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CATHODE PERFORMANCE DURING TWO BEAM OPERATION OF THE HIGH CURRENT HIGH POLARIZATION ELECTRON GUN FOR eRHIC*

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Abstract

Two electron beams from two activated bulk GaAs photocathodes were successfully combined during the recent beam test of the High Current High Polarization Electron gun for eRHIC. The beam test took place in Stangenes Industries in Palo Alto, CA, where the cathodes were placed in diagonally opposite locations inside the high voltage shroud.

No significant cross talking between the cathodes were found for the pertinent vacuum and low average current operation, which is very promising towards combining multiple beams for higher average current. This paper describes the cathode preparation, transport and cathode performance in the gun for the combining test, including the QE and lifetimes of the photocathodes at various steps of the experiment.

INTRODUCTION

The future Electron Ion Collider requires a high average current high polarization electron source. The average current requirement is 50 mA whereas the maximum average current demonstrated at other polarized electron sources is 4 mA. One very promising idea to obtain the high average current requirement is to combine multiple electron beams on to one axis by using a rotating magnetic field [1]. The key assumption in this proposal is that the operation of one cathode does not affect the lifetime of another cathode in the same vicinity. Therefore, based on the idea of combining multiple beams, a specialized DC electron gun has been designed at Brookhaven National Lab.

EXPERIMENTAL SETUP

For the low current proof of principle test in CA, the gun set up was simplified and is shown in figure 1. The major simplification being the absence of "Depressed collector" [2]. A Faraday cup, biased to 500 V, replaced the Depressed collector. The main goal of this test was to generate low current electron beams from two activated bulk GaAs situated radially opposite ends of the high voltage shroud. The maximum current from the cathodes were limited by a 2.88 G Ω current limiting resistor in series with the gun and a hard HV barrier at approximately 14 KV. Since two cathodes were to be operated at a very low repetition rate, the combiner magnet was essentially in a switch on-off mode. [3]

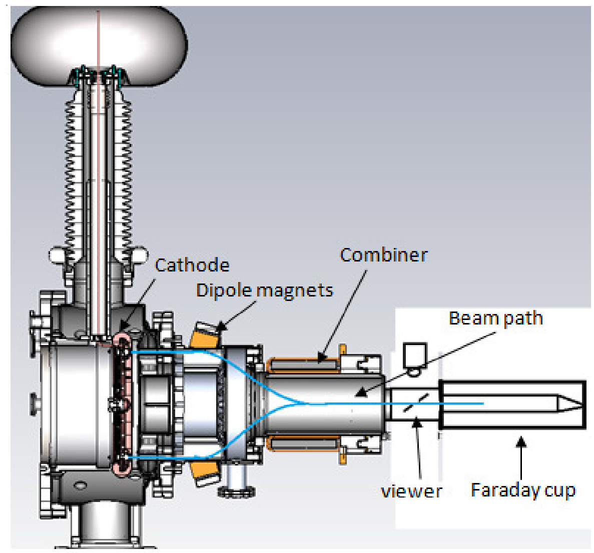

Figure 1: Schematic diagram of the gun.

Cathode Preparation Chamber and Transfer Line

The cathode preparation chamber and it's performance was described in the proceedings of PAC'13 [4]. In order to transport activated GaAs from the cathode preparation chamber to the gun, a transport line in between the gun and preparation chamber was installed. A custom made magnetic manipulator, manufactured by Transfer Engineering and Manufacturing, Freemont, CA [5], was attached to the other side of the preparation chamber.

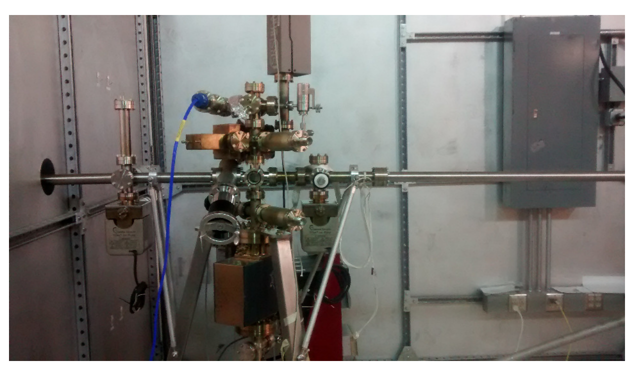

Figure 2: The transfer line, cathode preparation chamber and long manipulator, as shown from left to right.

In between the long manipulator and the preparation chamber, the placeholder cross was attached. This cross included

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two magnetically coupled holders for two Bulk GaAs cathodes, a window to view the transfer process and an ion pump. Note that the 20 cathode slots were initially populated with mirror finished Copper cathodes for HV conditioning purposes.

Once the conditioning was performed, and GaAs cathodes were activated in the prep chamber, only after that the actual GaAs cathodes were moved to the gun for beam extraction. The transfer line between the preparation chamber and the gun had a 20 l/s ion pump, a NEG pump and a hot filament ion gauge to measure pressure. Extensive high temperature baking was done on the transfer line to achieve a baseline vacuum of 10e-11 Torr level vacuum. During the transfer it was made sure that there was no metal to metal contact inside the vacuum chamber and the pressure in the transfer line never exceeded 5e-10 Torr.

Electron Gun

Two activated GaAs cathodes were placed in two radially opposite slots in the gun shroud. The beam optics was relatively straightforward with two fixed dipole magnet bends and a "Switch on-off" combiner magnet. A YAG crystal was placed downstream of the combiner to observe the beam profile. The YAG crystal had a hole in the middle and the objective is to steer the beam through that hole by tuning beam optics. Once the beam gets through the hole of the YAG, the downstream Faraday cup can measure the beam current. The Faraday cup was biased to 500 V to avoid back scattering of secondary electrons and a Keithley Picoammeter was connected directly to the Faraday cup for this measurement.

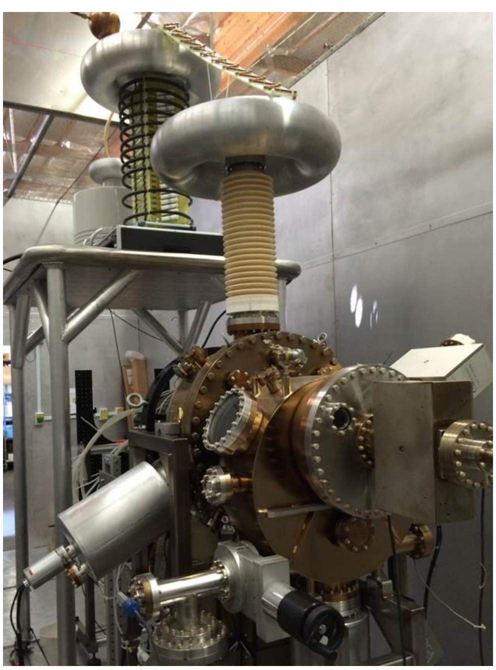

Figure 3: Back end of the gun showing the corona ring and the limiting resistor network.

CATHODE PREPARATION AND TRANSFER TO GUN

Bulk GaAs cathodes were activated in the preparation chamber under a base vacuum of 2e-11 Torr vacuum level. The beam test took place over two days. The first day, a single cathode was activated and transferred to the gun to extract beam. The second day, two cathodes were activated and the combining test was performed. Transferring a cathode from the preparation chamber to the gun took approximately 45 minutes for each cathode. It was made sure that the vacuum in the transfer line never goes above 5e-10 Torr such that the activated cathodes are still alive in the gun.

SINGLE BEAM TEST

For the single beam test, Yo-Yo process was used to activate the bulk GaAs cathode. For a laser wavelength of 650 nm, the QE in the preparation chamber was 1.2%. After the cathode was transferred to the gun, which took approximately 45 minutes, the cathode had a QE of 0.97% for the 532 nm drive laser. This was space charge limited since the operating voltage for the gun was 14 KV. The single beam spot as seen on the YAG crystal is shown in figure 4. The slit shaped beam profile is a result of large energy dispersion and non linear combiner magnet field [4].

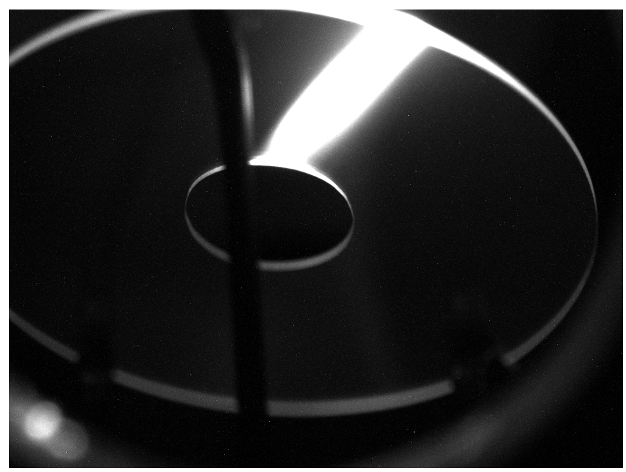

Figure 4: Single beam spot as seen on the YAG crystal.

Figure 5 shows the decay of photocurrent from the cathode during the beam test. The dramatic drop at the beginning of the operation is due to the first 20-30 bunches hitting the beampipe and outgassing which in turn contaminated the cathode. Also note that the beam spot was not seen on the YAG until after 200 seconds, then the current decay is not as dramatic. The lifetime towards the end of the curve is 1520 seconds.

TWO BEAM TEST

For the two beam test, the QE of the activated cathodes were 0.12% and 0.1%. The higher QE cathode was fresh since it was activated for the first time in the preparation chamber. The 0.1% cathode was the same cathode that was

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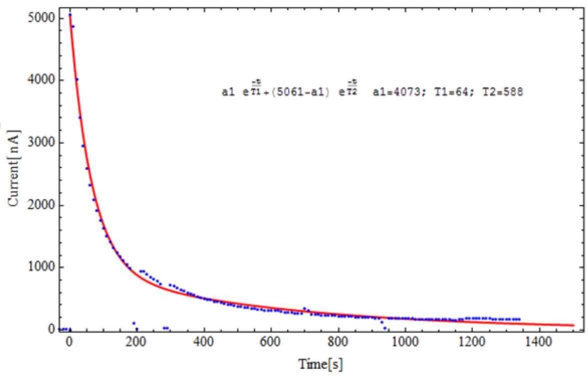

Figure 5: Single beam lifetime curve.

used during the previous day for single beam testing and was recesiated to obtain this QE value. The first cathode was transferred to the gun and there was a 2 hour gap before any beam was extracted from that cathode. The cathode QE's in the gun was 0.34% and 0.07% respectively. Figure 6 shows two beams obtained from two radially opposite cathodes steered and crossed on the hole of the YAG. The laser wavelength was 532 nm and average power on the cathodes were 1.2 mW. The beam frequency was 2 Hz at a bunch length of 100 milliseconds.

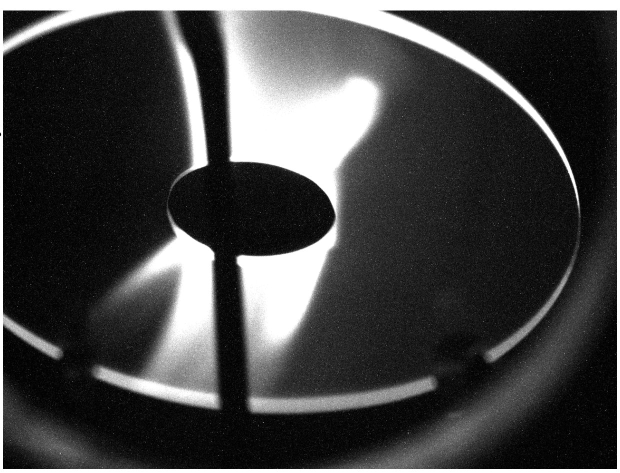

Figure 6: Two beams are crossed at the hole on the YAG.

Since the QE's of the photocathodes were an order of magnitude different, the measured current obtained from the photocathodes were different for the same laser power. As the current from the photocathodes would change, the voltage across the DC gap would also change due to the large voltage limiting resistor connected to the gun. For this reason, the beam spots on the YAG would move for a specific set of dipole and combiner magnet currents. Figure 7 shows the current decay curve during two beam operation. The two distinct boundaries represent current readings from two cathodes. In order to combine two beams, first beam from one cathode was extracted and a beam spot at the YAG was seen. Then the process was repeated for the second cathode. Once the optics were set, the laser was switched to trigger mode where both the cathodes would be illuminated for 0.1 seconds with a repetition rate of 2 Hz. The first beam did hit the beam pipe and outgassed, which explains the sudden drop of the QE of the first cathode. However, it is evident that the QE of the second cathode did not get affected by this outgassing since there is no considerable drop of current from the second cathode. After about 3000 seconds, as shown in figure 7, both the beams were stable, had similar QE and the lifetimes were measured to be 1980 seconds combined.

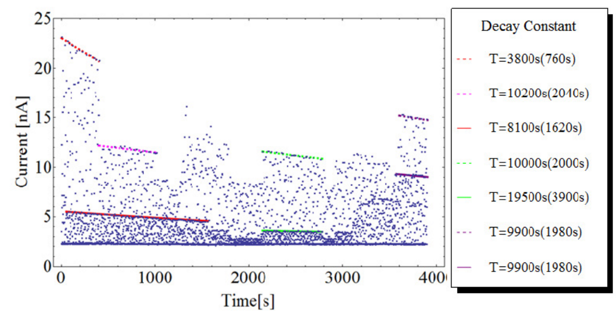

Figure 7: Two beam operation decay curve.

CONCLUSION

First beam was extracted from the funneling electron gun in CA at Stangenes Industries during the summer of 2014. Subsequently two beam combining test for low current was performed. The high voltage was limited due to field emission at 14 KV and the current was limited to hundreds of nA. However for this level of current extracted from each cathode, no significant cross talking between the cathodes was observed. The gun assembly has been shipped to Stony Brook University and has already been tested to have no field emission at 14 KV. In the next couple of months, the gun will be conditioned to some sufficient voltage to perform a two beam combining test at a higher current level.

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