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SCALABLE HV-MODULES FOR A MAGNETIZED RELATIVISTIC ELECTRON COOLER

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Abstract

At HIM in Mainz the test setup for the magnetized relativistic cooler is progressing. The first 600 kV module at 1:1 scale for the HESR-cooler has been installed in its pressure tank. Our goal is to show the scalability of the approach aiming at stacking 13 modules in the final version at HESR. Plans for the near future are reported. Ideas for converting the prototype into an experimental facility are presented.

INTRODUCTION

Research at Helmholtz Institute Mainz (HIM) is aiming to resolve technical challenges that are related to high energy electron cooling, in particular 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, which exceeds the voltage of the Jülich cooler [1] considerably, which is currently the cooler with the largest voltage and magnetized beam. In cooperation with BINP 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 5 kW turbo-generators which supply the solenoids and auxiliary devices such as electron source, collector or vacuum pumps. A first module was built by BINP and delivered to Mainz in 2018 [2]. These modules are intended to be 1:1 scale size prototypes for the HESR-cooler. A second module is currently under production at BINP and could be delivered during the first half of 2022.

During the last almost two years, our work was seriously hampered by the COVID-19 pandemic because of extended lockdowns. Nevertheless, some progress was achieved which we report in the next paragraph, including a description of the new pressure vessel and an improved concept for closed cycle operation of the turbo-generators. The main purpose of the ongoing work is to demonstrate the reliability of the power generation approach and the scalability of the stages.

HV TANK

The existing module was tested with turbine-based power generation. During these tests, high voltage (HV) was limited because of the absence of a pressure tank. This tank was ordered in 2019 and delivery took place in spring 21. The tank consists of three parts (see Fig. 1 and Fig. 2).

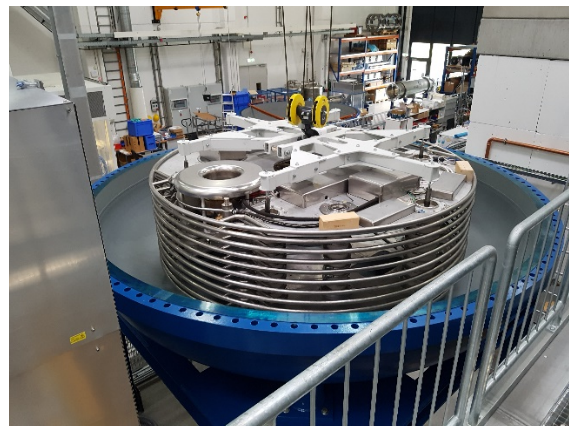

Figure 1: Lower part of HV tank at HIM with first platform installed. Inner diameter of tank is 4 meter.

In the bottom of the lower part, the feedthroughs for the gas supplies and for outgoing/ingoing beam are located. A manhole will allow maintenance once the device is fully assembled. Additional ports for filling with insulating gas are foreseen, the vessel is designed for a pressure of 10 bar and has been subject to the usual safety tests by the authorities. The gas filling is planned with nitrogen, the same gas will be used to drive the turbines. About 6 bar pressure of the insulating gas is sufficient to operate with two platforms at an acceleration voltage of 1.2 MV [2]. First HV tests under pressure are foreseen in 2022.

Figure 2: “Big-Blue-Bubble” HV tank with still open flanges.

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GAS FLOW FOR TURBINE DRIVE

The turbines shall be driven with nitrogen under ~3 bar inlet pressure which is generated by a single stage screw compressor. This already existing compressor is powerful enough to drive two turbines with 5 kW output power. Nitrogen will be used in a closed circuit. This requires a careful analysis of the operational parameters. In a cooperation with Prof. Wirsum from the institute of turbomachines at RWTH Aachen [3] it was shown that a stable operation can be expected if additional measures are taken. The main task is to install an additional regulation valve (outside the tank) into the high pressure line leading to the turbine. In addition, minor modifications of the existing circuit will take place, for instance increasing an already existing gas buffer tank by about 1 m^3. These modifications are currently under way. Tests of the turbine circuit are foreseen within the first half of 2022. The design of the hydrodynamic system for multi-turbine operation is ongoing. This will take into account load variations and behaviour under a fast shutdown.

DUAL-PLATFORM EXPERIMENT

After the second platform is delivered, a test of the scalability of the platform concept is mandatory. Practical experience with the gas-distribution system and the heat exchangers inside the HV-tank has to be gained. Demonstration of the HV-capabilities of the turbine driven approach is the most important point, including the hitherto more or less untested gas-flow under high electrical fields and voltages. Measurement of voltage-stability is planned, probably requiring to install an electron source and a spectrometer magnet external to the tank. This can be achieved in conjunction with the attempts for experiments mentioned in the next section. These experiments will extend over long a timespan. However, since the availability of HESR is still several years ahead, the period seems sufficient to come to conclusive result.

APPLICATIONS FOR EXPERIMENTS

With 1.2 MV the HESR-prototype does not deliver a very high energy, even if compared to existing DC-accelerators. However, the prototype with its "Big Blue Bubble" pressure tank (Fig. 2) has some distinct features which may become attractive for applied or even fundamental research. First there is the availability of sufficient electrical floating power on different levels of potential. This in conjunction with a good thermal management, because of the cooling down of the exhaust gas of the turbines [2]. Second, the space available on the HV-platforms is considerable and allows installing even bulky devices. We have plans to use this space for the installation of a photosource which has considerable space requirements that can be fulfilled here. The application is to generate short pulses of several ampere peak current with low duty cycle, i.e. small average current of less than 1 μA. These pulses can be guided to a tungsten target where short flashes of X-rays will be produced. Since the beam spots on the target can be made small, high peak brightness pulsed X-rays can be produced. Special collimators will allow producing a modulated radiation field in space. The apparatus will serve as a test stage for new types of dosimetry which are required for new approaches in radiation therapy such as "flash therapy" and "microbeam radiation therapy" [4].

Another application in fundamental research could be to build an electrostatic storage ring of the "figure of eight type" which employs two kinetic energies during one turn. Such a device was recently suggested to measure the hitherto not observed electric dipole moments of electrons [5] and would use polarized electrons with 200 and 600 keV energy. The space requirements of such a device can be met in our set-up.

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