

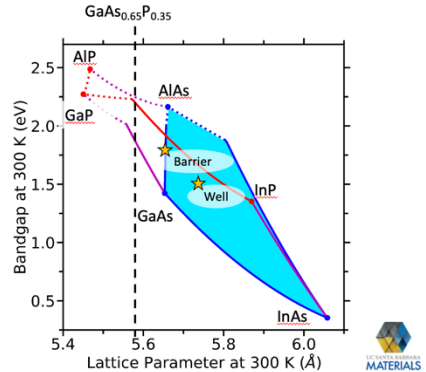
# Polarized Cathode Production Highlights from PSTP

# GaAs growth developments

## InAlGaAs/AlGaAs

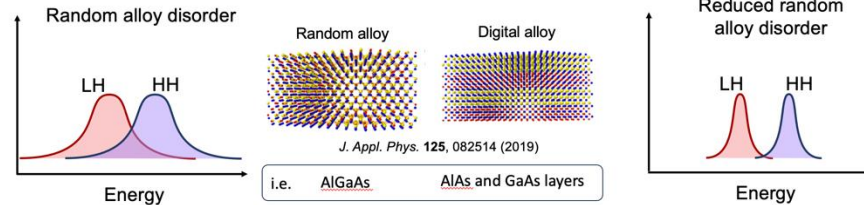
- Strain and valence band offset independent
- InAlGaAs & MBE: Common
- Growth temperatures: Similar
- Easily tunable DBRs in AlAs/AlGaAs system
- Best Polarization  $\geq$  GaAs/GaAsP
- Should be possible to get commercial vendor once optimized
- As capping straightforward

[1] L. G. Gerchikov, et al. *Semiconductors* 40, 1326–1332 (2006)



Jefferson Lab 9

## Approach to reduce alloy disorder and improve uniformity



- Digital alloying minimizes random alloy disorder
  - Broader high spin-polarization window
- InAlGaAs digital alloys should have
  - Better optical emission than random alloys
  - Better uniformity than random alloys

J. Dong, A. Engel, C. Palmström et al., *Phys. Rev. Materials* 8, 064601 (June 2024)



D. Song, ..., Y.T. Lee *J. Cryst. Growth* 270, 295 (2004)

I. J. Fritz, J. F. Klem, M. J. Haefich, A. J. Howard *Appl. Phys. Lett.* 66, 2825 (1995)

C.S. Wang, ..., A.C. Gossard, L.A. Coldren *J. Cryst. Growth* 277, 13 (2005) 15

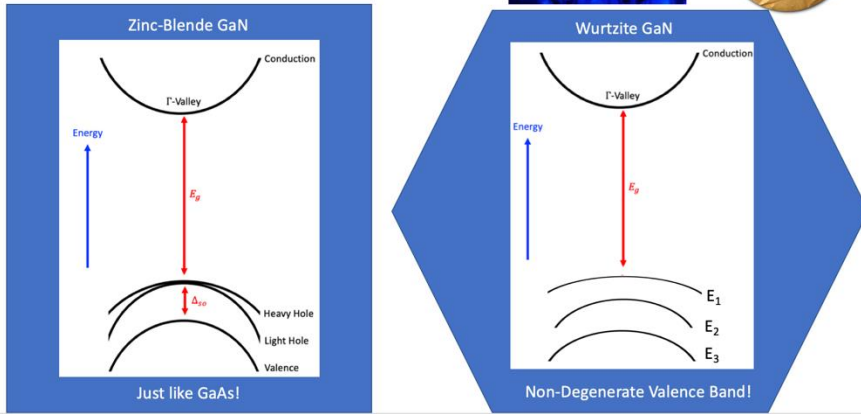
Marcy Stutzman PSTP 2024

M. Stutzman (UCSB) reported on growth of InAlGaAs/AlGaAs (as opposed to p-doped AlGaAs) – possibly a new source of high-polarized beam with ‘tunable’ bandgap, and possibly easy to make commercially

# GaAs growth developments

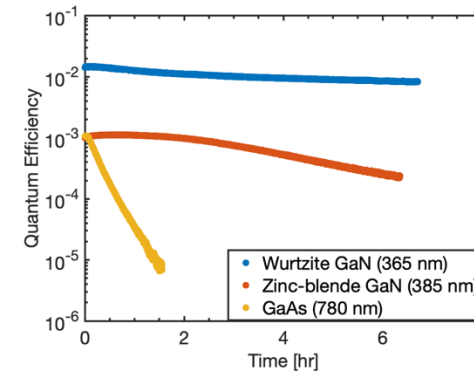
## Gallium Nitride (GaN)

Can be grown in hexagonal Wurtzite or cubic zinc-blende orientations



## Activation to NEA

Lifetime monitored at respective threshold photon energies



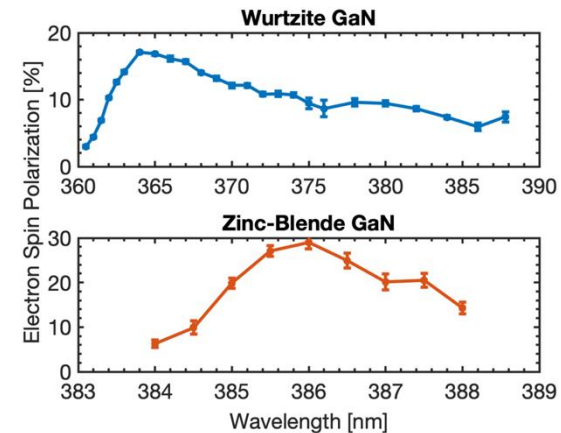
Higher QE/Lifetime in W-GaN likely due to better crystal quality

GaAs activated in same chamber, monitored at 780 nm for reference (factors of 20 & 12 lifetime difference)

S. Levinson (Cornell): Reported results of GaN cathode. Possibility to have very high polarization, but very narrow laser response curve.

## Results

Peaks: W: 17%, ZB: 29%



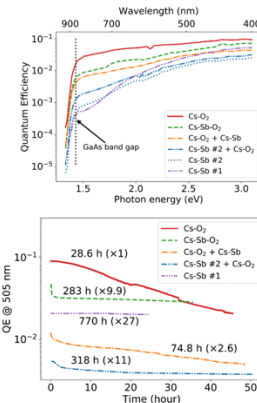
Do these measurements make sense?

# NEA Cathode Developments

**Sb-based recipes**

- Various activation recipes were compared to Cs-O<sub>2</sub>
  - Overall, Cs-O<sub>2</sub> produced the highest QE while Cs-Sb had the worse
  - Including O<sub>2</sub> in the activation improved QE of Sb containing recipes
- The QE was monitored over time to determine robustness
  - All Sb activations outperformed pure Cs-O<sub>2</sub> and pure Cs-Sb had the longest lifetime.
- Co-deposition of Cs-Sb-O finds a happy middle ground**
  - 10x Improved lifetime over Cs-O activation.
  - 10x improved QE over Cs-Sb activation at bandgap

September 25 2024 PSTP24

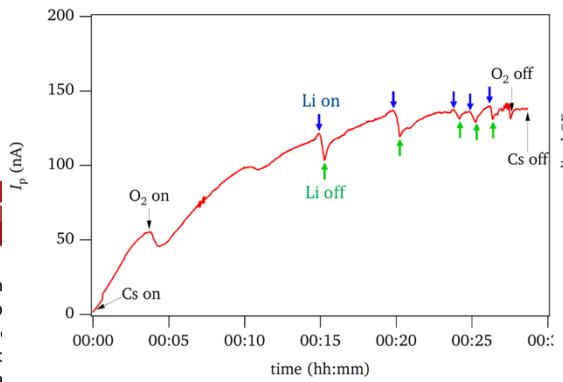


**Initial high current**

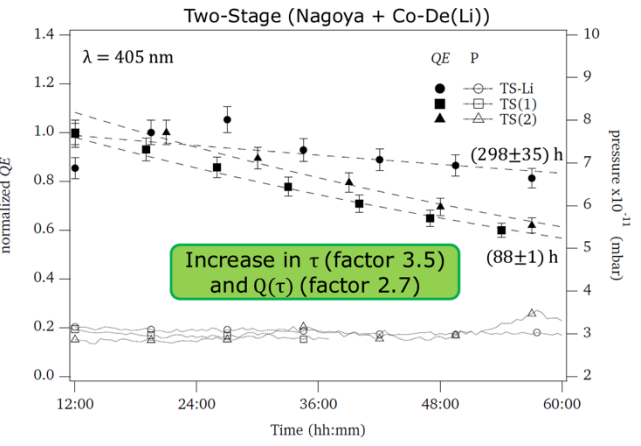
On going can determine optimal thickness for lifetime improvement

- Average current operation
- 10-15 extracted per run
- More runs to come!

	0	0	0	1	1	2
Sb Thickness (Angstrom)						
Lifetime (C)	14.3	9.88	29.7	26.7	26.1	6.4



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



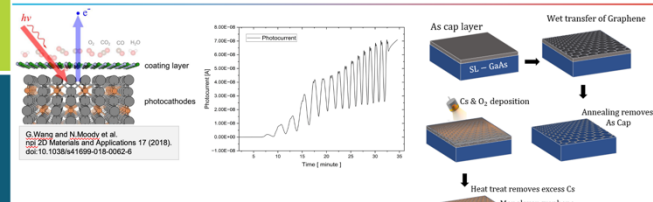
N. Kurichyanil *et al.*, Journal of Instrumentation 14 P08025 (2019), <https://doi.org/10.1088/1748-0221/14/08/p08025>

Darmstadt:  
Finds increased lifetime with Li-enhanced activation, trying to replicate results now

M. Andorf (Cornell):  
Determining optimal Sb-based recipe (similar to Hiroshima/Nagoya)  
High-current tests at their local gun

# EIC Cathode Developments

### GaAs with 2D protection layer



Successful growth of SL-GaAs with CsO activation layer underneath the graphene.

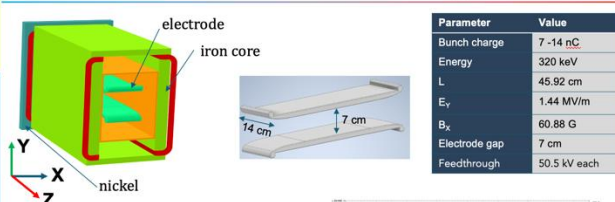
Similar activation of bulk GaAs was performed. We obtained better results on SL-GaAs with a cap layer.

Graphene protection layer makes the GaAs cathode less susceptible to heating.

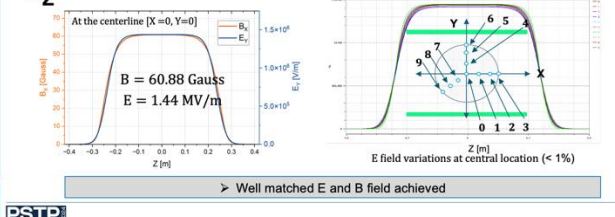
Can sustain coarse vacuum environment with the protection layer. Meaning vacuum transfer of activated GaAs is a possibility.

**PSTP**  
Electron-Ion Collider  
Jyoti Biswas

### EIC Wien Filter Design



Parameter	Value
Bunch charge	7-14 nC
Energy	320 keV
L	45.92 cm
$E_z$	1.44 MV/m
$B_x$	60.88 G
Electrode gap	7 cm
Feedthrough	50.5 kV each



Well matched E and B field achieved

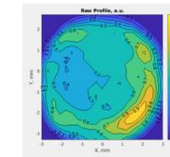
**PSTP**  
Electron-Ion Collider  
Jyoti Biswas

J. Biswas reported improved cathode lifetime with the addition of a protective graphene layer

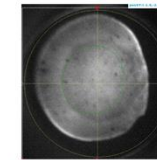
## 2nd GaAs cathode

Cathode operates with reasonably stable QE (0.08% -> 0.04% over the week)

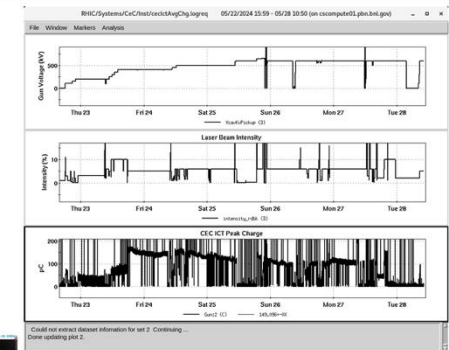
Characterize the cathode's performance for various voltages (200 - 700 kV) - emittances ~0.6 - 0.8 um for 100 pC per bunch



Not so uniform QE map



Real beam image shows QE dead spots ~ res. 100 um



Right part of the profile is distorted by the nonlinearities in the beam transport.

Y. Jing: reported using GaAs in RF gun. Low bunch charge (0.9 pC) but reasonably stable operation

# Recent Activation Test at HU

# Cs-Te Deposition Test

Working with new student (M. Isobe) –  
Trying to replicate results from

