2022-3 CsKSb NEA GaAs Activation Attempt

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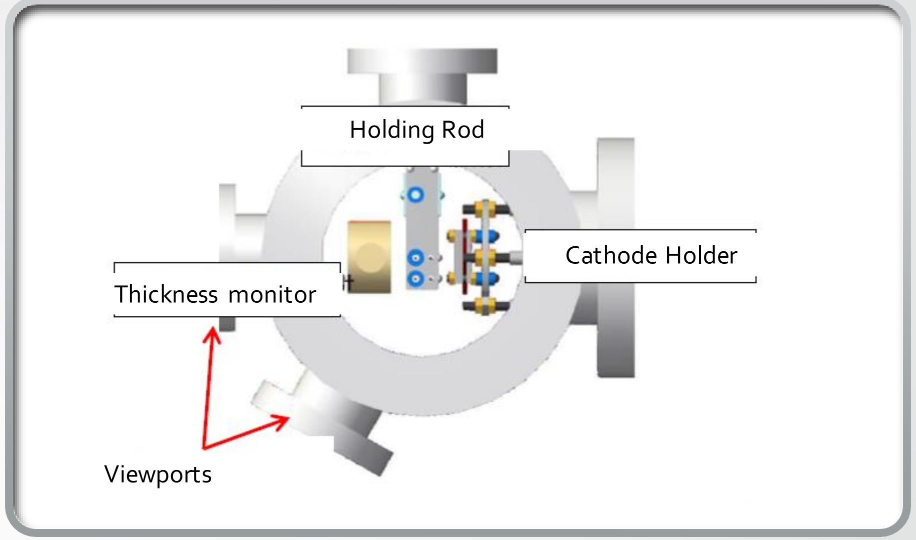
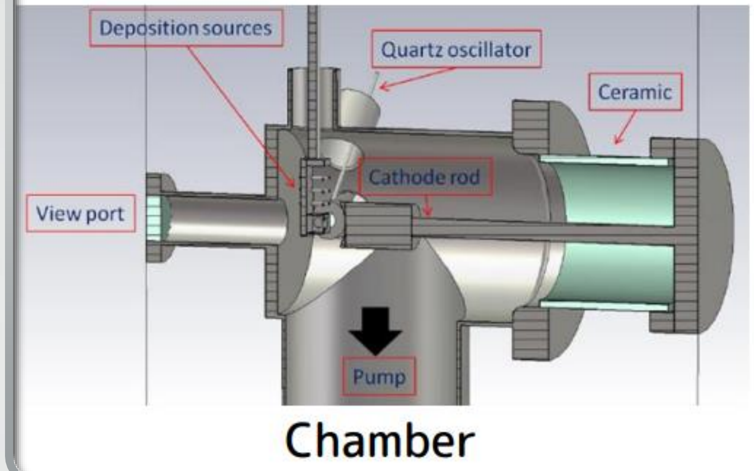
With material from H. Maeda's work/thesis

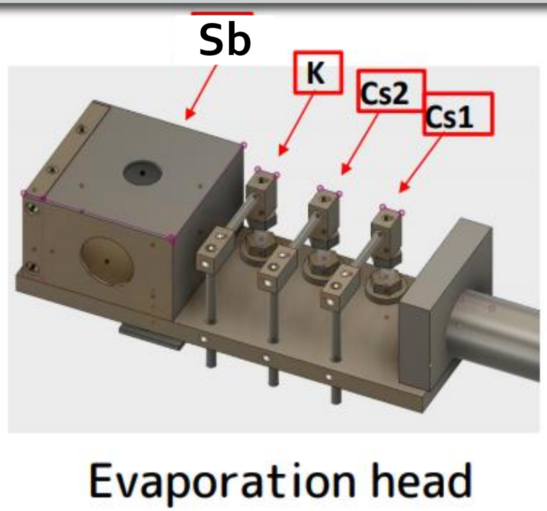
Experimental Apparatus

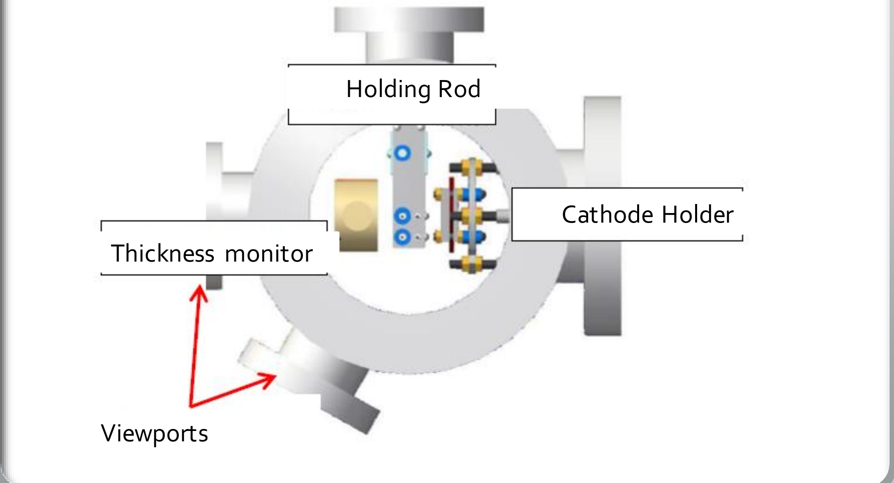


- Vacuum chamber with cathode （P-GaAs, Zn doped) mounted on a pedestal and Sb・Cs・K dispensers mounted on a rod
  - Chamber was pumped down to a vacuum of O(10^{-8} Pa), with the ion pump and NEG activated.
- Thin-film deposition is measured with a Q-Pod thickness monitor
- Tunable Xe lamp used to measure QE response from the cathode

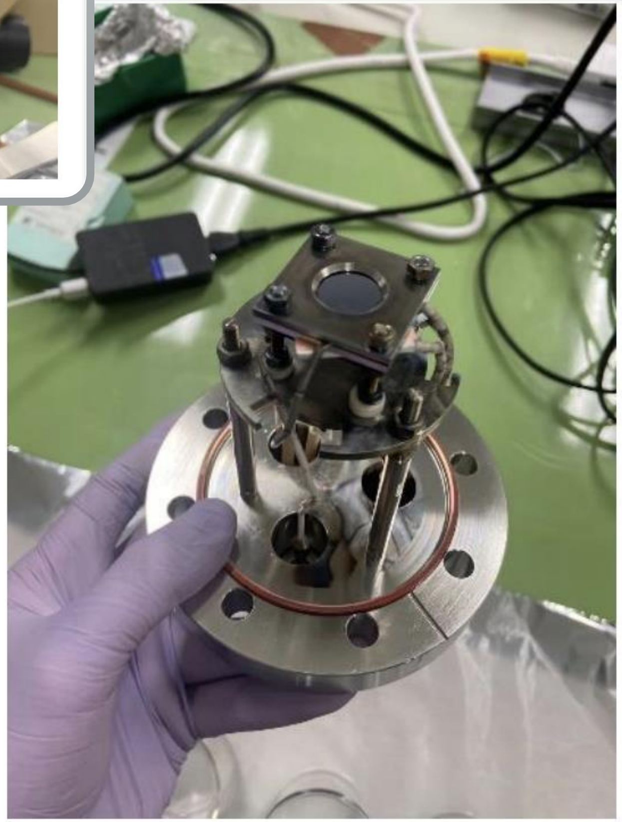
Experimental Apparatus

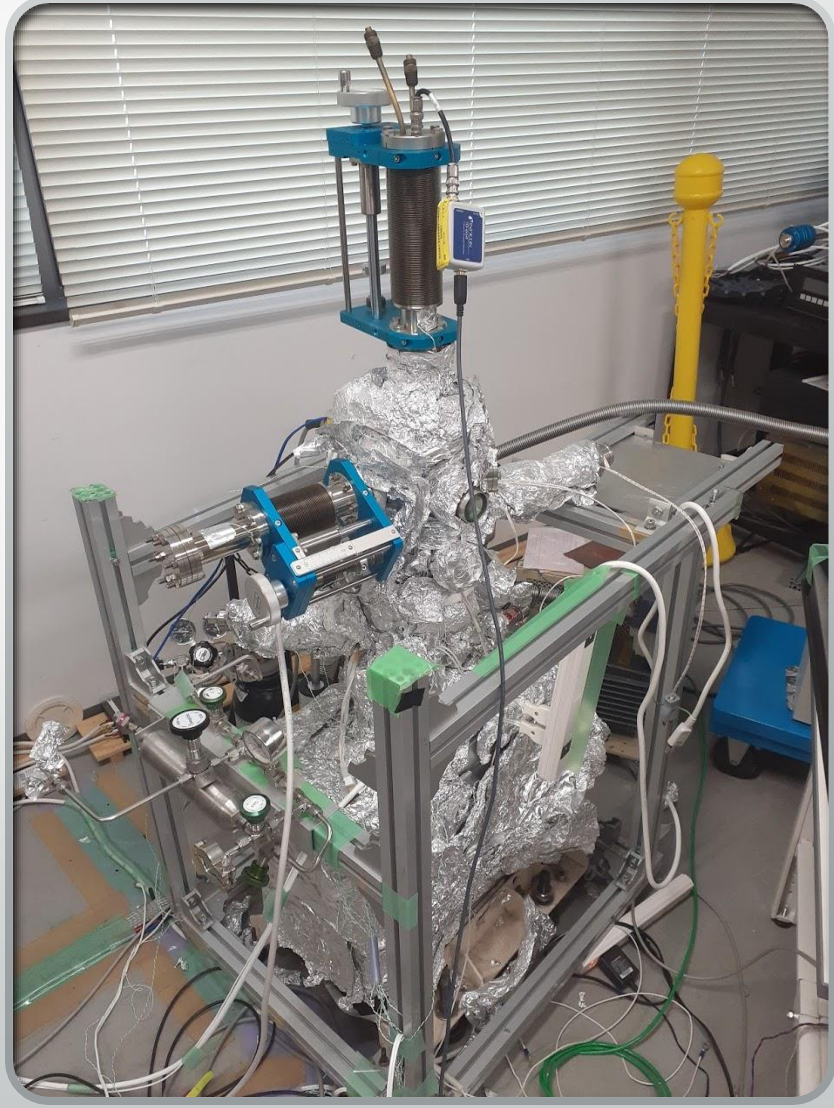


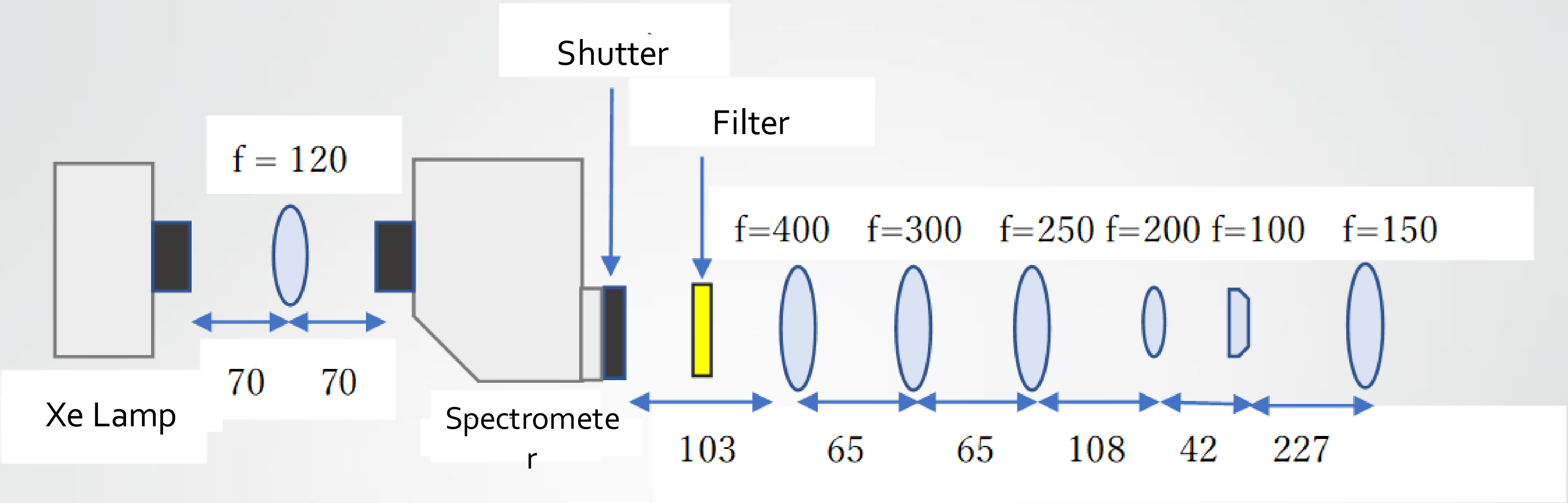


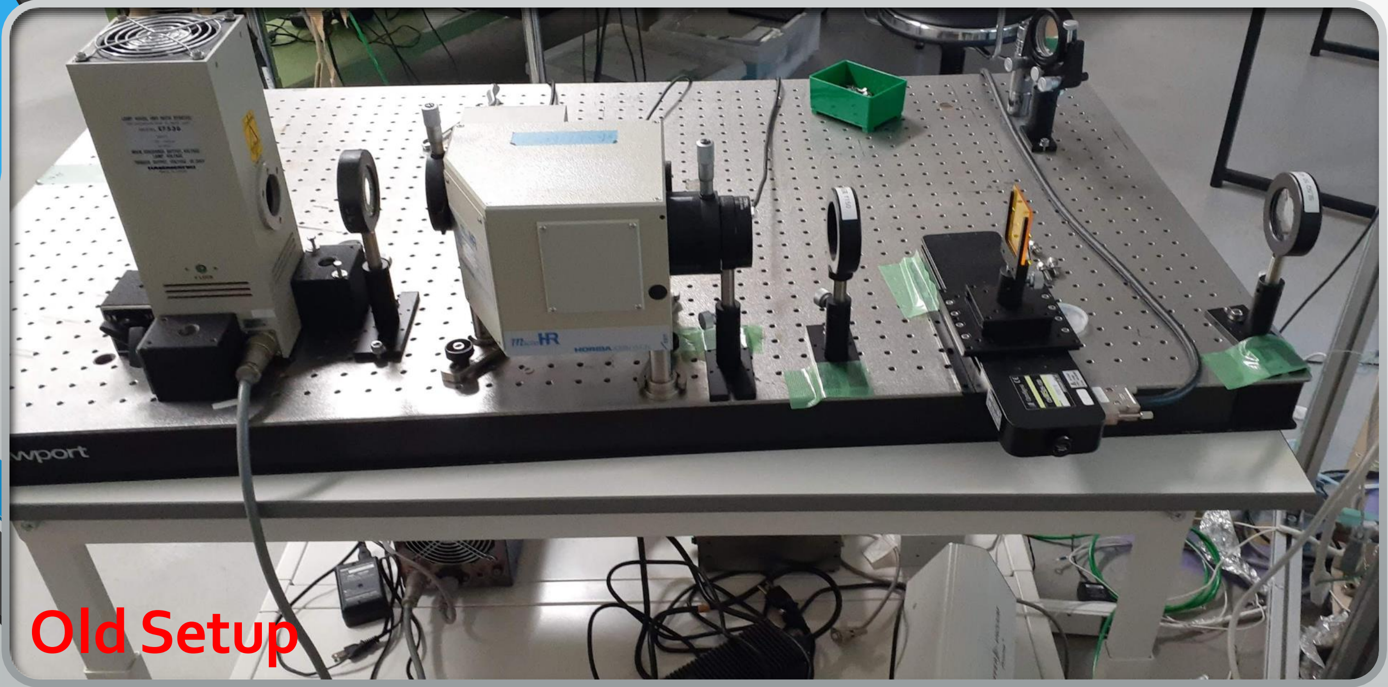


Experimental Apparatus









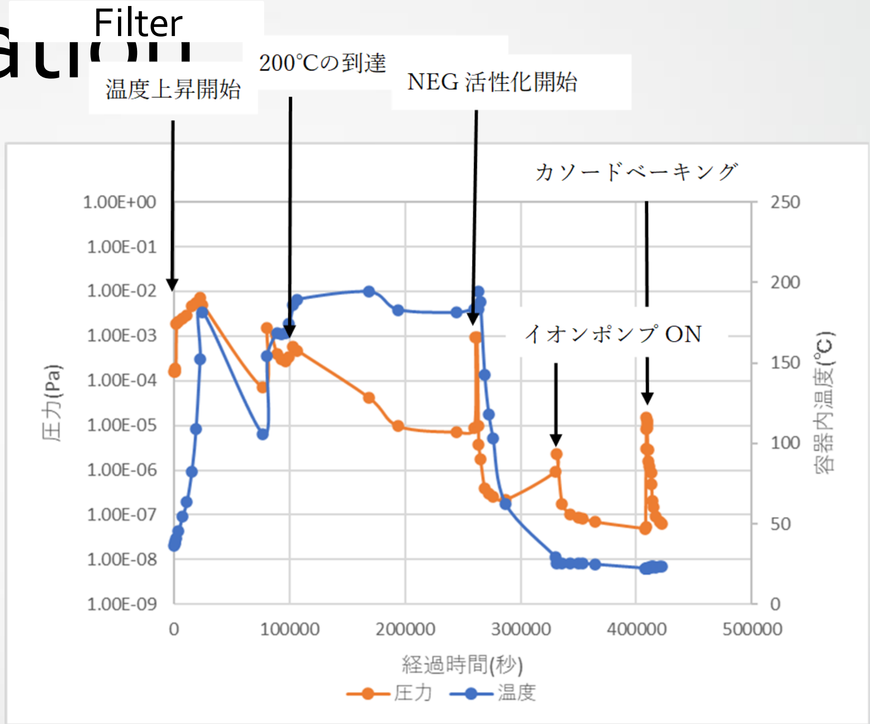
Apparatus

Spectrometer is used to select the wavelength from the Xe lamp, with the lens setup focusing it on the cathode face.

Power is measured at the viewport. (See slide 10)

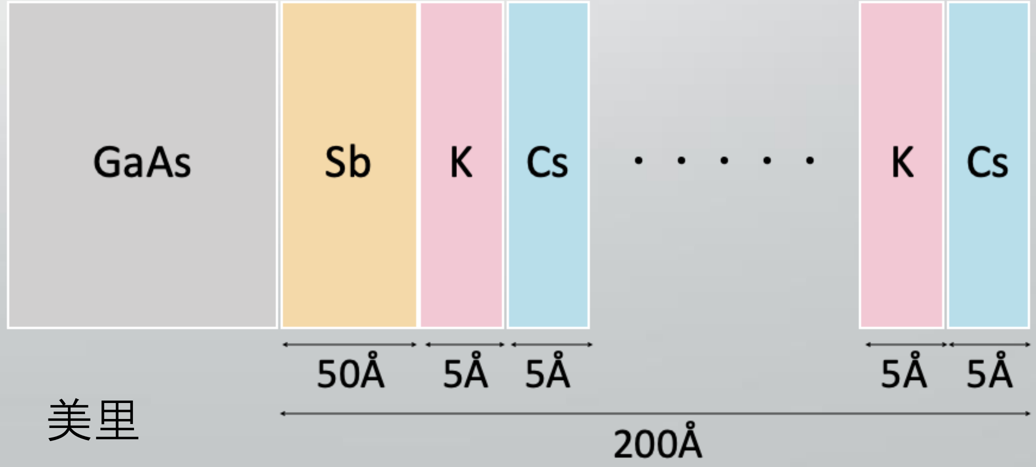
Control is performed by a LabView setup.

NEA Activation



- Bake the chamber after inserting the cathode and NEA dispensers.
  - Once pressure is low enough, turn on the ion pump and activate NEG for 1 hour.
- Deposit NEA materials on the cathode as follows：
  - Sb　５０Å
  - K、Cs in layers of ５Å to a total of ２００Å
- QE can be measured between deposition steps

- For the first step, the Sb evaporated/deposited much faster than anticipated and formed a thicker base layer than was called for.
  - We used the same voltage as previous runs



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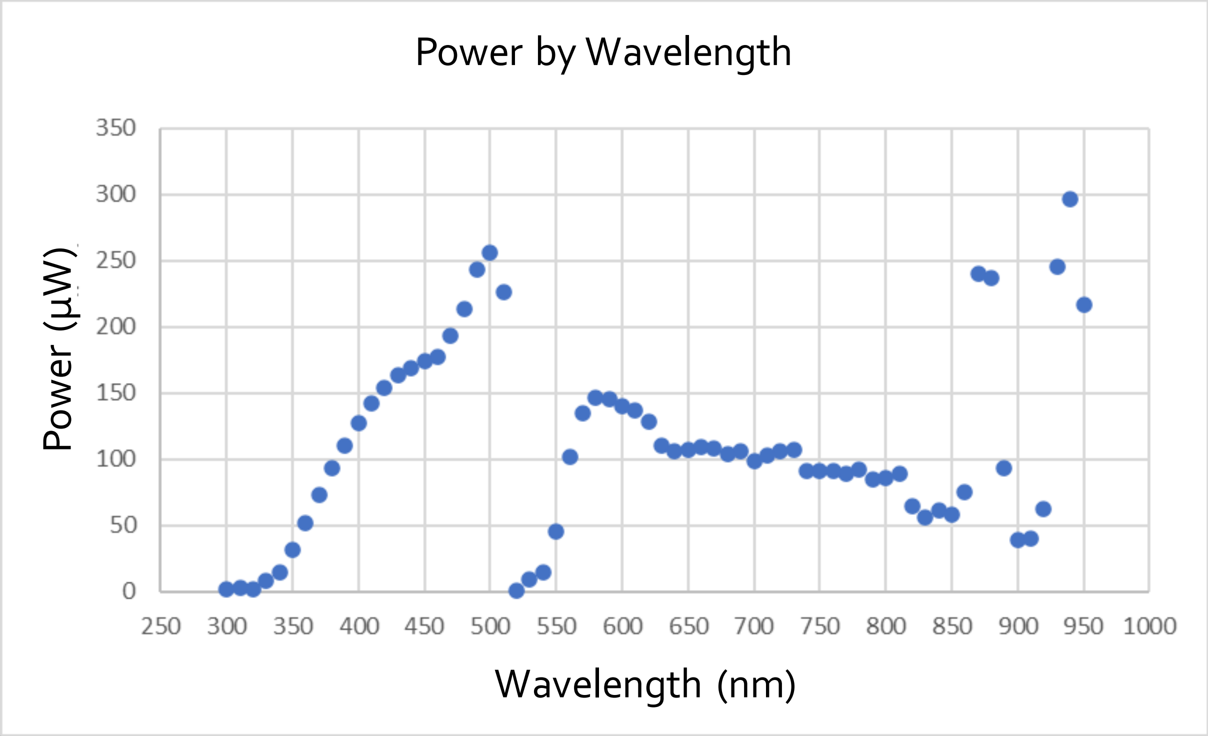
QE Measurement

$$QE[\%] = \frac{I_{PE}[A]}{\lambda[m] \times P[W]} \times \left(\frac{hc}{e}\right) \times 100$$



Using the spectrometer, we scan wavelengths from ~300 to ~950 nm with a power meter at the vacuum chamber viewport.

Results are recorded in 10 nm steps and combined with the voltage output from the cathode to calculate the QE.

Measurements I

CsKSb Total 450 Å (Sb250 Å, Cs100 Å, K100 Å)

Wavelength / Energy	QE (%)	Error (%)
350/3.54	1.53×10^{-3}	1.31×10^{-3}
890/1.39	2.05×10^{-4}	2.03×10^{-4}

QE shown above for a total of 450 Å. Signals observed were consistent with 0 and so the result was considered null.

H. Maeda

Measurements II

CsKSb Total 850 Å

Wavelength / Energy	QE (%)	Error (%)
350/3.54	1.83×10^{-2}	1.42×10^{-3}
890/1.39	-1.40×10^{-4}	1.83×10^{-4}

With further deposition, at short wavelengths (here, 350 nm) a small non-zero signal was observed, possibly indicative of activation. At longer wavelengths however, the results are again consistent with zero.

H. Maeda

Measurements III

CsKSb Total 1250 Å

Wavelength / Energy	QE (%)	Error (%)
350/3.54	3.44×10^{-2}	1.38×10^{-3}
890/1.39	2.16×10^{-4}	2.06×10^{-4}

A final run of deposition was performed, up to a total of 1250 Å. In this case, a stronger signal was recorded at short wavelengths and a small but nonzero signal at longer ones.

It remains unclear if this is the result of activation or simple semiconductor activity from Cs.

前田陽紀

Analysis

- We confirm deposition of the thin-film materials on the cathode, and a weak signal when illuminated with light. However, we don't consider it conclusive evidence of NEA activity.
  - We expect a stronger signal from actual NEA activity (i.e., electrons transported from the GaAs bulk).
  - We are preparing for a new experimental run in June/July to obtain more conclusive results.

Backup Slides

Background and Goals

- 次世代の加速器がスピン偏極ビームを利用するつもり
- 高すピン偏極率・量子効率かつ長寿命が理想的。
  - 70年代からNEAが用いられるが。。。
  - 従来のカソードは耐久性が低い
    - RF銃不可
    - 寿命が短い→頻繁に交代→タイムロス
- GaAsウェーハに新たにNEA活性化により耐久性を改善

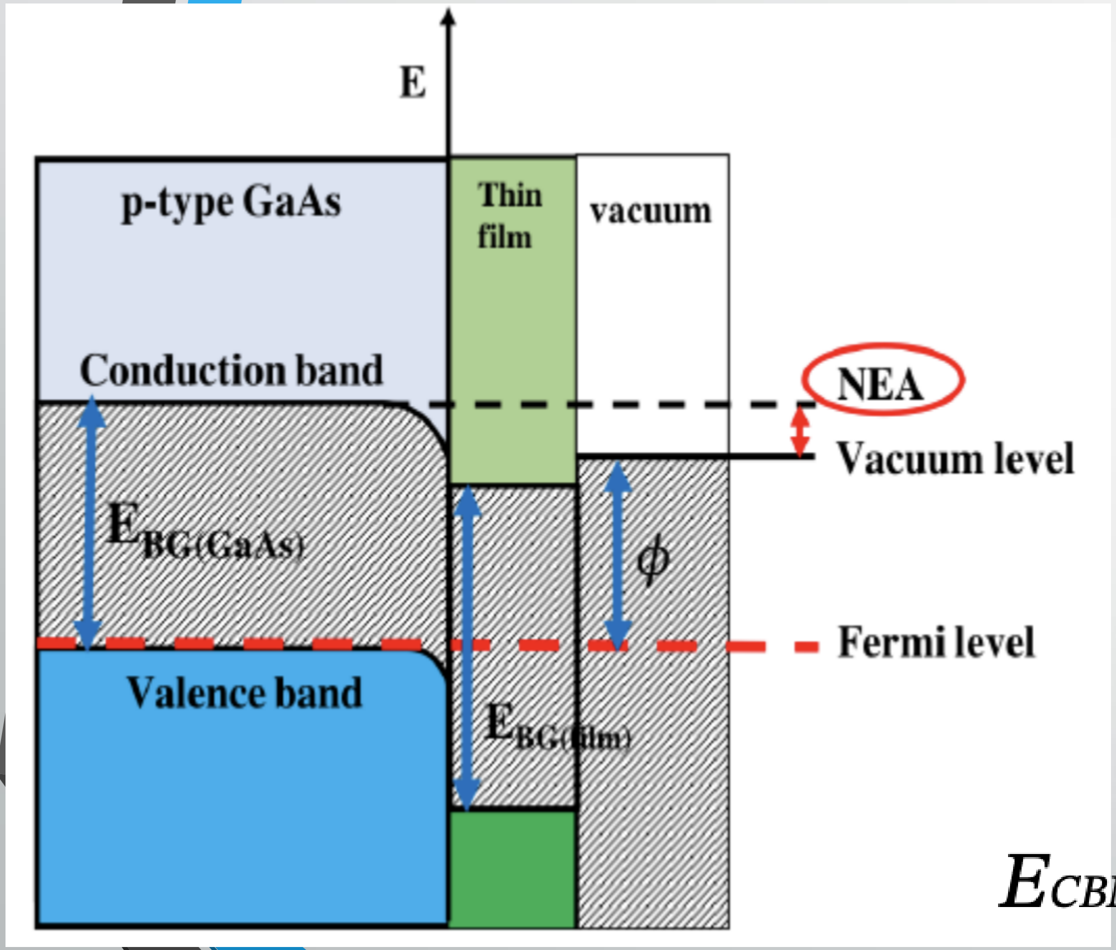
偏極ビームの物理モチベーション：
例えば
https://doi.org/10.48550/arXiv.1310.0763
（ILC Whitepaper)
https://doi.org/10.48550/arXiv.2205.12847
(Polarized SKB Snowmass Whitepaper)

Sources of Cs Film Degradation

- Csの熱脱離
- ガス吸着
- イオン逆流

以上の問題を緩和するため、CsやCsOより新しい薄膜作りを試してみる。

NEA Explanation



NEA：**N**egative **E**lectron **A**ffinity

GaAsウェーハに異種半導体薄膜を蒸着して、バンドギャップを縮める。

→　GaAs価電子帯へ励起された電子が真空へ遷移できる

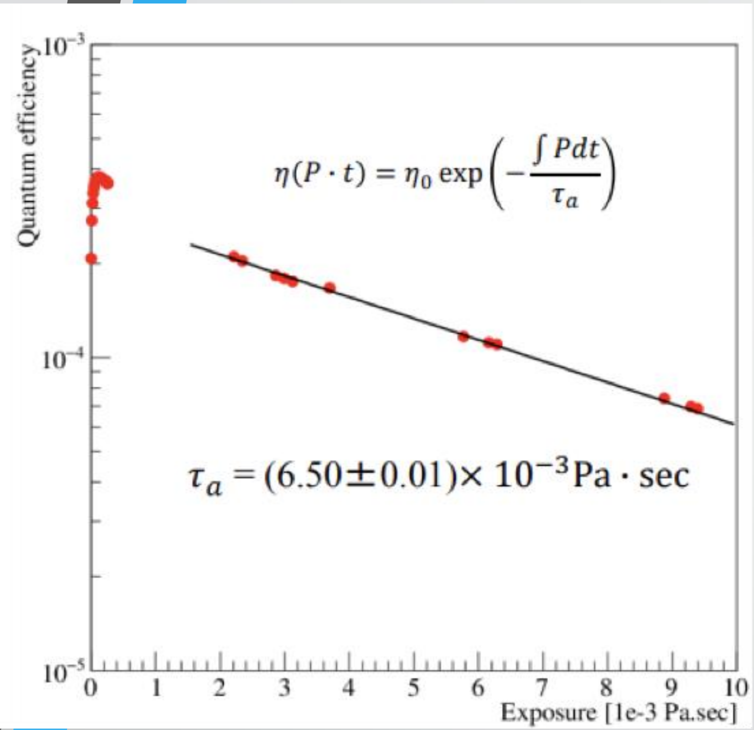
$$E_{CBM} - E_F > \Phi_{film}$$

E_{CBM}：伝導帯準位の底

E_F：フェルミ準位

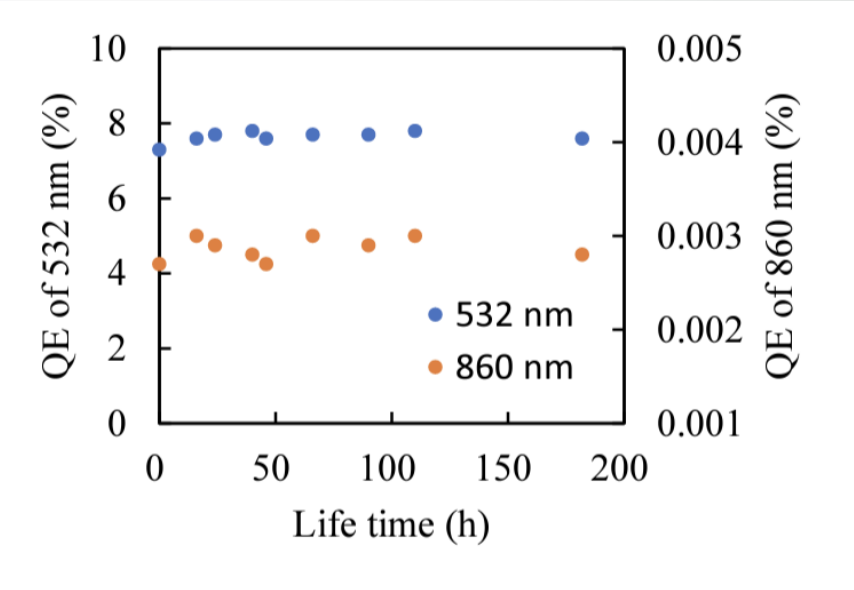
Φ_{film}：薄膜半導体の仕事関数

薄膜比較



Cathodes	Lifetime τ_a $[10^{-3}\mathrm{Pa\cdot sec}]$
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)



小杉 et al., PASJ2020 THPP49

従来のCsO薄膜に比べたら、CsKX薄膜は桁違いの耐久性が現れる。

Summary

- 将来の加速器は偏極ビームを使用する予定あるから、偏極（陽）電子源が必要。
- GaAsカソードの上に薄膜を蒸着するテクニークは数十年代知られるが耐久性・寿命が足りない。
- CsKSb薄膜を蒸着する実験を試行しました。
    - 従来のCsOより耐久性が高い且つ偏極率・量子効率はも高い。
- 実験を行えた上、薄膜をかけるのを出来たがNEAを監視しなかった。
    - 光・分光器のオプチカルシステムは改善が必要
    - 蒸着源制御が不十分で最初の層が厚すぎ

偏極ビーム生成

- GaAs格子から偏極をビームを生成するため、円偏光レーザーを使用。
  - 円偏光の向けよる、すピン偏極を決められる。