Polarized Source Development Activities at Hiroshima

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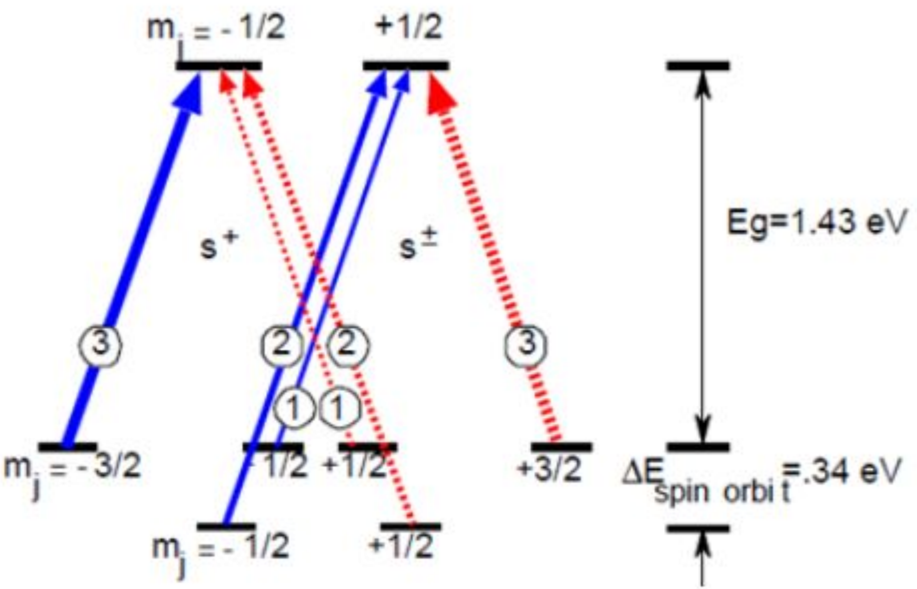
*: *with significant material from M. Kuriki*

Cathode Development

- HU Accelerator group (M. Kuriki + grad students, now myself) working on developing backup polarized source for ILC.
- Current focus is on GaAs cathode with a thin Negative Electron Affinity (NEA) surface.

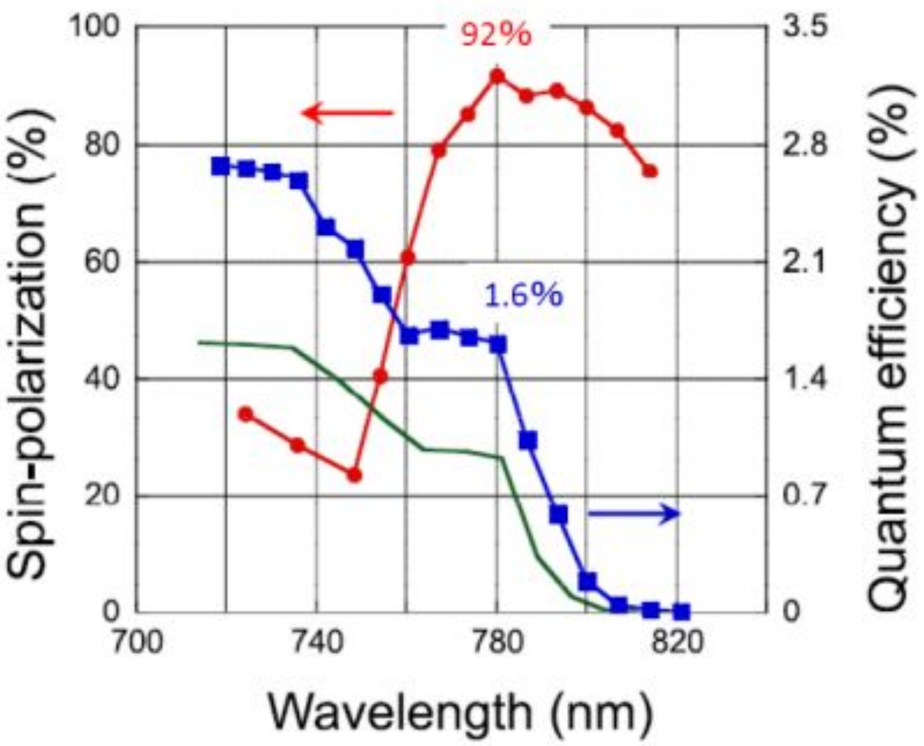
Generating a polarized beam



Right-handed **Left-handed**

- Electrons are excited with a laser
- Using a circularly polarized laser produces polarized excited electrons

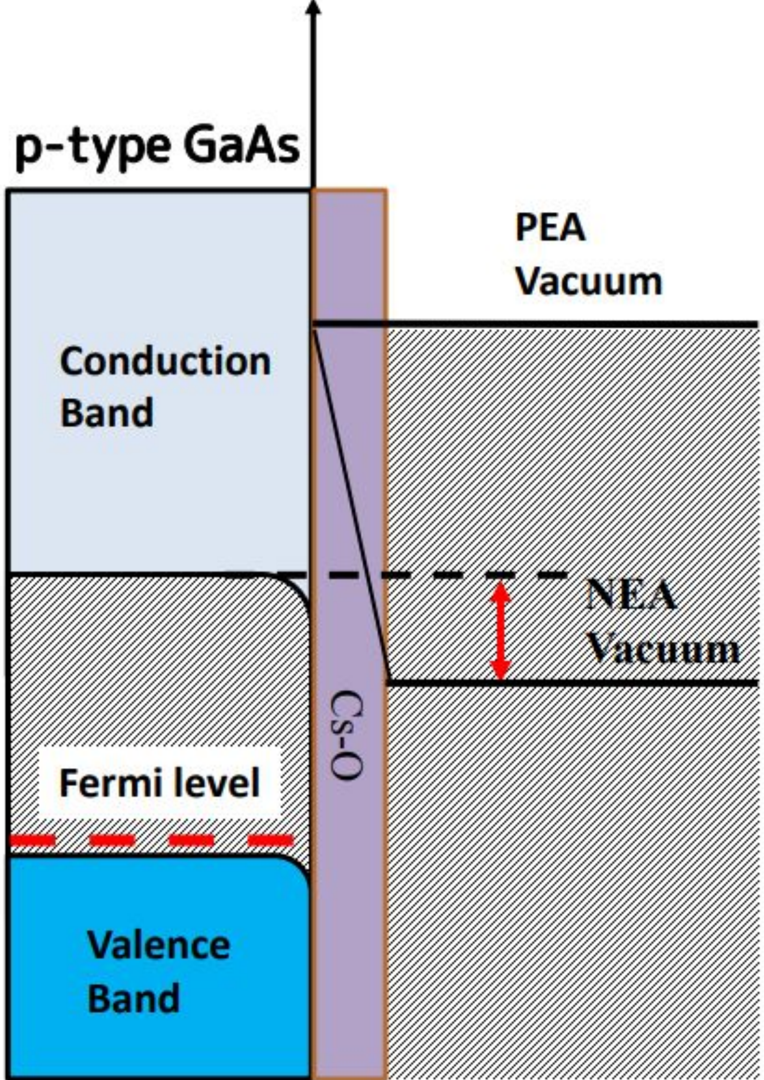
Polarization and Q_eff



- Polarization up to 92% has been achieved with a QE of 1.6% from GaAs.

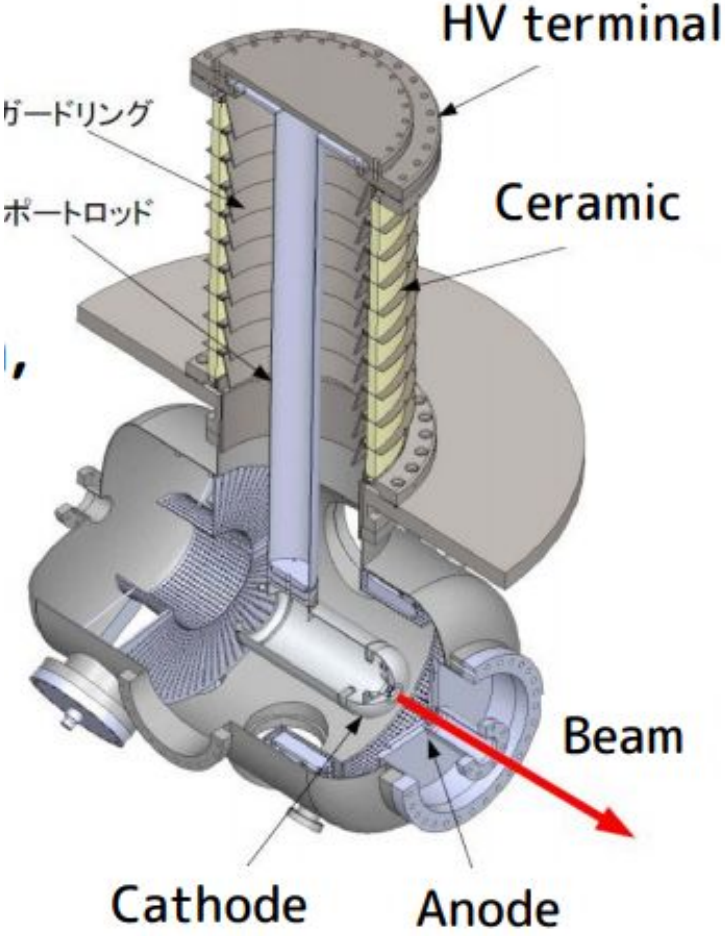
Negative Electron Affinity

- Electrons excited to conduction band in GaAs bulk have very little momentum.
- NEA surface with a lower CB bottom can be applied to the cathode surface to make it easier to extract and accelerate electrons.



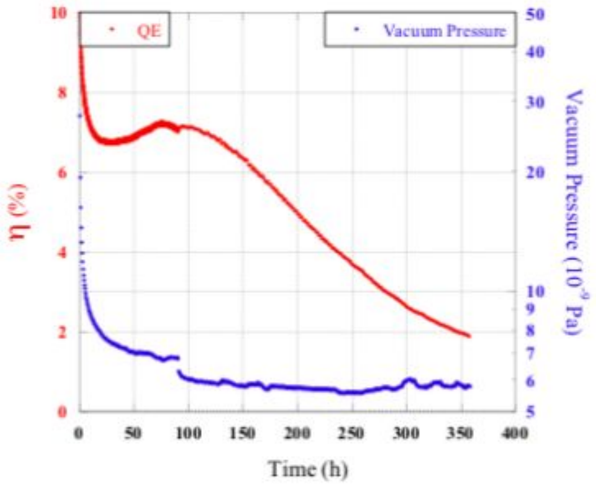
Electron Extraction

- RF Gun has a high gradient (up to 100 MV/m) but vacuum is insuffficent and GaAs + NEA lifetime is too short
- Use DC bias instead
  - Limited field: ~ 10 MV/m max
- Beam density is limited → need buncher to achieve high bunch density



Improving lifetimes of NEA surfaces

- Current NEA surfaces made of Cs-O
  - Require UHV (< 10^{-9} Pa)
  - Limited bunch intensity, long bunches and large emittance
- Working on developing more robust NEA surface: Cs-K-Te



1/e lifetime
3.0 – 4.0 x 10^{-4} Pa.sec

C. Shonaka, Master thesis, Hiroshima U. (2009)

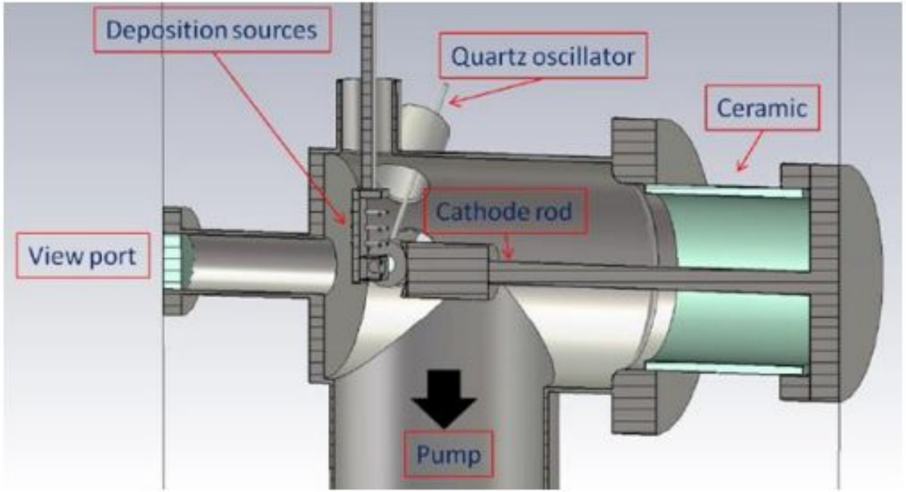
Improving lifetimes of NEA surfaces

Improving robustness of cathode would:

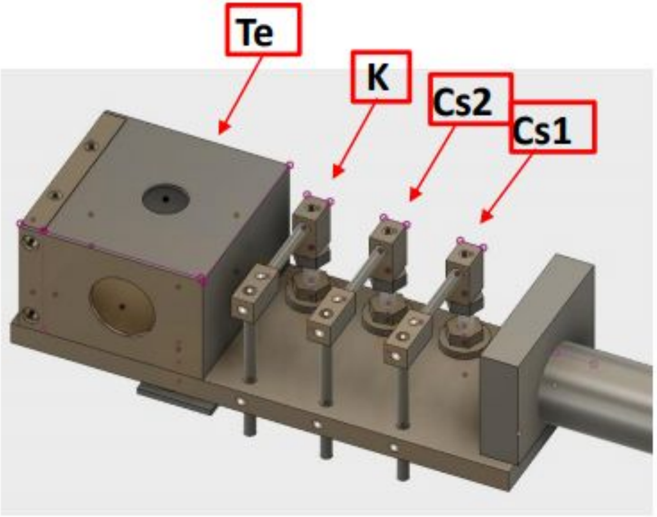
- Ease the vacuum requirements
- Possibly allow for use of RF electron gun
- Improve intensity, bunch length, emittance

HU working on a better NEA surface to produce the above improvements: Cs-K-Te shows promise as a candidate cathode.

NEA Production Apparatus



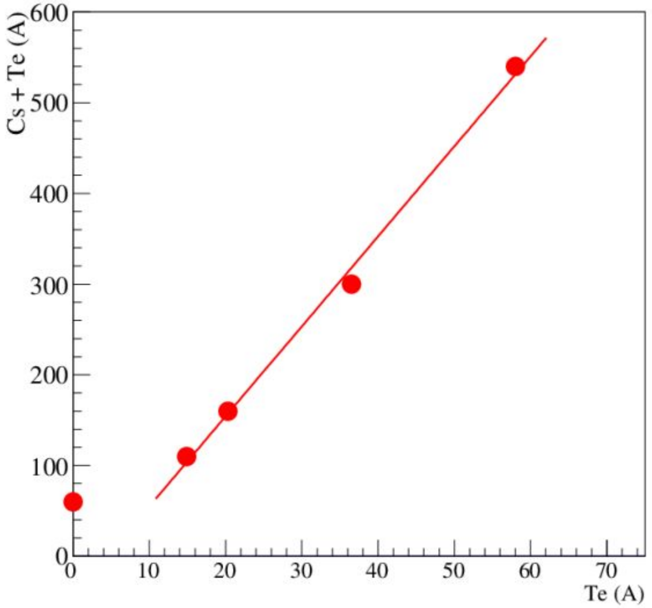
Chamber

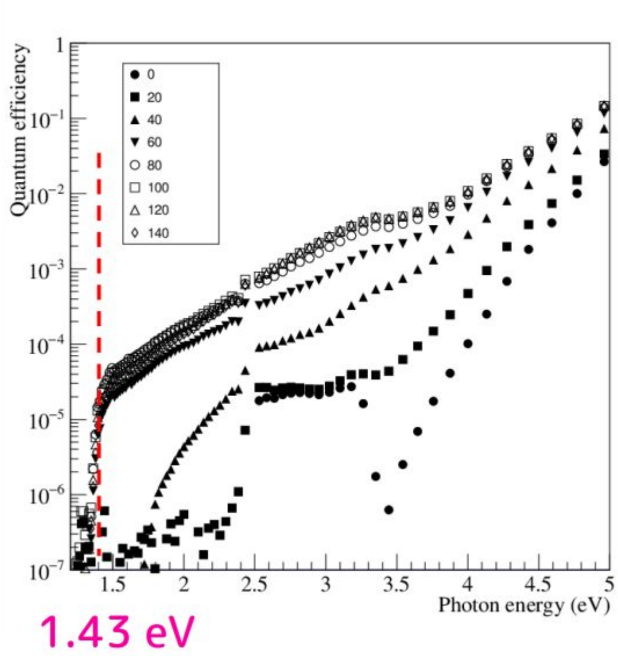


Evaporation head

- Chemically polished SUS chamber with NEA and ion pumps
  - Vacuum pressure ~1.5 x 10^{-8} Pa
- Quartz thickness monitor
- QE measurement taken with Xe lamp

Optimal NEA Thickness Evaluation

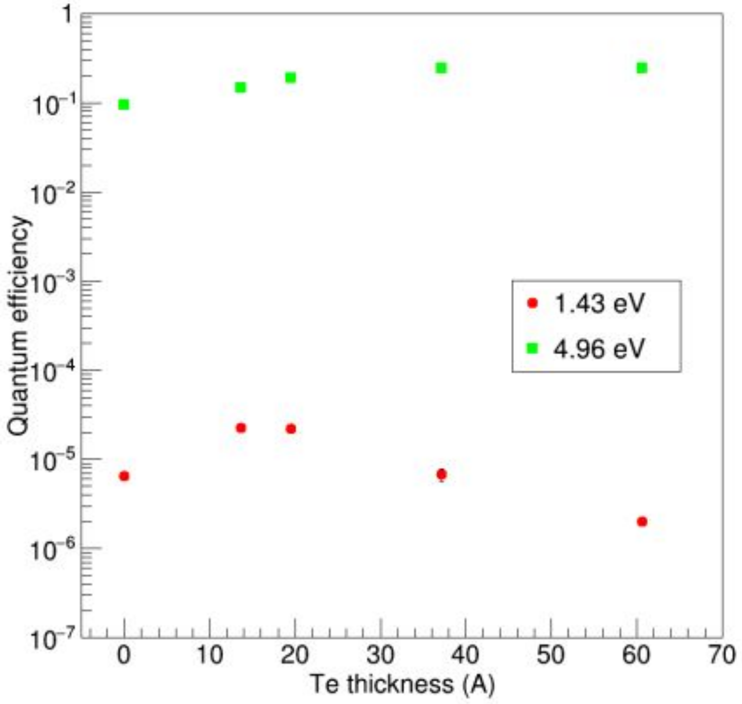




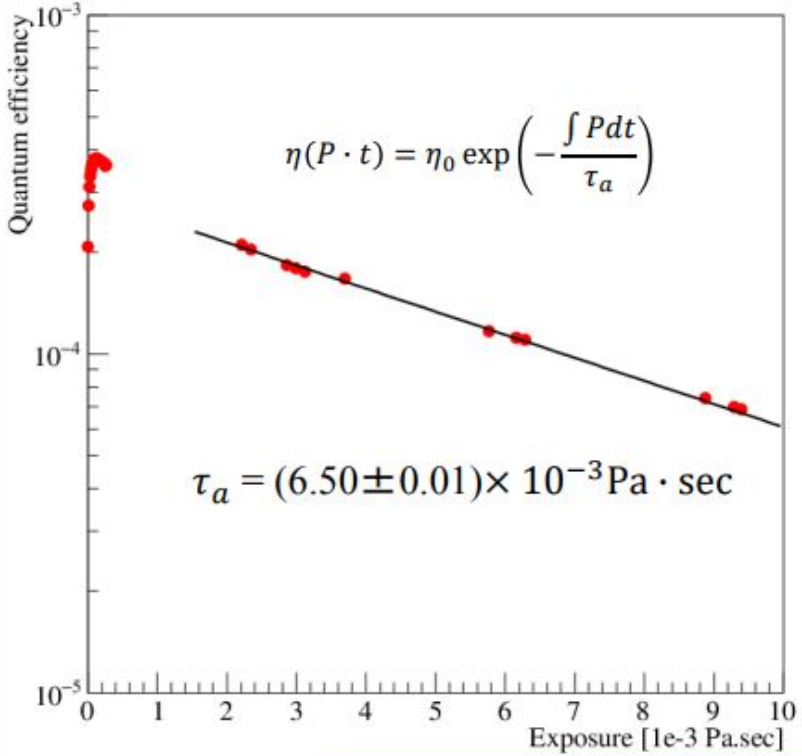
- Evaporate Te onto GaAs substrate to desired thickness
- Evaporate K and Cs repeatedly
- Measure QE spectrum after each K/Cs evaporation
- Optimum thickness is defined at that which has the maximum QE at 4.9 eV.

Optimal NEA Thickness Evaluation

- QE at 4.96 eV is saturated with Te thickness
- QE at 1.43 eV peaks at ~15-20 Å
- Consistent with electron emission with 4.96 and 1.43 photons from Cs-K-Te and GaAs, respectively.



Cs-K-Te lifetime



Cathodes	Lifetime τ_a [10^{-3}Pa · sec]
CsKTe/GaAs	6.50±0.01
Cs-O/GaAs	0.29±0.03 [1]
Cs-O/GaAs	0.40±0.02 [2]

[1]K. Miyoshi, M. Thesis, Hiroshima U. (2013)
[2]G. Lei, M. Thesis, Hiroshima U. (2014)

E-Gun	Pressure[Pa]	Life[h]
DC-gun	5.0×10^{-10}	1535.6
RF-gun	1.0×10^{-7}	7.7

Electron Damping Ring Considerations

- If an e^- damping ring were installed, development of e^- source would be eased significantly
  - Possibility exists due to emittance concerns in the HER
- With the relaxation of emittance requirements, DC source becomes a possibility
  - Vacuum is much better → longer lifetime for cathode sources
  - Would require a buncher as beam density and E field are limited (50 pC/10 MeV respectively)
- Current bunch charge/emittance requirements show in the table below

	e^+	e^-
Bunch charge	4 nC x 2	4 nC x 2
$\gamma\varepsilon$ (mm mrad)	< 6	< 20

Source: http://accwww2.kek.jp/oho/oho19/OHO19_txt/05_Zhou_Xiangyu.pdf

Questions for Development

- How much setup at KEK would need to be changed/added/implemented to use a polarized source?
- Is there an existing usable DC source?
  - If so, would the activation laser, buncher, &c. work with it or would they need to be added?
- What other technical considerations/challenges need to be considered?

Conclusion

- HU working on producing polarized electron sources
  - GaAs source can provide > 90% polarized electrons with
- Utilizing NEA film to improve emitted beam
- Cs-K-Te surface on a GaAs substrate looks like a promising candidate
  - Longer lifetime then previous Cs-O film
  - May be able to use RF gun (although this may require significant work)
- Optimal Te thickness is around 15-20 Å
  - QE found to be 2.0 - 3.0 x 10^{-4} at this level
  - More Te reduces QE, while GaAs emission is saturated.