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MIST – THE MESA-INJECTOR SOURCE TWO*

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Abstract

The new accelerator MESA (**M**ainz **E**nergy recovering **S**uperconducting **A**ccelerator) will provide an average CW electron beam current of up to 10 mA. Operating at 1.3 GHz, this corresponds to a bunch charge of 7.7 pC. The new DC-photoemission source MIST (the **MESA**-**I**njector **S**ource **T**wo) is optimized for these requirements. A challenge is heating of the photocathode at high laser power. By a suitable mechanical construction and the use of specific materials, the heat can be dissipated during operation. Options for further improvements are discussed.

INTRODUCTION

MESA (**M**ainz **E**nergy recovering **S**uperconducting **A**ccelerator) will be able to operate with two different photoemission DC-electron sources at an extraction energy of 100 keV. The primary electron source STEAM (**S**mall **T**hermalized **E**lectron Source **A**t **M**ainz [1]) can provide spin-polarized electrons with an average beam current of 150 µA up to 1 mA [2]. The second source MIST can provide up to 10 mA unpolarized average beam current.

Laser intensities of 1 W or more are required to extract beam currents 10 mA from photocathodes. Most of this laser power is converted into thermal load within the cathode and has to be dissipated to avoid excessive heating of the device and thus a significant reduction in lifetime.

The MESA beam line in the low-energy range from STEAM up to the pre-accelerator booster consists of various elements, e.g. for spin manipulation or a chopper-buncher system [3]. Therefore, the beam line is too long for bunch charges higher than 1 pC in order to reach the booster as loss-free as possible [4, 5].

Due to the beam dynamics at high bunch charges, the distance between MIST and the pre-accelerator booster should be as short as possible in order to reach the booster as loss-free as possible. In a second beam line above the MESA injector main beam line MIST will be arranged together with a Mott polarimeter at a same height. A dogleg arrangement with two bending magnets was developed to enable both: transport high bunch charges from the source to the booster, or guide the spin polarized beam from STEAM to the Mott polarimeter [6].

DESIGN OF MIST

The design of MIST is based on the compact construction of the high voltage (HV) photoemission source CEBAF at Jefferson Laboratory [7]. The HV is provided by a R30 connector, the corresponding jack is a bakable Al2O3 insulator on a CF–200 flange. With a biased cathode at −100 kV, the anode and the whole vacuum chamber are grounded. The emission is in horizontal direction, allowing the source to be integrated into the accelerator along beam axis (see Fig. 1).

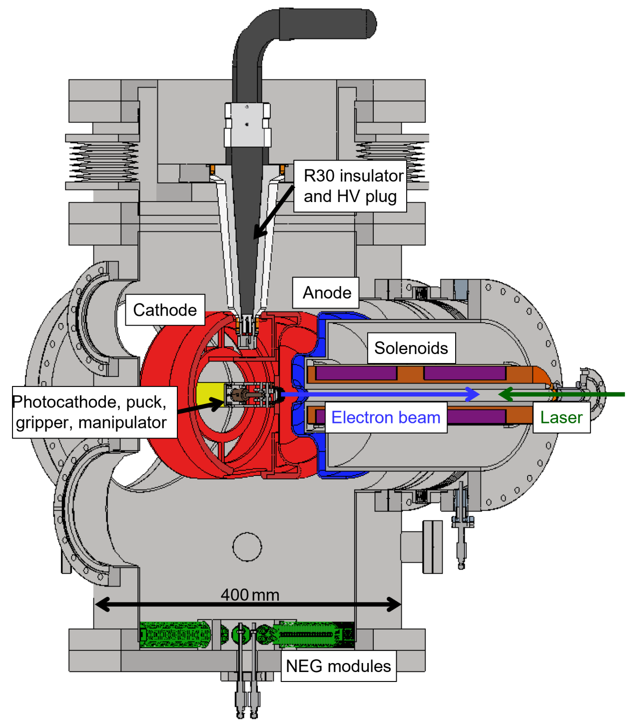

Figure 1: CAD model of MIST (MESA-Injector Source Two). A magnified view of the cathode (red) and anode (blue) region is given in Fig. 3.

An ion getter pump and NEG modules provide pressure conditions in the low UHV range. A load-lock system is directly connected to enable a photocathode change without breaking the source-vacuum.

Photocathode

MIST is planned as the high current electron source at MESA and will be operated with more robust and higher charge lifetime than GaAs-based photocathodes. The favored candidate is here the multi alkali K_2CsSb and can be produced in house. However, the photocathode is located in a so called puck. The thermal energy has to be transferred from the puck towards the boron nitride (BN) via the metallic gripper. The BN finally transports the heat towards compo-

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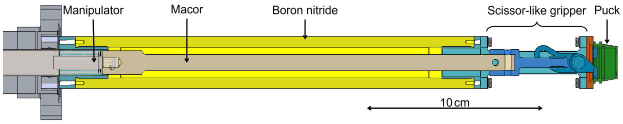

Figure 2: Preliminary CAD model of the gripper. A dual-axis manipulator is used. The yellow parts are insulating materials (boron nitride respectively Macor®).

nents at ground potential which are kept at room temperature or can even be cooled if necessary.

Photocathode Mounting

For a heat dissipation away from the puck containing the photocathode it is necessary to have a good thermal contact between the puck and other parts of the source. The puck is attached to the manipulator by a gripper and remains in the source during operation. Due to the HV environment, the gripper must be electrically isolated from the manipulator by ceramic materials.

With a dual-axis manipulator, the puck is pulled towards the manipulator by a mechanical, scissor-like construction in order to provide the necessary pressure for heat conduction (see Fig. 2) [8]. A special featrure of this arrangement is that all mechanically stressing actions – e.g. the pressing of the puck to the gripper – are performed outside the high voltage chamber. The electrode structure and the HV vacuum insulator remain free from stress.

Electrodes

For an excellent beam quality especially at high bunch charges of 7.7 pC a high field gradient at the surface of the photocathode is required. Therefore the cathode to anode distance is 22 mm (see Fig. 3) and leads to a field gradient of 4.9 MV/m. A repeller-like mounting of the anode allows on the one hand to detect beam losses on the other hand to protect the photocathode from ion back bombardment by applying a small supressor voltage.

MIST Solenoids

After passing the anode, the electron beam shows a large transverse divergence of about 4 mrad (see Fig. 4, blue curve). Thus, two water cooled long solenoids (first with 14 mT, second with 11.5 mT) are placed close behind the anode. For particle tracking simulations, a radial Gaussian distribution with $\sigma = 0.5$ mm was assumed as the starting parameter. The emission area was limited to $6 \times \sigma$. The simulation result shows the positive influence of those solenoids (red curve). A smooth focusing of the electron beam is possible so there is no extreme expansion due to space charge effects, a transverse emittance of $< 0.5\,\mu$mrad can be achieved. By a proper positioning of subsequent beam line elements such as quadrupoles, the MESA booster can be reached without significant beam losses.

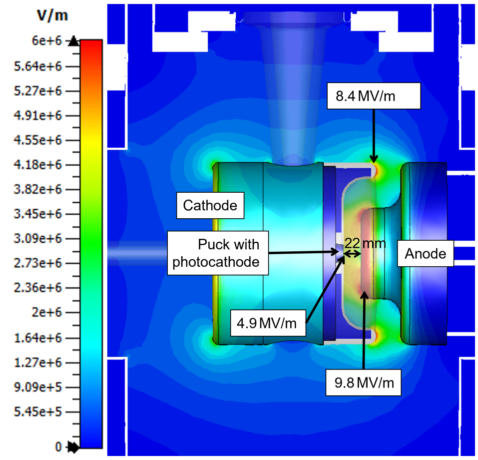

Figure 3: Results of field simulations (with CST® Studio Suite) at −100 kV base power of the cathode. At the photocathode, the field gradient is 4.9 MV/mwhile at the peripherie of the cathode it reaches 8.4 MV/m. On the anode side, the maximum is 9.8 MV/m.

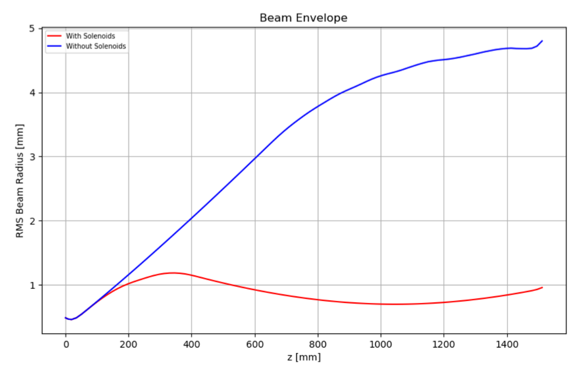

Figure 4: Beam envelope with a bunch charge of 7.7 pC with (red) and without (blue) the MIST solenoids.

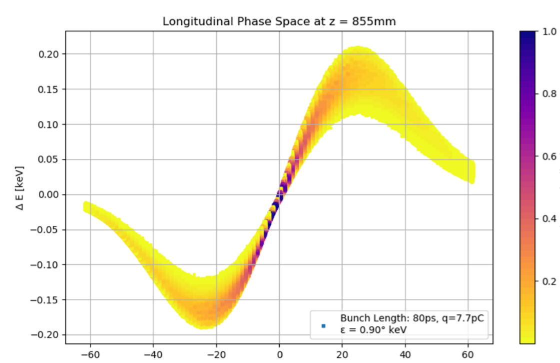

Figure 5: Charge distribution in the longitudinal phase space with a bunch charge of 7.7 pC and 80 ps bunch length.

Longitudinal Phase Space

Simulations were performed with CST Studio Suite for a single bunch with a bunch charge of 7.7 pC and a bunch length of 80 ps. Figure 5 shows the longitudinal phase space 855 mm behind the photocathode where the first bending magnet of the MESA injector beam line can be placed [6].

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Figure 6: Detail of the CAD model of the heating setup. The numbers 1 – 4 indicate the position of the temperature sensors. Position 5 shows a part of the manipulator axis (gray) and optional passive cooling clamps (red).

HEAT DISSIPATION

Experimental Setup

The mechanical construction of the gripper was tested in a small vacuum chamber for investigation of the heat dissipation. Instead of a puck with a photocathode, a dummy body made of aluminum with a blackened front surface was used to improve laser absorption. The heating power was 1.5 W at 532 nm wavelength. Figure 6 shows a detail of the experimental setup. The numbers 1 – 4 indicate the position of the temperature sensors. Position 5 shows a part of the manipulator axis (gray) and optional cooling clamps (made from copper and aluminum, red). Two series of measurements were performed: during measurement A the optional cooling clamps were not used; during measurement B, they were attached to the manipulator axis.

Results

Figure 7 shows the temperature development at the 4 measuring positions of both series of measurements. In both cases, the equilibrium temperature is reached well after 4 hours and is at approximately 55 °C (measurement A, red) and 54 °C (measurement B, blue) at the puck dummy, respectively.

The main temperature difference of more than 5 °C is between the points 2 and 3. This can be improved by replacing the gripper cage by a more conductive material, e.g. Elmedur X™ [9]. The small difference of about 2 degrees between point 3 and 4 shows that the transition from the gripper end to the manipulator axis do not have a large effect, so their thermal resistance is small against that of the BN.

Between measurement A and B, the temperature difference is only 1.2 degrees but indicates that a cooling effect is achieved by attaching the clamps to the base of the BN slab.

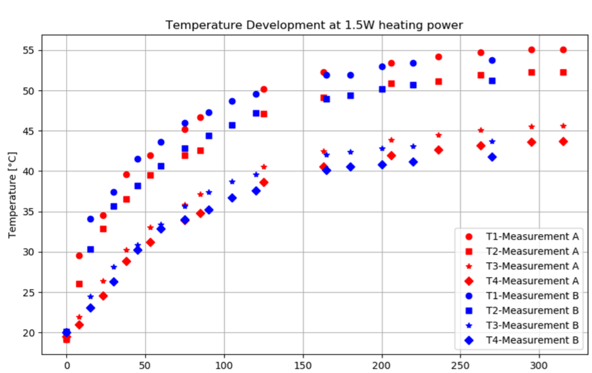

Figure 7: Measurement results under different conditions.

This can on one hand be improved mechanically. On the other hand the clamps can be cooled below room temperature which offers the possibility to compensate the temperature increase at the photocathode to a large extend or even completely.

CONCLUSION AND OUTLOOK

MESA will be operated with two different electron sources: one source for spin-polarized beam (STEAM) and one for high bunch charges (MIST). With MIST, a high field gradient of 4.9 MV/m at the photocathode ensures a good beam quality.

Heating experiments of the puck gripper have shown that the chosen design is promising, but still has potential for improvement. On the one hand, the choice of materials for single components should be revised, and on the other hand, the design of the cooling blocks attached to the manipulator axis can be further optimized. The next step will be to introduce the cathode holder in the electrode structure to test the HV capability of the arrangement.

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