High Current Performance of Alkali Antimonide Photocathode in LEReC DC gun

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Low Energy RHIC electron Cooling (LEReC)



LEReC photocathode: Production and Transportation







LEReC Photocathode Deposition

Base pressure 6x10⁻¹¹ torr

3 pairs of getter sources for each alkali species.

Produces 10~12 cathodes for each installation

QE mapping system



Bldg 535B, Instrumentation Division, BNL



LEReC Photocathode Characterization

QE vs Temperature



- Sequential growth with 10 nm of Sb, followed by K and Cs deposition.
- Both K and Cs step are monitored with green light QE
- Each deposition takes ~ 2 hrs
- Each deposition cycle takes ~ 12 hrs(2 cathode/day)

QE uniformity



- Off-center design for the LEReC run 18~19
- Cathode is 6 mm in diameter
- Cathode QE was mapped after the deposition, with X-Y stepper motors controlling a green laser.





Summary of 2018-2019 cathode production



	Run 2018	Run 2019 (to May)	
# of cathodes	28	38	10
AVG Deposition QE (%)	5.41	6.28	10.87%
SDEV of QE (%)	0.97	0.85	0.12

28 cathodes total in 2018 38 cathodes total in 2019





New Features in the next deposition system

Tunable cathode mask for different cathode size and position

Increased capacity of heating station to increase the production rate

Cooling capacity at the sample stage

Designed extra ports for recipe upgrade

Summary of cathode transportation



LEReC cathode transporter (Ferris Wheel)

Base pressure 7x10⁻¹¹ torr in the transfer system

3 systems in standby, each stores 12 pucks

Cathode QE can be measured 1 at a time

Travels 1.3 mi in vehicle to RIHC tunnel







Summary of cathode storage

Cathode production	Lifetime	# of cathodes
Feb, 2018	> 2 months	3 cathodes
May, 2018	20 days	8 cathodes
Jul, 2018	No decay	9 cathodes
Aug, 2018	No decay	8 cathodes
Dec, 2018	No decay	8 cathodes
Feb, 2019	No decay	9 cathodes
Mar, 2019	No decay	8 cathodes
May, 2019	No decay	9 cathodes
Jun, 2019	No decay	4 cathodes



- ~5% QE decay during loadlock bakeout
- No QE decay in the transporter during transportation and storage



Cathode lifetime in the gun: 2018

30 mA beam current, t = 87 h, QE > 4%



QE decay accompanied with gun trip





25 mA beam current, t = 142 h, QE > 4%

Gun trip in high current operation status



QE map





- Cathode material is least in the center of these spots and most on the rim.
- The crystalized cathode streak on the rim shows high QE











Possible particles on the puck



- We observed the crystalized cathode material around the trip point and cause the QE increase.
- We saw AI-O particles on the cathode and confirmed the Alumina particles come from polishing.





Gun trip in high current operation status

Changed the cathode design from 11 mm in diameter in the center to 6mm in diameter and off- centered on puck

Improved cleaning procedure of pucks

Improved laser stability

date	l, mA	time, min	laser fluctuations	gun	cathode
30-Jul	30	130	very large	trip	center
6-Aug	30	130	small	trip	center
8-Aug	30	110	small	no trip	center
9-Aug	30	115	large	trip	center
13-Aug	26	140	large	no trip	center
13-Aug	30	75	large	trip	center
27-Aug	25	480	large	no trip	center
14-Sep	30	180	feedback	no trip	Off center
14-Sep	30	240	feedback	no trip	Off center





Cathode lifetime in the gun: 2019

17mA beam current, QE =5.5 %, infinite lifetime during CW operation





X-ray characterization for LEReC cathode

Growth controls: $\Box T_{sub}$ \Box Flux rate

Characterization: QCM XRD XRR XRR QE

Upcoming: Photoconductivity RHEED



Experimental setup: Operando chamber



X-ray characterization for LEReC cathode

X-ray characterization of the LEReC alkali antimonide photocathode at NSLS 2. Determined the cathode recipe developed for the LEReC project yields the stoichiometry of KCs_2Sb , with a relatively large grain size of 14 nm.





Grain size ~ 14 nm



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LEReC cathode under high heat



Possible solution for robust cathode: large crystal







Samples	K	Cs	Sb
1	2.50	1.16	1.00
2	2.37	0.91	1.00
3	2.21	0.95	1.00
4	2.07	0.94	1.00
5	1.98	0.88	1.00
mean	2.23	0.97	1.00





Summary

- The LEREC cathode production system has demonstrated its capability of stably and repeated producing high QE and uniform bi-alkali antimonide photocathodes in a timely manner.
- The cathodes show great lifetime in high current operation. The gun trip issue is in study.
- LEReC cathode has been studied by x-ray characterization at synchrotron light source. The Results show that this bi-alkali antimonide photocathode is KCs2Sb with good crystallinity, which explains the high QE.





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Thanks for your attention! Q&A



