ISBN: 978-3-95450-245-5 ISSN: 2226-0374 doi:10.18429/JACoW-COOL2023-THPAM1R2

# SUSTAINING COMPETENCES FOR ELECTRON COOLING AT HESR

Kurt Aulenbacher, Thomas Beiser, Juergen Dietrich, Wolfgang Klag
Helmholtz Institute Mainz (HIM), Germany

*Abstract*

The HESR storage ring will be operated with a high intensity antiproton beam to serve the PANDA experiment.

Due to several reasons its completion is presently postponed which causes the issue how to keep competences required to develop and operate the electron cooler. We will present mitigation plans that will enable Helmholtz-Institut Mainz (HIM) to pursue its goals even if the present situation would last for a long time.

## INTRODUCTION

The research group ACID-II at Helmholtz Institute Mainz (HIM) is aiming to resolve technical challenges related to high energy electron cooling. This is connected to a possible relativistic magnetized electron cooler for the High Energy Storage Ring HESR at FAIR. An electron kinetic energy of almost 8 MeV would be required, exceeding the voltage of the Jülich cooler [1] considerably, which is currently the cooler with the highest voltage and magnetized beam.

In cooperation with the Budker Institute for Nuclear Physics (BINP) at Novosibirsk in Russia we have proposed a modular concept based on high voltage platforms, each delivering a potential of 600 kV. The floating electric power is provided by turbogenerators which supply the solenoids and auxiliary devices such as electron source, collector-supply, or vacuum pumps. A first module was built by BINP and delivered to Mainz [2]. These modules – called platforms - are intended to be 1:1 scale size prototype for the HESR-cooler.

Since the last conference of this series all HESR related projects have been confronted with uncertainties because of cost increases and the political situation. These will probably lead to an additional delay of several years before HESR can start operation. In particular, the cooperation with most Russian institutions has been suspended and it is presently not clear when such co-operations will become possible again. This also applies to our plans to test the scalability with more than one HV-platform.

In this paper we describe the progress we have achieved since the last conference COOL'21 and try to sketch a strategy how to sustain the competences that have been gained at HIM until the timeline of the HESR becomes more predictable.

## PLATFORM OPERATION

The arrangement was described in the paper covering our status at COOL'21 [2] where more details can be found. A pressure tank of 4 m inner diameter is intended to hold a stack of 600 kV high voltage platforms (Fig. 1).

† aulenbac@uni-mainz.de

Since the cooperation with BINP was suspended, no delivery of the second platform took place. This will inhibit our tests for scalability until either the cooperation is resumed, or we build the other stages from our own means. The latter is feasible but would require considerable engineering capacity. Considering the delays in the timeline of HESR it seems reasonable to postpone such decisions and restrict ourselves to operation of the first 600 kV platform. We will operate the gas-expansion turbines for power generation with dry nitrogen at the beginning. An input pressure of 3 bar can be generated by our screw compressor with a mass-throughput that suffices to drive at least two turbines. It was considered most favourable to use a closed Nitrogen circuit, i.e., feeding the exhaust gas of the turbines back to the compressor, the input and the exhaust flanges can be seen in Fig. 2. In first tests it turned out that stable operation of the system, e.g., when changing the load on the turbine, was difficult to achieve.

Figure 1: Lower part of HV tank at HIM with first platform installed. Inner diameter of tank is 4 meters.

In cooperation with Prof. Wirsum from the Institute for turbo electric power generation at RWTH Aachen a thorough analysis of the pneumatic circuit was completed [3]. The reasons for the instabilities were identified and countermeasures proposed. The modifications were delayed by the supply chain problems that occurred during 2022, for instance by a very long delivery time for regulation valves. However, the modifications were finalized in spring 2023 and stable operation of a turbine in the closed cycle configuration was achieved. As a next step we will connect the already installed turbine on the 600 kV platform to the circuit. In this configuration the gas supply line is made from insulating material and integrated into the platform. Later, HV-tests will start, with the goal to reach 600 kV operation. This step will be challenging because the support from the designers of the platform at BINP is presently missing. To have stable HV-conditions on the platform, the supply lines and the turbine will be exposed to a moderate overpressure

ISBN: 978-3-95450-245-5 ISSN: 2226-0374 doi:10.18429/JACoW-COOL2023-THPAM1R2



in the HV-tank, which will be generated by filling the tank with nitrogen at 2-3 bar. We expect to finalize these experiments within the next two years.

Figure 2: "Big-Blue-Bubble" HV tank with several ports in the bottom flange. Besides the input/output port for the cooler beam, the bottom flange also comprises input/output ports for the gas flow.

## MEDIUM TERM STRATEGY

The experiments described in the last section will be performed with the available resources at HIM. From the R&D point of view, further developments are well defined and have been described in [2]. In the same paper, several alternatives how to use our competences and installations have been sketched. These projects can be related to R&D in particle physics as well as for applied science. They can allow us sustaining the special competences needed for the cooling device until the present period of uncertainty concerning the HESR-experiments is over. There are two different areas in which continuity must be maintained. Besides the expertise in handling the HV-modules, it is our experience in handling and diagnosing the high beam currents needed for magnetized cooling, see also the contribution by Thomas Beiser in these proceedings [4].

The most promising recent development where these competences can be used is a medical application. We have been asked to contribute to such a project where a similar beam current and energy as in our HESR-device is needed. This project is pursued by a collaboration of German national research centres and universities. It deals with generating a spatially modulated X-ray field for cancer therapy. Promising results of such radiation fields have been obtained at the ESRF-synchrotron, but clinical application requires to miniaturize the accelerator system needed. It turns out that a so called "Line focus X-ray tube (LFXT)" could achieve this [5]. The line focus on the anode with dimensions of approximately 0.05*15 mm is adapted to make optimum use of a linear X-ray collimator grid. A device suitable to be used in cancer treatment will have to operate at a beam energy of 600 keV with a beam current of about 2 Ampere. This is accidently a similar parameter region as in the cooler-prototype. For the LFXT, we have already designed and build a prototype gun for 300 kV, 300 mA which is currently being commissioned at TU-Munich [6]. Such an X-ray tube fulfils the desire to have a compact device that fits into a hospital, see Fig. 3.

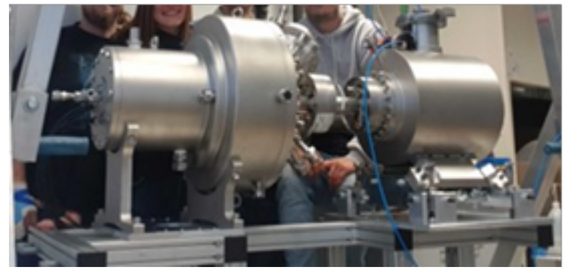

Figure 3: 300 kV, 0.3 Ampere prototype of the Line Focus X-ray Tube (LFXT-1). Tube length is about 1.5 m. Electron gun and focusing system (right half of vacuum vessel) have been built by us [6]. The system uses conventional HV-Isolators and HV-power-supplies to accelerate the beam.

One may note that there are differences between the Cooler- and the LFXT-prototype. First, the LFXT does not use energy recuperation. It dumps the full beam power on the anode, albeit only for a period of a few seconds which is enough to create the X-ray dose needed for treatment. Therefore, it relies on stored electrical energy, not on continuous power flow as in the cooler case. Second, it is not necessary to have a big HV-tank for only 600 kV. On the other hand, even if the turbines and the "big-blue-bubble"-tank would not be used it is evident that the aforementioned competences fit very well to this project.

## CONCLUSION

Our group will continue to develop important components for a possible electron cooler at HESR/PANDA. After a successful test of a turbogenerator in closed circuit last summer we will continue with an installation of the turbine at our high voltage platform with the goal to demonstrate operation of the system under 600 kV. If the situation concerning the future of the HESR-experiment remains unclear, it is possible to maintain the competences by bridging even a long-lasting time gap by applied physics research for X-ray tubes which need beam powers comparable to those at needed for HESR-Antiproton-cooling. This project can be handled in parallel to the ongoing cooler-activities since additional funding and personnel may become available.

## REFERENCES

[1] V.B. Reva *et al.*, "Experimental Observation of Longitudinal Electron Cooling of DC and Bunched Proton Beam at 2425 MeV/c at COSY", in *Proc. COOL'15*, Newport News, VA, USA, Sep.-Oct. 2015, paper MOXAUD02, pp. 10-14.

[2] K. Aulenbacher *et al.,* "Scalable HV-Modules for a Magnetized Relativistic Electron Cooler", in *Proc. COOL'21*, Novosibirsk, Russia, Sep. 2021, pp. 31-32. doi:10.18429/JACoW-COOL2021-S501

ISBN: 978-3-95450-245-5 ISSN: 2226-0374 doi:10.18429/JACoW-COOL2023-THPAM1R2

[3] R. Wirsum, Konzeptpapier – Potentialfreie Stromversorgung mit Turbogenerator (Mainz, 2021, unpublished)

[4] Th Beiser *et al.,* "Investigation of Ion Trapping and Beam-Induced Fluorescence at the Electron Cooler Test-Bench at HIM", presented at COOL'23, Montreux, Switzerland, Oct. 2023, paper THPOSRP13, this conference.

[5] J. Winter *et al.,* "Clinical Microbeam Radiation Therapy with a Compact Source: Specifications of the Line-Focus X-Ray Tube", *Phys. Imaging Radiat. Oncol.,* vol. 14, pp. 74-81, 2020. doi:10.1016/j.phro.2020.05.010

[6] Ch. Matejcek *et al.,* "A Novel Electron Source for a Compact X-Ray Tube for Microbeamradiotherapy with Very High Dose Rates, *Physica Med., EJMP,* 102532, 2023. doi:10.1016/j.ejmp.2023.102532