Preparation of MOCVD-grown Photocathodes containing a Strained GaAs/GaAsP Superlattice

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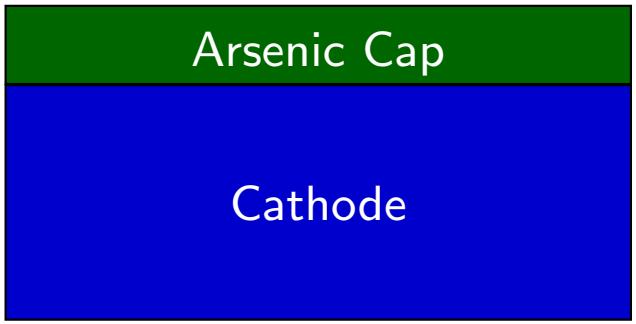
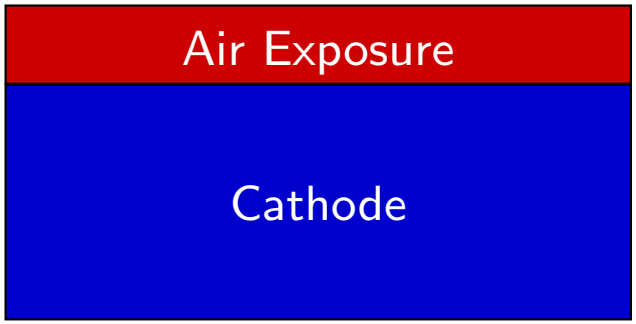
Motivation

MBE



MOCVD



- MOCVD w/o quality cleaning 10x worse than MBE at 780 nm - this can be better!

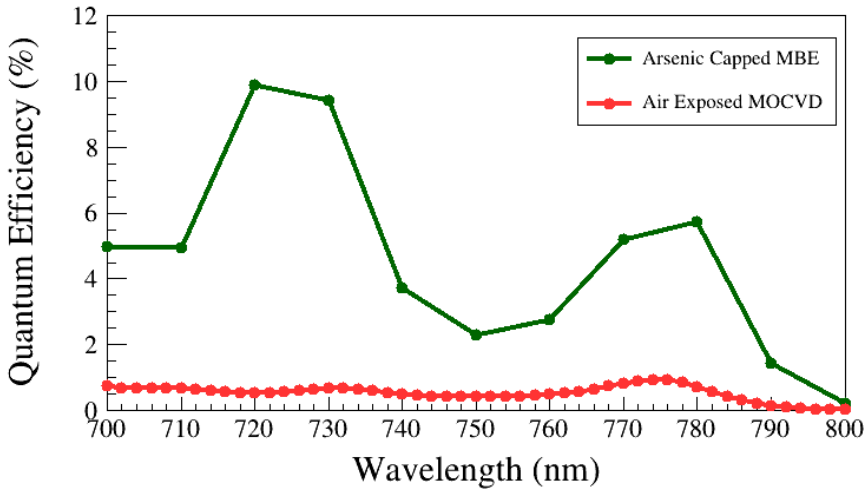


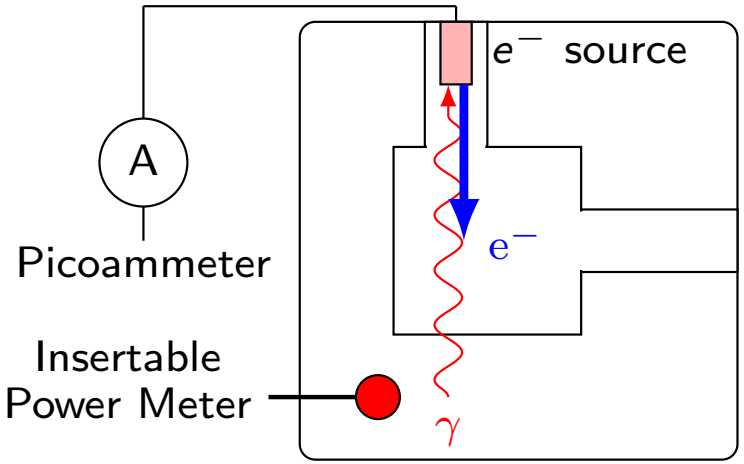
Figure: W. Liu, et al. *Record-level quantum efficiency from a high polarization strained GaAs/GaAsP superlattice photocathode with distributed Bragg reflector*, Applied Physics Letters 109, 252104 (2016)

Outline

- Theory and Measurements
  - Photocathode metrics
  - Mott Polarimetry/JLAB microMott
  - Impact of of Surface Contamination
  - Devices
- Results
- Outlook

Photocathode metrics

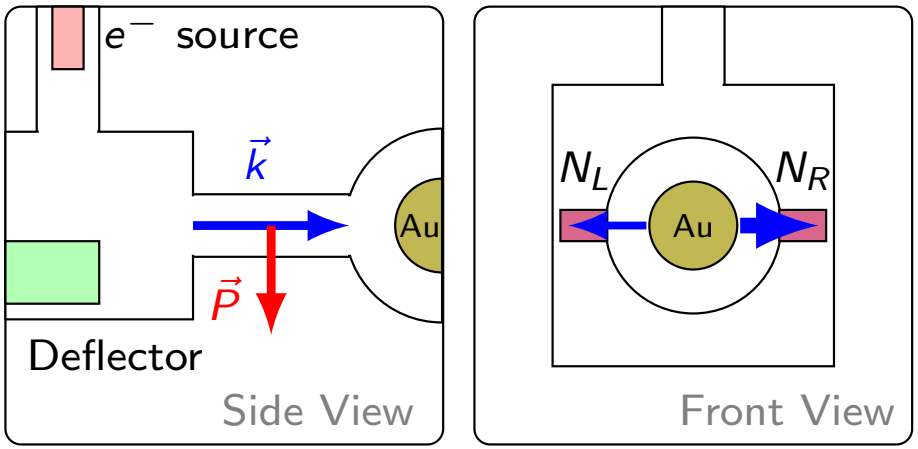
Quantum Efficiency



- # of electrons out vs. # of photons in

$$QE = \frac{hc}{\lambda q}\frac{I}{P}$$

Polarization



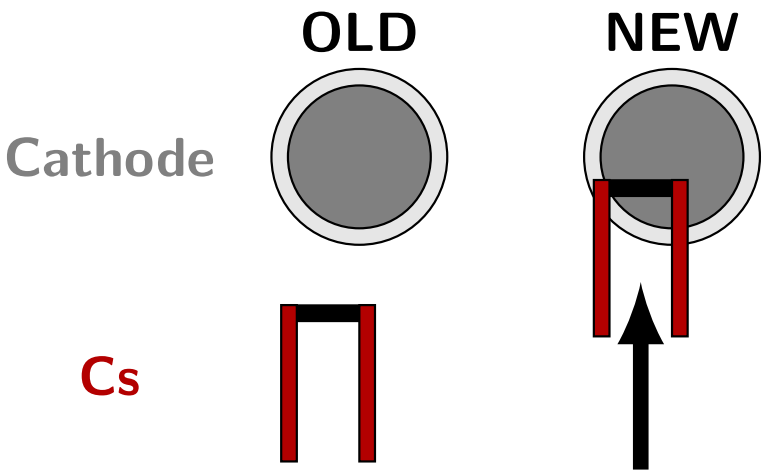
- Asymmetry in counts

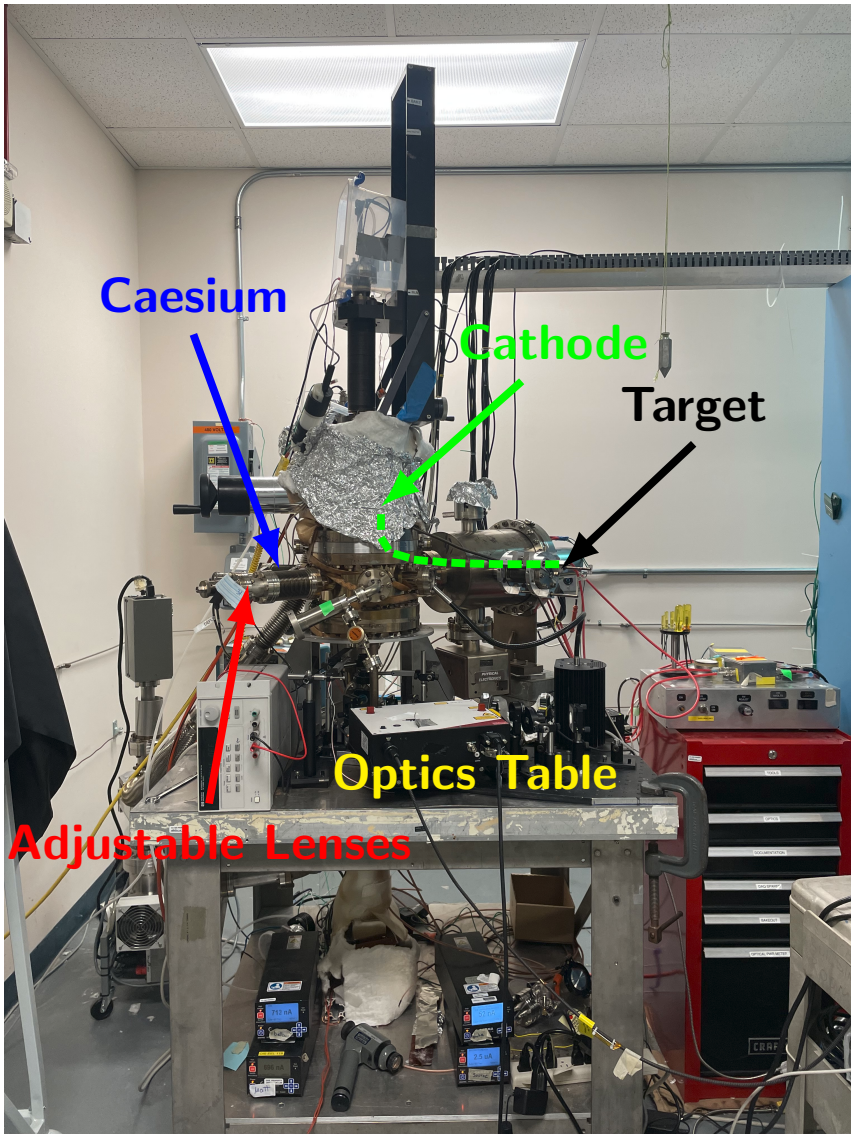
$$A = \frac{N_L - N_R}{N_L + N_R}$$

$$P = A/S(\theta)$$

microMott upgrades

- Optimized laser polarization to 99.8 %
- Adjustable transmission location increased transmission to 6.5 %
- Adjustable Cs position improved activation uniformity





Theory of Surface Contamination

- Arrhenius equation defines rate constant for a **single** chemical reaction dependents on activation energy

$$k(T) = Ae^{\frac{-E_a}{k_b T}}$$

- "Surface Contamination" as a function of time and rate constant via Polanyi-Wigner equation [1]

$$N(t, T) = e^{-k(T)t}$$

- Impact on quantum efficiency is maximum with high surface contamination

$$\eta(t, T) = \eta_f \times (1 - N(t, T))$$

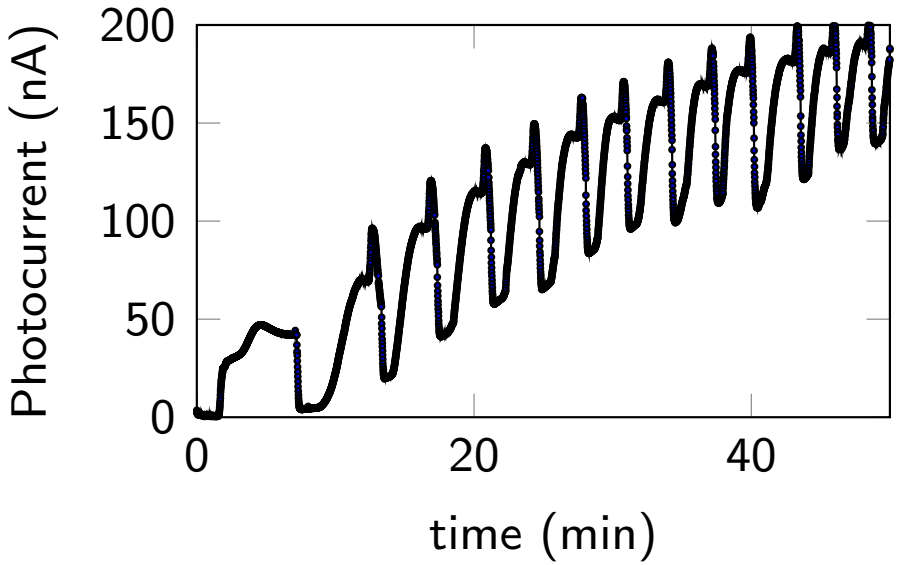
- Impact of increased heat on a polarization was modelled linearly

[1] Redhead, P.A. (1962). "Thermal desorption of gases"

Experiment

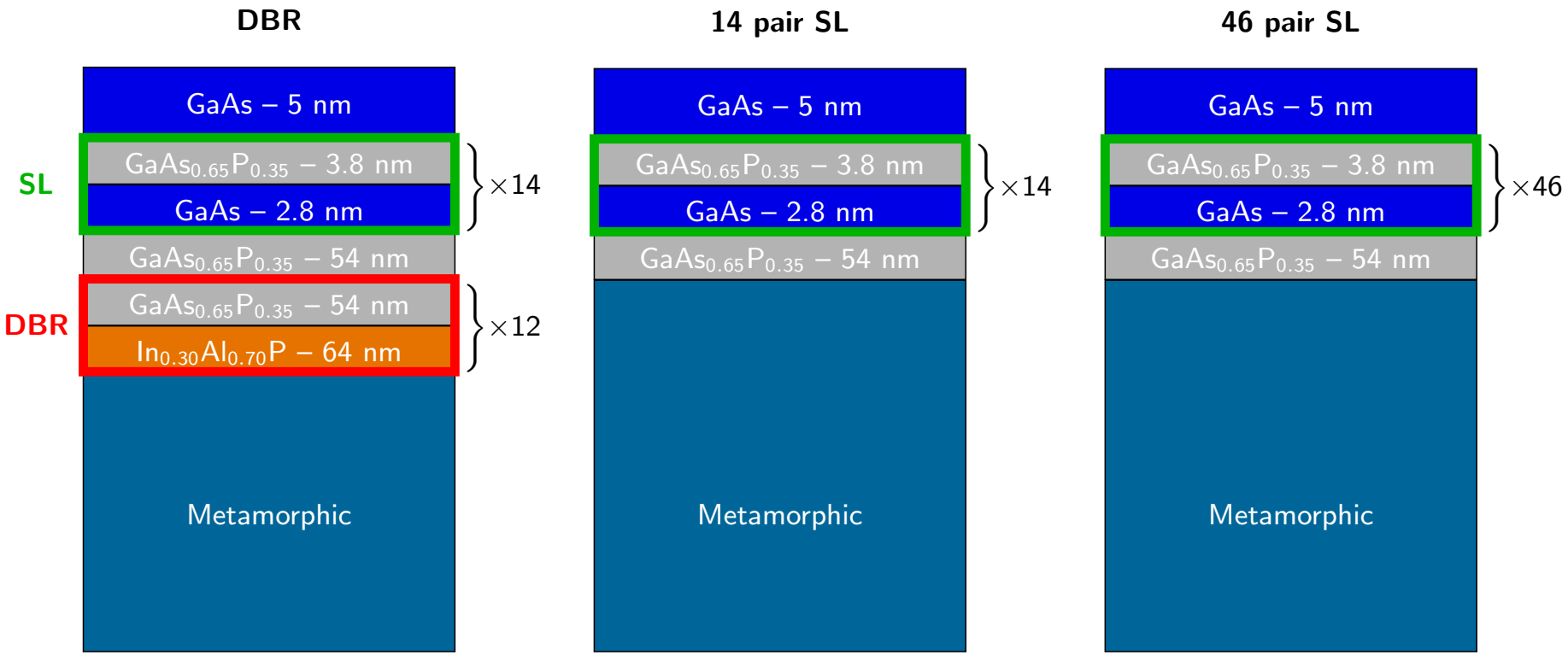
Goal: Optimize heat and time recipe for maximum QE without reducing peak polarization

- Fixed temperatures (450 and 550 °C)
- Small time steps (30 minutes)
- Uniform activation (example right) following each heat treatment
- Measure QE and polarization for each activation



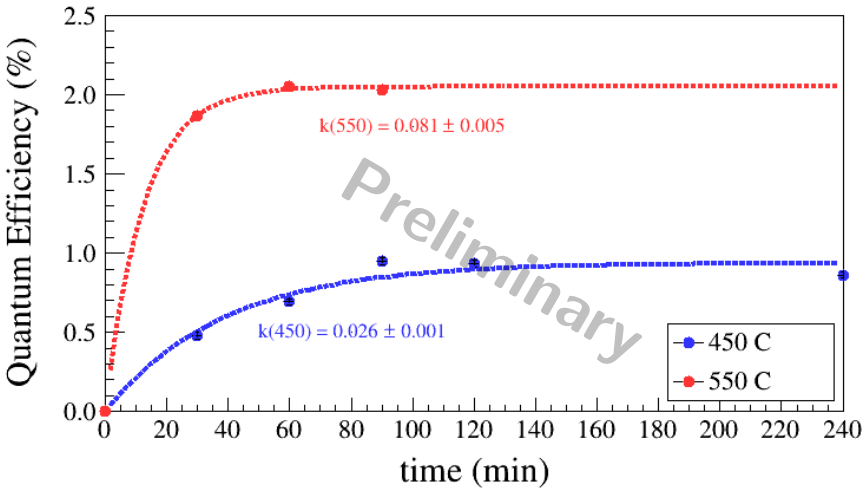
- Yo-yo activation of Cs and NF_3

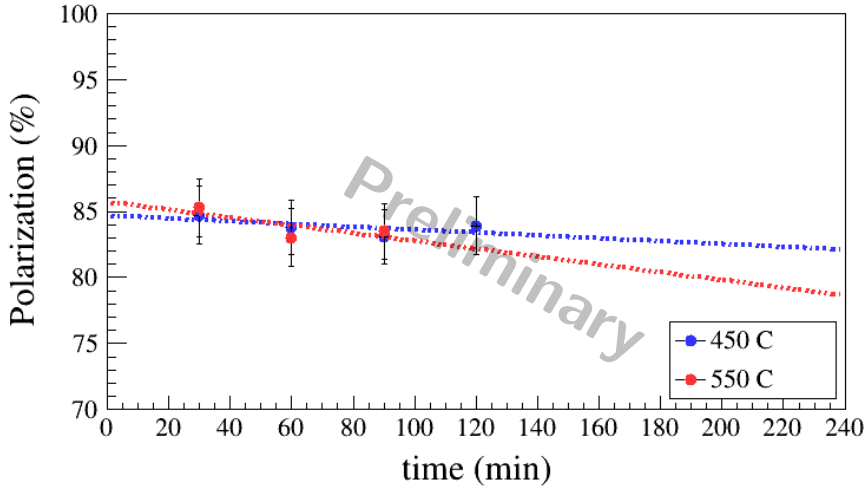
Devices



- Our recipe was developed on a DBR type sample and the later tested on all three sample types

Results





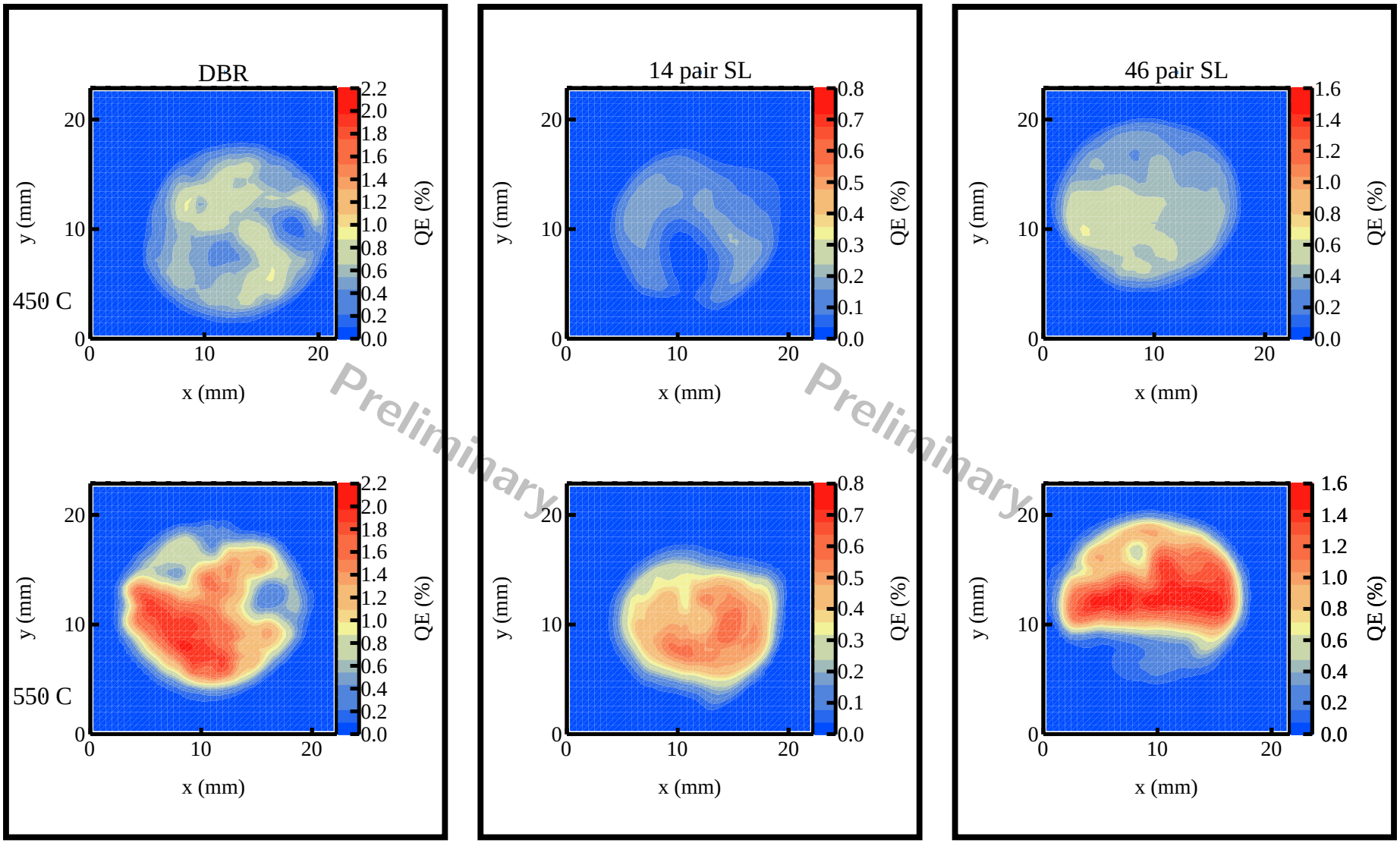
- Peak QE increased by > 200 % for increased temperature
- Rate constant is nearly 4 times larger at 550 °C

- Cannot draw conclusion on polarization decay at this time scale

$$P(t, T) = P_0 + m(T)t$$

Surface Quality Improvement

Peak surface QE increases by 2-3x at 550 °C for ALL sample types



Impact and Outlook

- A recipe was developed to optimize testing of MOCVD cathodes
- Thermal desorption (time and temperature) is the primary driver of QE maximization
- Polarization drop may be small for short time periods
- Future parametric scan will use this recipe to improve MOCVD cathode performance