Enhanced durability NEA surface layer for GaAs photocathodes using Cs, O_2, and Li*

M. Herbert – J. Enders, M. Engart, M. Meier, J. Schulze, V. Wende, V. Winter

*Supported by BMBF (05H18RDRB1) and by DFG (GRK 2128 „AccelencE“, project-id 264883531)

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Emission of polarized electrons from GaAs:

$E_\gamma < 1.76$ eV or $\lambda > 705$ nm

Photoemission threshold for GaAs:

$E_{th} > 5.52$ eV or $\lambda < 225$ nm

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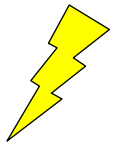

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Activation with NEA layer required to reduce work function!

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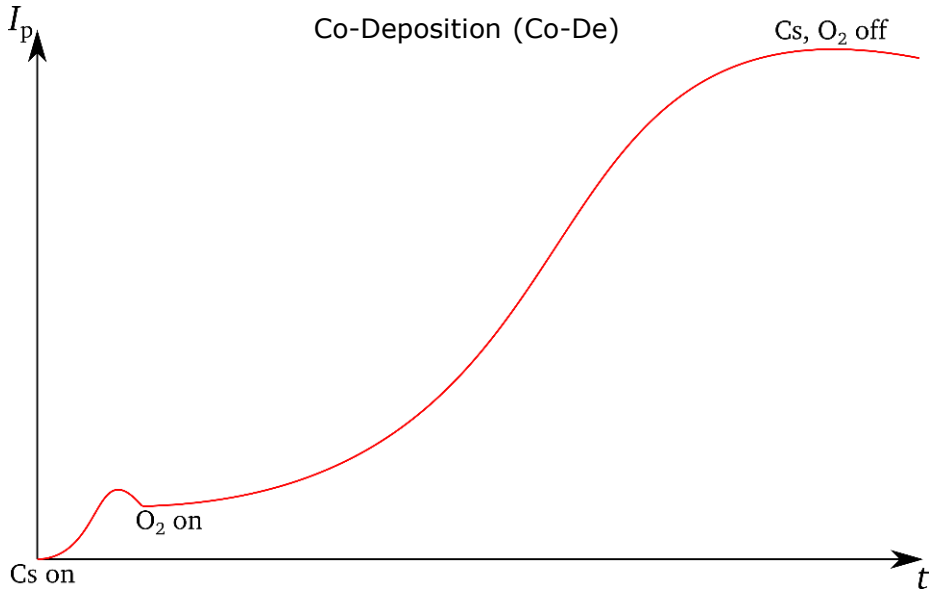

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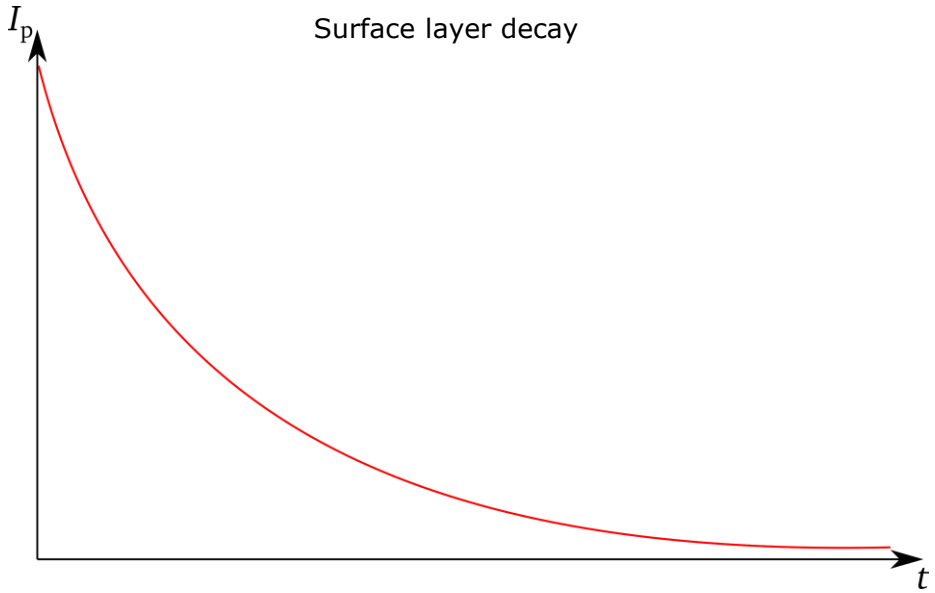

Surface layer decay

Main parameters: η_0, τ, $Q(\tau)$

$$\eta(\lambda) = \left| \frac{hc_0 I_p}{eP_L \lambda} \right| \cdot 100\%$$

$$\eta(t) = \eta_0 \cdot e^{-t/\tau}$$

$$Q(\tau) = I_0 \cdot \tau \cdot \left(1 - \frac{1}{e}\right) \approx 0.63 \cdot I_0 \cdot \tau$$

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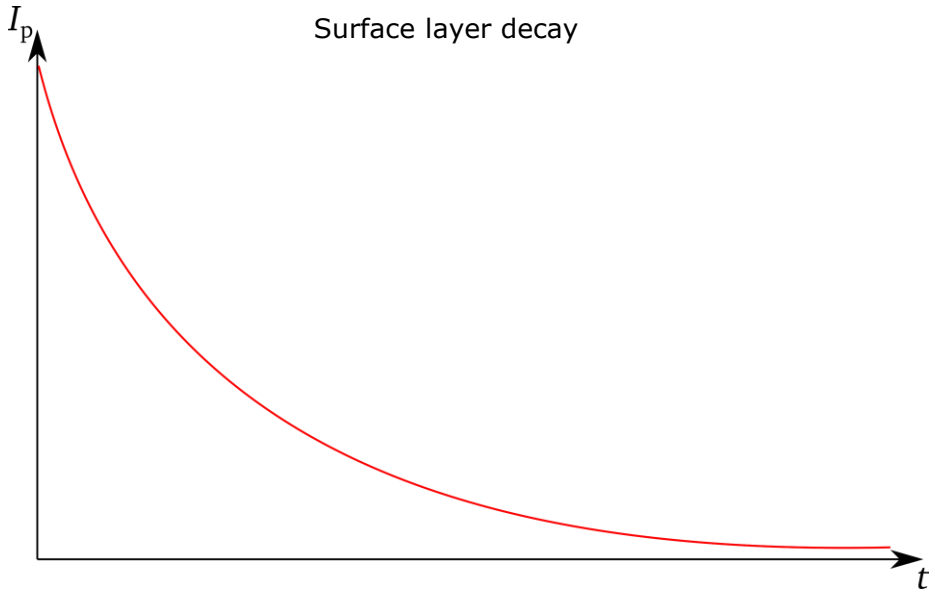

Surface layer decay

High lifetime and extracted charge required

Enhanced NEA layer

Main parameters: η_0, τ, $Q(\tau)$

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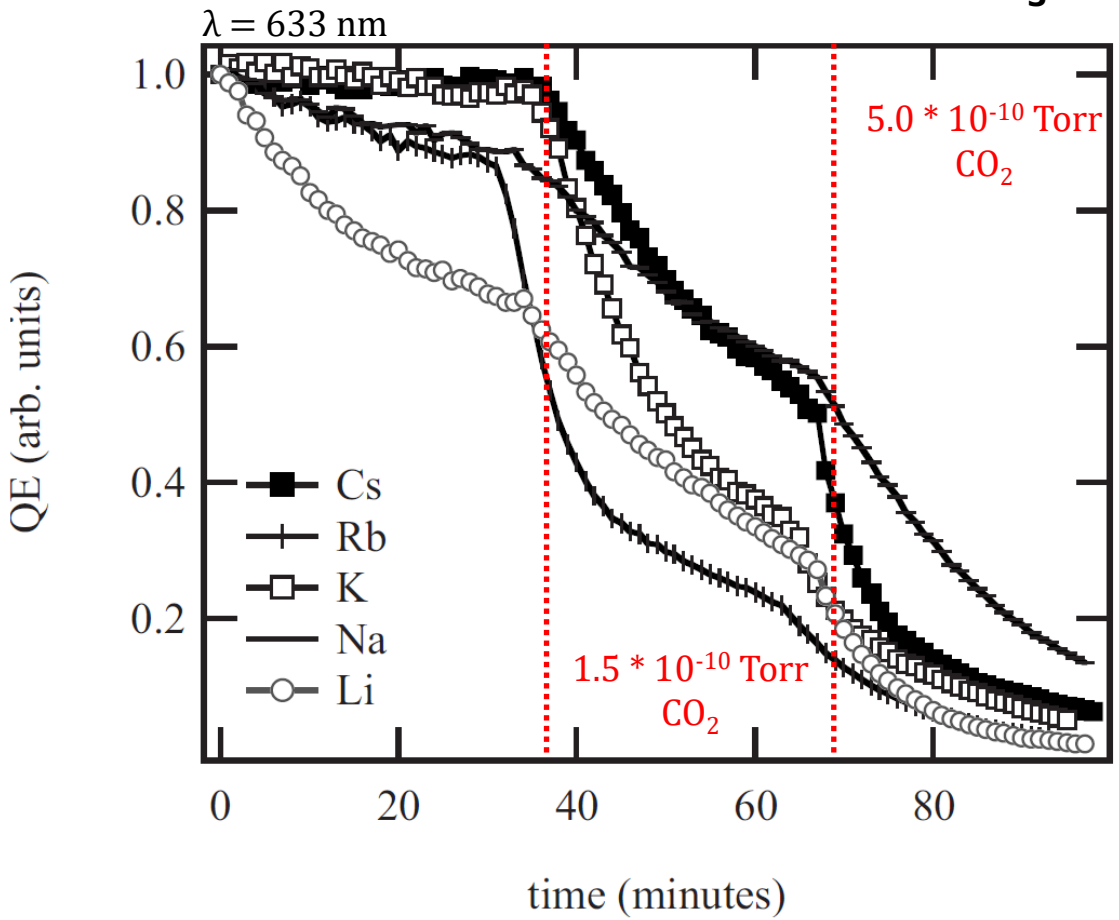
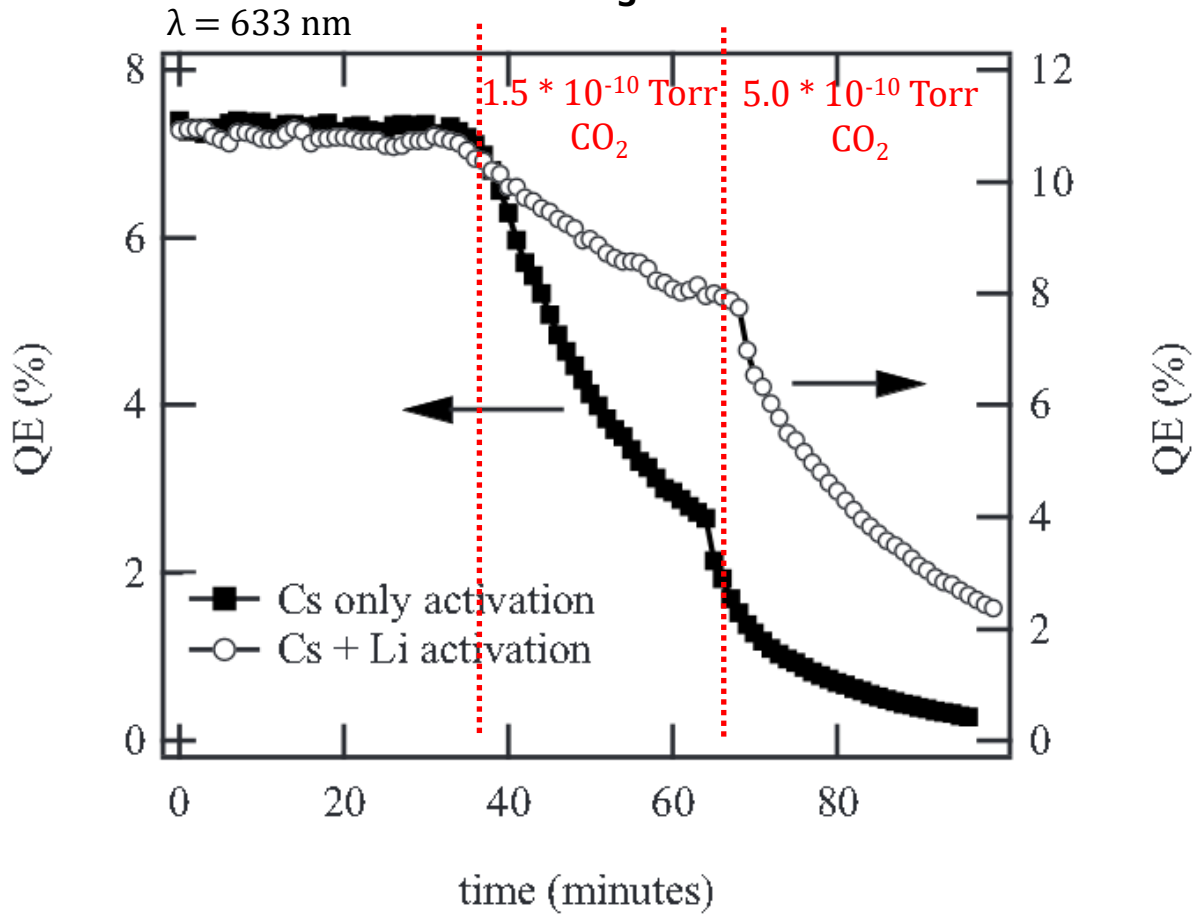
Dual alkali activation with NF_3



Cs + NF_3 + Li



G. A. Mulhollan and J. C. Bierman, J. Vac. Sci. Technol. A, Vol. 26, No. 5 (2008), https://doi.org/10.1116/1.2965816

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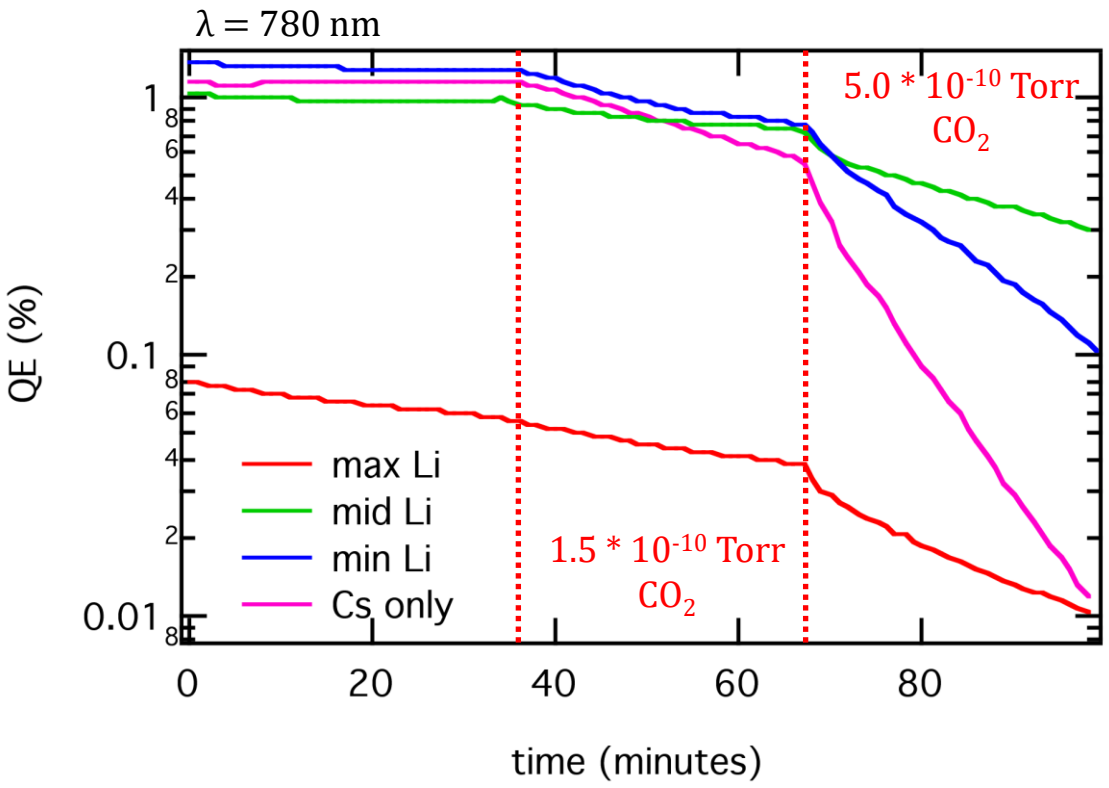
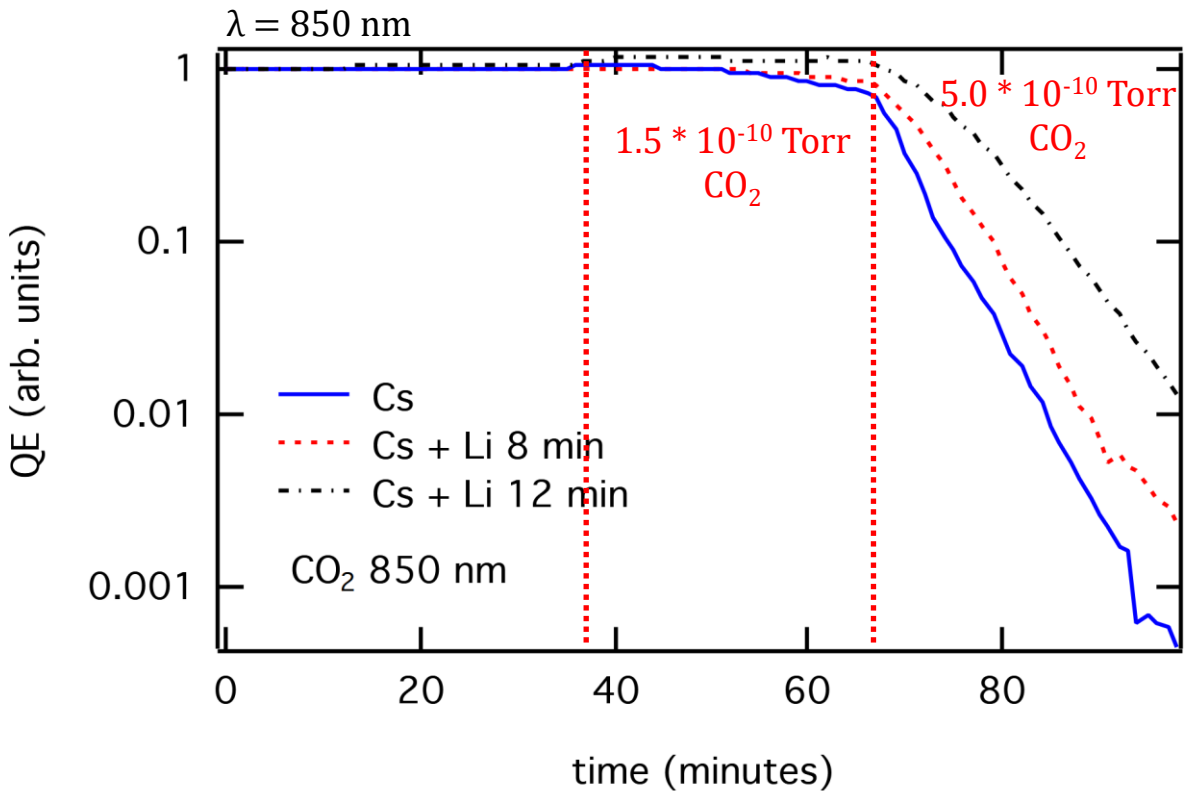
Cs + NF_3 + Li (GaAs/GaAsP SL)



Cs + O_2 + Li (bulk)



G. A. Mulhollan, *Activation Layer Stabilization of High Polarization Photocathodes in Sub-Optimal RF Gun Environments* (2010), https://doi.org/10.2172/992578

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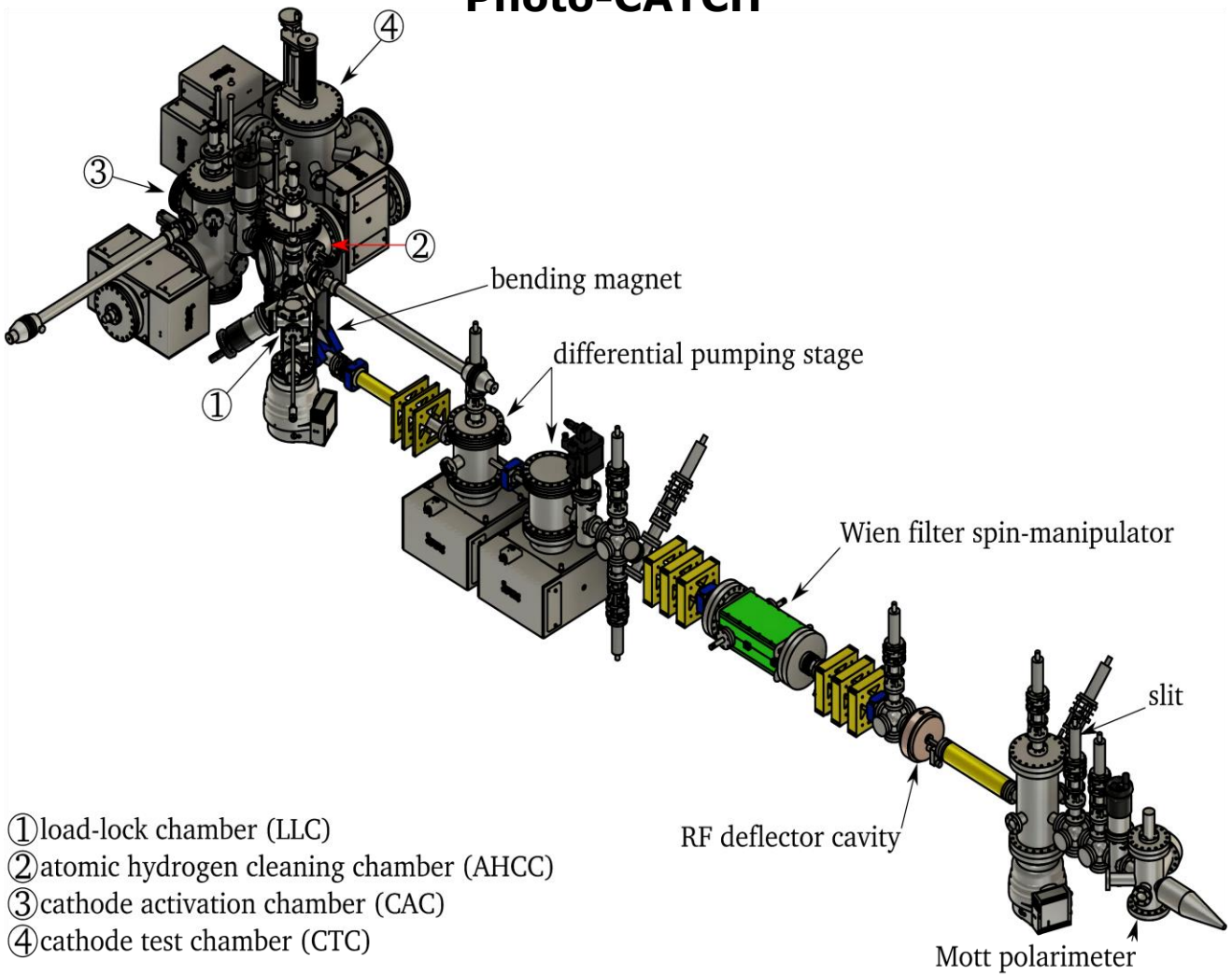
Photo-CATCH



①load-lock chamber (LLC)
②atomic hydrogen cleaning chamber (AHCC)
③cathode activation chamber (CAC)
④cathode test chamber (CTC)

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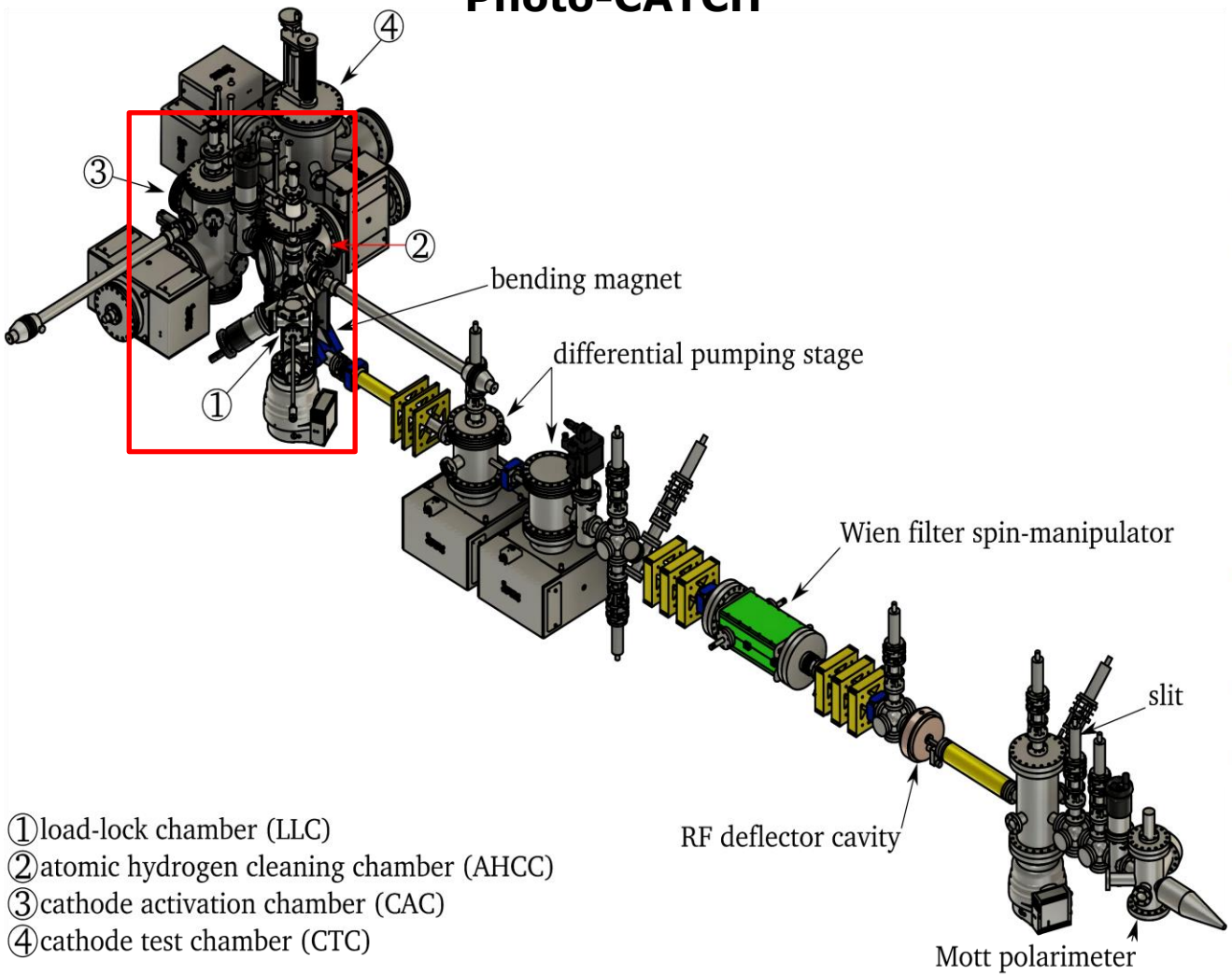

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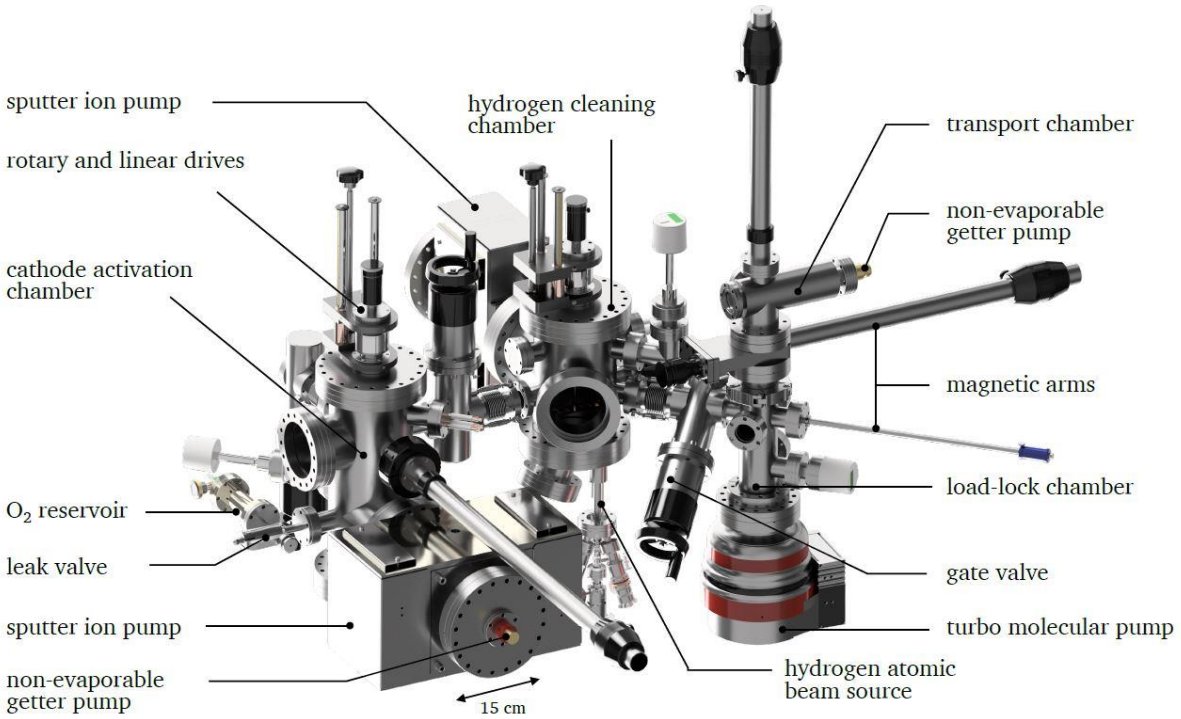
Activation & Cleaning System



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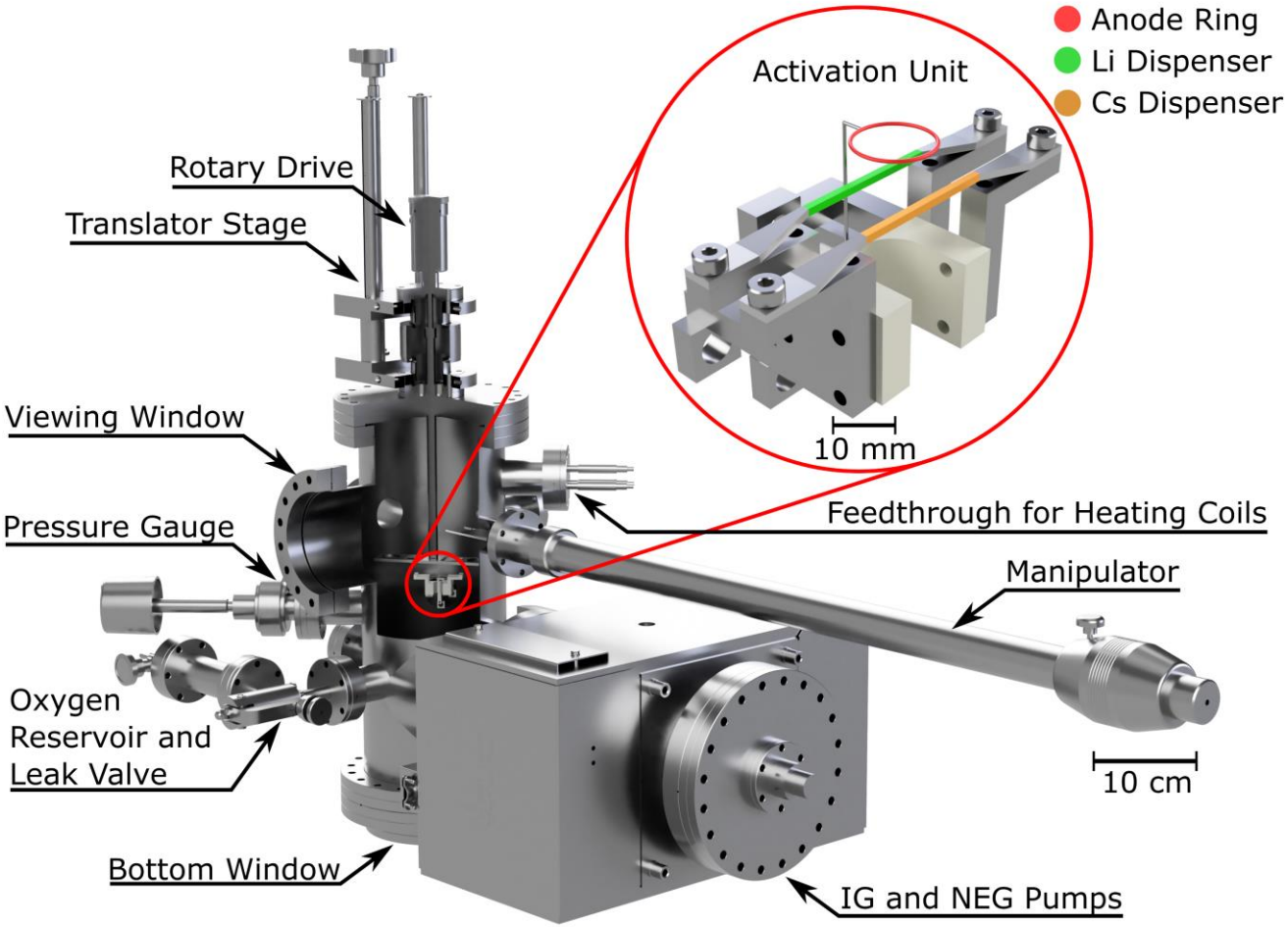
Activation Chamber



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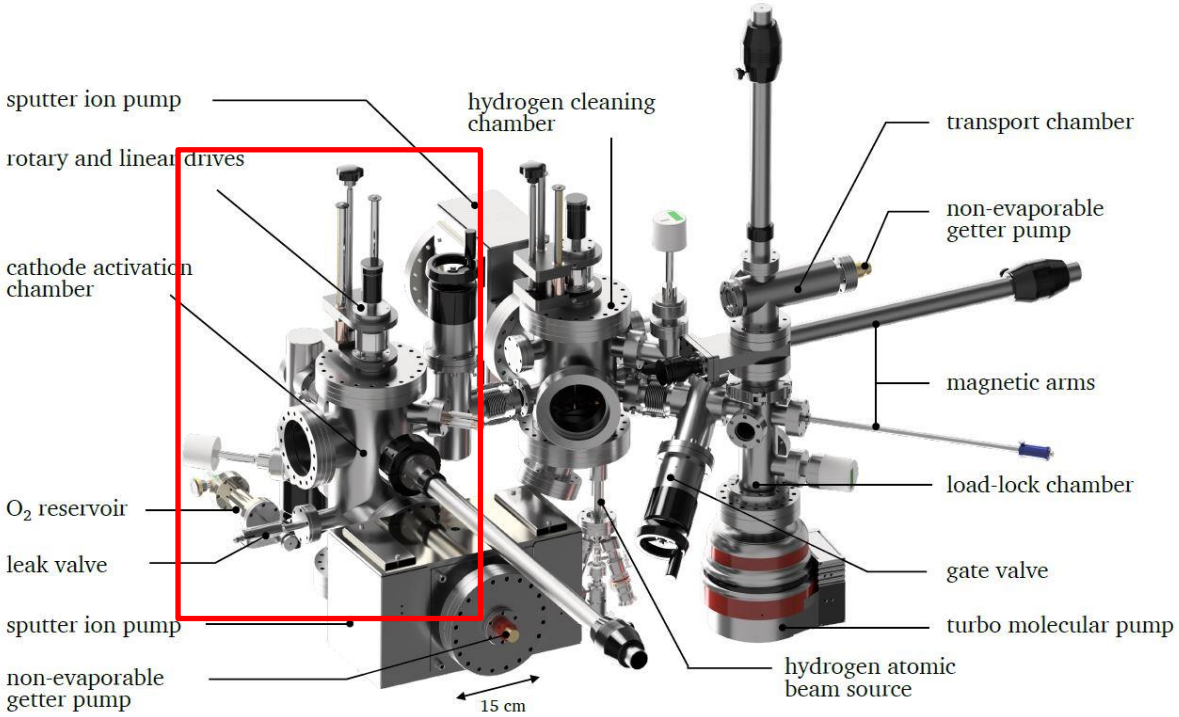

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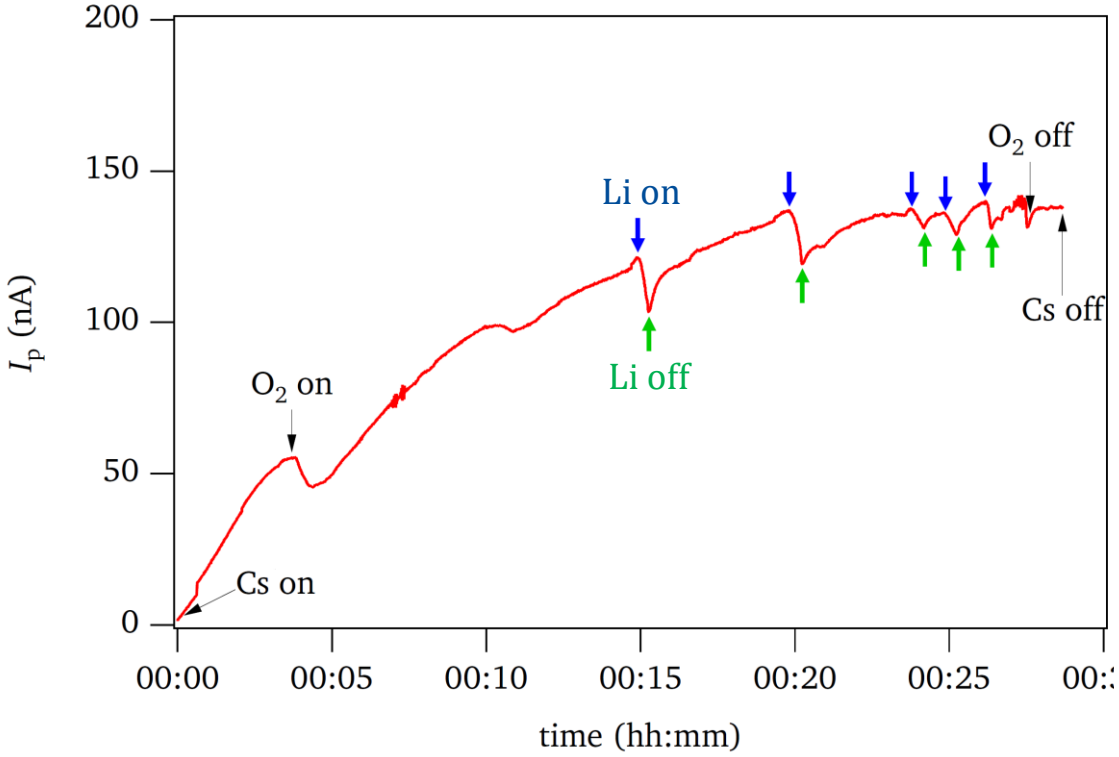
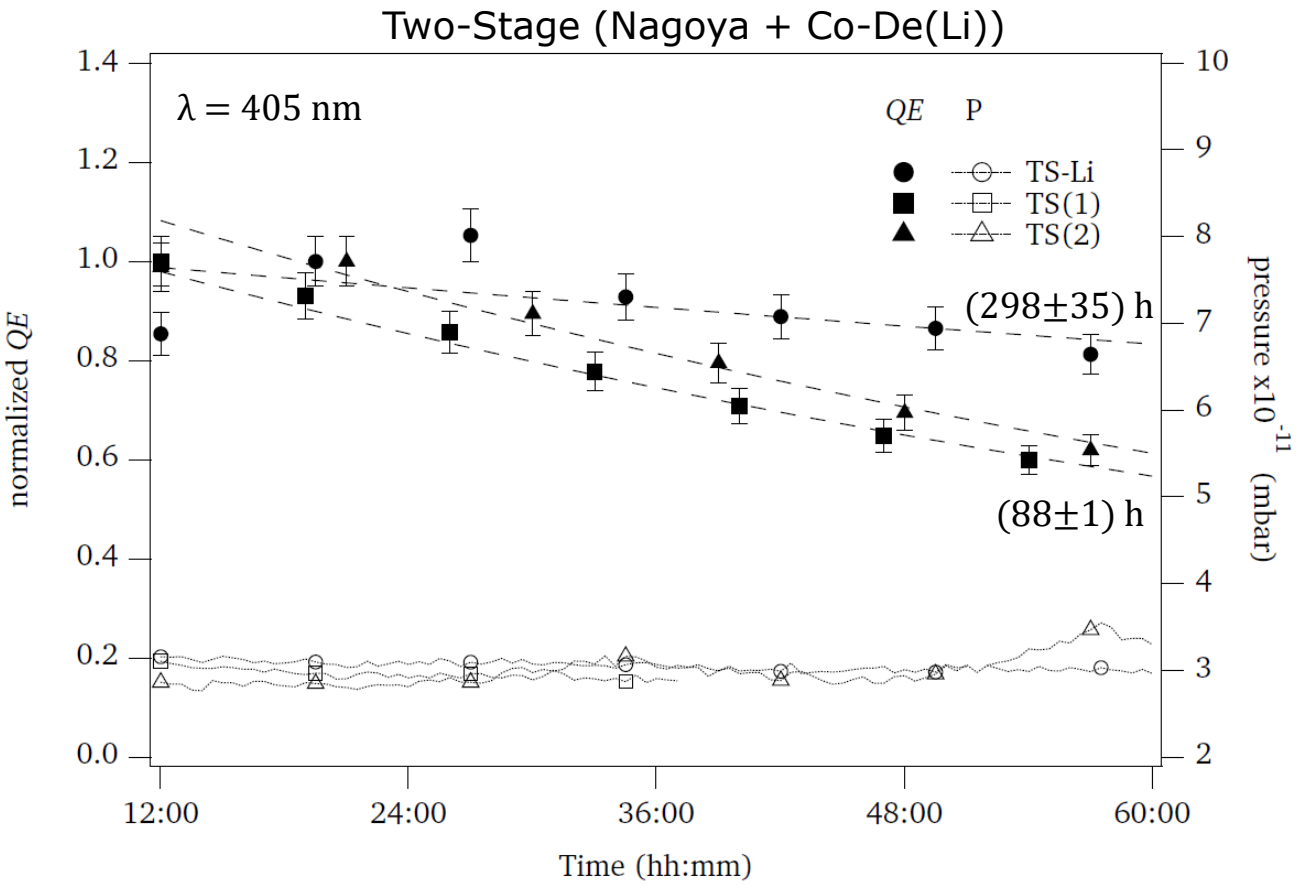
Pulsed Co-De (part 2)



N. Kurichiyanil, Doctoral dissertation (2017),
https://tuprints.ulb.tu-darmstadt.de/id/eprint/5903



N. Kurichiyanil *et al.*, Journal of Instrumentation 14 P08025 (2019),
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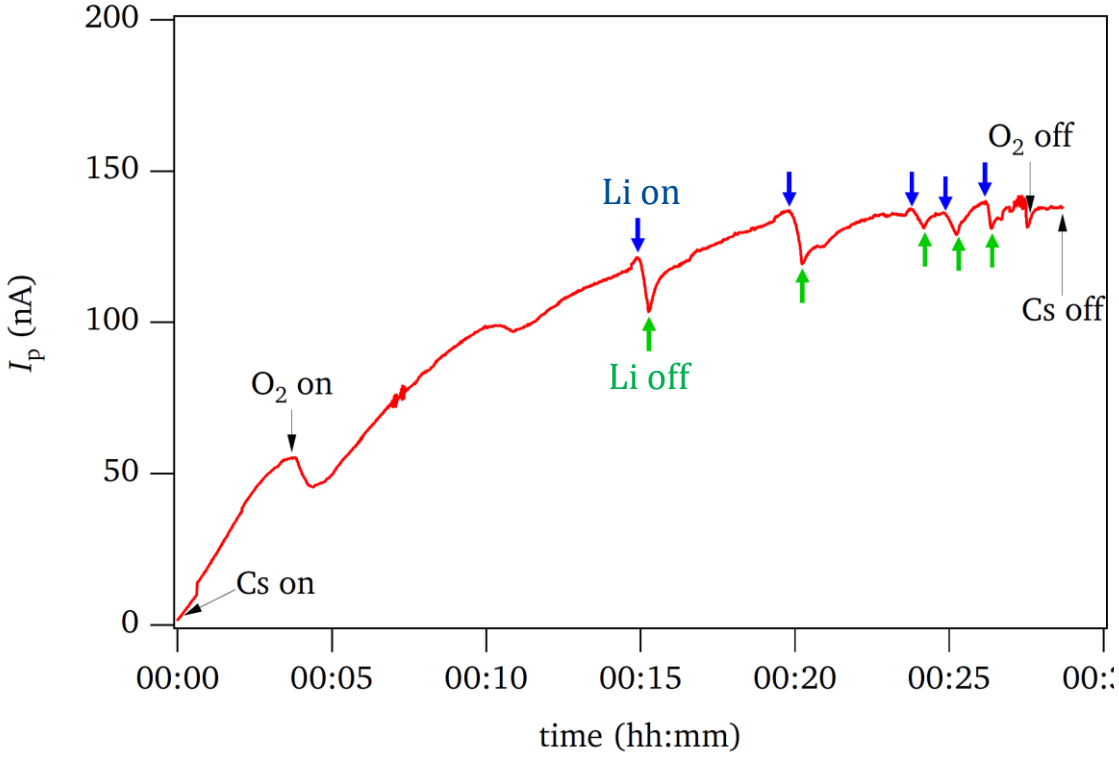

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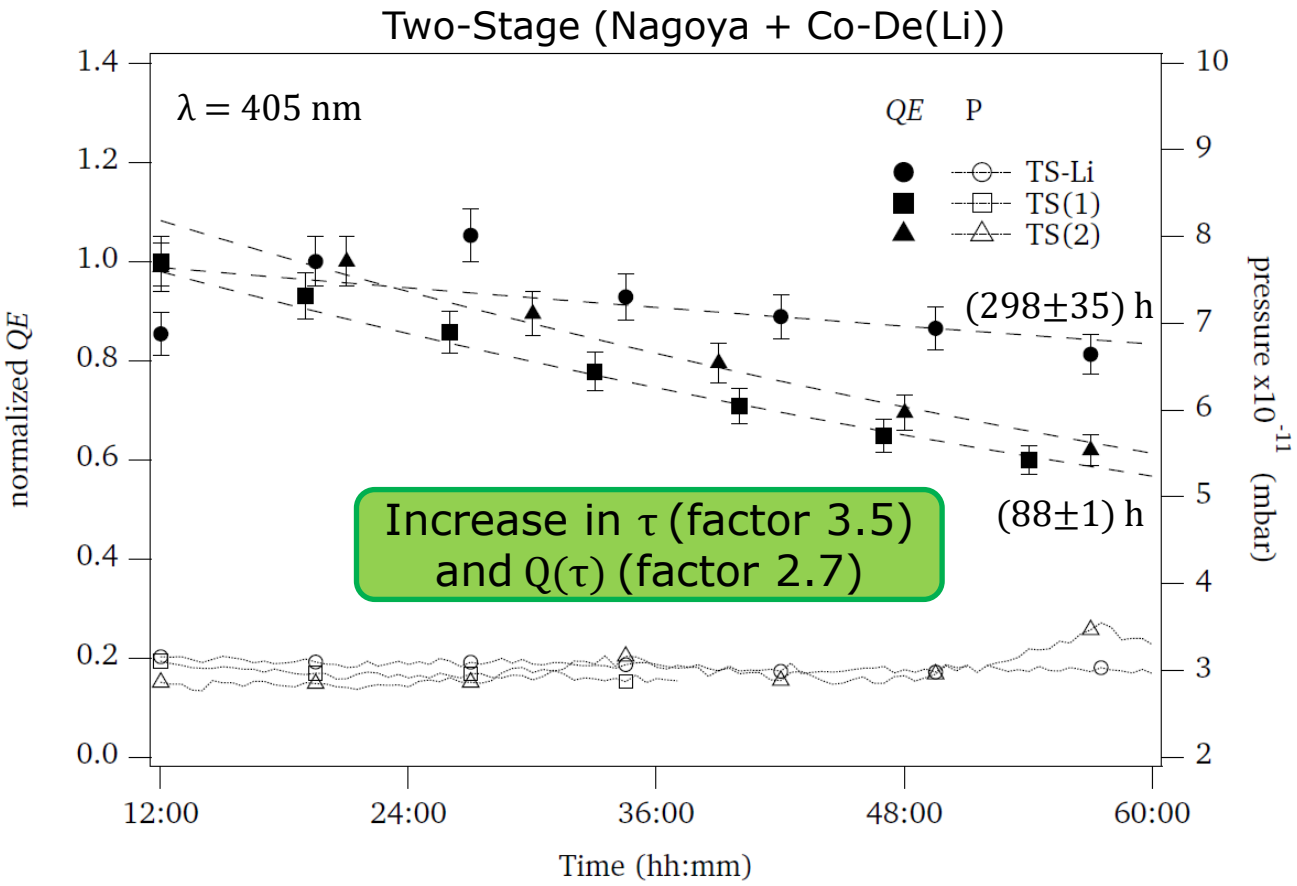

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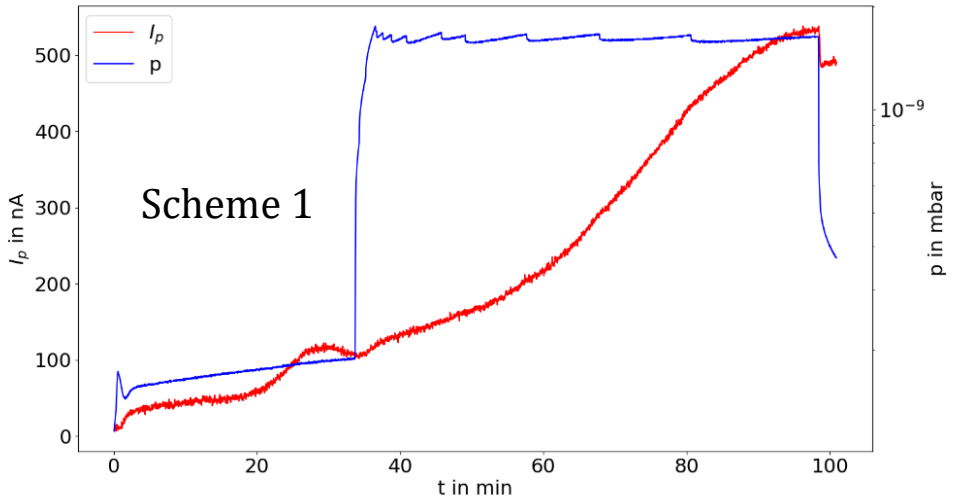
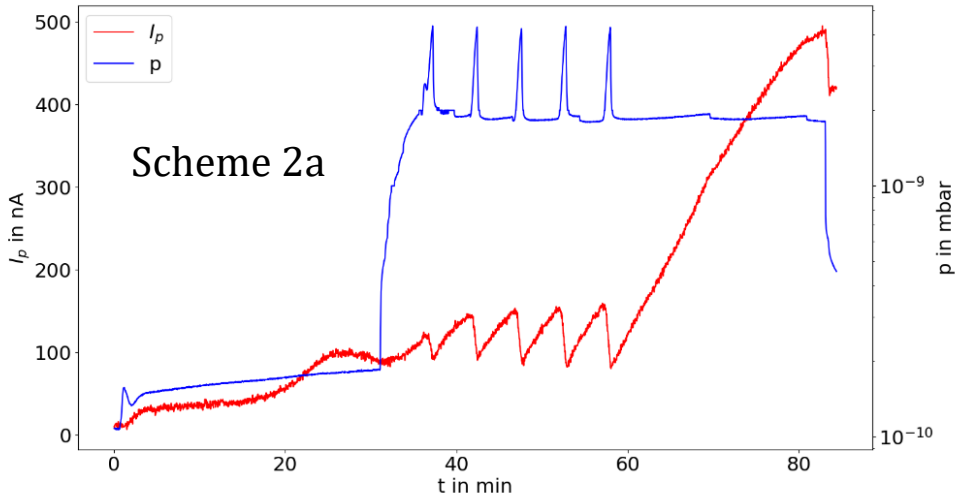
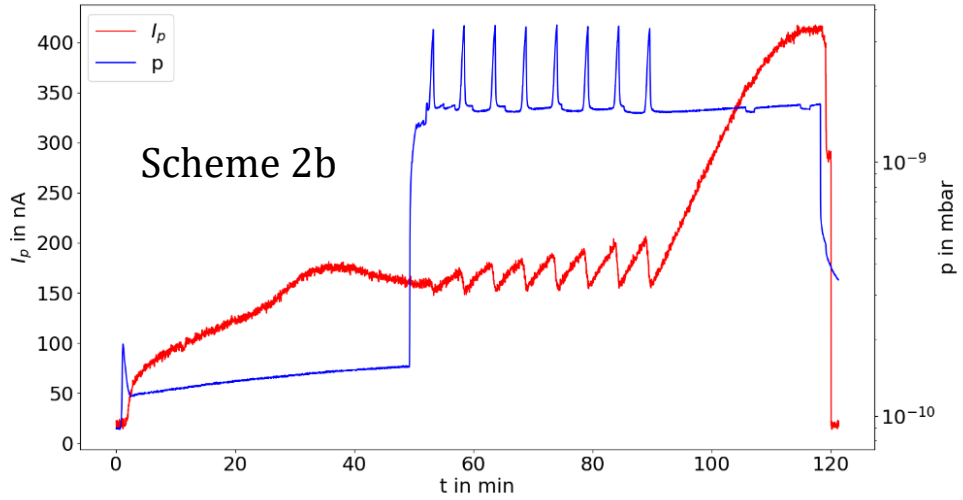


- Goal: enhanced lifetime
- Co-De with pulsed Li, based on previous study
- Scheme 1: Cs + O_2
- Scheme 2a: Cs + O_2 + Li, 5 pulses
- Scheme 2b: Cs + O_2 + Li, 8 pulses





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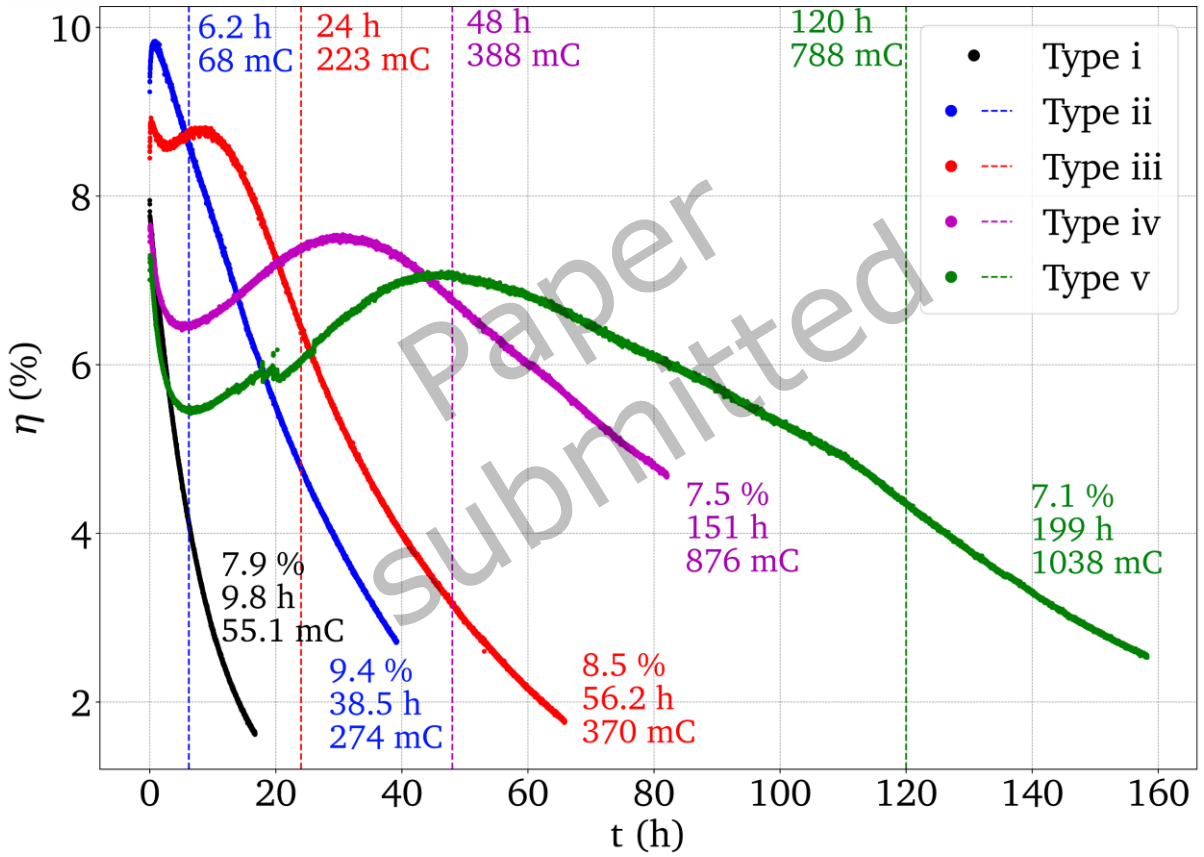

Paper submitted, Pre-Print available:
http://arxiv.org/abs/2409.04319

- QE & Lifetime measurements in activation chamber
- P_{laser} = (50 ± 5) µW, λ = (785 ± 2) nm, U_{bias} = 100 V
- 5 types of activations:
  i. Scheme 1, no prior scheme 2
  ii. Scheme 1, subsequent to scheme 2a
  iii. Scheme 2a, subsequent to scheme 1
  iv. Scheme 2b, subsequent to scheme 1
  v. Scheme 2b, subsequent to scheme 2b
- Effect of Li on subsequent activations observed

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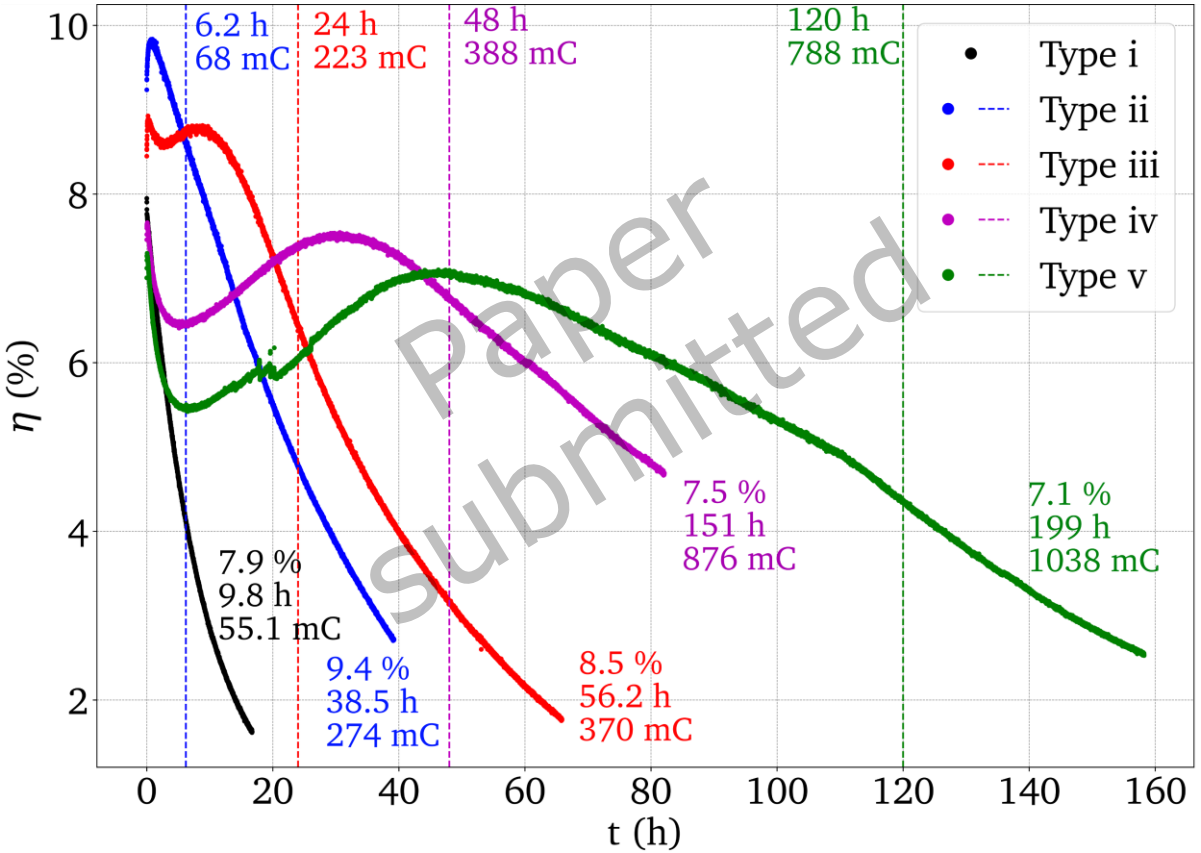

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  - iii. Scheme 2a, subsequent to scheme 1
  - iv. Scheme 2b, subsequent to scheme 1
  - v. Scheme 2b, subsequent to scheme 2b
- Effect of Li on subsequent activations observed

Significat increase in τ (up to factor 19) and Q(τ) (up to factor 16.5) observed!

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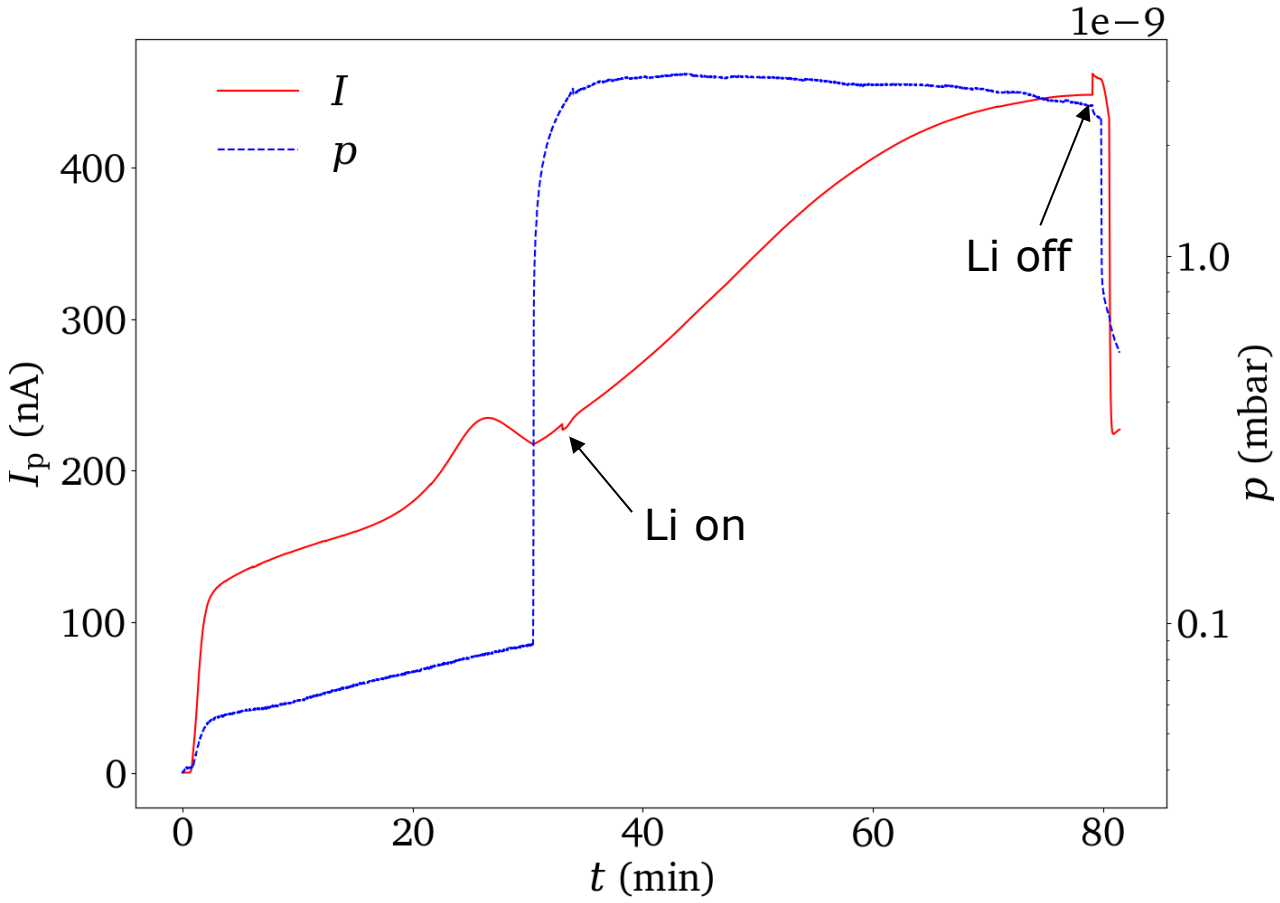
Li-enhanced activation (cont.)



- Additional measurements after maintenance
- Idea: simultaneous co-deposition of Li along with Cs and O_2 instead of pulsed Li
- First activations successful, QE comparable to Cs+O_2 activation

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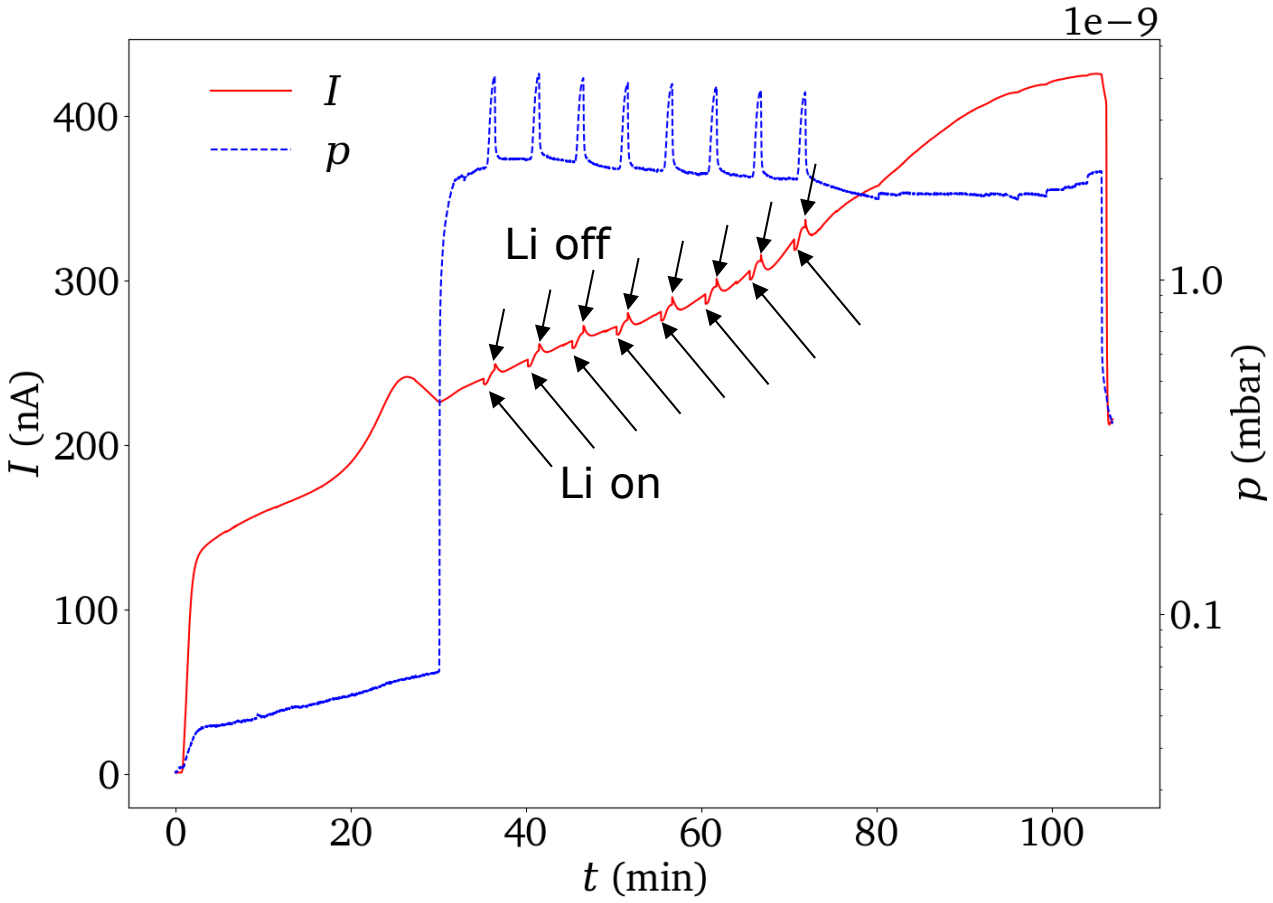
Li-enhanced activation (cont.)



- Goal: reproduce scheme 2b
- First activation successful, QE lower than for $Cs+O_2$ activation
- Anode current curve different → less pronounced impact from Li
- First lifetime measurement: ongoing

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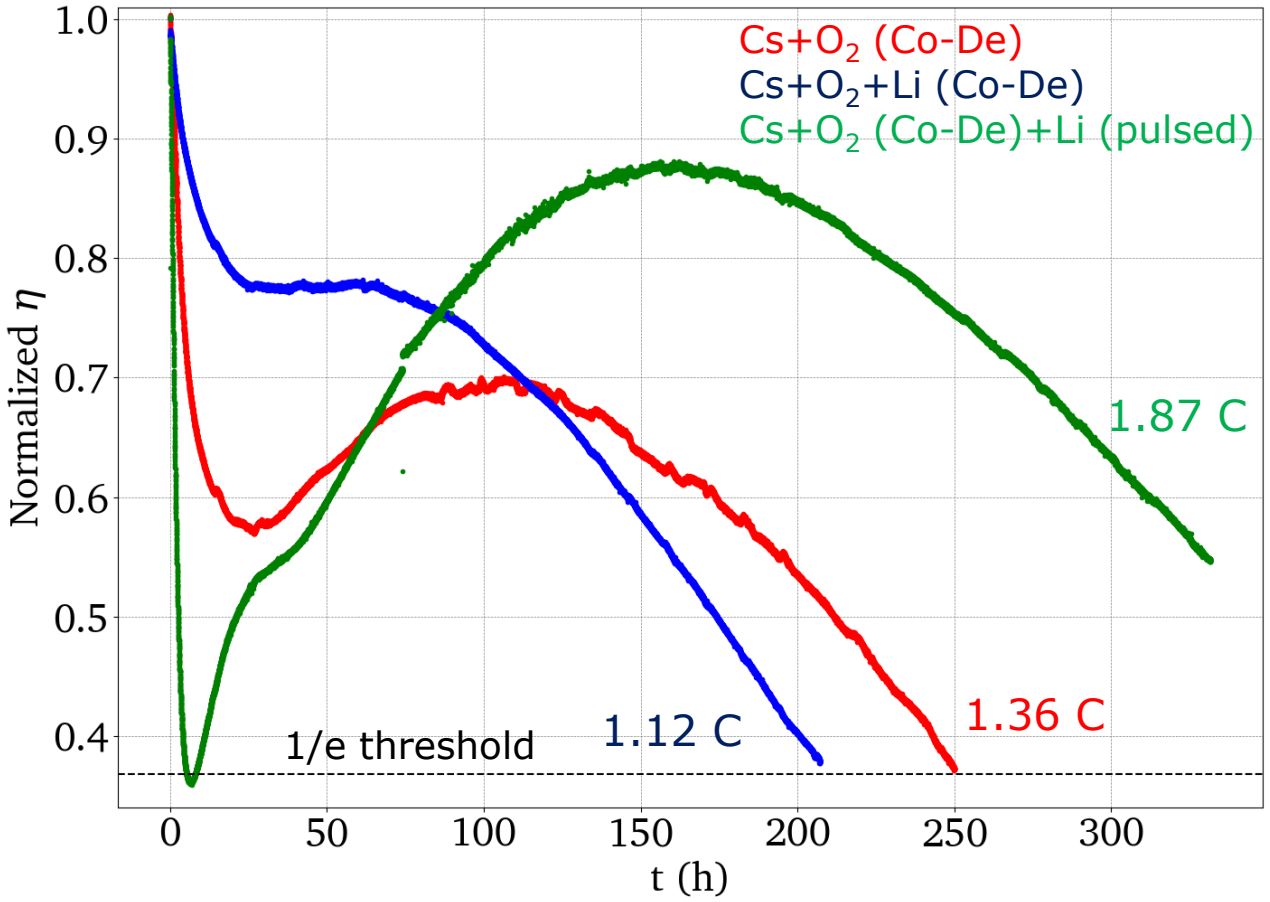
Li-enhanced activation (cont.)



- Higher lifetimes after chamber maintenance
- Lifetime measurements show no improvement for co-deposition of Li
- Lifetime measurement for pulsed scheme: looks promising, still ongoing!
- Additonal measurements with higher Li dosage for both enhanced schemes planned

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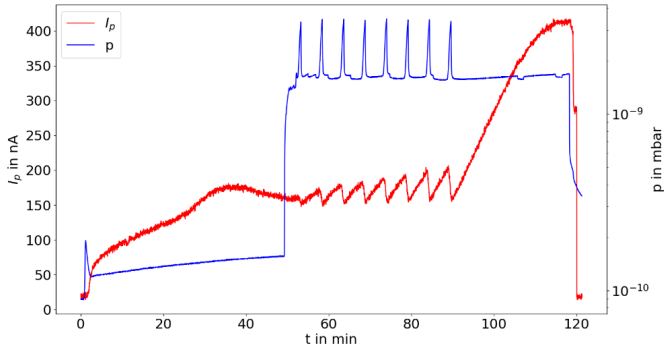
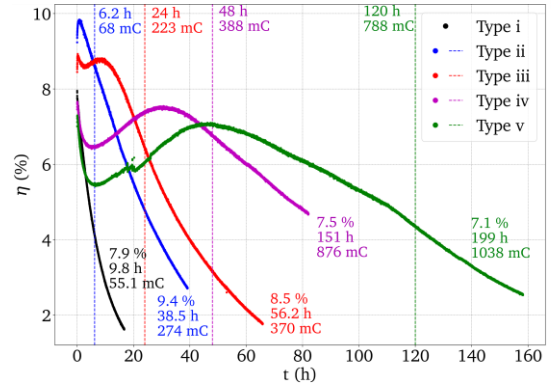
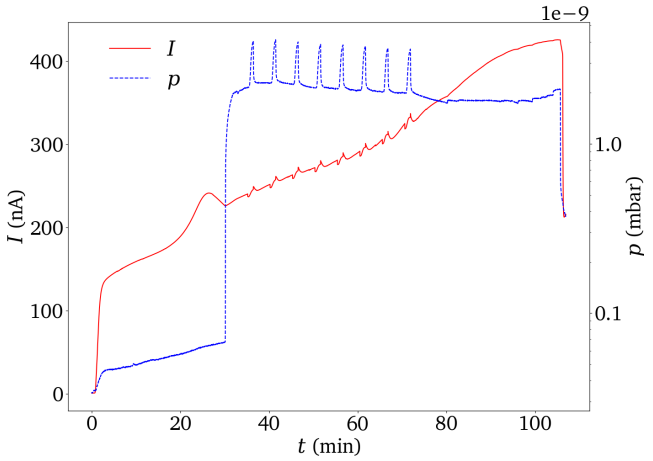
Conclusion

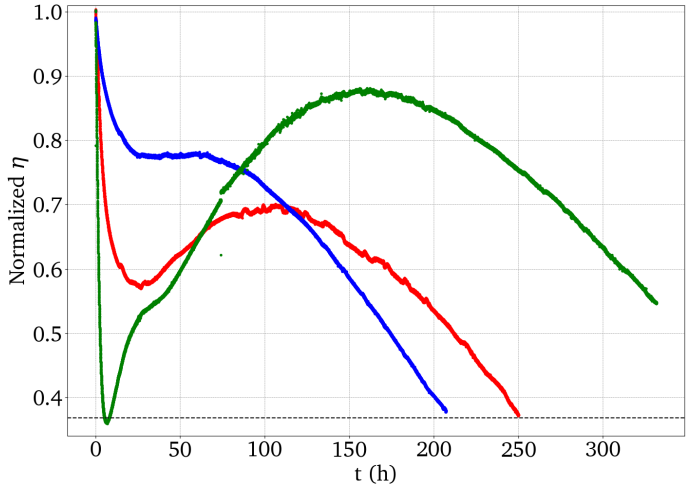
- ✓ Co-De scheme with pulsed Li established
- ✓ Li-enhanced Cs+O_2 layer shows significant increase in lifetime and extracted charge





- 🕒 Additional studies of Li-enhanced activation after chamber maintenance
- 🕒 Test of Li co-deposition instead of pulsing
- 🕒 Analysis of decay behavior





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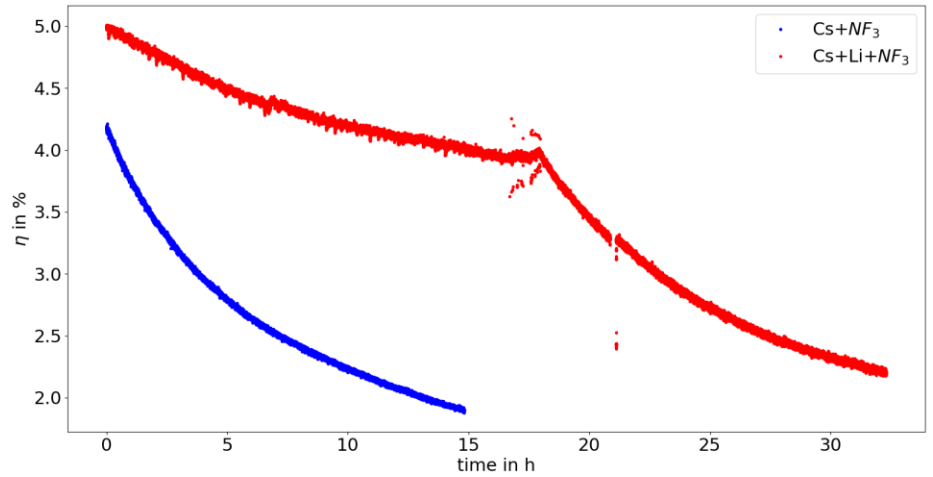
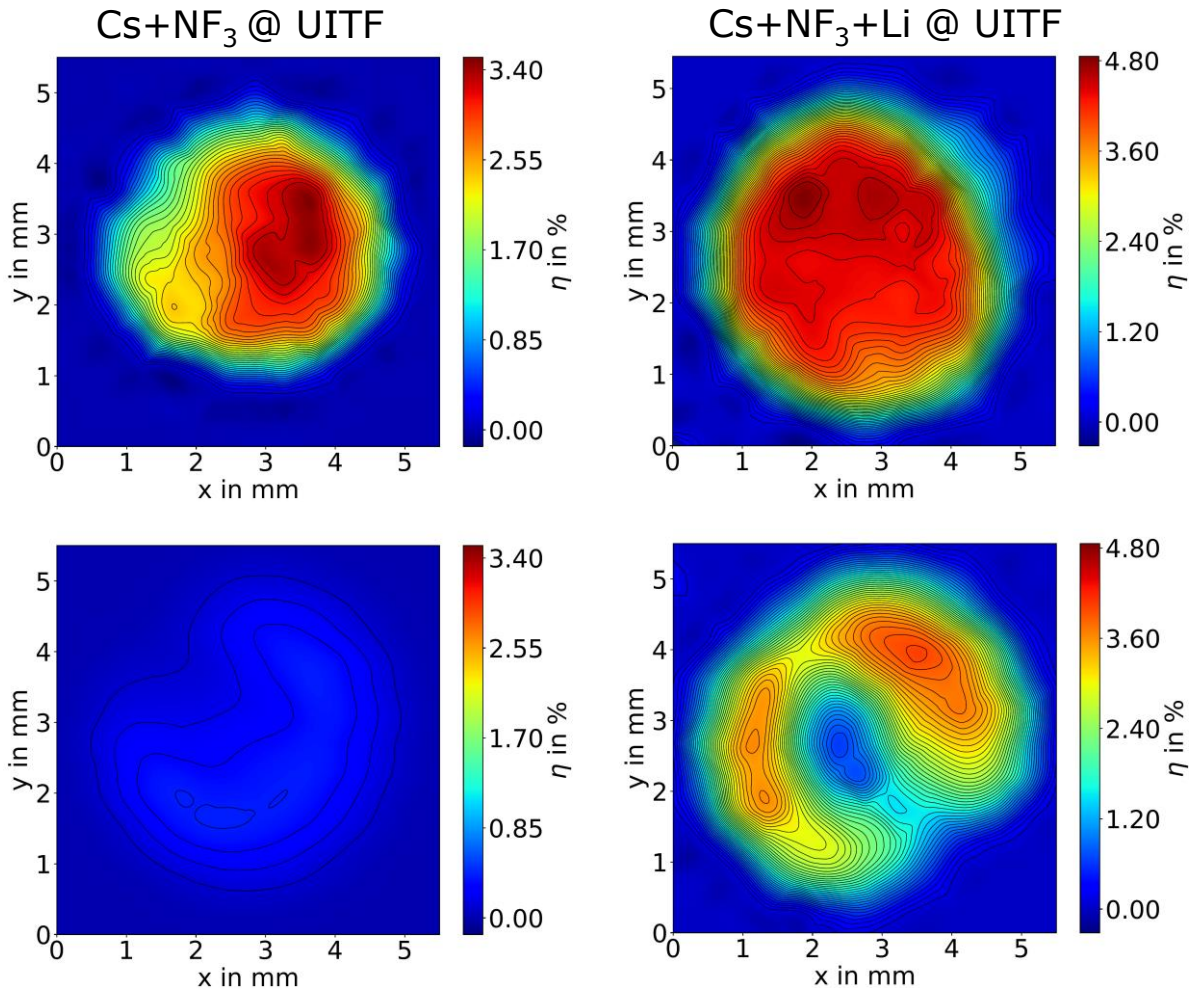
Outlook

- Additional studies with Li-enhanced activation @ Photo-CATCH (QE scans, Photogun, ...)
- High-polarization cathodes
- Comparison with $Cs+NF_3+Li$ → JLab?
- Other enhancement agents (Sb, Te, ...)



M. Herbert *et al.,* PSTP'19 (2020), https://doi.org/10.22323/1.379.0042



M. Herbert, Doctoral dissertation (2022), https://doi.org/10.26083/tuprints-00020707

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THANK YOU!

AG Enders: Joachim Enders, Markus Engart, Maximilian Meier, Vincent Wende, Victor Winter
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S-DALINAC: Ruben Grewe, Felix Heyer
Alumni: Manuel Steinhorst

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ACCELENCE