The attempt of using GaN (Cs) as a photocathode in SRF injector

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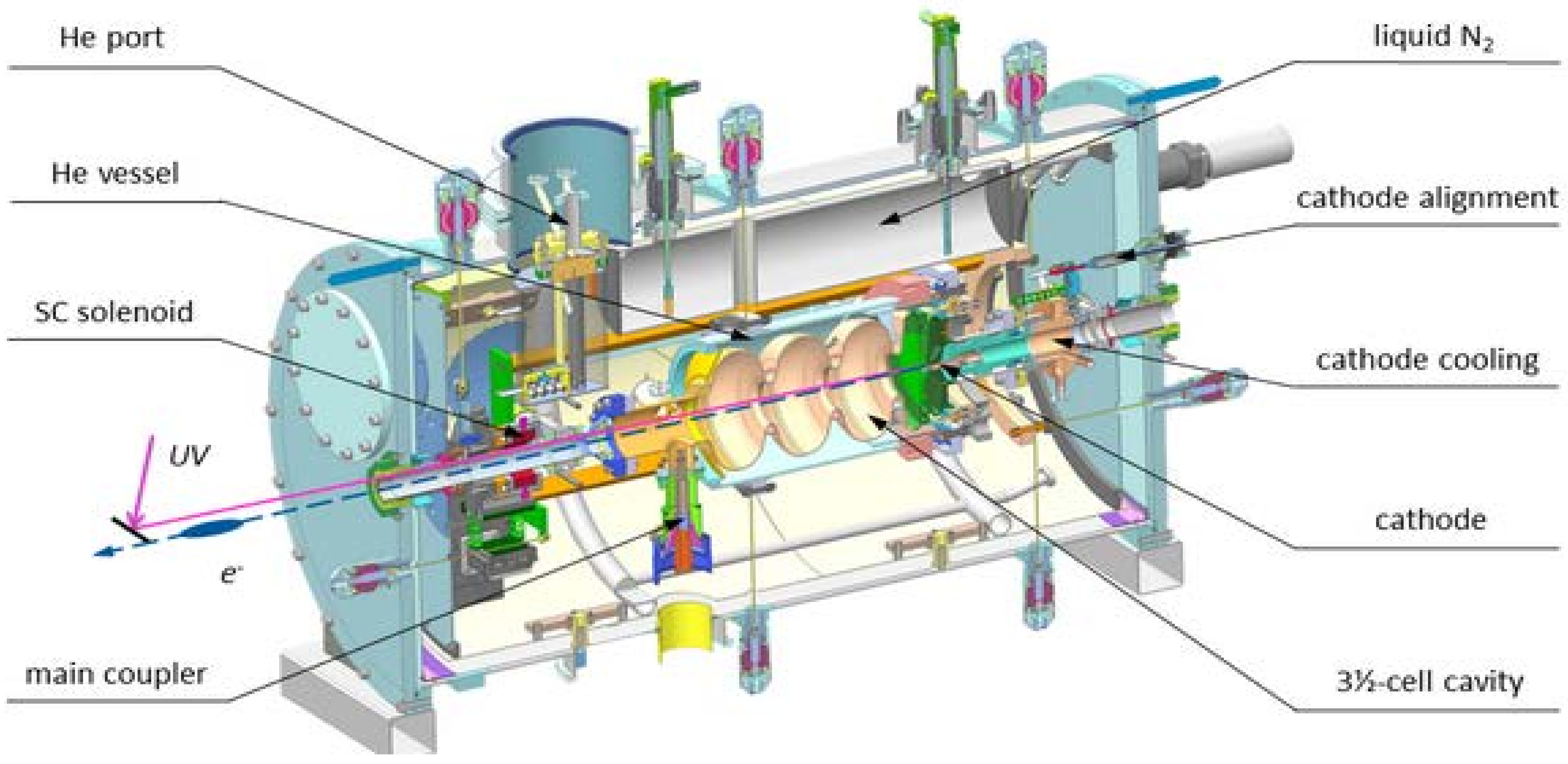
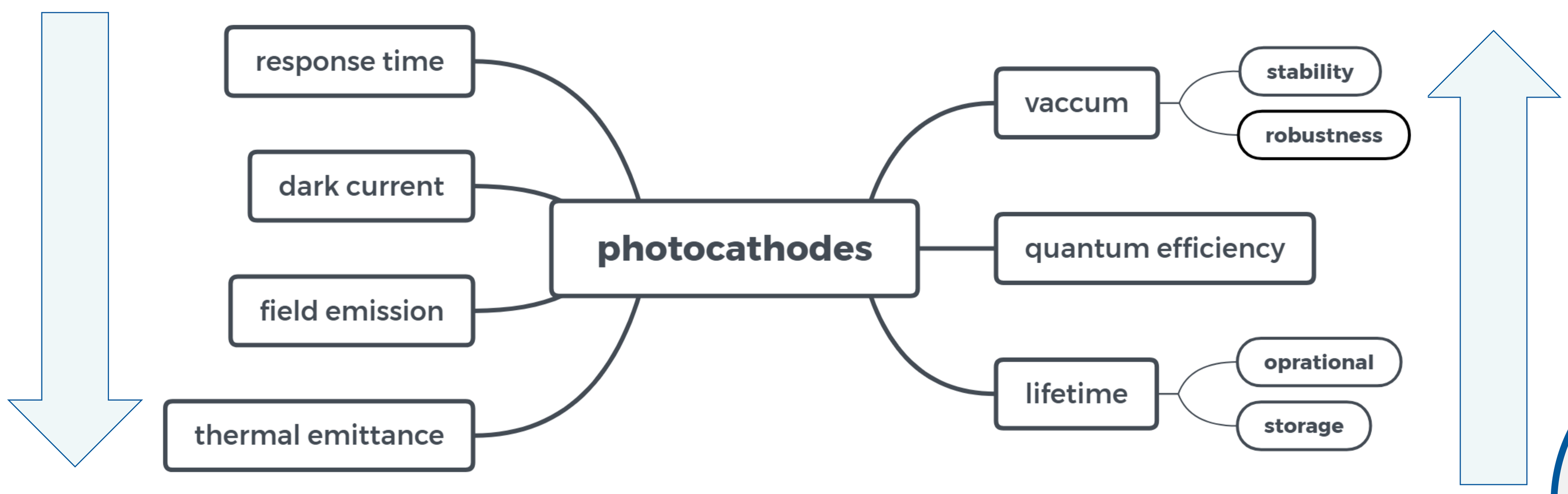
1. Introduction

SRF Gun II



desireable requirements for photocathodes

- searching for better photocathodes is one of the principle challenge for photoinjectors
- average current up to several mA is desireable
- novel III-V semiconductor with direct & wide band gap (3.4 eV)

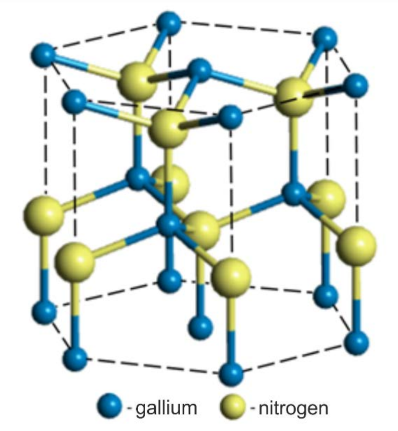


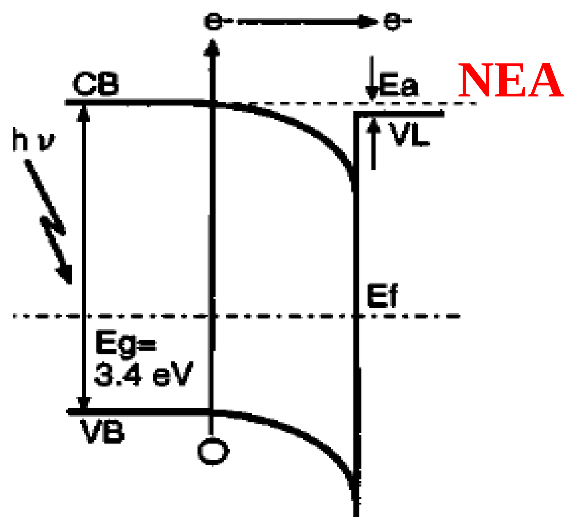
2. GaN (Cs)

$$QE = \frac{N_{generated\ electrons}}{N_{incident\ photons}}$$

GaN & its characteristics

- high QE (~40%)
- working wavelength range of 150 nm- 400 nm
- negative electron affinity (NEA) → only with Cs
- High robustness: resitant to vacuum contamination
- Good storage: ~3 years under nitrogen atmosphere





[S. Uchiyama., et al., APL 86, 103511 (2005)]

cesium activation & NEA

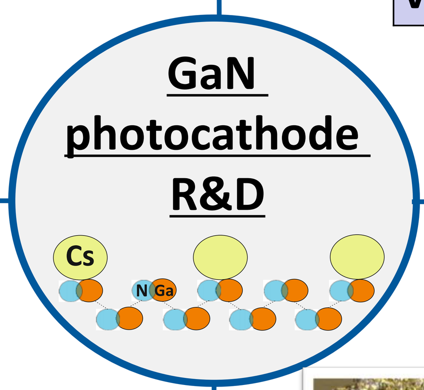
- Mg doping is necessary
  → increases diffusion length of e⁻ to surface
- activation with monolayer of Cs
  → work function near surface is lowered below vacuum level (NEA)

Table 1: Comparison of different photocathodes for SRF Guns

Property [Unit]	K_2CsSb	Cs_2Te	GaAs	Cu	Mg	GaN
harmonic *	2	4	2	4	4	3
λ [nm]	532	266	532	266	266	365
QE [%]	8	5	5	1.4E-2	0.5	~40
lifetime [hours]	4	> 100	~58	> 1 year	> 1 year	several years
response time [ps]	prompt	prompt	< 40	prompt	prompt	???
vacuum tolerance	poor	very good	poor	excellent	excellent	excellent

* For drive laser: Nd:YAG, output at 1064 nm

Introduction to the physics of electron emission, K.L.Jensen, 2017, p. 444 f.
Bazarov, Ivan V. et al. 2009. "Thermal Emittance and Response Time Measurements of a GaN Photocathode." Journal of Applied Physics 105(8).

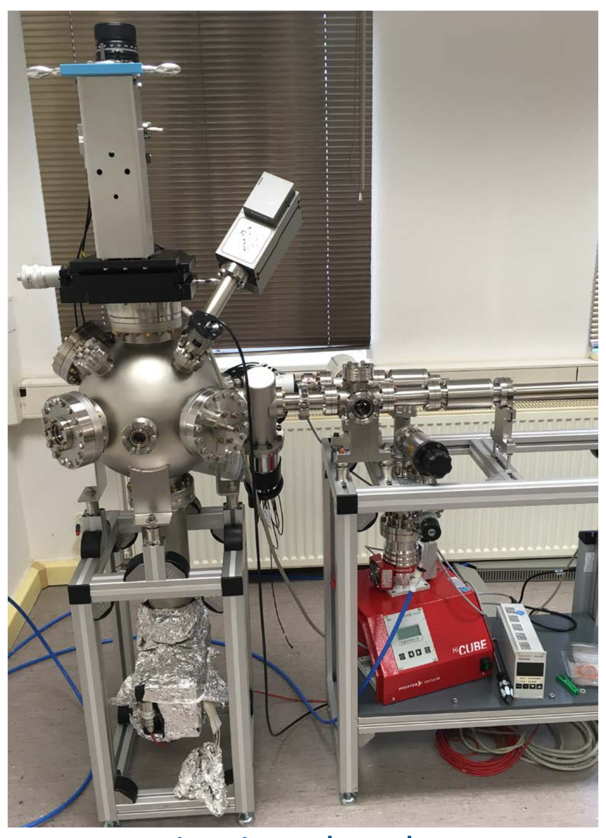


4. Ongoing working plan

analytical chemistry

- SEM, TEM & AFM
- XRD, XPS & EDX
- RBS & AES
- PL & QE

- cleaning process of GaN wafer? (analytic surface chemistry)
- compare GaN on different substrate material
- chemical stability under intensive laser?
- processing in SRF Gun II?



activation chamber

Modification of activation chamber

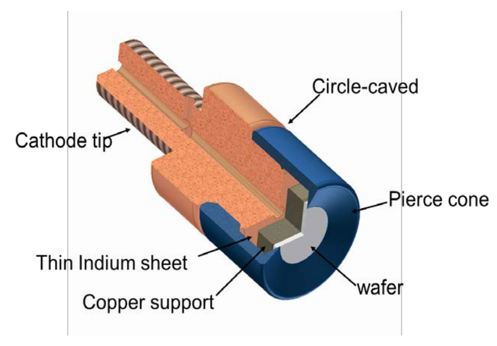
combination with SEM/EDX

- easy measurement of activated GaN
- detect contaminations/ lattice impurities

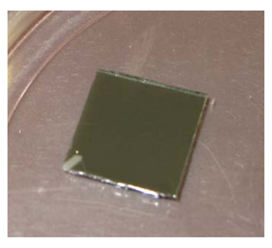
sample changement

- easy handling
- transfer from glove box without air exposure

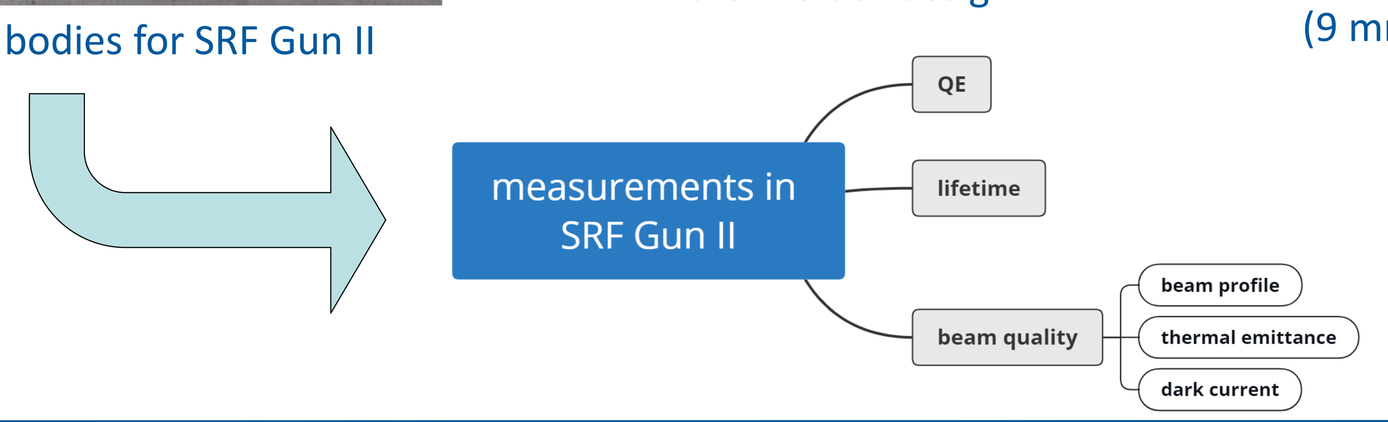
cathode bodies for SRF Gun II



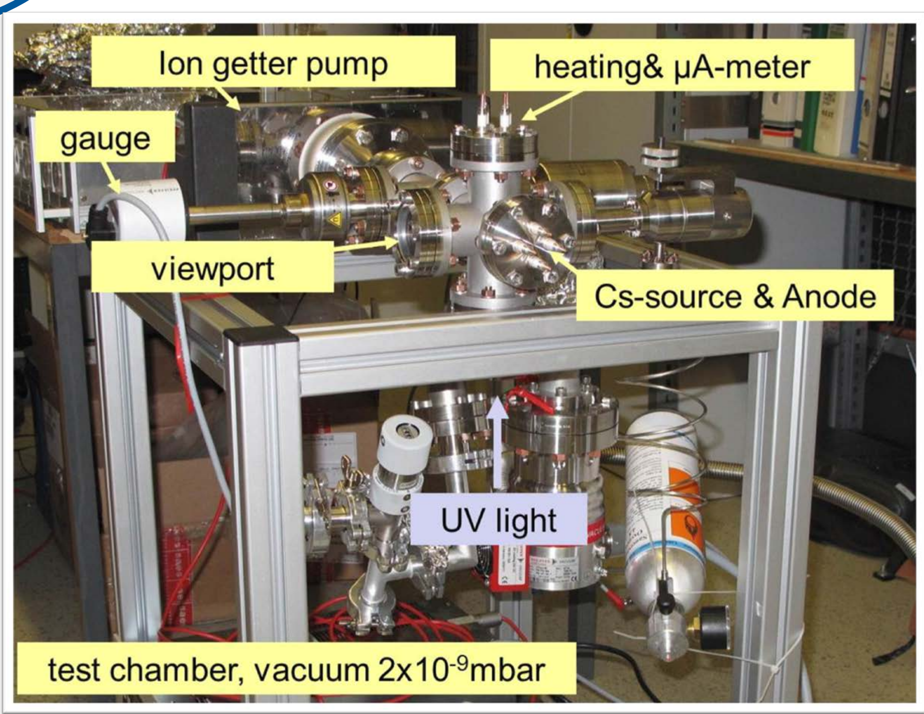
wafer holder design

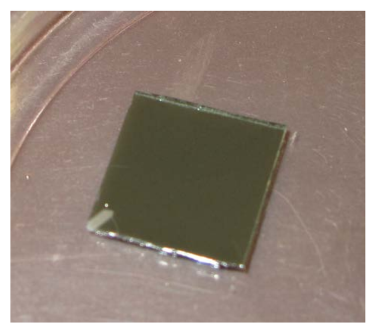


GaN
(9 mm x 9 mm)



3. First activation treatments



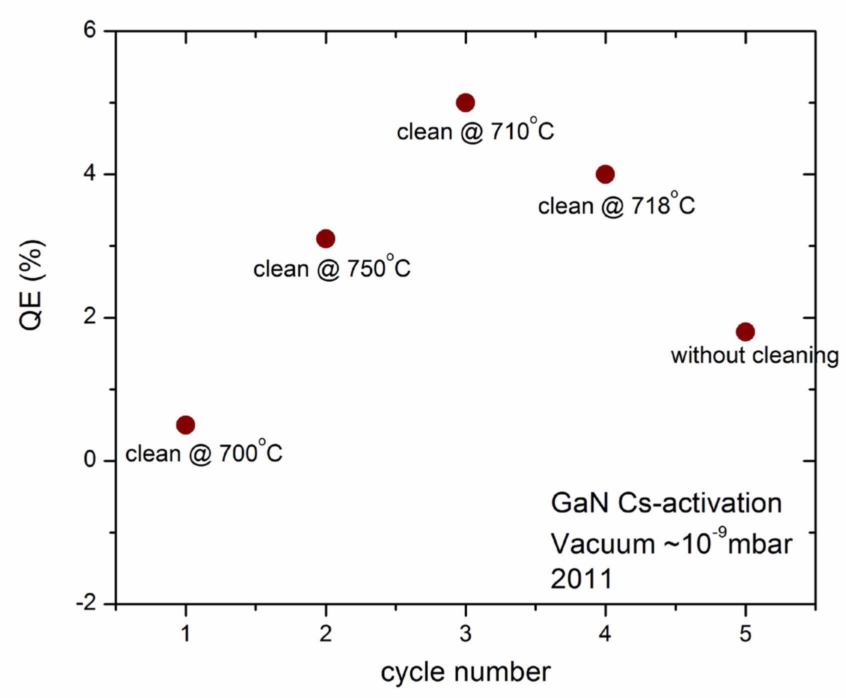


GaN on sapphire

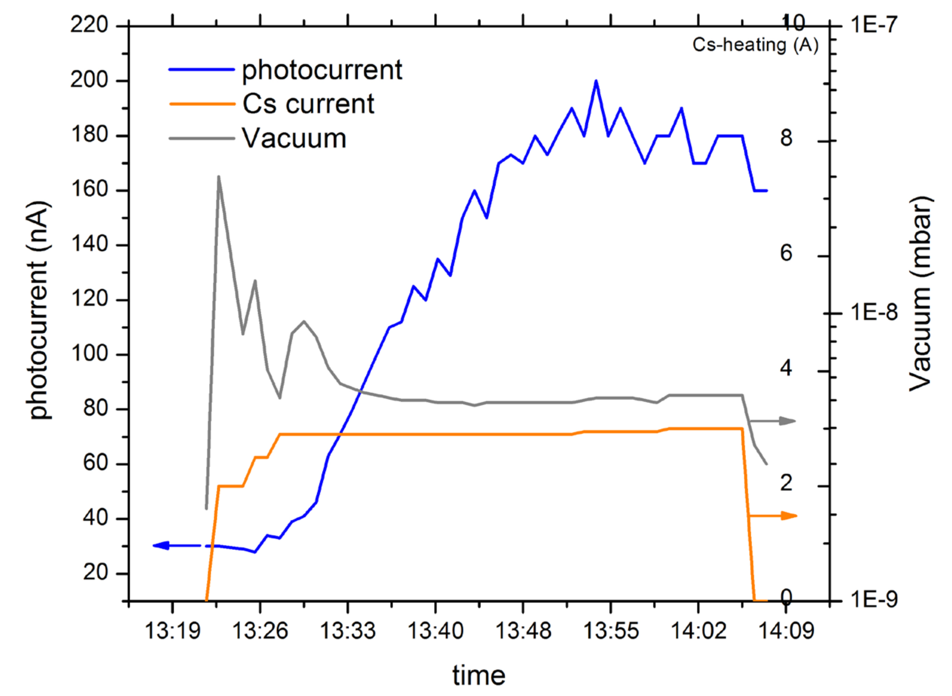
sample pre-treatment

- Ultrasonic bath in MeOH (3 min)
- etch in H_2SO_4: H_2O_2 (4:1) (5 min)
- rinse with H_2O and MeOH

- sample of 10^{17}-level p-doped GaN grown on sapphire substrate
- Pre-heat treatment to remove absorbed residual gases on GaN surface
- activated with Cs-dispenser (SAES) to achieve the NEG surface
- background vacuum in the test chamber droped down during activation



710°C seems suitable for the heat cleaning of GaN. 5% is the best QE in the activation tests on the same sample



The process of the 4[th] cycle activation. 262 nm laser is used for the process detect. 500 V bias is added on the anode

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HOPE II

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