POWERING OF THE HV-SOLENOIDS AT THE HESR ELECTRON COOLER

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Abstract

Many experiments at the planned High Energy Storage Ring (HESR) require magnetised electron cooling [1]. One of the challenges in the future HESR electron cooler is the powering of HV-solenoids, which need a floating power supply.

In this report we discuss the possibility of using turbo generators. We give an overview, including an introduction, status report and a road map.

INTRODUCTION

An essential part of the Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt is the HESR project, which is dedicated to the field of high energy antiproton research. The HESR is a storage ring with a circumference of 575 m and can operate in two modes, the "High Luminosity" (HL) and "High Resolution" (HR) mode. The experiments occur in the PANDA detector [2]. Some experimental demands are summarised in Table 1 [3]. To meet these requirements for the high resolution mode, magnetised electron cooling with a 4.5 MeV, 1 A electron beam is necessary to counteract the emittance blow up due to scattering processes.

Table 1: Experimental Demands of the HESR

	HL	HR
Momentum range	$1.5 - 15\ \frac{\text{GeV}}{\text{c}}$	$1.5 - 9\ \frac{\text{GeV}}{\text{c}}$
Peak luminositiy	$2 \cdot 10^{32}\ \frac{1}{\text{cm}^2\text{s}}$	$2 \cdot 10^{31}\ \frac{1}{\text{cm}^2\text{s}}$
Momentum resolution	$\frac{\Delta p}{p} = 10^{-4}$	$\frac{\Delta p}{p} = 10^{-5}$

An intention for the HESR is an upgrade to the Electron Nucleon Collider (ENC). The ENC will allow experiments with polarised electrons and protons [4], which also need magnetised electron cooling. In that case, an 8 MeV, 3 A electron beam is needed.

The Helmholtz-Institut Mainz (HIM) promotes a collaboration with other institutes such as Forschungszentrum Juelich (FZJ) and Budker Institute of Nuclear Physics Novosibirsk (BINP), Russia, in order to solve critical design issues for the HESR electron cooler. One of the challenges is the powering of HV-solenoids, because they are located on different electrical potentials inside a high voltage vessel. As a consequence, the HV-solenoids need floating power supplies. A concept that is currently being discussed to power them is the usage of cascaded cascade transformers, powered by turbo generators. The turbine is powered by gas under high pressure, consequently driving the generator.

The paper is organised as follows. In the first section, we show an overview of the HESR/ENC electron cooler and define the problem. In the following section, we present the concept currently under discussion and in the last part, the further road map is given.

HESR ELECTRON COOLER

The design of the HESR electron cooler as it was originally planned by the Svedberg Laboratory, Uppsala University, is shown in Figure 1 [5]. The cold electron beam

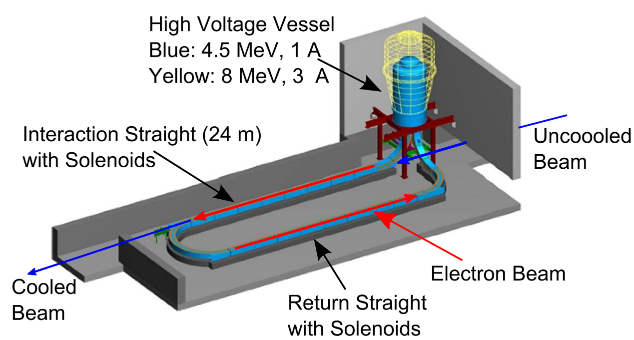

Figure 1: Proposed design of the HESR electron cooler.

is generated and accelerated within the high voltage vessel and is directed into the interaction straight, where the cooling process takes place. At the end of the interaction straight, the cooled antiproton beam is separated from the electron beam, which is returned to the high voltage vessel and deposited in a collector in order to restore energy [6]. Along the entire path from the source to the collector, the electron beam is guided in a homogeneous magnetic field generated by solenoids. Inside the high voltage vessel the magnetic field strength is 0.07 T, in the interaction and return straight 0.2 T. To prevent discharges, the high voltage vessel is filled with sulphur hexafluoride (SF_6) at an absolute pressure of 6 bar.

The interior of the high voltage vessel is illustrated in Figure 2. The main components are the DC-thermionic electron source, the collector, the acceleration and deceleration tube. The accelerating/decelerating voltage is provided by a high voltage column. It is built in a modular way and consists of decks. Every deck has a defined electrical potential. The potential difference between two decks should be in the range of 60 kV, which is a presently available technology already used in the 2 MeV COSY cooler (Forschungszentrum Juelich) [7]. The potential difference of 750 kV between the decks, as proposed in the swedish design, is not pursued further. The solenoids generating the homogeneous magnetic field inside the high voltage ves-

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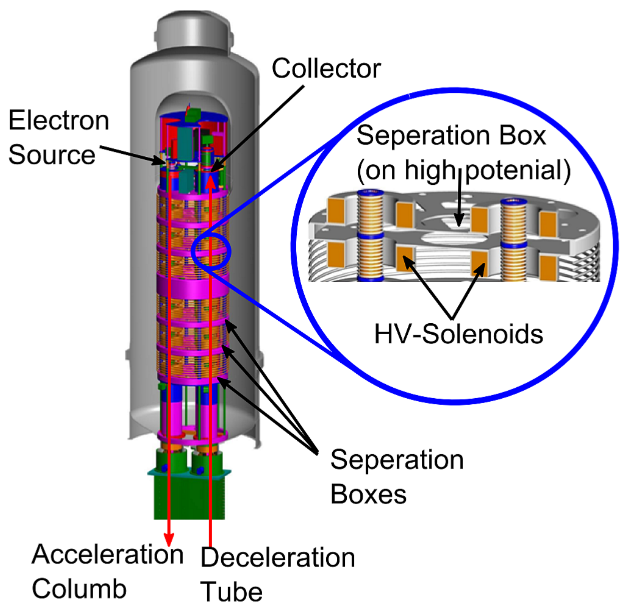

Figure 2: Interior of the high voltage vessel.

sel, the so called HV-solenoids, are mounted on the decks. This results in a problem with the power supply to the HV-solenoids. Because the decks are on a fixed electrical potential, the power supply for the HV-solenoids must not be grounded. Ideally the cooler should operate continuously for time scales of several months to allow for a reasonable scheduling of HESR experiments. Therefore a high reliability, in particular of the powering system for the solenoids, is a must. Due to the fact that the high voltage vessel is filled with sulphur hexafluoride, all components must be compatible with that. In addition to the HV-solenoids there are more devices on the HV-platform, which also need powering, e.g. vacuum pumps. A rough estimation of about the power consumption of the individual components within the high voltage vessel for the 8 MeV cooler is given in Table 2. In total the power supply has to deliver 150 kW. Therefore, in order to reduce the operational costs, the power supply must have a high efficiency.

Table 2: Power Consumption of Each Component (8 MeV)

Component	Power Consumption
HV-solenoids	100 kW
Gun & Collector	30 kW
Vacuum Control	5 kW
Diagnostics	5 kW
Micellaneous	10 kW

TURBO GENERATOR FOR POWERING THE HV-SOLENOIDS

The proposal to use turbo generators, a combination of a turbine and a generator, as power supplies came originally from the BINP to power the solenoids and to generated the accelerating/decelerating voltage at the COSY cooler. Every deck should be equipped with a small turbine and a generator [8]. Due to various difficulties, e.g. the reliability of the turbines, that approach was not pursued anymore. Instead of turbo generators on each deck, a cascade transformer is now used to power all coils and to generate the potential difference between the individual decks [9]. However, the energy range of a cascade transformer is limited to 2.5 MeV [10], which is why a single cascade transformer is is probably difficult to realise for the HESR/ENC. But because the cascade transformer is well tested, there is a wish to use it also for the new electron cooler. Therefore, the BINP has proposed a modified structure [11]. Instead of a single cascade transformer, a modularised cascade transformer should be used, as it is sketched in Figure 3. Each unit consists of a cascade transformer

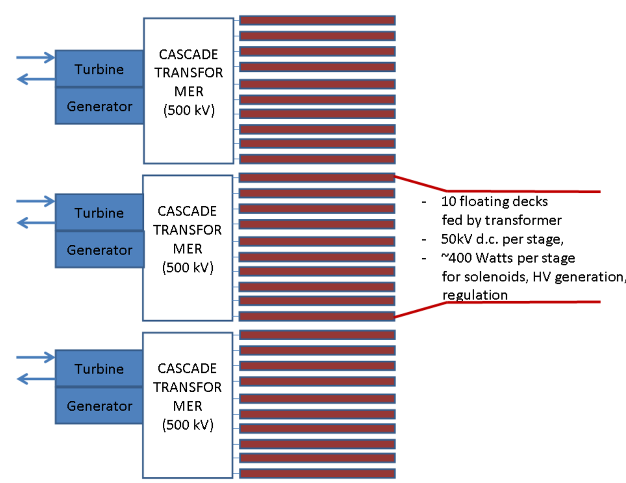

Figure 3: Principle of powering the HV-solenoids and generating the accelerating voltage.

(e.g 500 kV), which generates the potential difference between the individual decks and powers the HV-solenoids mounted on these decks. In order to achieve the full energy of 4.5 MeV or 8 MeV respectively, the modules are cascaded. In this structure, every cascade transformer needs a floating power supply. In this context, the concept of turbo generators was taken up again to power the cascade transformers. The advantage compared to the original approach of the COSY 2 MV electron cooler using small turbines (i.e. one for each 60 kV deck) is that it is possible to use larger turbines, which have a higher efficiency. The turbine is powered by a gas under high pressure, which could be generated outside of the high voltage vessel with an compressor and is directed to the turbine afterwards. Because of the sulphur hexafluoride environment, the ideal gas to drive the turbine is SF_6. In this case, after the expansion

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within the turbine, the sulphur hexafluoride could also be used to cool the HV-solenoids.

FURTHER ROAD MAP

A test setup at the BINP and HIM with a conventional turbo generator is in preparation as a feasibility study of the whole power concept. In this setup the Green Energy Turbine (GET) produced by the company DEPRAG [12] should be used (Figure 4), which operates with dry compressed air. Further properties of the GET are listed in Table 3. Two turbo generators have been ordered and will be delivered at the beginning of 2014.

Figure 4: Green Energy Turbine (www.deprag.com).

If the test is successful the next step would be to develop turbo generators which are adopted to our conditions and to design the module. For the development of the turbo generators, a collaboration, e.g. with a technical university, is foreseen.

Another point related to the efficiency is under discussion. The efficiency decreases for smaller turbines and the efficiency of a compressor is on the order of 10 %. This means high operating costs. An alternative way to generate high pressure gas could be an Organic Rankine Cycle (ORC) like process. An ORC allows to use waste heat from other processes, which would reduce the operational cost and also solves the efficiency problems.

Table 3: Properties of the GET

Component	**Power Consumption**
HV-solenoids	100 kW
Gun & Collector	30 kW
Vacuum Control	5 kW
Diagnostics	5 kW
Miscellaneous	10 kW

SUMMARY

The new experiments at the planned HESR need magnetised electron cooling. A challenge for the new electron cooler is the powering of the HV-solenoids within the high voltage vessel, which need a floating power supply. In the currently discussed concept, a modularised cascade transformer should be used, wherein each transformer is powered by a turbo generator. To find out if the concept works, a test setup at BINP and HIM is in preparation.

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