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HEAT DISSIPATION OF PHOTOCATHODES AT HIGH LASER INTENSITIES FOR A NEW DC ELECTRON SOURCE*

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Abstract

Laser intensities of 1 W or more are required to extract average beam currents of more than 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 cathode and thus a significant reduction in lifetime. At Johannes Gutenberg-Universität Mainz, we are developing a new high current DC electron source operating at an energy of 100 keV, where an efficient heat dissipation of the photocathode is achieved by a mechanical design of the supporting structure.

INTRODUCTION

MESA (**M**ainz **E**nergy recovery **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. One of the main experiments at MESA – MAGIX (**MESA** **G**as **I**nternal target e**X**periment) [2] – requires in a second stage up to 10 mA unpolarized beam current. A beam current of 10 mA at the operating frequency of 1.3 GHz of MESA corresponds to a bunch charge of 7.7 pC. Laser intensities of 0.5 W or more – depending on the wavelength – are required to extract average beam currents of more than 10 mA from most photocathodes. Previous measurements without dedicated heat dissipation with NEA GaAs photocathodes have shown that the lifetime is reduced to less than ten hours at a laser power of 800 mW and a wavelength of 800 nm [3]. With the high demand on the beam quality and therefore a transverse emittance < 1 mm mrad, a laser spot with a radius < 0.5 mm is also necessary.

Furthermore, 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 [4]. Therefore, the beam line is too long for higher bunch charges than 1 pC in order to reach the booster as loss-free as possible [5, 6].

Due to the construction design, the possibilities of heat dissipation from the photocathode in STEAM are limited. Therefore, an additional electron source at MESA is indispensable.

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CONCEPTUAL DESIGN OF MIST

MIST (**M**ESA **I**nverted **S**ource **T**wo) is a normal conducting DC photoemission source operating at 100 keV. The cathode is biased at −100 kV while the anode and the whole beam line are grounded. The emission is in horizontal direction, allowing the source to be integrated into the accelerator along beam axis. MIST is planned as the high current electron source at MESA and will be operated with more robust and higher charge lifetime than available with GaAs-based photocathodes. The favoured candidate is here the multi alkali K_2CsSb.

Due to the more compact design, the high voltage supply is provided by an inverse shielded commercial R30 insulator. For an excellent beam quality especially at high bunch charges a high field gradient at the surface of the photocathode is required. Therefore the cathode to anode distance is 22 mm (see Fig. 1) and leads to a field gradient of 4.2 MV/m. Because of the large beam divergence two water cooled solenoids are placed close behind the anode.

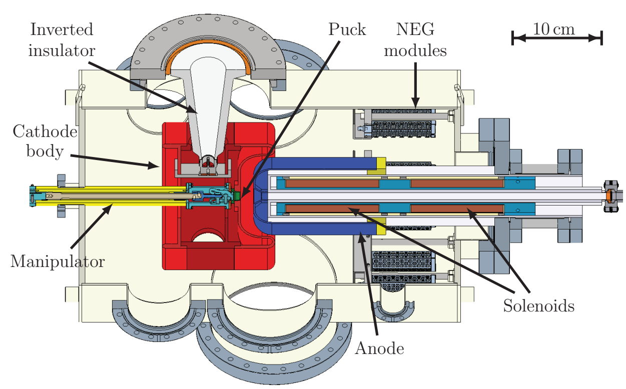

Figure 1: CAD model of MIST. The cathode (red) to anode (blue) distance is 22 mm. The photocathode is mounted in a puck (green). The puck-transfer-manipulator remains all the time during operation in the source.

The Gripper

The photocathode itself is located in a so called puck. 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. For this reason the contact surfaces must have the lowest possible roughness and require a high contact pressure. To avoid breakage of the R30 insulator a high contact pressure between puck and cathode creates a risk but can be established between puck and manipulator. The puck is attached to the

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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). The materials used represent a compromise between mechanical stability, physical properties for thermal conduction, and use in the UHV and HV capability. The metallic components of the gripper are mainly made of molybdenum, while the choice of a suitable electrical insulation material with the given requirements is more challenging. Typically, crystalline Al_2O_3 or glass-ceramics (e.g. Macor® [7]) are used, but these have a poor thermal conductivity coefficient (20 – 30 W/(K m) respectively 1.46 W/(K m). In contrast, boron nitride (BN) has a relatively good thermal conductivity of 78 W/(K m) or 130 W/(K m) (depending on the direction). BN is very soft and porous and can be machined well, however, it cannot withstand high mechanical stresses. Therefore, a combination of BN and Macor will be used.

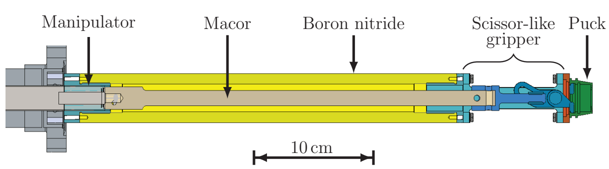

Figure 2: CAD model of the gripper. A dual-axis manipulator is used. The yellow parts are insulating materials (BN respectively Macor).

PRE-EXPERIMENT ON HEAT DISSIPATION

Experimental Setup

In a first experiment on the heat dissipation, a body made of molybdenum (Mo) was mounted on a BN rod in a small vacuum chamber (see Fig. 3). The Mo body was irradiated with a controllable filament as a heat source. The thermoelectric voltage was registered at three lateral measuring points (Mo body bottom at 6 mm, Mo body top at 35 mm, BN rod top at 134 mm). In addition, the temperature was measured at the top flange (at 156 mm).

Results

The equilibrium temperature under three different conditions are shown in Fig. 4: the red dots were taken with a heating power of 2 W, the blue squares with 4 W, and the black triangles show the cooling effect of a simple fan in front of the top-flange at 4 W.

Of most interest is the temperature at the bottom of the Mo body (at 6 mm), where the photocathode will be located later. The temperature remains below 45 °C. Air cooling with a fan of the connection point of BN and the chamber flange

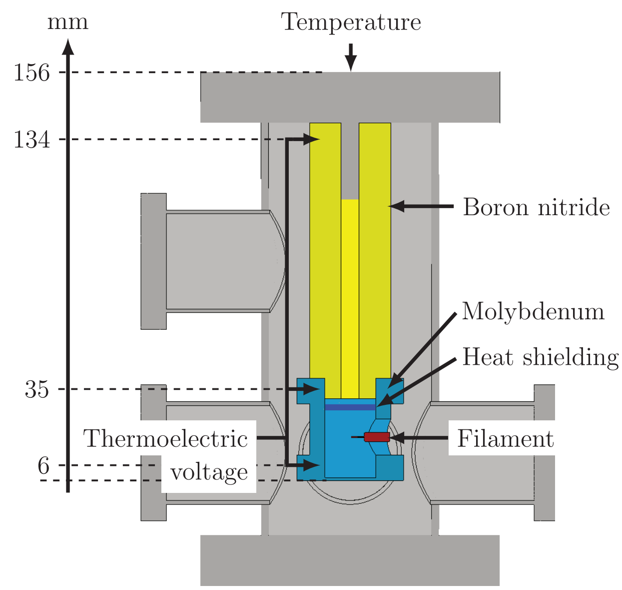

Figure 3: Sketch of the Heating experiment. The Mo body is irradiated with a halogen filament from inside and shielded from the BN rod.

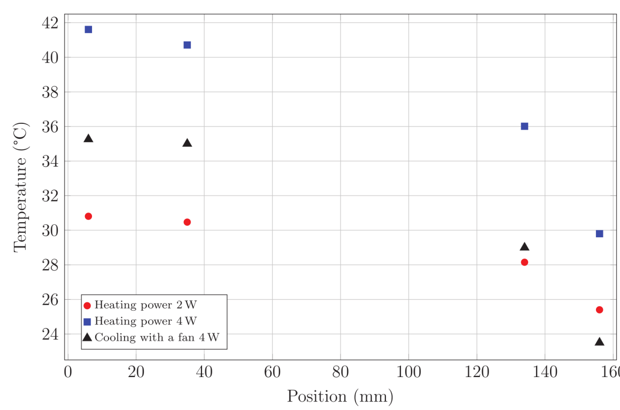

Figure 4: Measurement results under different conditions.

also has a positive effect on the equilibrium temperature. This shows that BN is a promising insulation material for this particular application.

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). At MIST, the necessary heat dissipation from the photocathode during operation will be realized by a permanent connection between the photocathode – respectively the puck – and the manipulator. The insulating materials used are Macor an BN, Macor because of its mechanical robustness and BN because of its good thermal conductivity.

First heating experiments have shown that BN is promising. In a next step, the functionality of the later source manipulator with its gripper will be verified under real conditions. On the one hand, it must be tested whether a sufficient

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contact pressure between puck and gripper can be achieved. On the other hand, this gripper construction consists of a number of separate components that have to be assembled together (see Fig. 2). Therefore, it must be checked whether the thermal conductivity of all the resulting contact surfaces of the scissor-like gripper is large enough for the necessary heat dissipation.

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