ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-THPAB141

NOVEL DESIGN OF A HVDC MAGNETIZED ELECTRON SOURCE*

O. Rahman†, J. Skaritka, E. Wang, Brookhaven National Lab, Upton, NY, USA

Abstract

The hadron beam in EIC is flat with the transverse size ratio about 1:3. The cooling rate of the hardon beam can be maximized if the electron beam from the strong hadron cooler fully overlaps with the hadron beam. Therefore, generating a flat electron beam is essential. The most efficient way to generate a flat electron beam is to produce a magnetized beam first, and then convert it to flat to the desired transverse size ratio. Using a Magnetized electron beam is a promising way to cool high energy hadrons. One of the major challenges in producing magnetized beam is fine tuning the longitudinal magnetic field on the cathode surface and maintaining the desired field uniformity over the emission area. In this paper, we discuss the design of a novel high voltage DC gun capable of fine tuning the B field on the cathode. This is achieved by installing a permanent magnet inside the cathode puck, in conjunction with a solenoid field at the front of the cathode. We show magnetostatic simulation to prove the feasibility of this idea. We also show preliminary beam dynamics simulations showing emittance from the gun as the permanent magnet and solenoidal fields are tuned for minimum emittance.

INTRODUCTION

There have been many efforts to generate magnetized electron beam [1–3]. These efforts generally consisted of placing a solenoid right outside of the gun, and rely on the solenoidal field to reach the cathode surface to provide magnetization. However, this method has clear disadvantages in terms of controlling the field quality and uniformity on the cathode surface. For example: the radial dependence from a single solenoid could be too big and eventually lead to poor emittance. Instead of a solenoidal field, just a permanent magnet can be used to provide magnetization at the cathode surface. However, this will provide an overall defocussing in the DC gap which would create significant problem in transporting high bunch charge beams with high space charge. Therefore, a hybrid setup - with a permanent magnet in the back of the cathode holder and solenoid right outside of the gun, can be a promising solution towards providing a more uniform field and being able to transport the beam with manageable envelope and lower emittace.

PERMANENT MAGNET IN CATHODE HOLDER

Cathode Holder Mechanical Design

The cathode holder used for this simulation is the same cathode holder used for the EIC polarized prototype gun [4]. The base of the holder is made out of Molybdenum, whereas the stem is Titanium. A ferrite disk is used on the base, under the cathode, for collimating the magnetic fields from the ring magnets. A tungsten crown, with the help of 4 vented screws, can be used to hold the cathode down. The two ring magnets are placed at the back of the cathode, behind the moly base and over the Titanium stem, to provide a permanent magnet field on the cathode surface. A retainer case for the ring magnets are used to hold the ring magnets in their position. The proper positioning of the magnets are of critical importance to achieve the desired longitudinal magnetic field value on the cathode surface. Figures 1 and 2 show the different parts of the cathode holder.

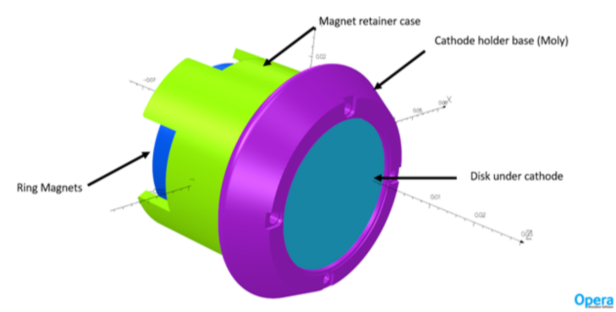

Figure 1: Cathode puck holder with different components.

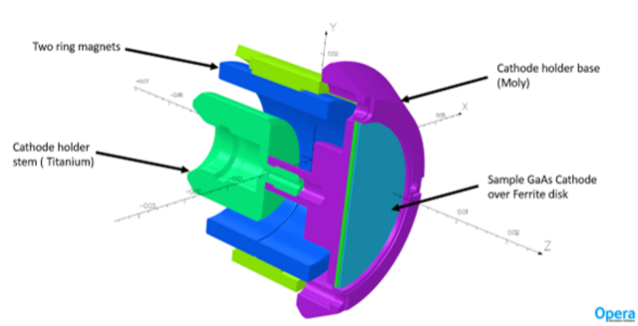

Figure 2: Cross section of the cathode holder, showing the permanent magnet arrangement.

Opera3D Simulation

For Opera3D simulation [5], we tried to optimize the following variables to obtain good field uniformity at the emission area on the cathode (we assumed a 3 mm diameter emission spot): distance between the ring magnet and the back of the moly base, different materials for the ring magnets for which we obtained the BH curves from the vendor, different shapes and geometry from the ferrite disk under the cathode. We tried 4 different types of magnets: Alnico, Samarium Cobalt, NE38AH and NE35AH. The last two

* Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.
† orahman@bnl.gov

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magnets are proprietary from K & J Magnetics who provided us with the BH curves for the Opera3D simulation [6]. Figures 3 and 4 show results from the Opera simulation for different parameters.

We found from our simulations that by choosing the magnet material carefully, one can generate the desired amount of magnetic field at the cathode. The uniformity of the field on the cathode surface, i.e. the radial dependence of the field magnitude, can also be controlled by optimizing the geometry of the ferrite disk under the cathode. For example: we could achieve a maximum of 2% variation over a 3 mm radius on the cathode by using a ferrite disk of the size of a British Penny. One concern for this method is that if the magnets are permanently attached to the back of the cathode, during cathode preparation and such, these magnets need to be tolerant of high temperature since most cathode preparation include heat cleaning the puck at high (500 degree Celcius) temperatures. Another option could be having a "buffer chamber" between the gun and the cathode preparation chamber, where the magnets are installed at the back of the cathode.

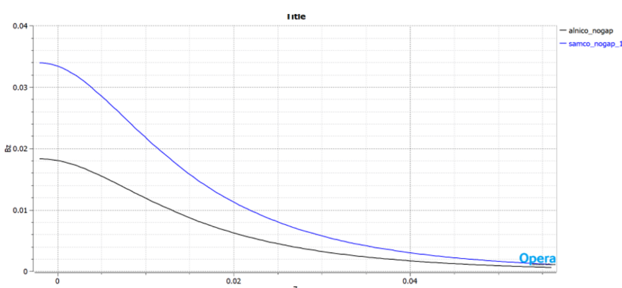

Figure 3: Field distribution along beam axis for different magnets.

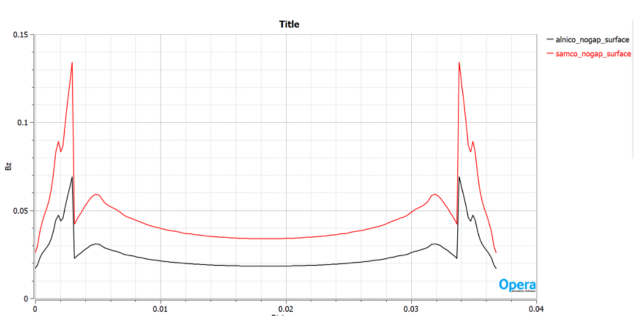

Figure 4: Field profile on the cathode surface for diffe magnets.

BEAM DYNAMICS

For the GPT simulation, we used a setup such that a permanent magnet (represented by magplate in GPT) is placed at the cathode and a solenoid is placed 10 cm from the cathode [7]. The idea behind this simulation was to see if using both permanent magnet and solenoidal field, the emittance from the magnetized beam from the gun can be controlled. We also wanted to determine if a specific combination of the permanent magnet and solenoidal field can optimize the emittance. Figure 5 shows the magnetic field profile on the beam path for different configurations. We used a Cornell type DC gun (reference) with 400 KV DC voltage. The bunches were 100 ps long with 1 nC bunch charge, with 4 mm spot size. The maximum magnetic field on the cathode was 600 gauss.

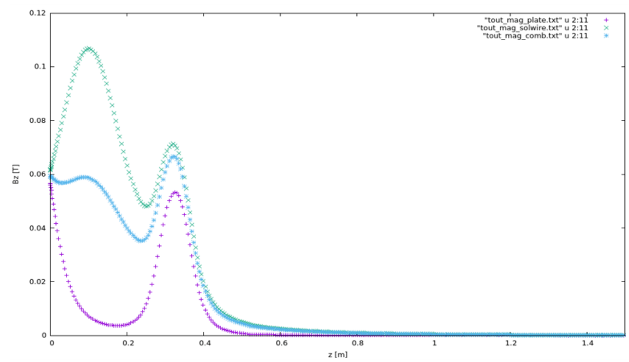

Figure 5: Field profile generated from GPT for different configurations- only magplate, only solenoid and the hybrid magplate+solenoid approach.

We varied the contribution from the permanent magnet from 50 Gauss to 600 Gauss, while the solenoid provided the rest of the magnetic field to keep the magnetic field on the cathode surface a constant 600 Gauss. For example: when the permanent magnet provided 200 Gauss, the solenoid will provide 400 Gauss and vice versa.The emittance plot is shown in Figs. 6 and 7. It seems that the emittance dilution is much controllable when the longitudinal field has about 50-50 mix of permanent magnet and solenoidal field. This result is promising towards exploring this option and performing a full scale study on this particular setup in the future.

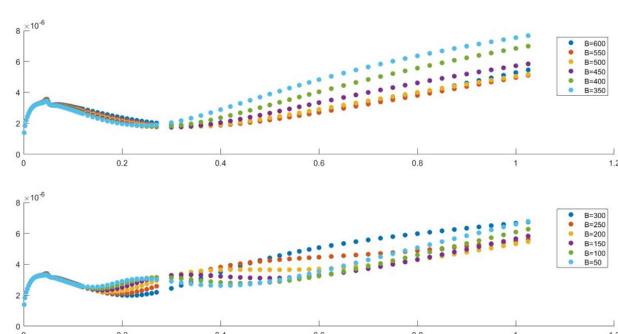

Figure 6: Normalized emittance along beam trajectory for different configuration of magplate and solenoid. B in the legend represents the amount of the field from the magplate, the rest of the field was contributed by the solenoid. Total field on the cathode was kept constant at 600 Gauss for every case.

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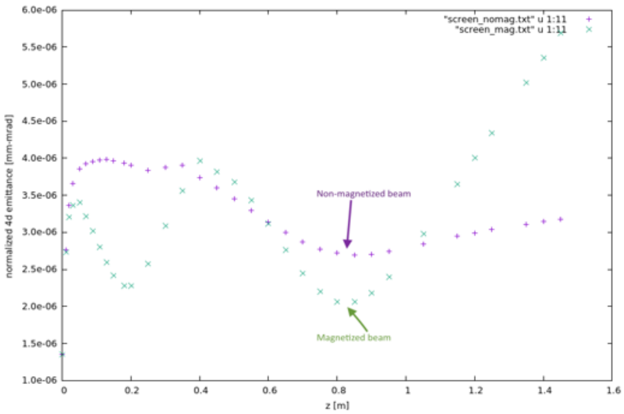

Figure 7: Comparison of magnetized and non-magnetized beam emittance from the same beam parameters. The magnetized beam was generated using the hybrid (mag-plate+solenoid) method.

CONCLUSION

We have explored a scheme in which a permanent magnet installed in the cathode holder, in conjunction with an solenoid at the exit of the gun, is used to generate magnetized beam from a HVDC gun. Initial simulations on Opera3D shows promising results towards achieving the desired 600 Gauss magnetic field on the cathode using ring magnets installed on the cathode holder. GPT simulations were performed and it shows that a hybrid scheme, where both a permanent magnet and solenoid is used, can lead to lower emittance from the gun compared to the regular single solenoid scheme.

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