Institute of Radiation Physics

Radiation Source ELBE

Status report of GaN photocathode

BETH Meeting, online, 10th July 2020

Jana Schaber
Helmholtz Zentrum Dresden-Rossendorf
j.schaber@hzdr.de
www.hzdr.de

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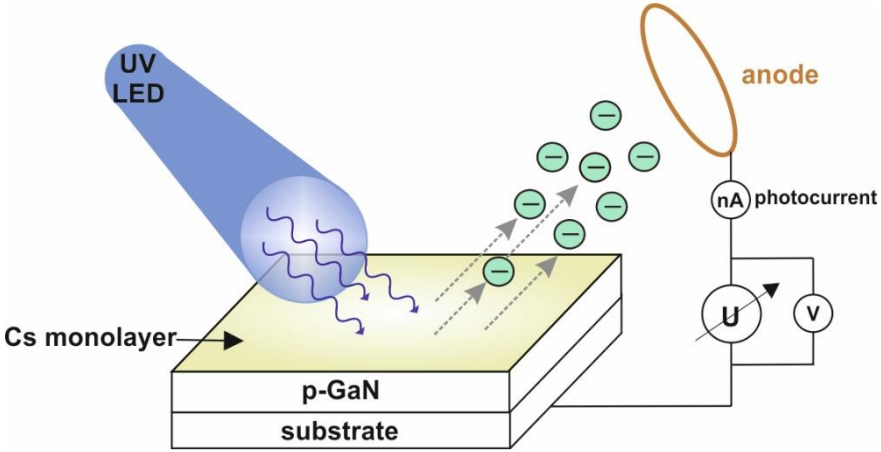
GaN Photocathode

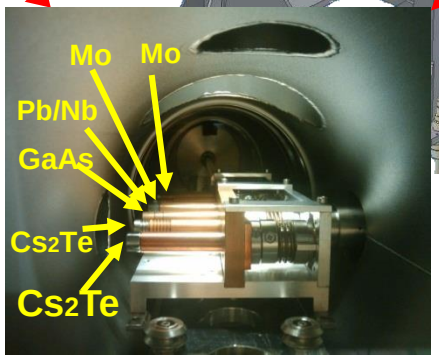
- p-GaN (Mg doped) on substrate with monolayer of Cs on top
- Using photoeffect to eject electrons
- Electrons are collected by ring anode

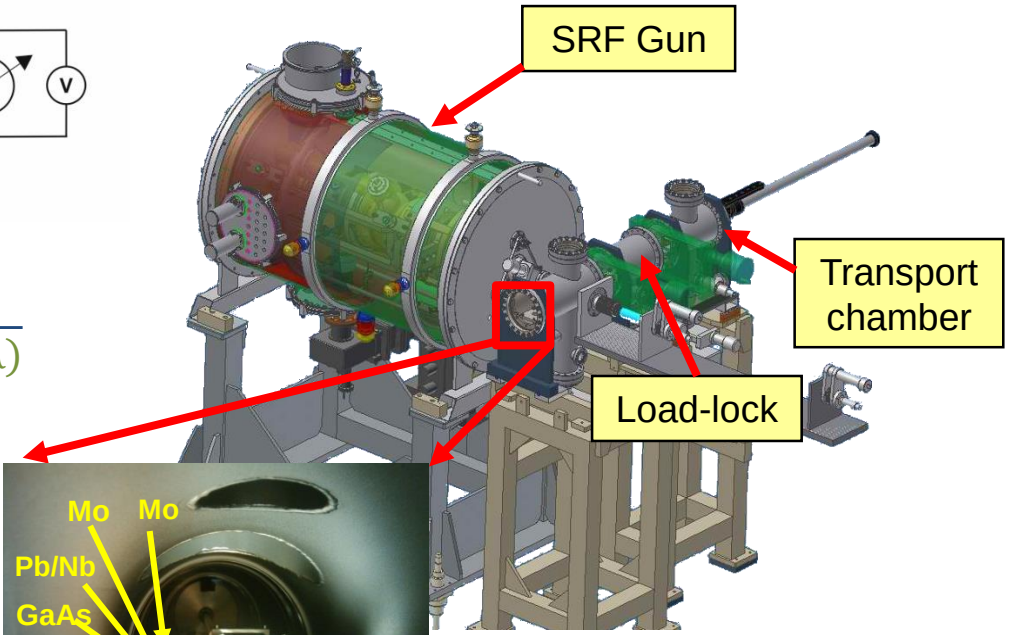


Search for new materials:

- High QE
- Lifetime (robust)
- Low emittance
- Dark current

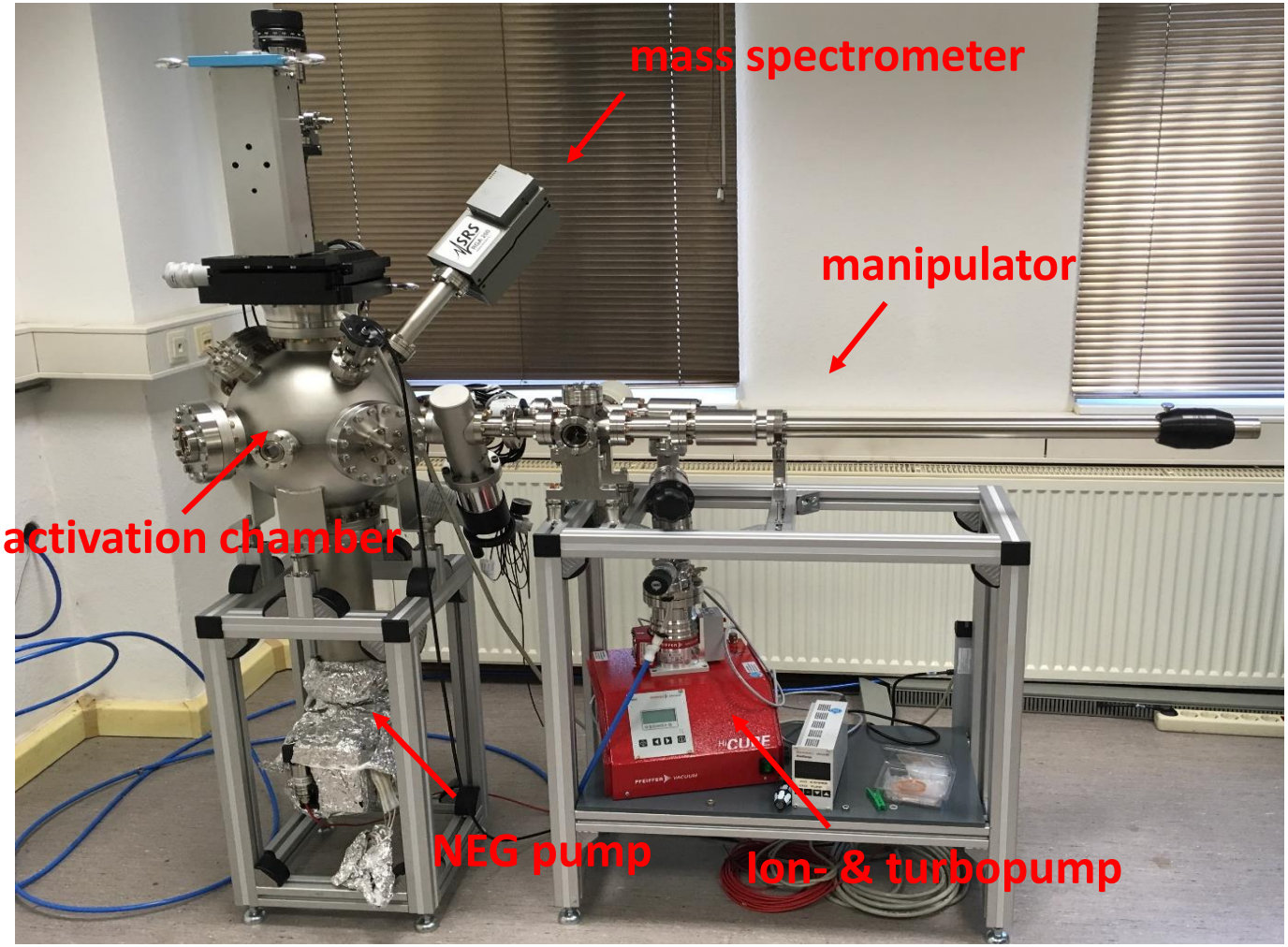
$$QE = \frac{N_{electrons}}{N_{photons}} = \frac{h \cdot c}{q_e} \cdot \frac{I}{\lambda \cdot P_{Light}(\lambda)}$$





GaN Photocathode Research

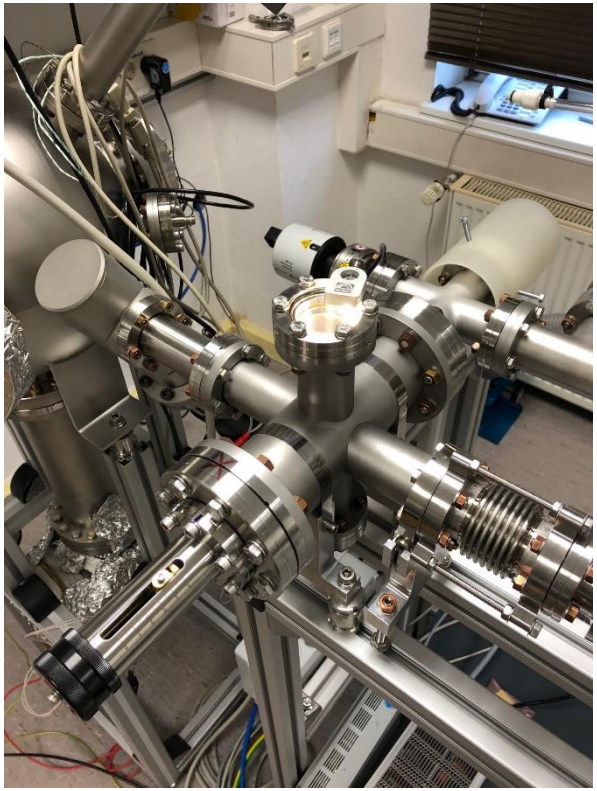
GaN chamber

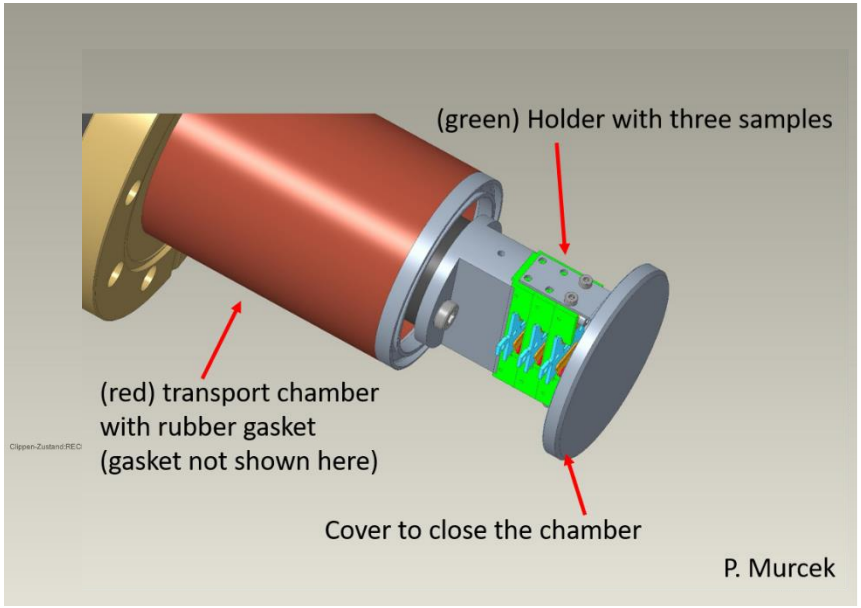


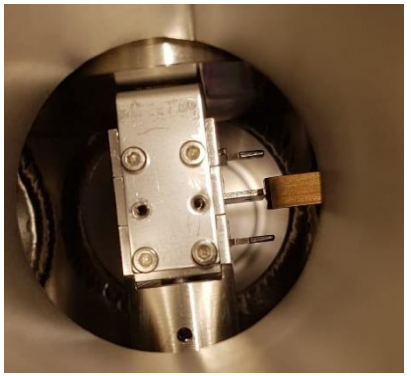
GaN Photocathode Research

new improvements

GaN chamber





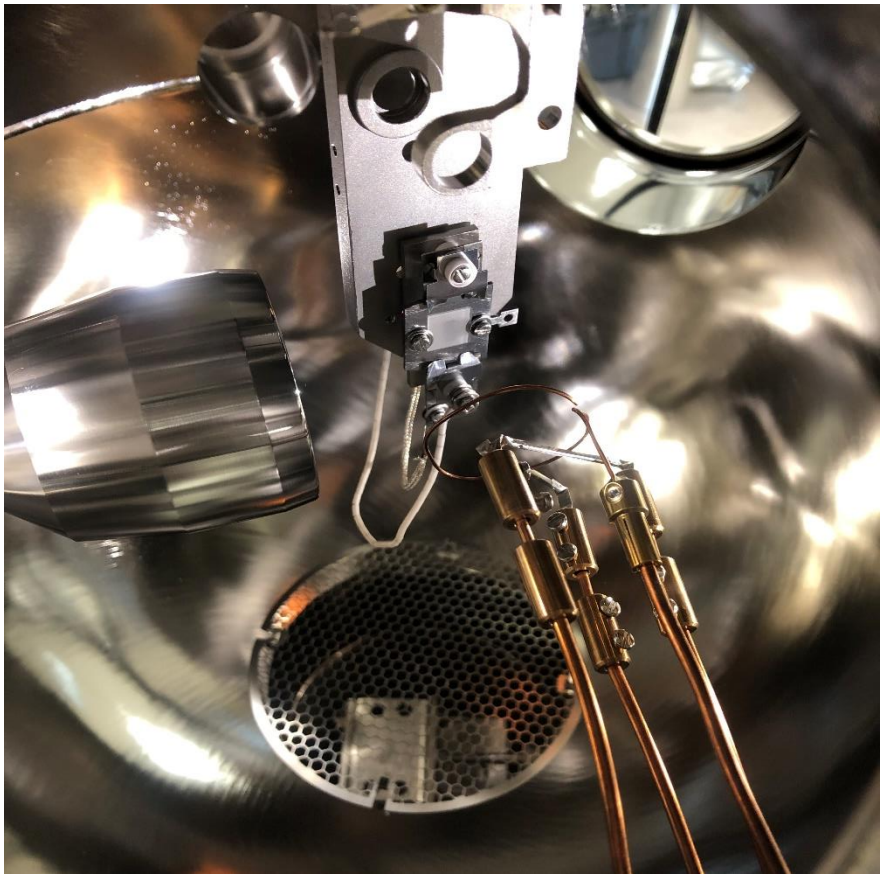


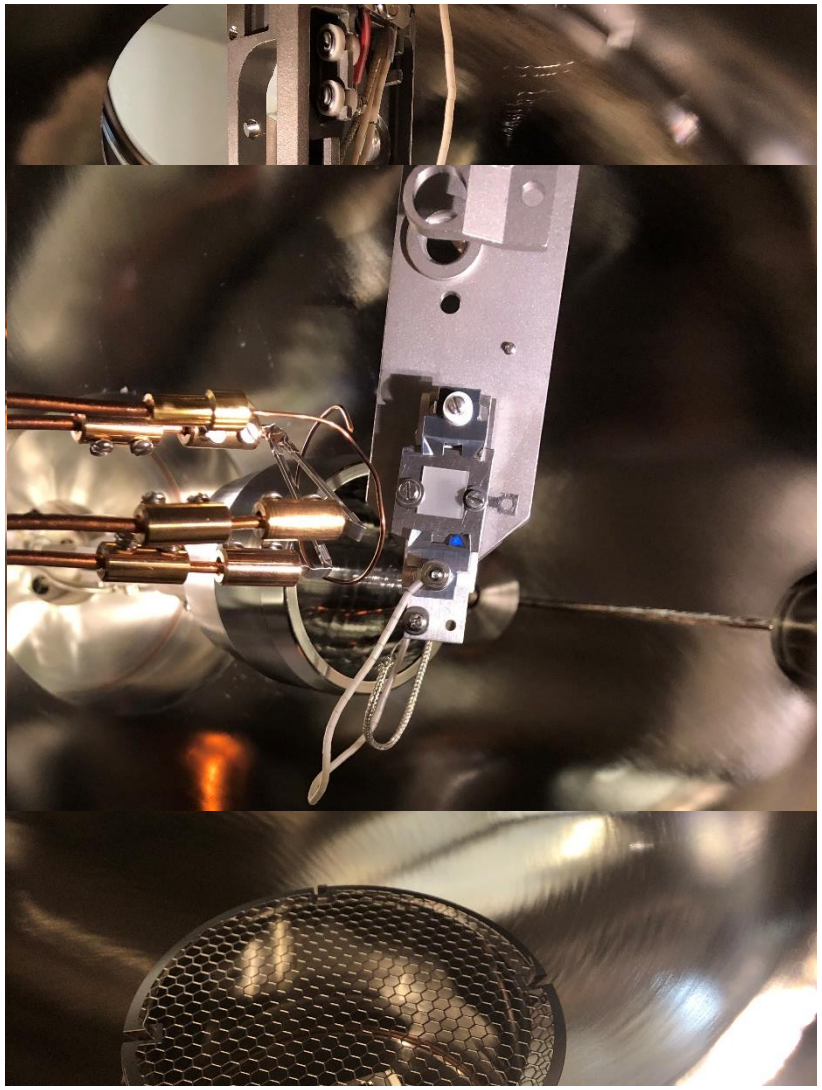
New suitecase/cross at the loading chamber

- ensures safe enviroment/ transport between glovebox and loading chamber
- Up to 3 samples can be stored at same time
- Easy pick up system with manipulator
- Flushing with nitrogen also possible to transport old, used samples
- Transport to other facilities under safe atmosphere guaranteed

GaN Photocathode Research

GaN chamber





DRESDEN concept

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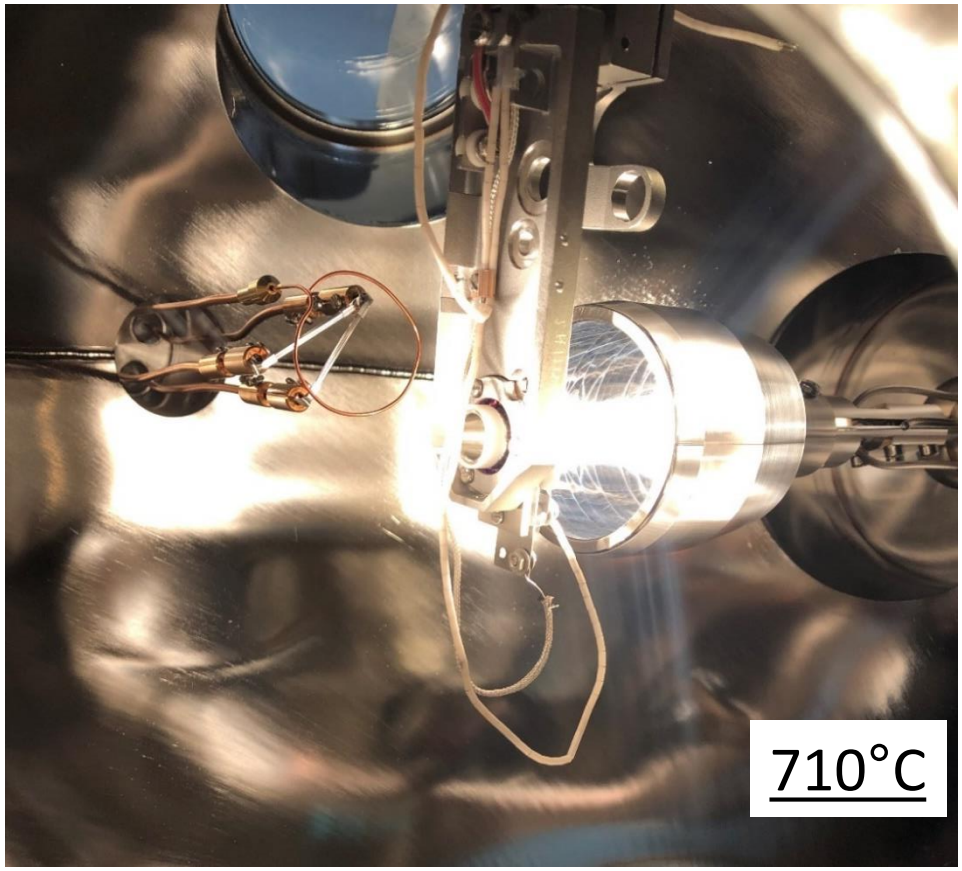
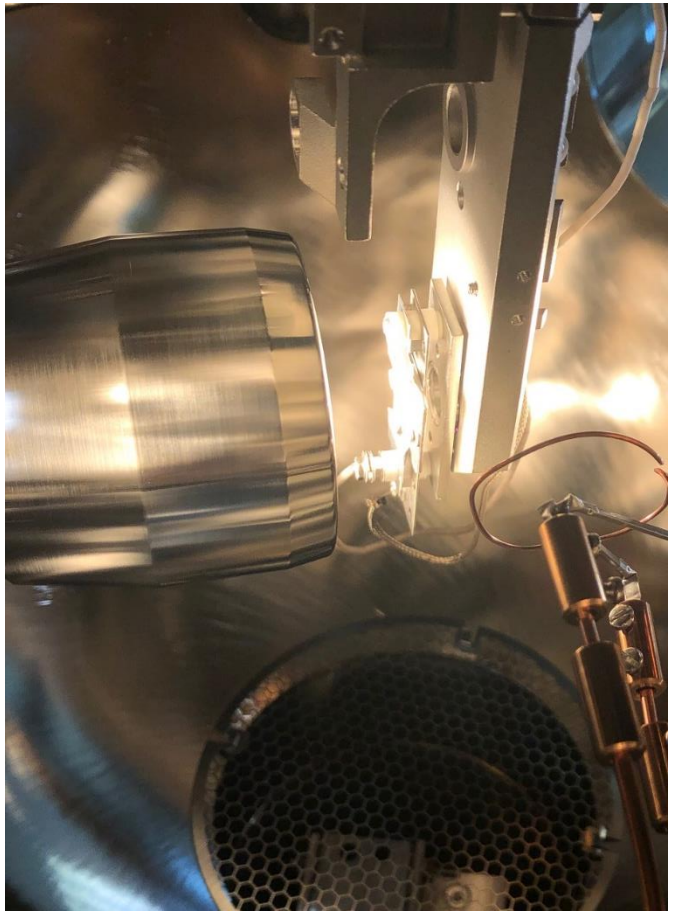
GaN Photocathode Research activation

Heat cleaning

→ Removal of adsorbed gases such as N_2, O_2, H_2O, CO, CO_2, …

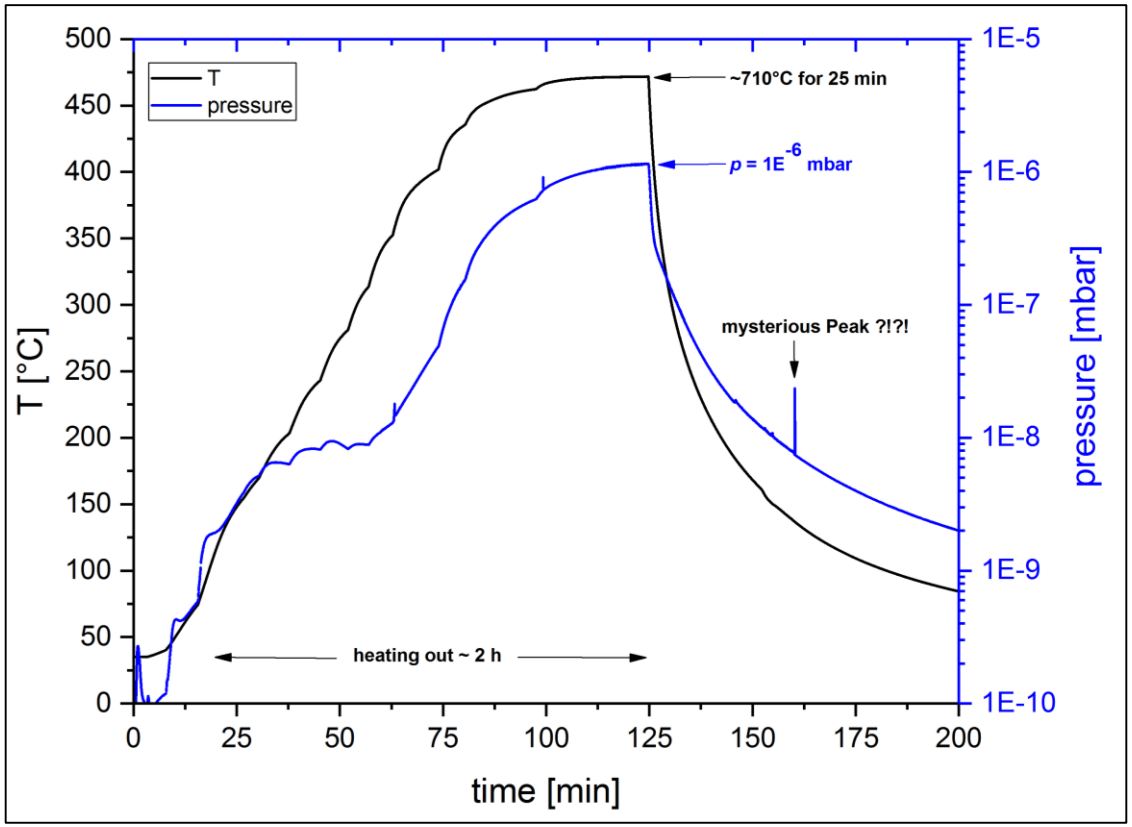




- Reached T on sample: 710°C → on sensor 466°C
- Heating time: 25 min
- Vacuum in good 10^{-6}mbar or better

GaN Photocathode Research activation

Heat cleaning

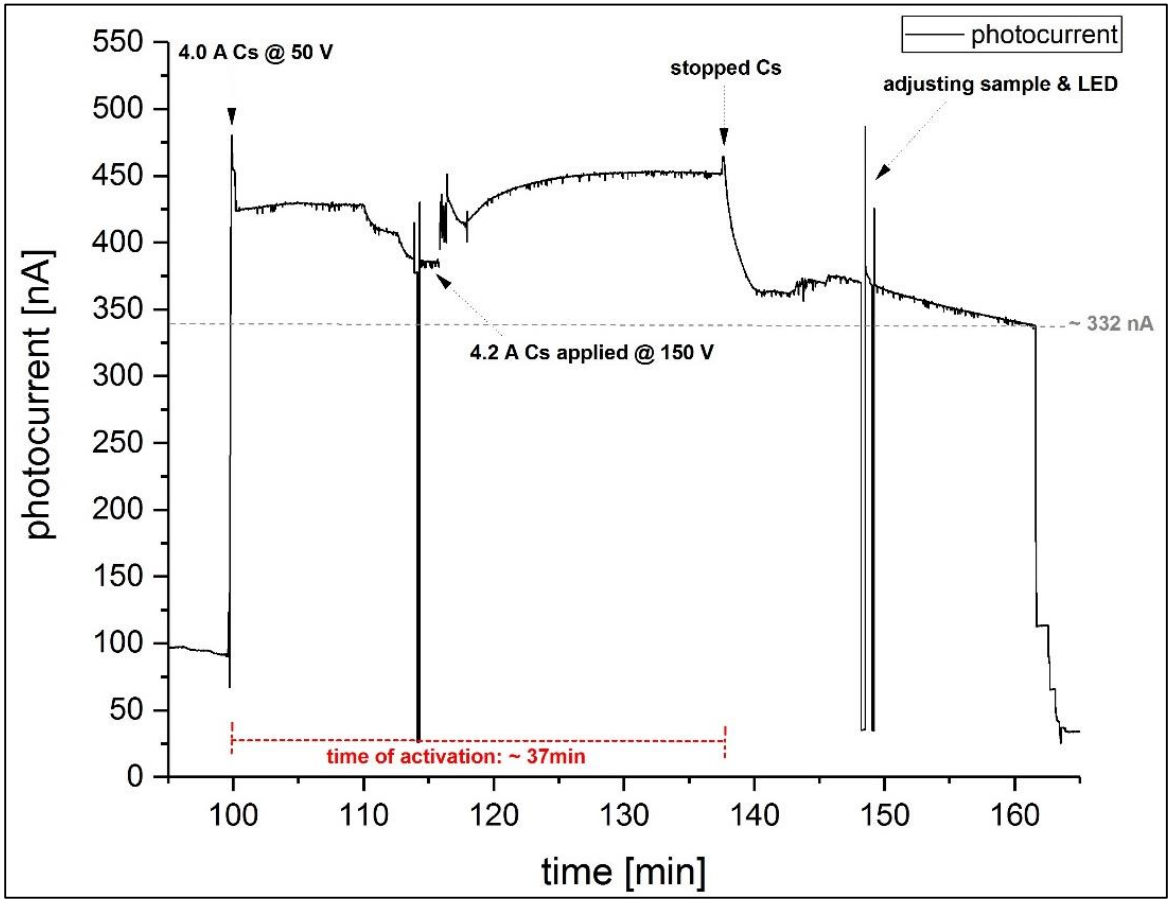


- Applying stepwise current to the halogen lamp → observe vacuum
- Wait till vacuum stabilizes/ lamp released adsorbed gases
- When 466°C on sensor is reached → means 710°C on sample in real
- Hold 710°C on sample for 25 min then turn off
- Wait overnight till vacuum and cathode temperatur dropping back in normal range

GaN Photocathode Research

1st activation

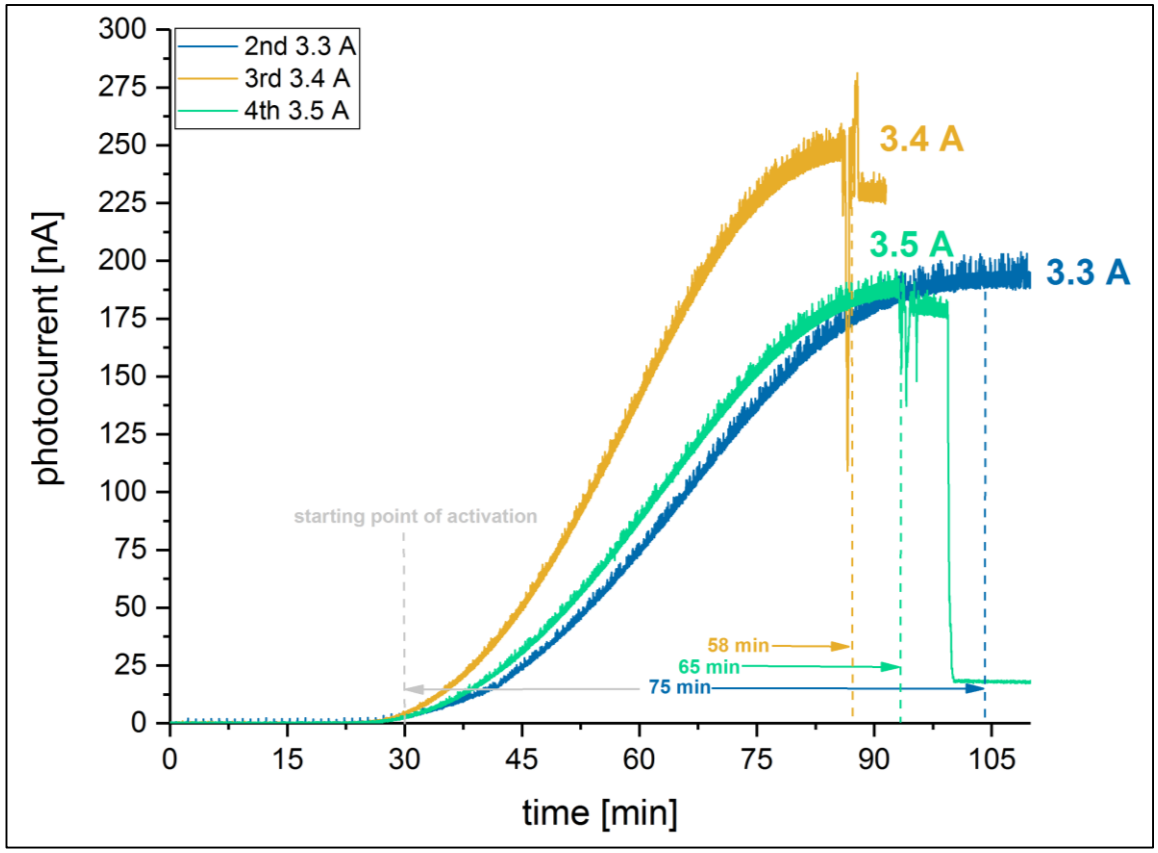
activations on GaN/sapphire #2020.01



- First activation on cleaned sample was carried out at 3.8 to 4.0 A → too much Cs → resulting in just photocurrent of metallic Cs ?!?!

GaN Photocathode Research

activations on GaN/sapphire #2020.01



activation(s)

GaN activation curves

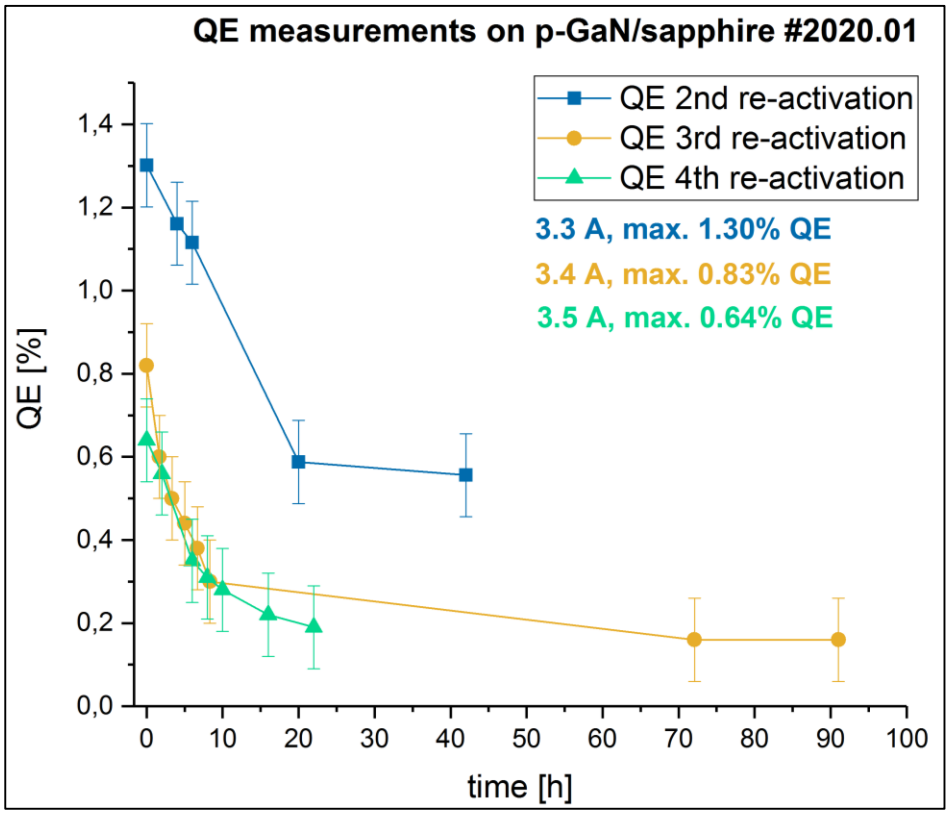
- Heating of Cs source with different T
- 150 V on anode and UV LED (310 nm)
- Needs about 30 min to start
- Vacuum was kept in 10^{-10} mbar range
- Resulting in saturation plateau

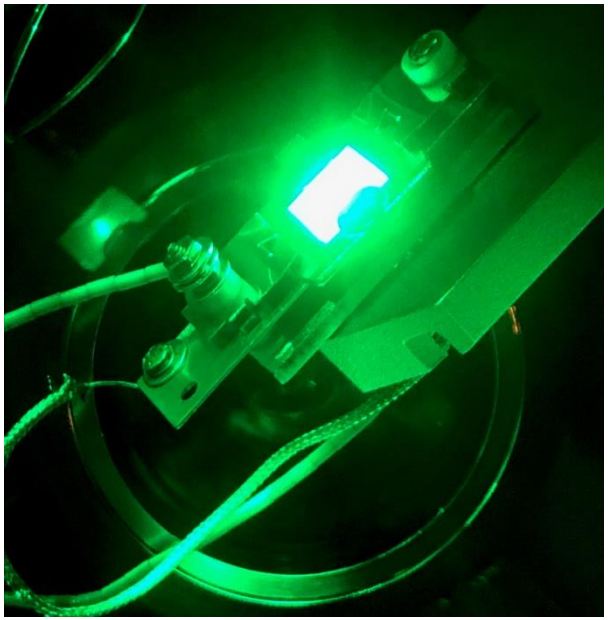
- Activate sample and detect photocurrent over time
- Reactivating the sample by heating out at 710°C again several times
- Reactivate again
- Try several re-activations

GaN Photocathode Research

QE

activations on #2020.01

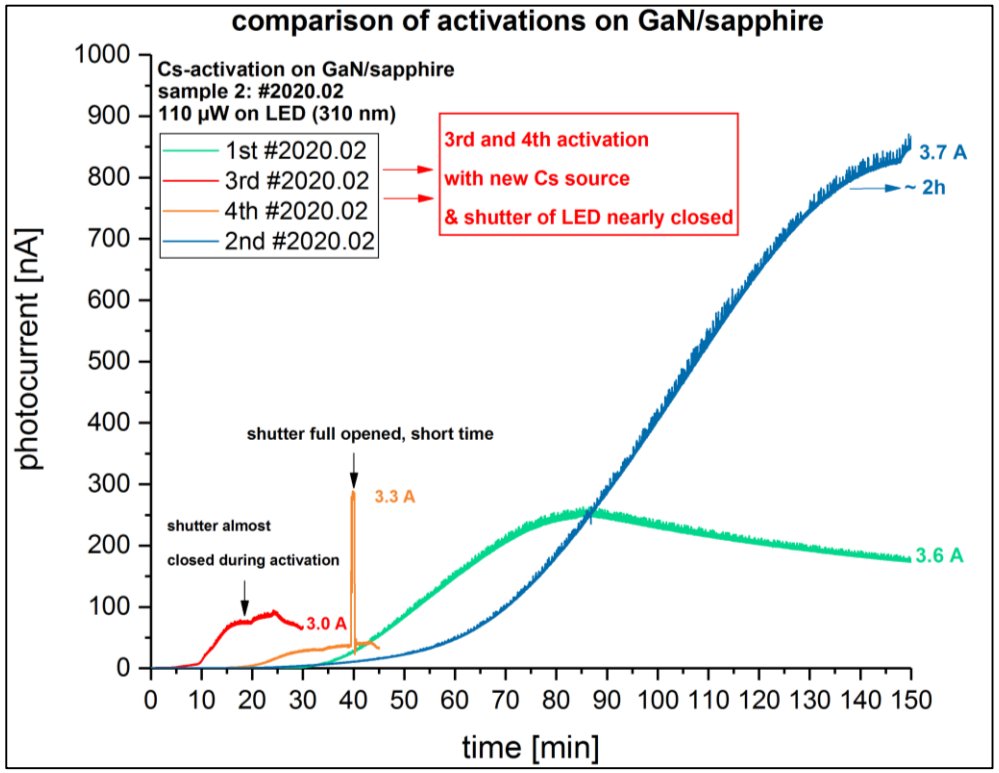


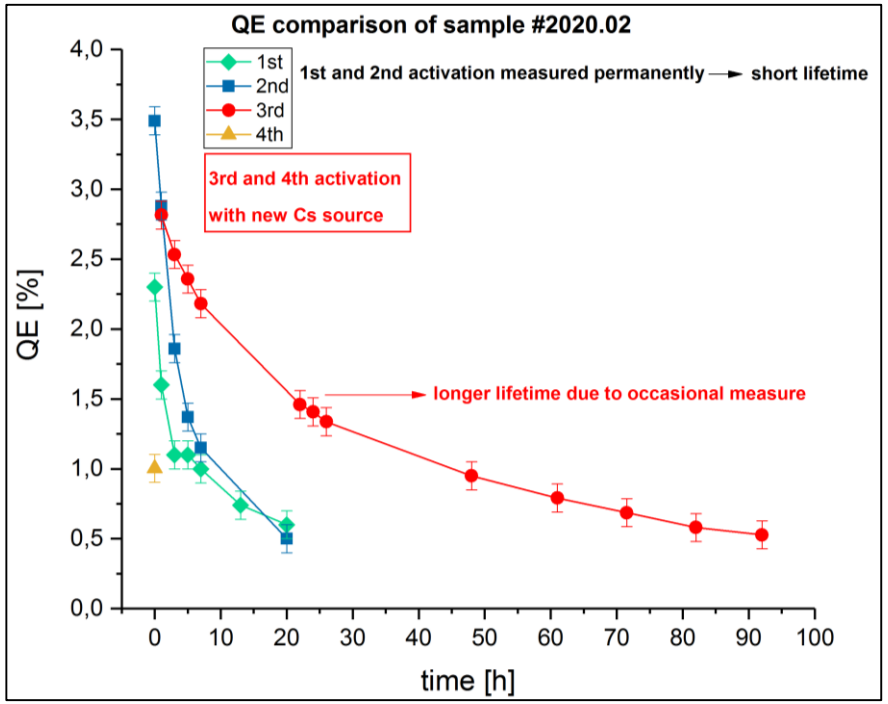


- First QE does not shown → seems to result from metallic Cs → very fast drop down in QE
- 2nd re-activation shows the highest QE with 1.3%
- The other re-activations just reaching less than 1% QE
- All QE curves have an exponential decay which is typical for photocathodes
- The cathode was also illuminated with green laser (535nm) to detect photocurrent from metallic Cs (2.0 eV=620 nm)→ but no photocurrent could be observed → all photocurrent derive from GaN cathode itself

GaN Photocathode Research activation

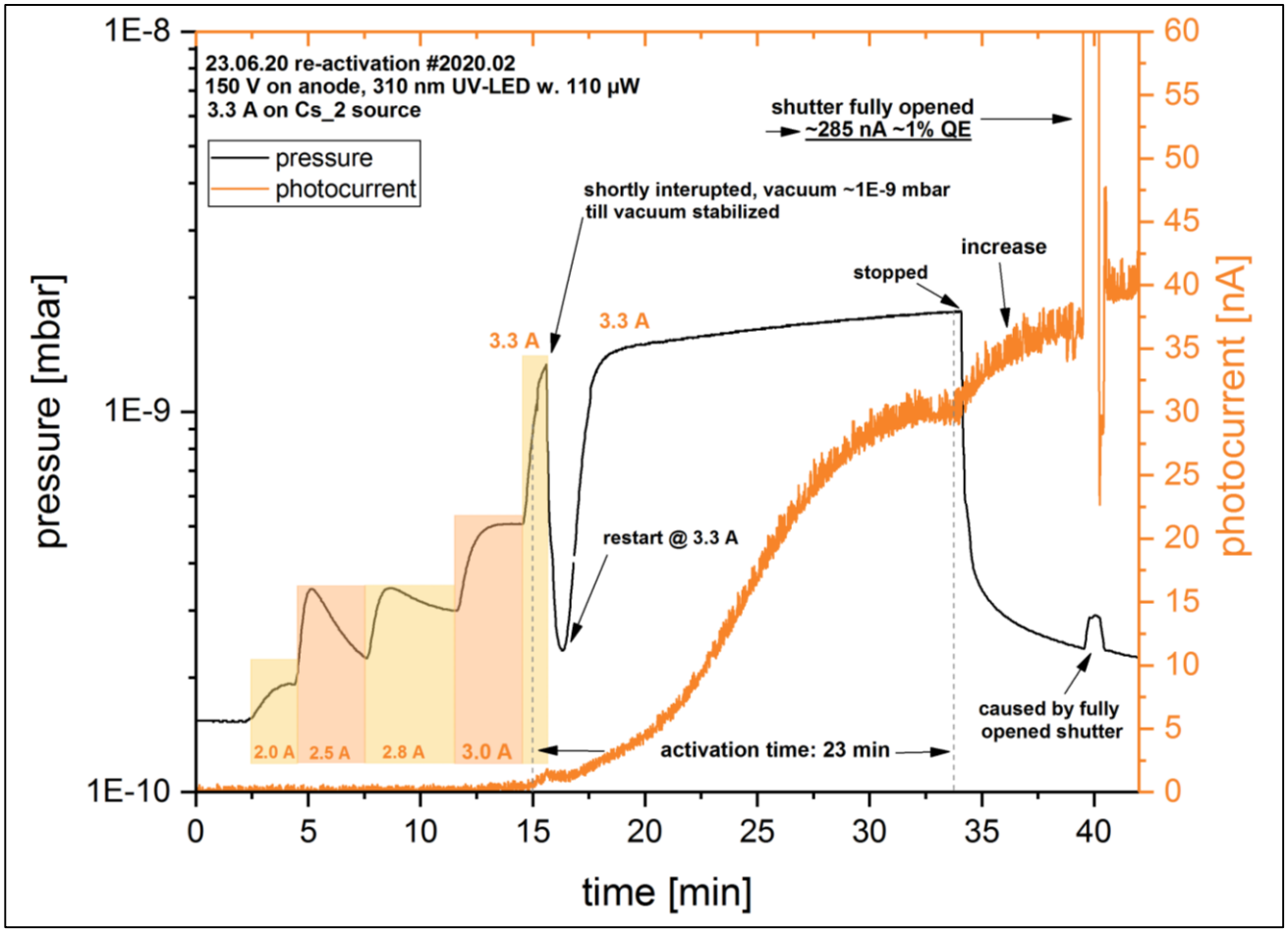
activations on GaN/sapphire #2020.02





- 1st and 2nd activation made with „old“ caesium source → too long activation (2h)
- Degradation because of permanent measurement (UV and anode turned on)
- Using new caesium source → searching for right current but short time activation (~20 min)
- Try several re-activations with different currents on Cs source, limited LED power via shutter and detect QE occasionally after activation

GaN Photocathode Research activation

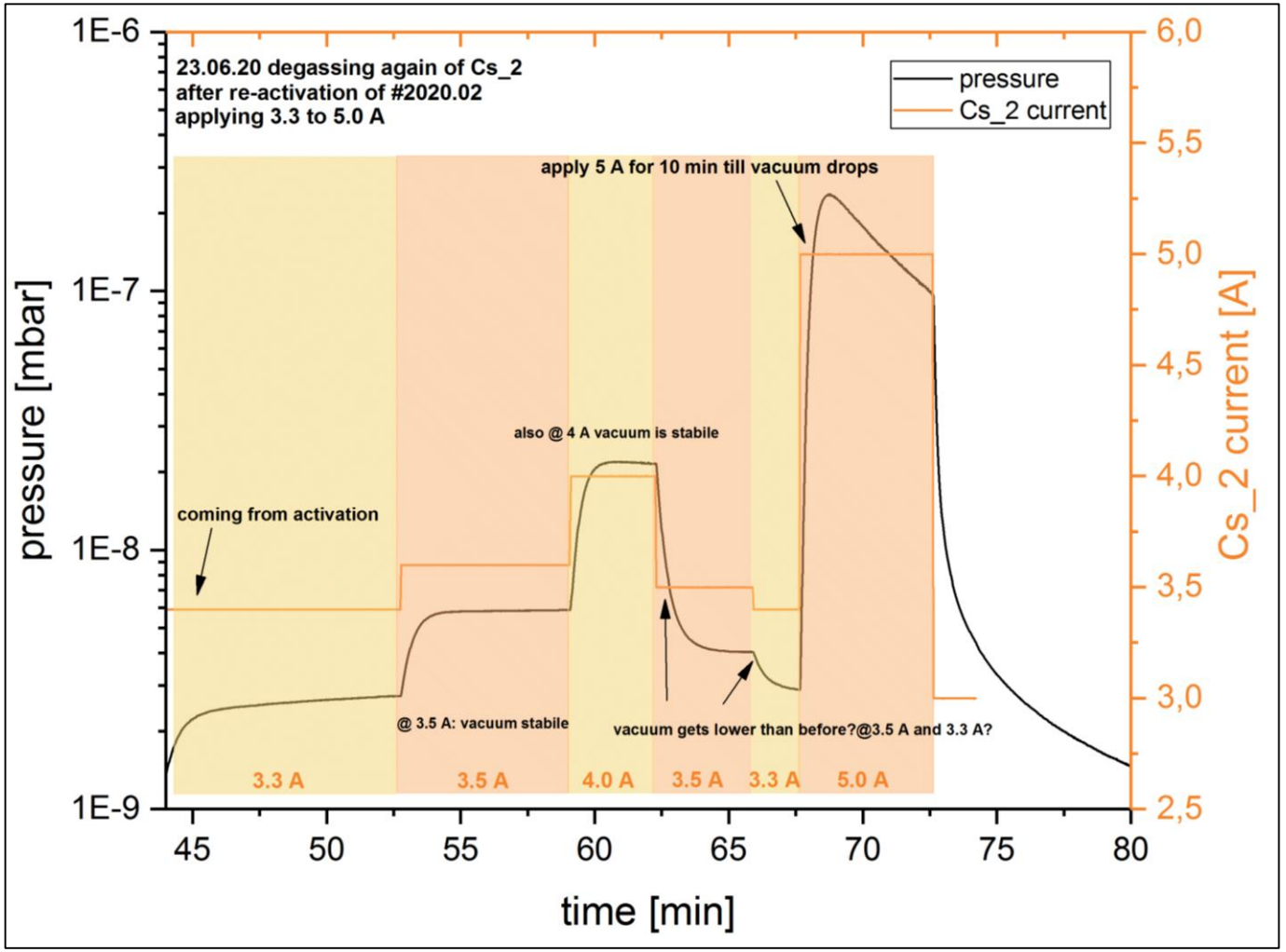


- 4th activation on #2020.02 with new Cs source → was outgassed already before @ 5A for 20s
- Wait after each current increase for the vaccum to stabilize
- Applying up to 3.3 A → shortly abort because of „bad“ vacuum (10^{-9} mbar range)
- Starting again→ till saturation is seen
- After stopping → vaccum goes back in 10^{-10} mbar range → increase of photocurrent

GaN Photocathode Research

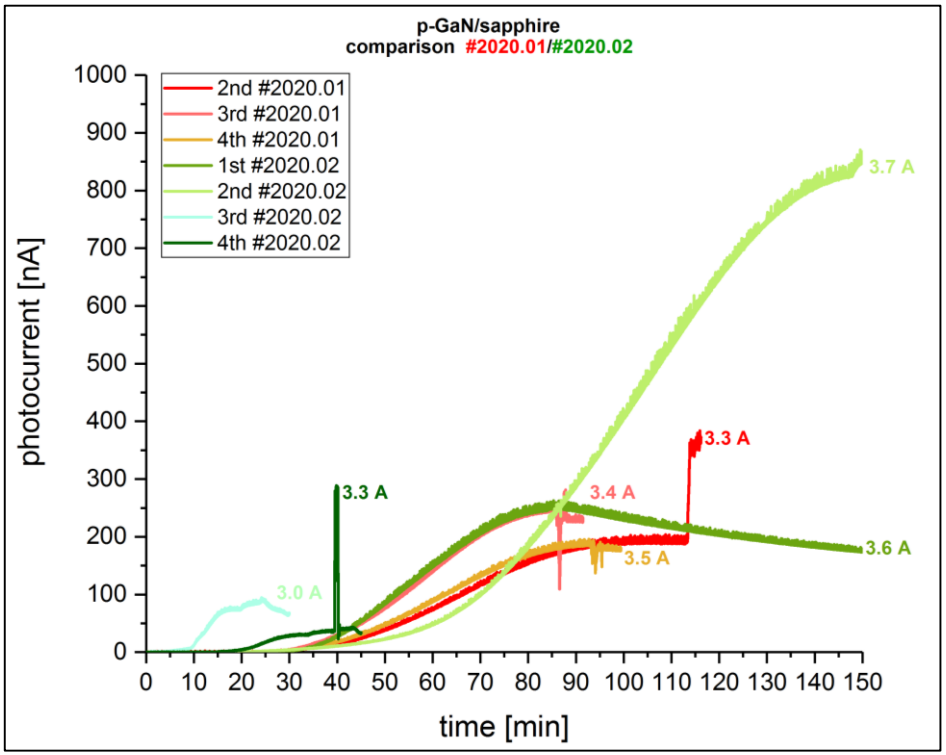
Back-Up

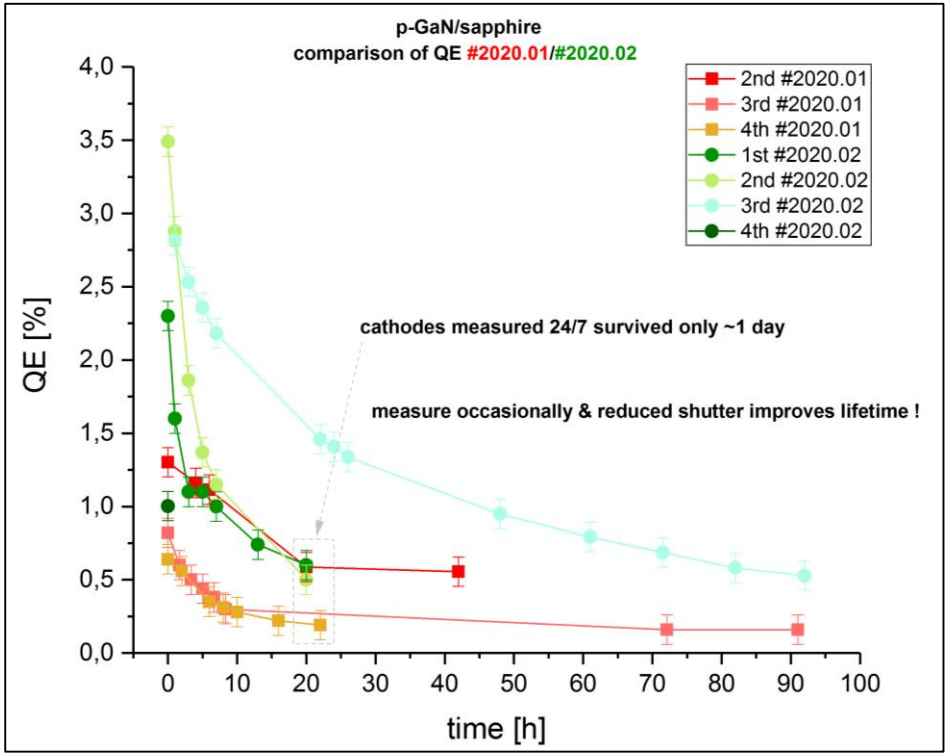
Degassing Cs source



- new Cs source was outgassed already before usage in activation @ 5A for 20s
- Outgassing again after last activation, again @ 5A for ~10min

GaN Photocathode Research activation

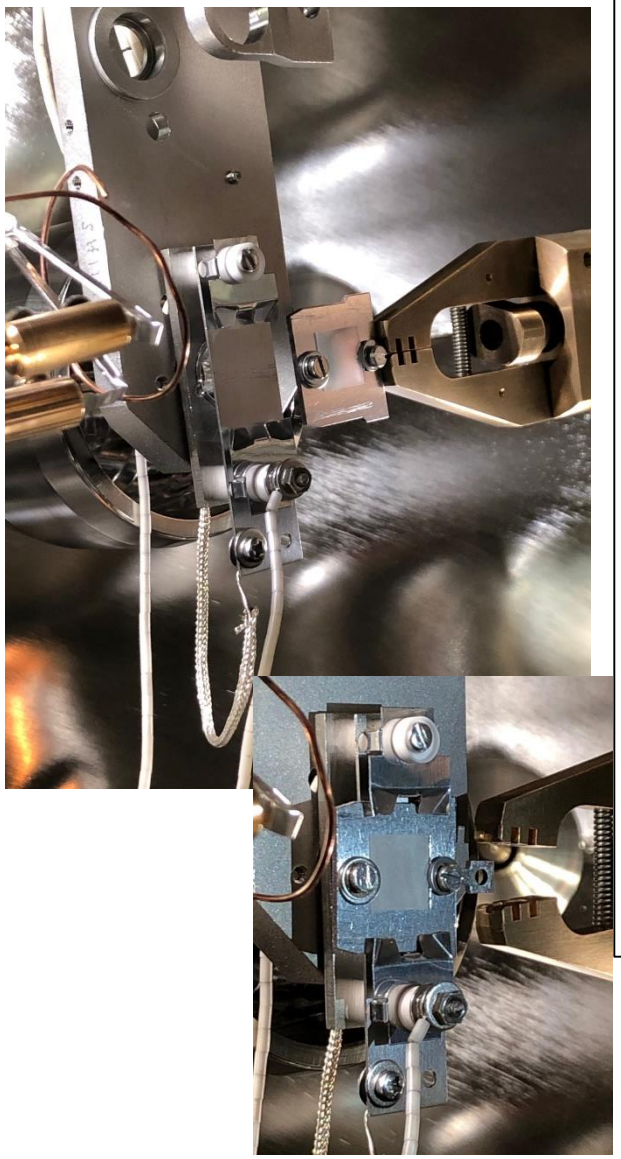


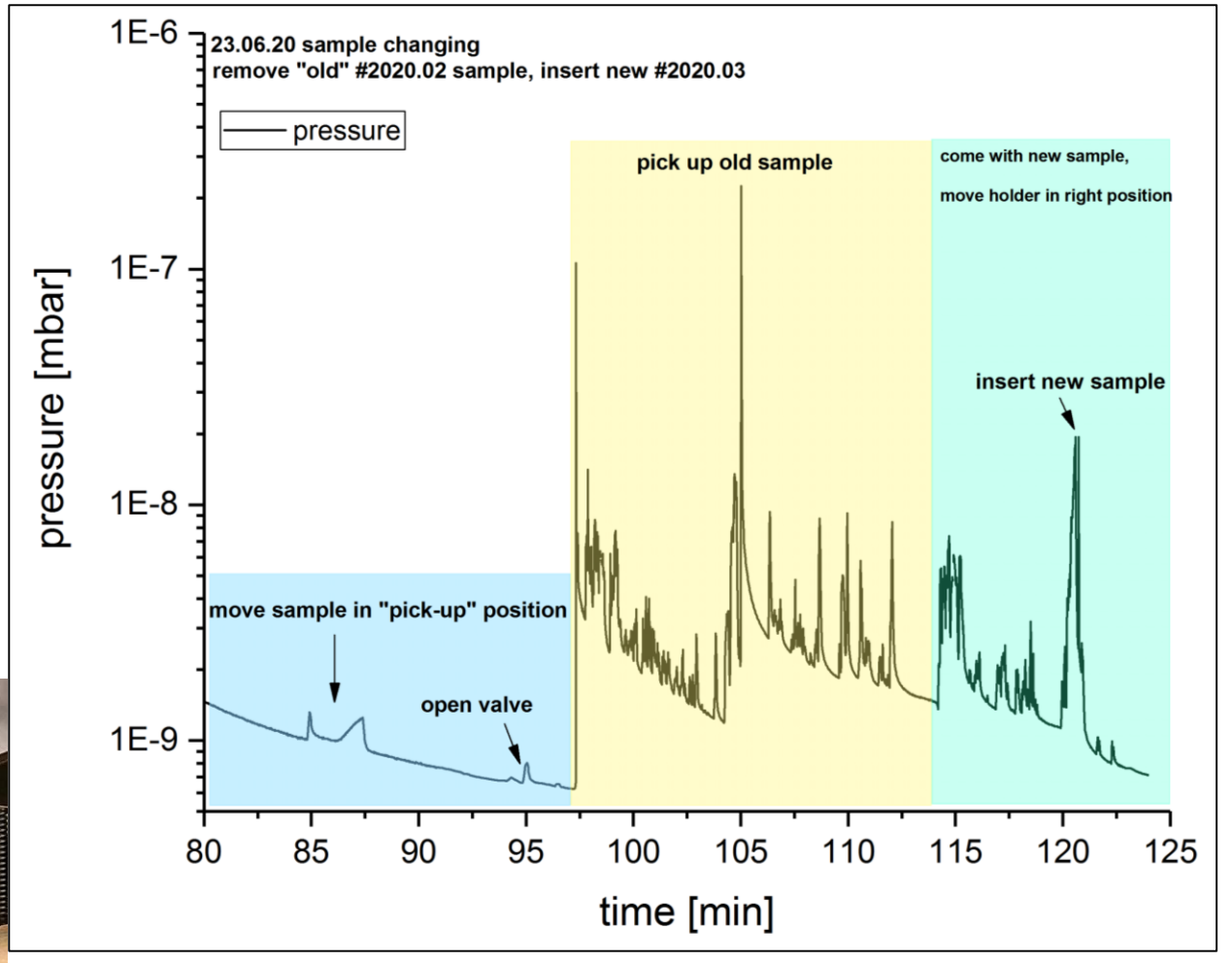


Sample	Cs current [A]	Max. photocurrent [nA]	Max. QE [%]	Activation time [min]	$T_{1/2}$ [h]
#2020.01	3.3	373	1.26	100	41
Cs_1	3.4	230	0.79	85	92
	3.5	178	0.61	90	6
#2020.02	3.6	242	0.83	85	? (35)
	3.7	895	3.49	145	5
Cs_2	3.0	600	2.67	20	50
	3.3	283	0.97	35	-

GaN Photocathode Research

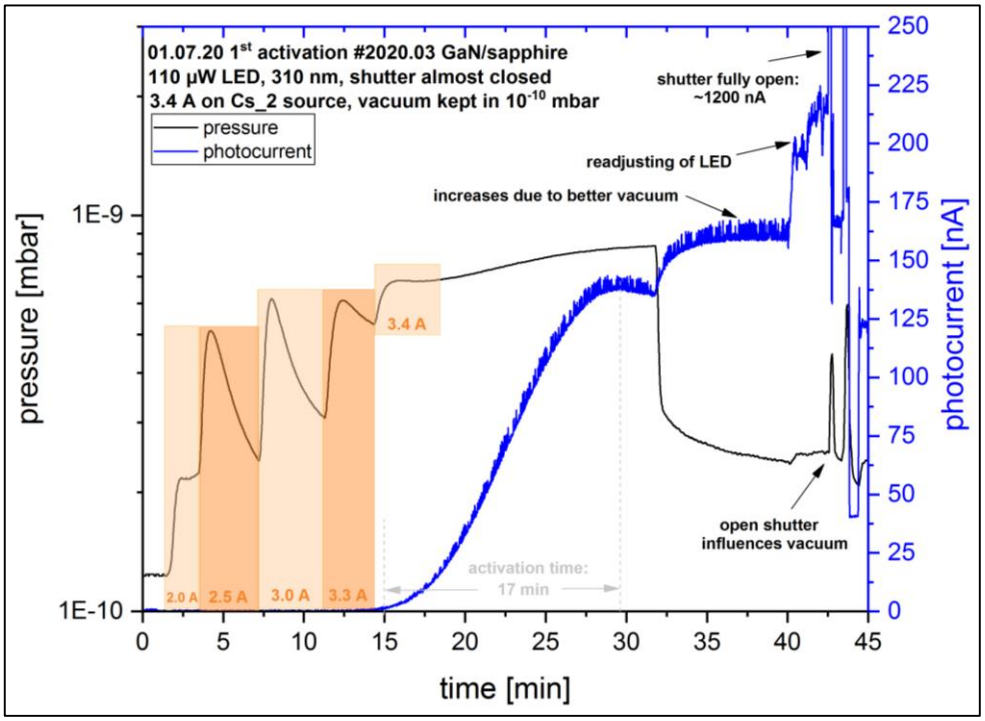
Sample changing

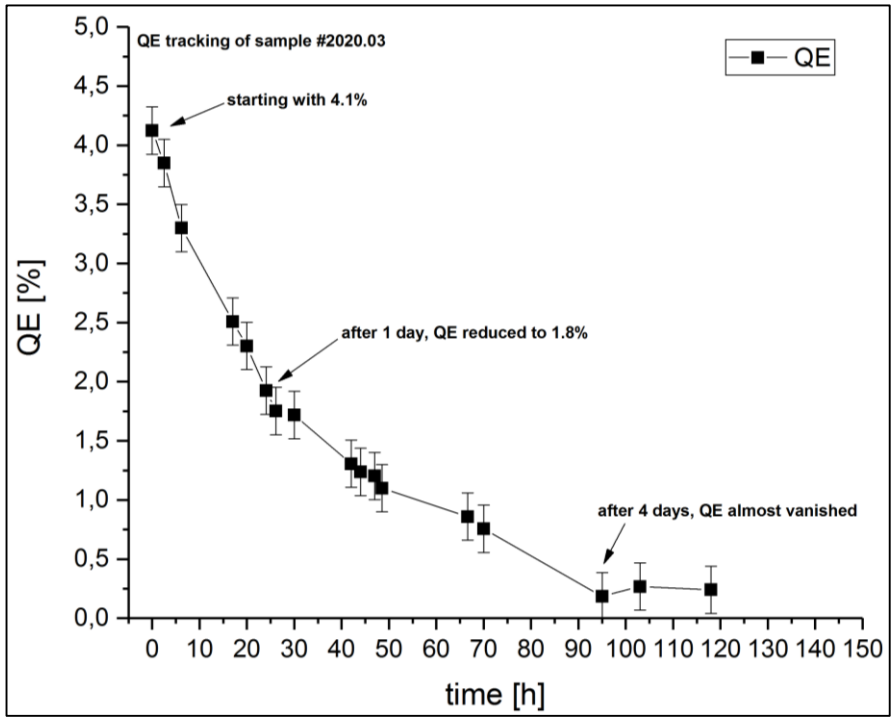




GaN Photocathode Research activation

activations on GaN/sapphire #2020.03





- Activation with new Cs source was working out well → vacuum kept in 10^{-10}mbar range
- Still it released some gasses
- Activation was done @ 3.4 A in 17 min ! → pretty fast
- After stopping Cs → increase in photocurrent due to better vacuum
- Max. photocurrent was 1200 nA → 4.1% QE.
- Cathode survived about 4 days

GaN Photocathode Research — Summary

What we have learned from the first GaN activations ?

- GaN/sapphire can reach max. 4.1 % QE (so far)
  → depending on vaccum → keep in best as possible range
- Outgassing of new caesium source before activation is important
- Find out the best activation time (Cs current)
- Lifetime was 1-4 days
  → reduce the power of LED via shutter (during activation) and open just shortly to get the maximum photocurrent
  → detect the QE after activation not permanently (side effects from anode ?!!?)

- Effect of excess of Cs???

- Influence of heat-cleaning???
  → finding out the right temperature and time

GaN Photocathode Research

For GaN:

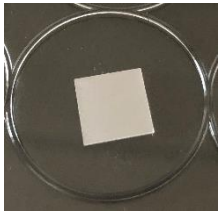
- Charaterization and comparison of commercial available GaN wafer
  → GaN on sapphire, Si, SiC (different substrates)
  → AFM, XPS, EDX, SEM, RBS
- Connection from activation chamber to XPS chamber
  → planned in 1st quarter 2020→ delayed now because of COVID-19 → shifted to fall 2020 ?!?!
- Activation of GaN wafer with Cs and characterization of activated GaN
  → further activations and improvement
- Comparision to GaAs & selfmade GaN (Uni Siegen)

For Cs_2Te:

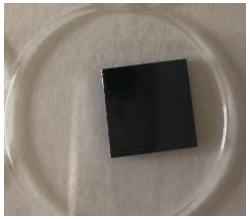
- Continue preparation of Cs_2Te cathodes for ELBE use
- Compare to other substrates → molybdenum plug
- GaAs, Cu and Mo substrate as 9x9mm square
  → install additional a Te evaporator in chamber 119
  → XPS analysis would be possible

Outlook

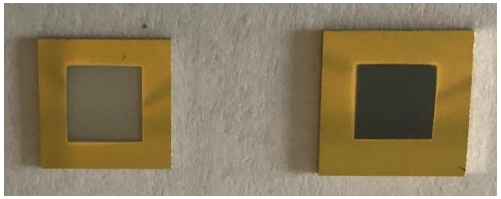
XPS facility in front of GaN chamber



GaN on sapphire



GaN on Si



GaN on sapphire and Si sputtered with gold

Thank you for your attention!

Thanks to the ELBE team

J.Teichert, R.Xiang, A. Arnold, P. Zwartek, S. Ma, P. Murcek, P. Evtushenko, M. Freitag, M. Justus, M. Kuntzsch, U. Lehnert, P. Michel, A. Ryzhov, C. Schneider, R. Steinbrück, K. Zenker

and our co-workers

P. Kneisel, G. Ciovati JLAB, Newport News, USA

I. Will MBI, Berlin, Germany

T. Kamps, J. Kühn, M. Schenck, M. Schmeißer, G. Klemz,

J. Voelker, HZB, Berlin, Germany

J. Sekutowicz, E. Vogel, F. Stephan, H. Qian, DESY, Germany

K. Aulenbacher, JGU, Mainz, Germany

M. Vogel, X. Jiang, Uni Siegen, Germany

R. Nietubyć NCBJ, Świerk/Otwock, Poland

U. van Rieken, E. T. Tulu, Uni Rostock, Germany

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