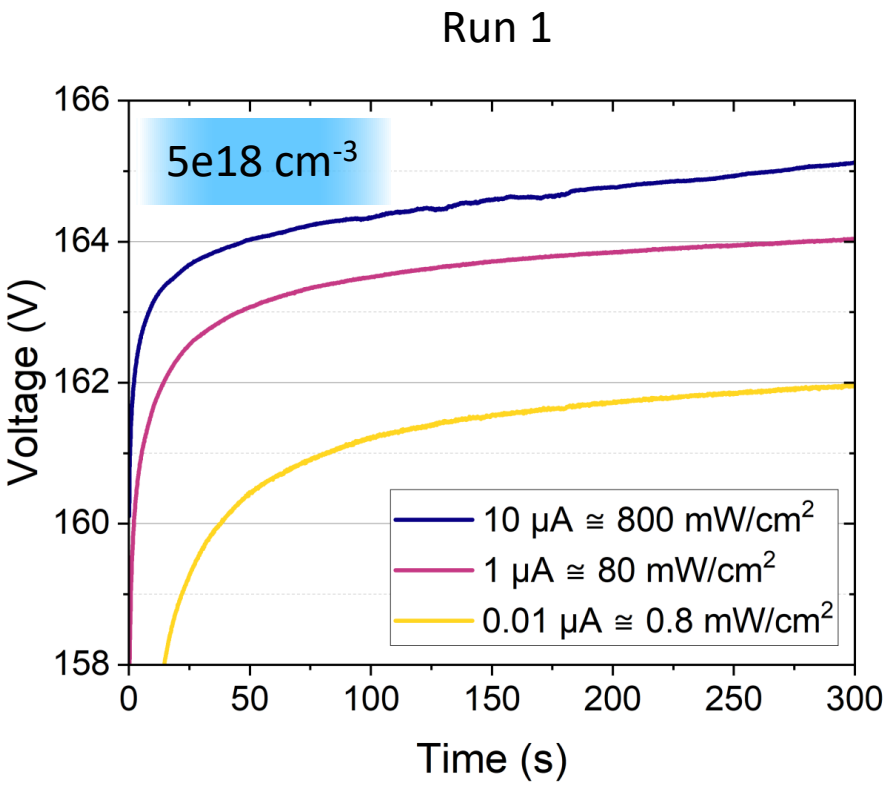

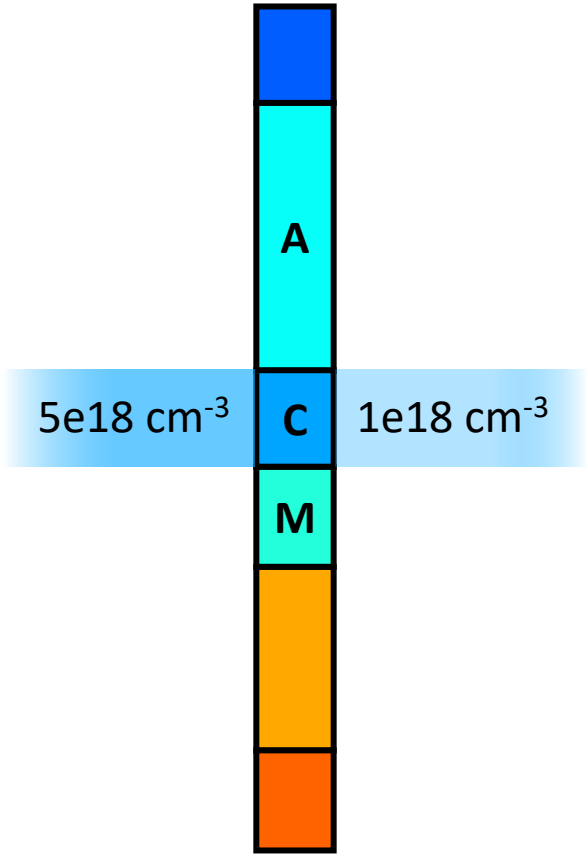

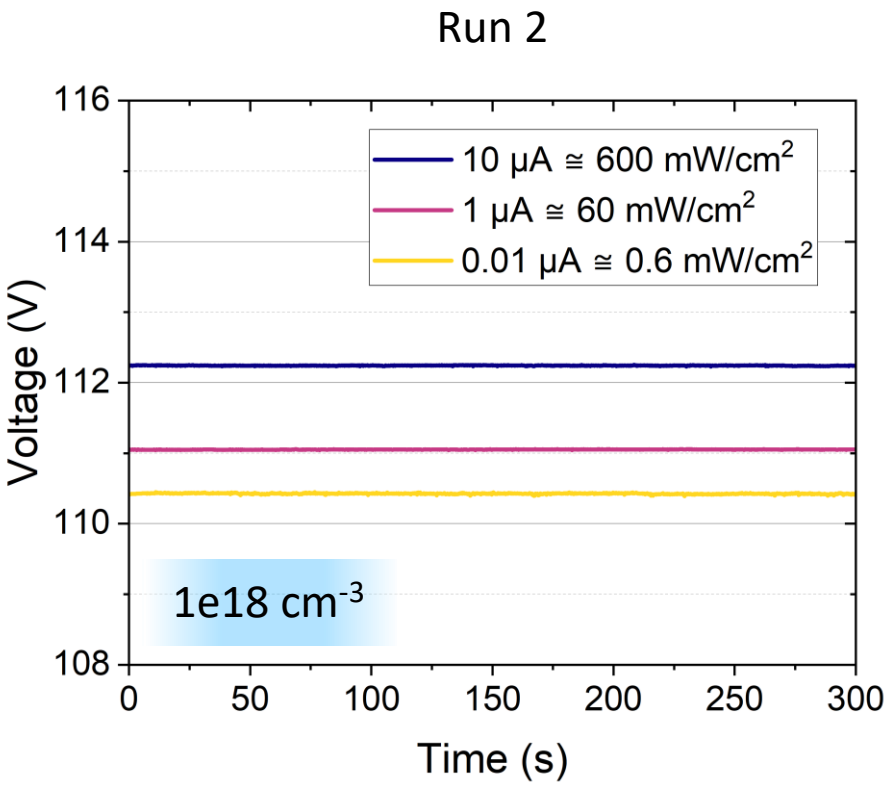

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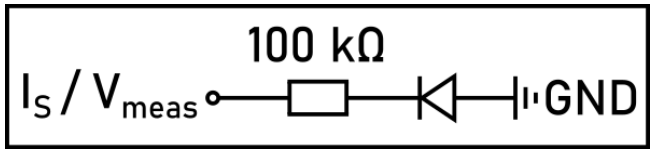

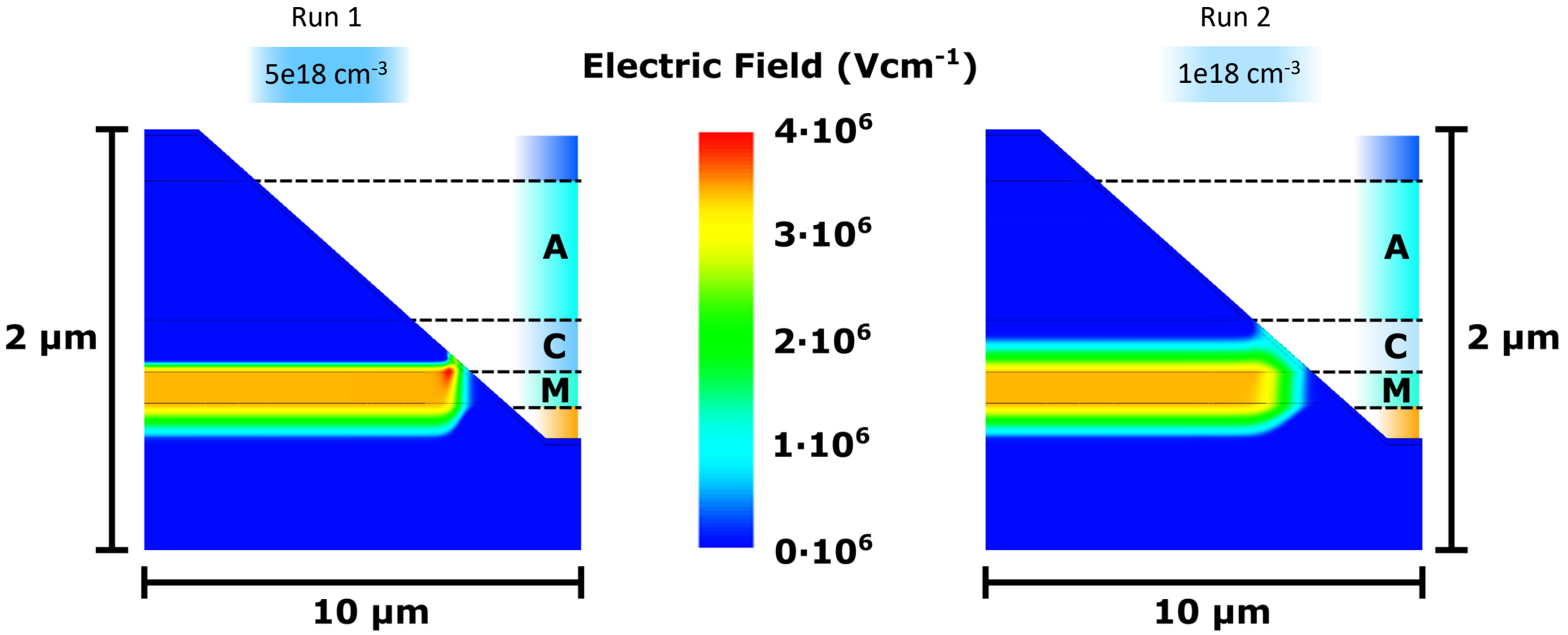

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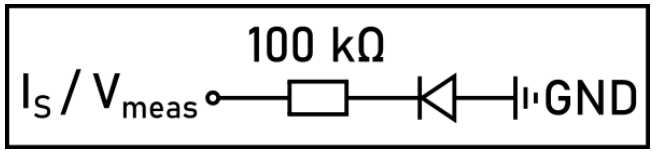

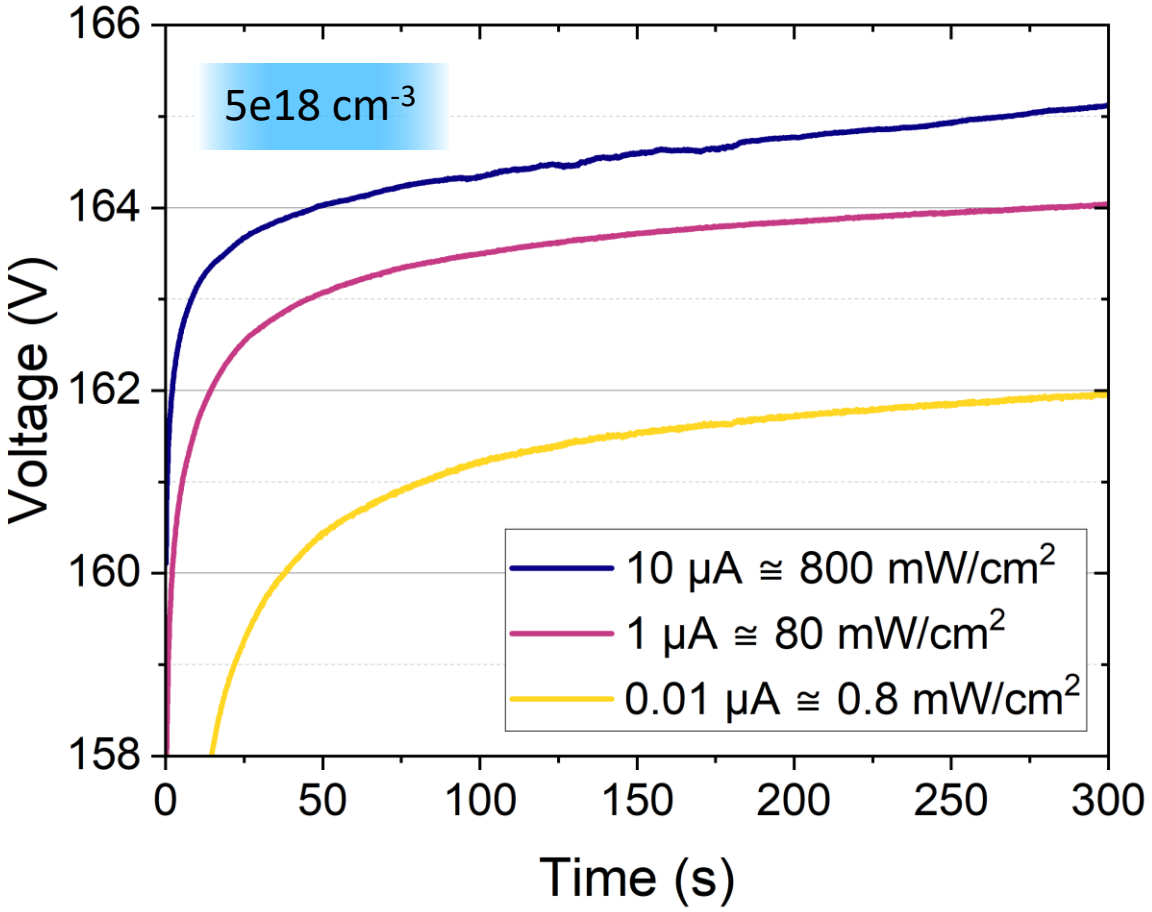

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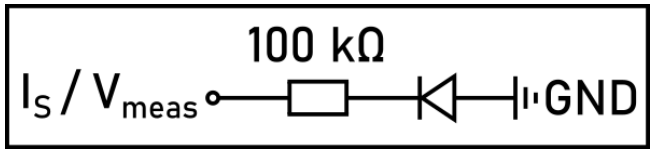

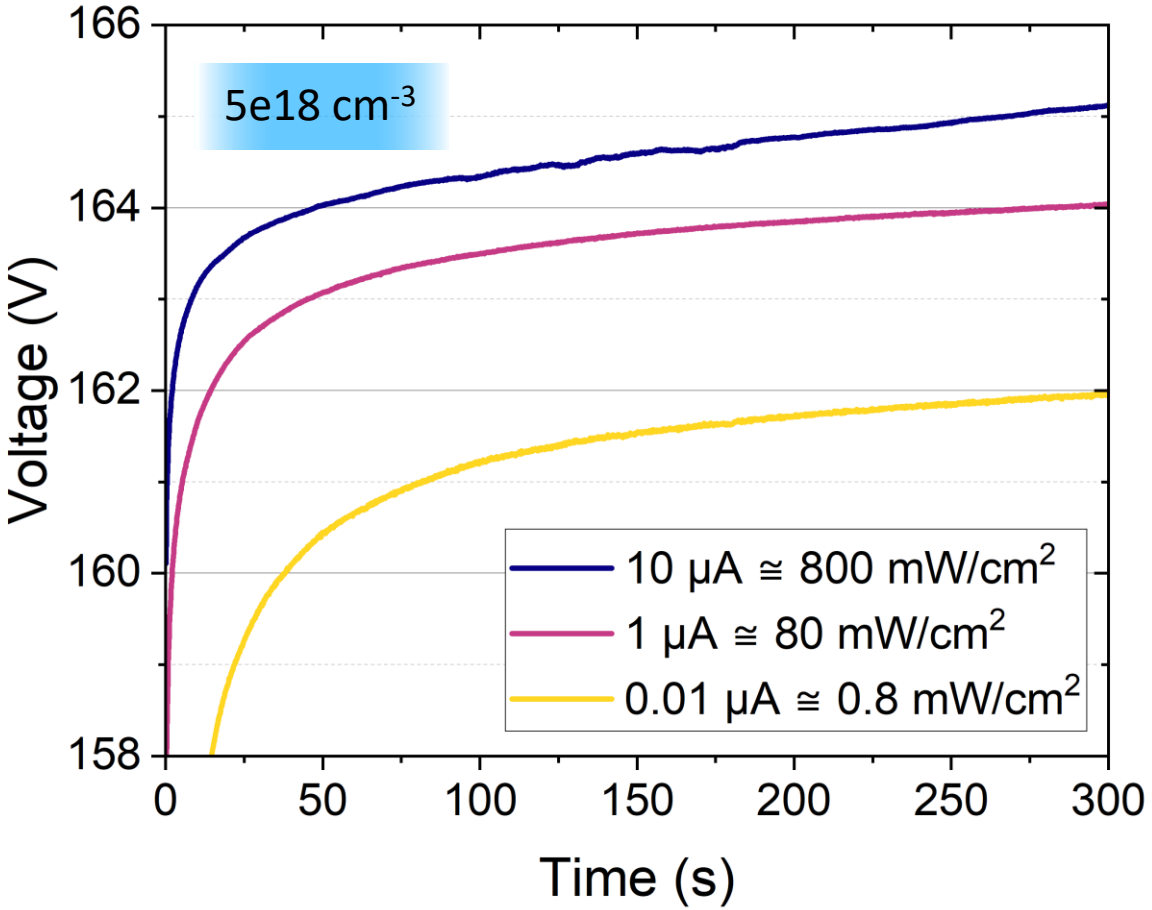

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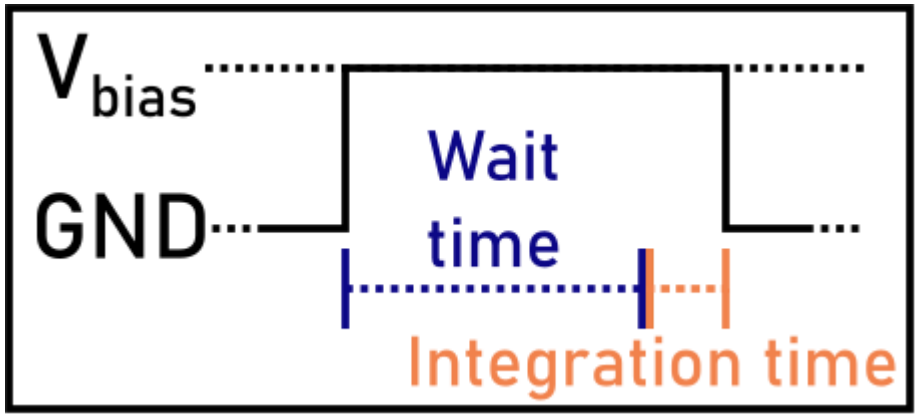
- Long-lasting temporal effect
- Similar behavior with even smaller currents

- Assumption: injected current increases the lattice temperature locally in the multiplication region
  - → Breakdown / operation voltage must increase
  - → Even more power is injected into the diode
  - → Self-heating of the diode

Pulsed photocurrent measurement



t_{wait} = variable : Wait time

t_{Int} = 1 NPLC : Integration time

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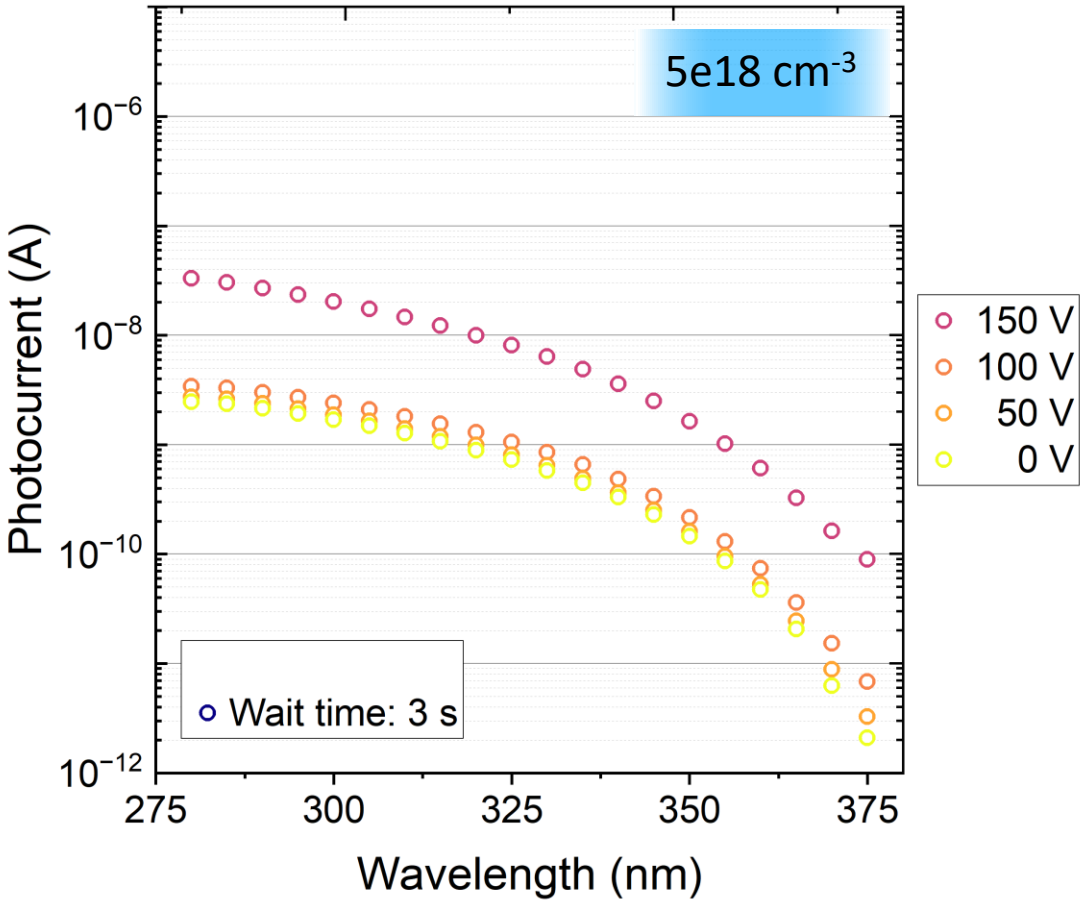

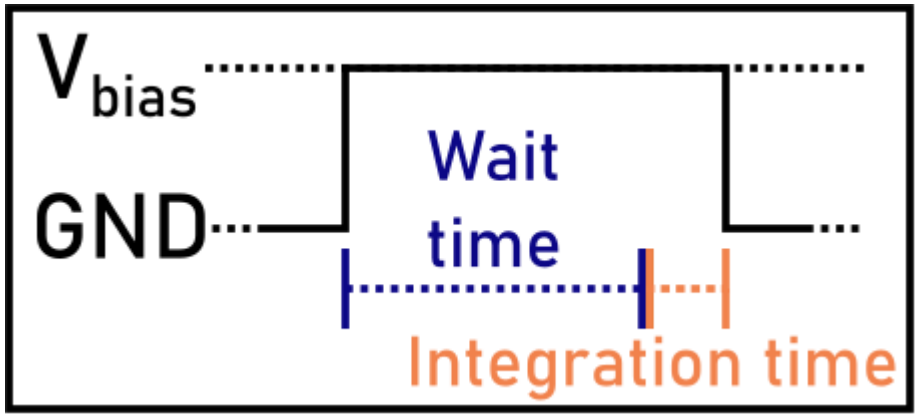

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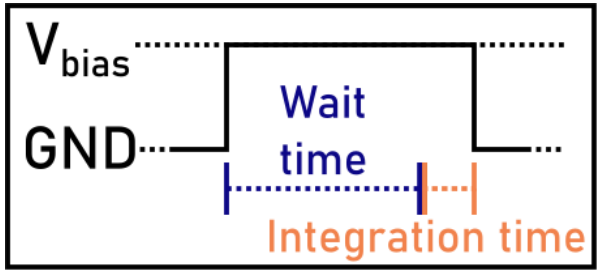

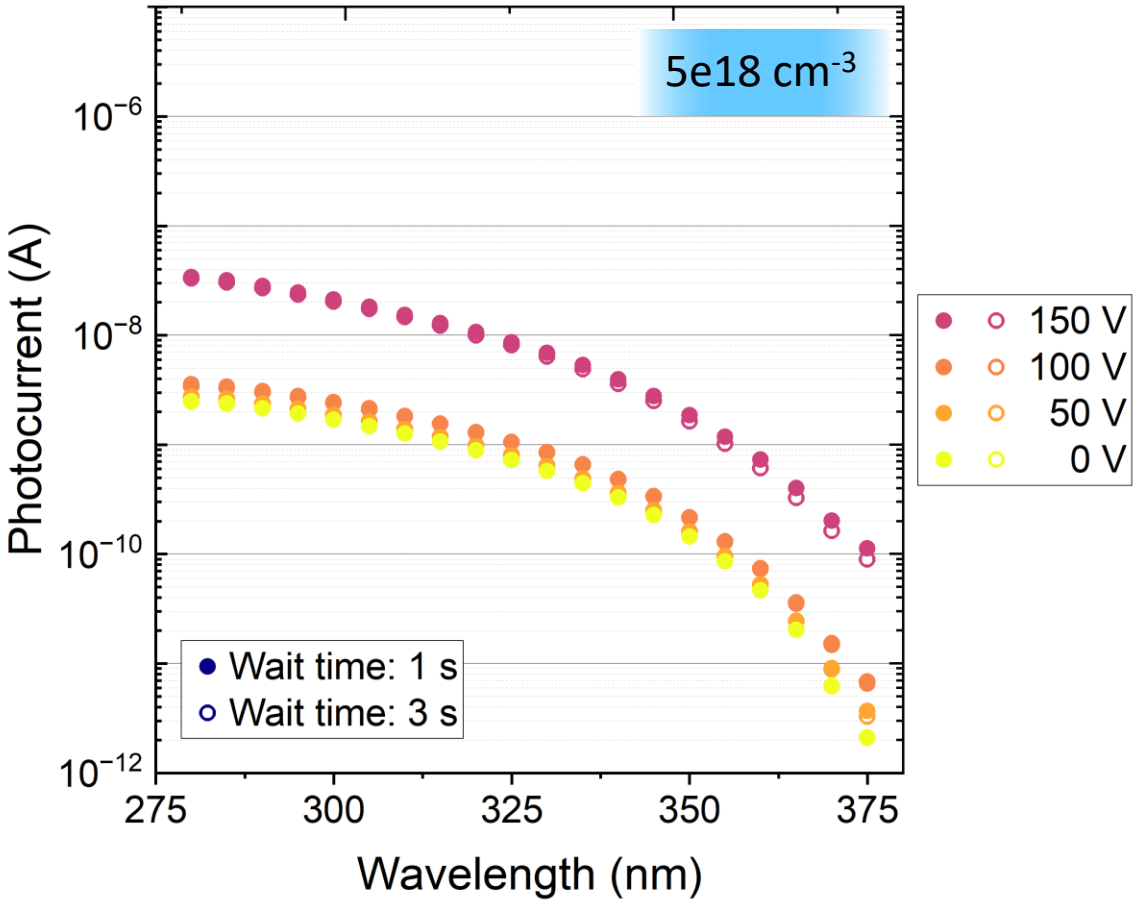

- $V_{bias} \leq 150$ V: Similar results

  → Measurements not dominated by capacitive effects

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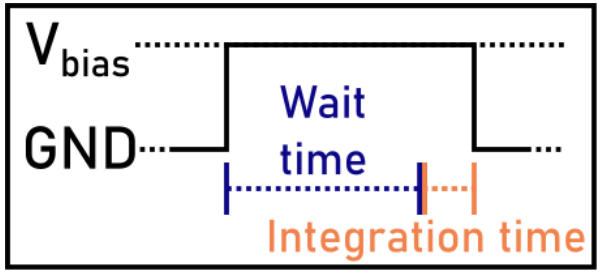
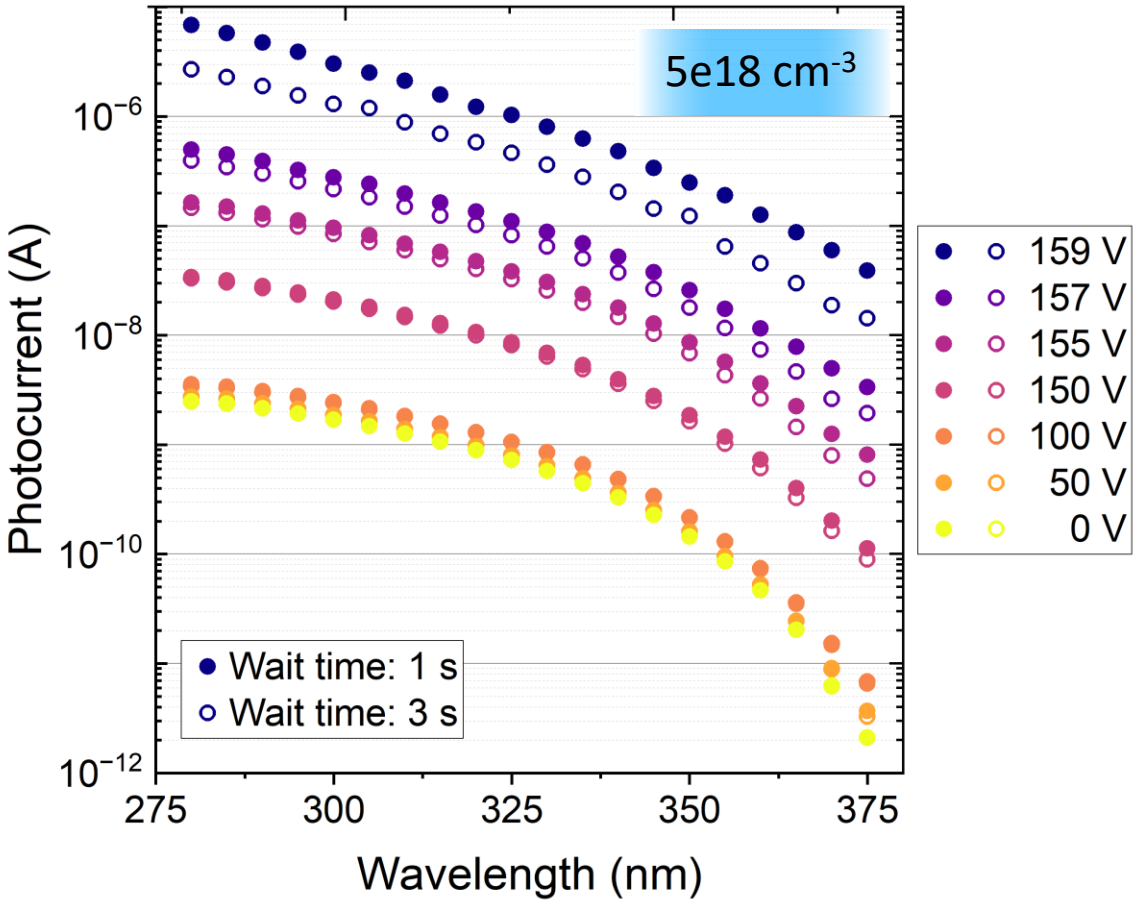
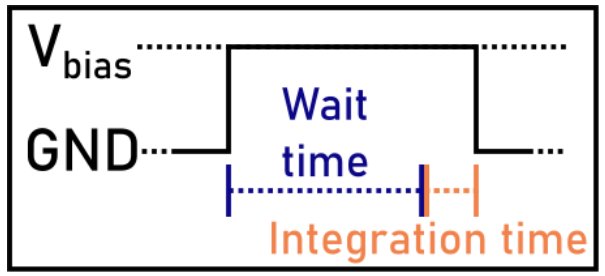
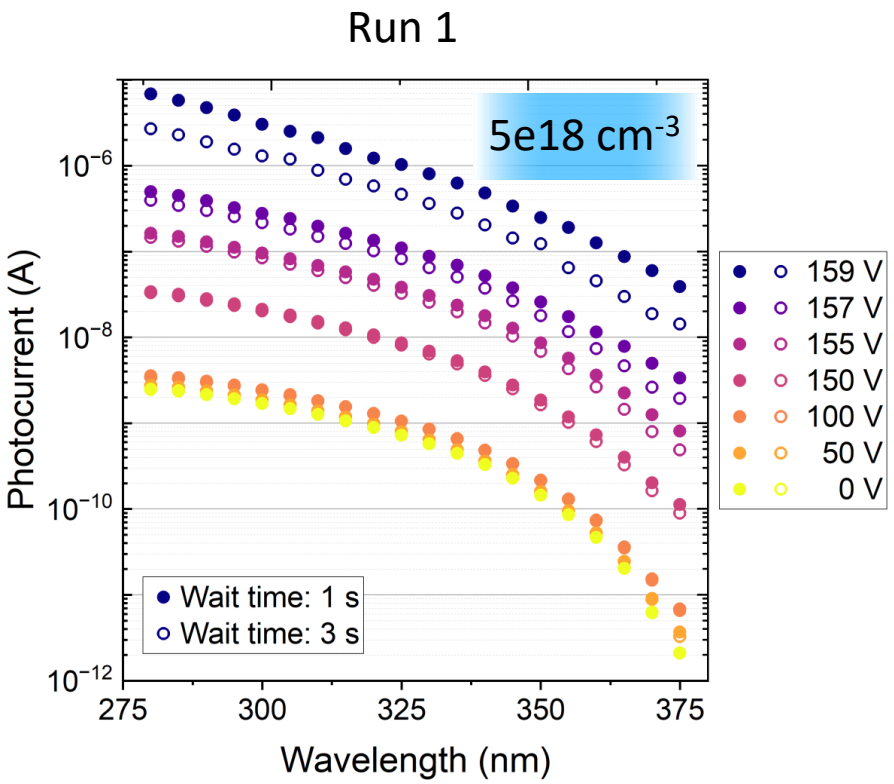


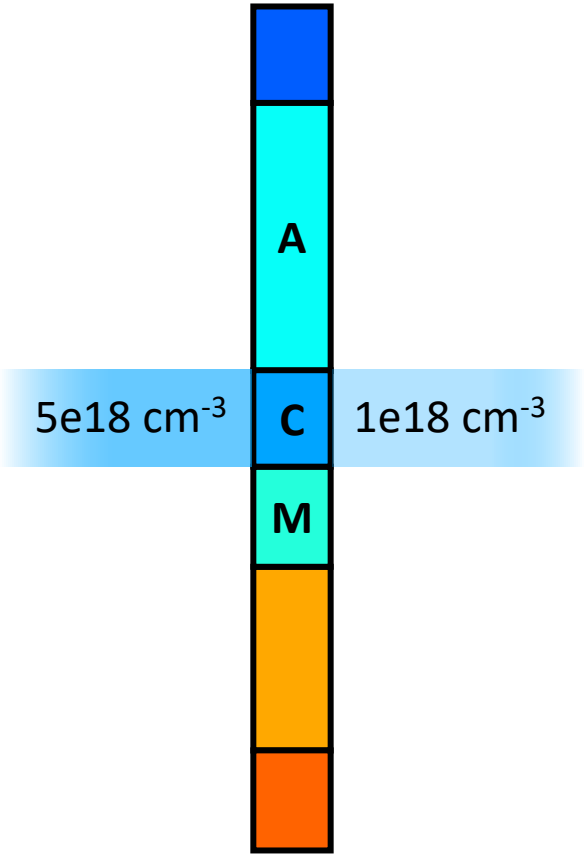


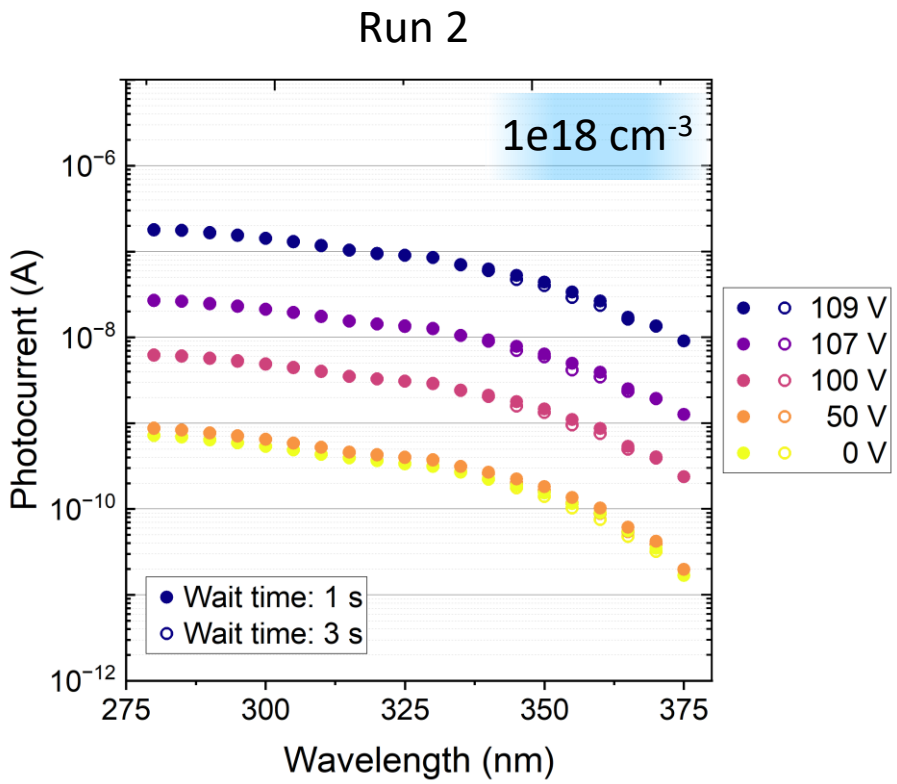
- $V_{bias} \leq 150$ V: Similar results
  - → Measurements not dominated by capacitive effects
- $V_{bias} > 150$ V: Differing results
  - → Longer wait time leads to increased lattice temperature
  - → Increased breakdown voltage / decreased current flow

Pulsed photocurrent measurement

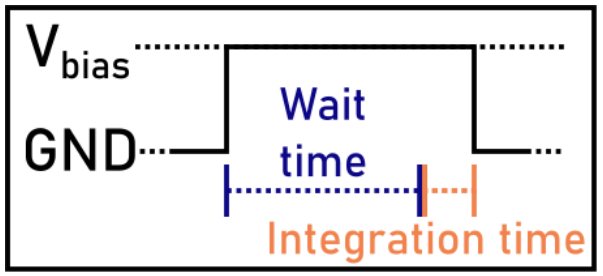


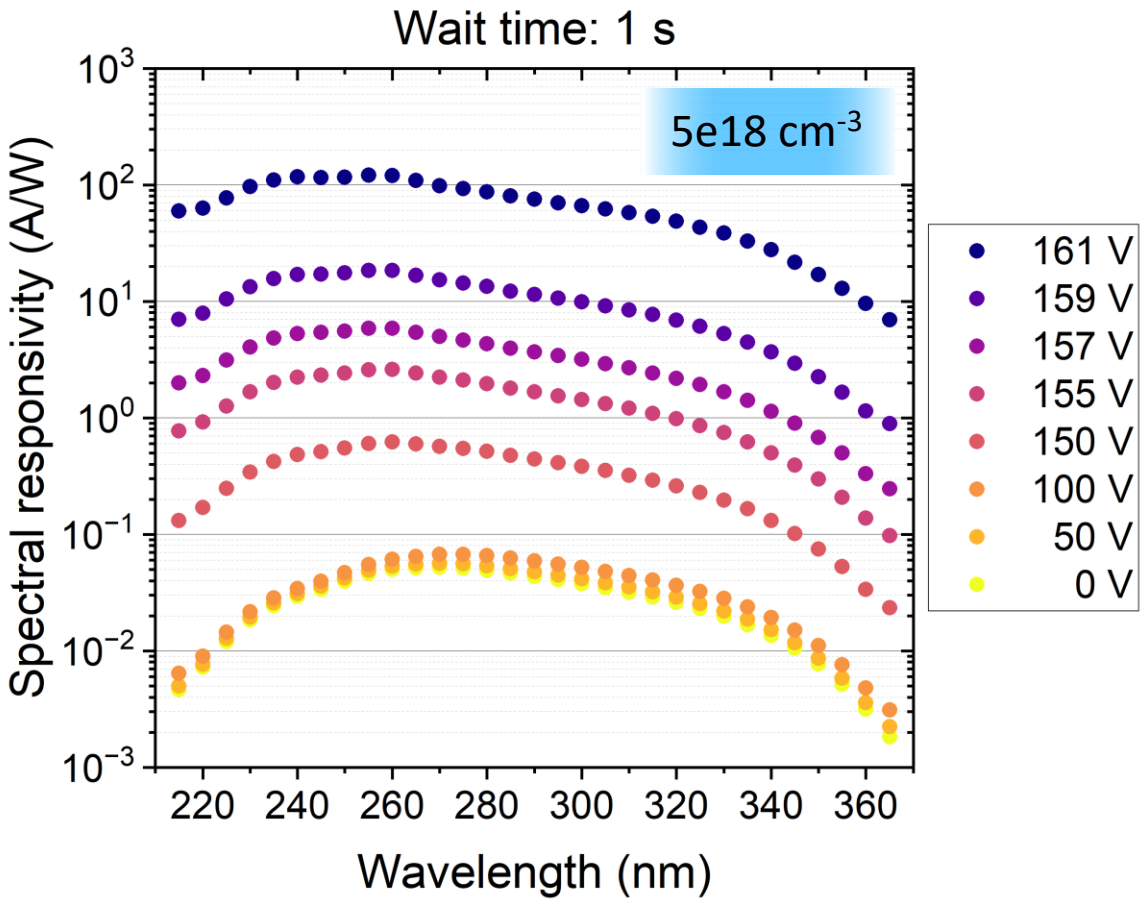






Pulsed spectral responsivity measurements





- Spectral responsivity of up to 100 A/W
- Gain of over 2000

→ SiC-APDs show promise as an alternative to photomultiplier tubes

  - Lower operation voltages
  - Better cost efficiency
  - Gain to be optimized

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This research and development project was funded by the German Federal Ministry of Research, Technology and Space (BMFTR) within the "SME-innovative: The Future of Value Creation" funding measure (funding number FZK02P22K030) and managed by the Project Management Agency Karlsruhe (PTKA). The author is responsible for the content of this publication.

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Thank you for your attention!