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STATUS OF THE HESR ELECTRON COOLER TEST SET-UP

M. W. Bruker, J. Dietrich, S. Friederich, T. Weilbach, K. Aulenbacher
Helmholtz Institute Mainz, Mainz, Germany

Abstract

For the High Energy Storage Ring (HESR) at FAIR, it is planned to install an electron cooling device with a beam current of 3 A and a beam energy of 8 MeV. A test set-up was built at Helmholtz-Insitut Mainz (HIM) to conduct a feasibility study. One of the main goals of the test set-up is to evaluate the gun design proposed by TSL (Uppsala) with respect to vacuum handling, electric and magnetic fields, and the resulting beam parameters. Another purpose of the set-up is to reduce recuperation losses to less than 10^{-5}. To measure this quantity and to mitigate collection losses, a Wien filter has been designed and installed. Beam diagnostics will be carried out with a COSY-style beam position monitor. The latest progress of the project is presented.

INTRODUCTION

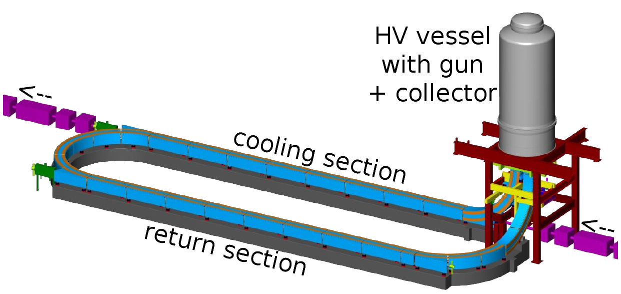

Figure 1: Proposed design of the HESR electron cooler [1].

At the High Energy Storage Ring (HESR) at FAIR in Darmstadt, it is planned to store antiproton beams at energies up to 15 GeV [2] and possibly heavy ions at 740 MeV/u [3]. Since the internal experiment PANDA increases the emittance of the stored beam, beam cooling mechanisms have to be employed. One possible way of reducing the emittance of the stored beam is an electron cooling device as depicted in Fig. 1. In this device, a high-intensity electron beam moves coincidentally along the axis of the hadron beam, allowing for unwanted momentum components to be shifted into the phase space of the electrons, which are subsequently extracted and dumped in a collector. In order for the electron plasma to appear at rest from the perspective of the hadron beam, one has to ensure that the beams meet the requirement

$$v_e = v_{\overline{p}} \quad \Rightarrow \quad E_e = \frac{m_e}{m_{\overline{p}}} E_{\overline{p}}. \qquad (1)$$

Therefore, an electron beam with an energy of up to 8 MeV is needed. Calculations done by BINP [4] show that the current should be of the order of 3 A for maximum cooling rate. Additionally, the demand for magnetized cooling requires the beam to be constrained within a longitudinal magnetic field.

The device is designed for energy recuperation so that the total deposited energy is independent of the acceleration voltage. However, the electrostatic symmetry induced by this approach leads to the problem that secondary electrons reflected from the collector surface can traverse the beam pipe in the wrong direction. Recent progress made by BINP [5] suggests that this effect can be eliminated using a Wien filter, at the same time allowing for measurement of the secondary electron current. Consequently, such a filter has been designed and successfully implemented in our cooler test set-up with the different properties of the components in mind [6].

COMPONENTS OF THE TEST BENCH

Electron Gun

The electron gun used in our set-up has been designed and built by TSL based on the FNAL cooler gun [1] and transferred to Mainz in 2010 along with the solenoids and the mechanical supports. It consists of a thermionic cathode operated at about 1000 °C, a Pierce shield that is also used as a control electrode, and a conical anode. Several improvements to the original design have been made with respect to vacuum quality, non-magnetic materials, and mechanical stability. Therefore, the gun can be operated at a base pressure of 5×10^{-11} mbar with a magnetic field of about 100 mT and a voltage of 26 kV. With the current design, it does not seem possible to further increase the magnetic field without risk of gas discharges. Furthermore, due to the dual purpose of the control electrode, the beam shape cannot be controlled independently of its current, which complicates beam diagnostics.

Collector

The collector is a copy of the one used in the COSY cooler [7] built by BINP. It is designed for a beam energy of up to 5 keV after deceleration at a current of up to 3 A. The cooling medium is oil. So far, our collector has only been in use without any cooling at low currents. Installation of a compatible oil heat exchanger is in preparation.

Wien Filter

The Wien filter has been designed and built at HIM. It operates at a voltage of +/- 8 kV, which corresponds to a transverse magnetic field of about 3 mT, and a longitudinal magnetic field of 50 mT. An insulated collector plate is installed on the gun side of the filter to measure the secondary electron current captured by the deflecting fields.

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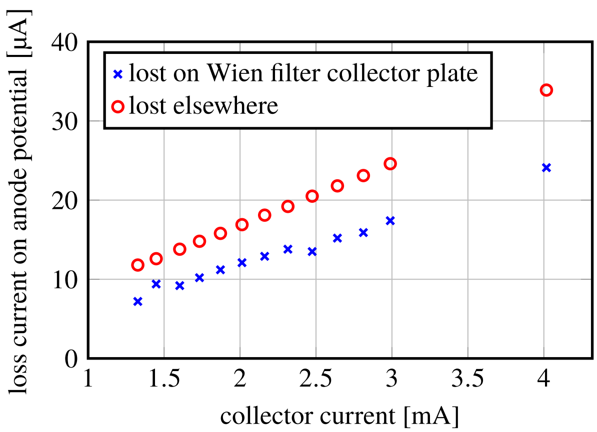

Figure 2: Electron current lost on anode potential.

PRESENT STATE OF THE EXPERIMENT

The test bench has been successfully set in operation with $U_{\text{Anode}} = 26\,\text{kV}$, $U_{\text{Collector}} = 3.5\,\text{kV}$, and a continuous current of up to 4 mA. A short test with 20 mA showed a fast decrease in beam current over time, thus requiring investigation. Undesired loss currents on the order of 0.5 % can be observed. The relative loss current is independent of the beam current in this range (shown in Fig. 2), so the cause is assumed to be related to electron optics, i.e. misalignment of magnets/electrodes. Unfortunately, the present configuration does not allow for systematic measurements of the beam position and shape.

PLANS FOR THE NEW SET-UP

Mechanical Alignment

In order to systematically eliminate beam optical errors caused by mechanical misalignment, a complete reconstruction of the mechanical set-up will be performed. Each solenoid will be mounted on a modular plate that allows for horizontal, vertical and angular adjustment (see Fig. 3). The modules and their supports will be constructed in a way that will allow us to remove and reinsert the modules without the need for readjustment. This approach will greatly simplify the bakeout procedure as it will be possible to measure the magnetic field with the vacuum chamber in place but with the gun removed. This ensures parallel alignment between the vacuum chamber and the solenoid axis. After that, the gun can be mounted and the whole system evacuated and baked out with the solenoids removed. A preliminary model is shown in Fig. 4.

Beam Diagnostics

Even with the magnets aligned, systematic experimental evaluation of the beam optics will be necessary. The steps to take in the future are threefold.

First, a non-destructive beam position monitor will be inserted between Wien filter and collector. It has been ordered from BINP, but its delivery cannot be expected prior to next winter. Because of that, to gather some information about the beam parameters, albeit only possible at very low currents, an optical diagnostics module has been developed (shown in Fig. 5). It consists of a fluorescent screen that can be moved into the beam axis with a rotational feedthrough, a sapphire viewport, and an extra flange that supports a 200 L s^{-1} NEG

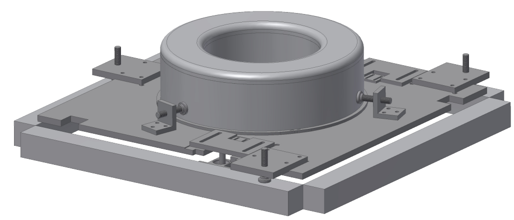

Figure 3: Alignable solenoid module.

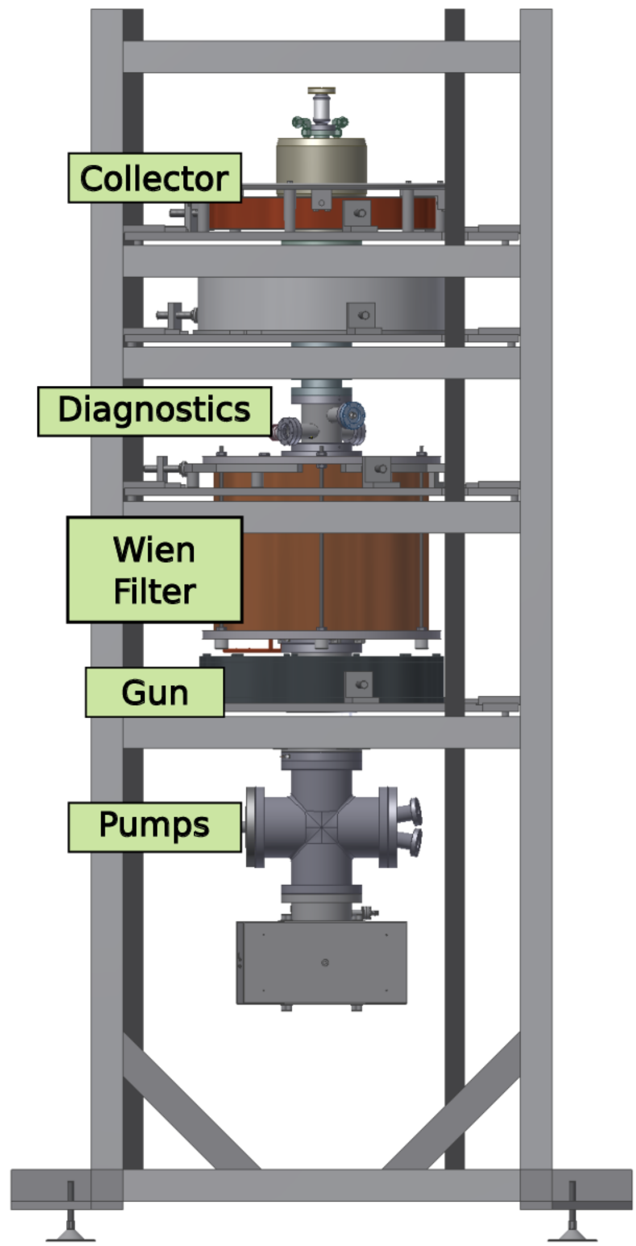

Figure 4: Preliminary model of the new mechanical set-up.

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pump. The tight design stems from the fact that the module must not collide with any solenoid. Third, the fixed scraper electrode in front of the collector aperture will be replaced by a segmented current sensing electrode that will facilitate distinguishing primary beam losses in the vicinity of the deceleration gap from secondary electrons that are randomly scraped away. A model of this electrode is shown in Fig. 6.

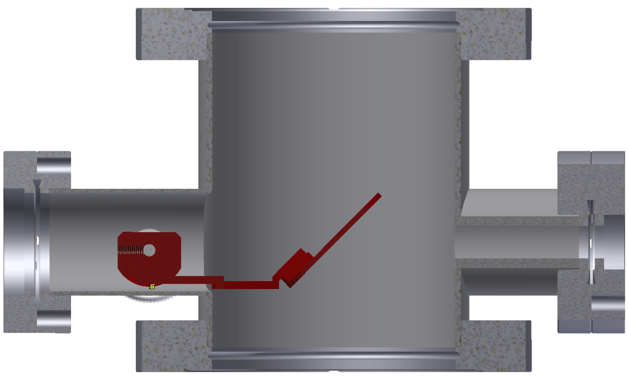

Figure 5: Optical beam diagnostics module.

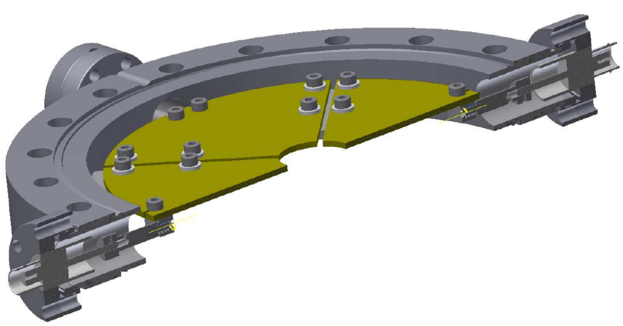

Figure 6: Segmented current sensing scraper electrode.

OUTLOOK

With the future possibilities for mechanical alignment and beam diagnostics, we hope to be able to eliminate all undesired beam losses. The desired beam current of 1 A can then be achieved with this set-up, possibly allowing for future experiments involving BIF or TLS type diagnostics [8].

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