MODIFIED ELBE TYPE CRYOMODULES FOR THE MAINZ ENERGY-RECOVERING SUPERCONDUCTING ACCELERATOR MESA*

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Abstract

At the Institut für Kernphysik of Johannes Gutenberg-Universität Mainz, the new multi-turn energy recovery linac MESA is under construction. Two modified ELBE-type cryomodules with two 9-cell TESLA/XFEL cavities each will provide an energy gain of 50 MeV per turn. Those are currently in the production process at RI Research Instruments GmbH, Bergisch Gladbach, Germany. Modifications for the tuner and the HOM damper are under development. In addition, a 4K/2K Joule Thomson expansion stage will also be integrated into the cryomodule. The current status of the development of the cryomodules and their modifications will be discussed.

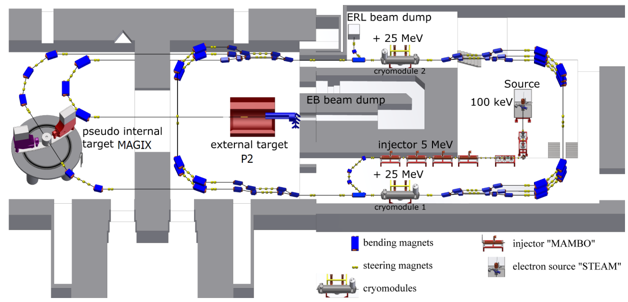

Figure 1: Possible configuration of the MESA design. The beam pipe is allocated around an existing beam dump which will be used in external beam (EB) mode.

INTRODUCTION

At the Mainz Energy-Recovering Superconducting Accelerator MESA, superconducting radio frequency (SRF) accelerator modules are of particular importance. The cryomodules, based on the ELBE-type cryomodule [1], have been ordered at RI Research Instruments GmbH, Bergisch Gladbach, Germany.

The ELBE-type cryomodule has to be modified to comply with the special requirements of MESA, e.g. the c.w. beam. Each cryomodule will contain two 9-cell TESLA/XFEL-type cavities that will provide 12.5 MeV energy gain each. Besides smaller adaptations, three major modifications are made: the tuner, the feedthrough of the higher order mode antenna, and the helium supply.

MAINZ ENERGY-RECOVERING SUPERCONDUCTING ACCELERATOR MESA

The Mainz Energy-Recovering Superconducting Accelerator MESA will be a new recirculating electron accelerator and shall operate in two different modes: an energy recovering (ER) mode and an external beam (EB) mode. It will provide a continuous wave beam with a duty cycle of 100 %. A possible design can be seen in Fig. 1.

At the ER mode there will be high beam currents from 1 mA up to 10 mA and an energy of 105 MeV, while at the EB mode the electrons will be polarized with a current of 150 µA and 155 MeV [2].

A photoemissive source will produce the electrons [3], which will be pre-accelerated by a normal conducting linac up to 5 MeV before they are guided into the main accelerator [4]. Two cryomodules accelerate and decelerate the electrons depending on the mode of operation. The beamline will be stacked at two arcs similar to CEBAF [5].

In EB mode there will be three passes through the cryomodules. In ERL mode four passes are made (two ramp up, two ramp down). A pseudo internal target experiment will be done in ERL mode with a high resolution spectrometer facility named MAGIX [6]. The external beam mode will be used for an fixed target experiment P2 which aims at a precise measurement of the Weinberg angle [7].

MESA CRYOMODULE

The MESA cryomodules are based on ELBE-type cryomodules, which are in use at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany. Each module contains two 9-cell TESLA/XFEL cavities and operates at 2 K. Each cryomodule will provide an energy gain of $\Delta E \geq 25$ MeV. The dimensions of the cryomodule are given in Fig. 2.

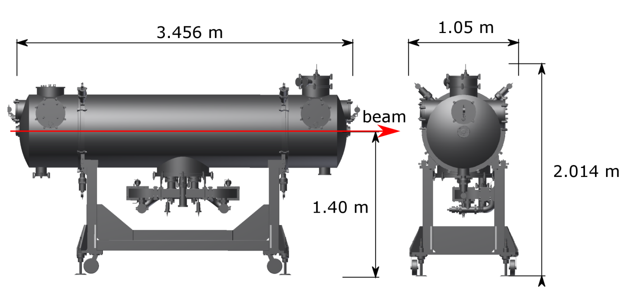

Figure 2: Dimensions of the cryomodule. The beam pipe is at a height of 1.40 m.

To suit the purposes and considering the beam parameters of MESA, there will be some modifications of the ELBE-type cryomodules. Because of multi turn ERL operation, it

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is necessary to have a faster control of the detuning by beam interaction, than the ELBE tuner can provide. Therefore a piezo tuner has to be integrated.

The c.w. operation at a duty cycle of 100 % will produce higher order modes (HOM) and those have to be damped. This damping causes heat, which can lead to a quench. To avoid that, the antenna has sapphire as feedthrough material and heatbridges from the flange to the helium vessel to optimize the heat extraction from of the HOM antenna.

In contrast to the ELBE-type cryomodule, the MESA cryomodule will be equipped with a helium subcooler stage to cool helium from 4 K to 2 K.

Tuner

Instead of using the original slow ELBE tuner, the XFEL/Saclay tuner including piezos for fast tuning will be used. The ELBE tuner does not have any piezos because of the beam parameters of ELBE [1], but during multi turn (especially the ERL mode) operation it is necessary to have a fast tuner to avoid resonances [8]. Both tuner types have for coarse cavity tuning a spindle-lever system, which push or pull the cavity. The XFEL/Saclay tuner has an additional piezo actuator support. The basic principle of the tuning system of the XFEL/Saclay tuner can be seen in Fig. 3. Important data of both tuner typs can be found in Table 1.

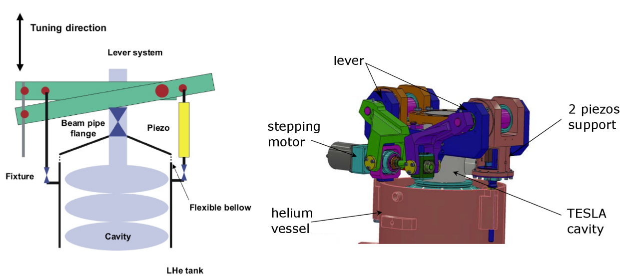

Figure 3: XFEL/Saclay tuner.
Left: Basic principle of the XFEL/Saclay tuner with piezo elements for fast tuning [9].
Right: 3D drawing of the tuner. [10].

Table 1: Comparison of the tuner resolution and range of the original ELBE tuner and the XFEL/Saclay tuner. The data of ELBE tuner are original published in [11]

Parameter	**ELBE**	**XFEL/Saclay**
Coarse resolution	0.28 Hz/step	0.176 Hz/step [9]
Coarse range	404 kHz	920 kHz [12]
Piezo range	-	700 Hz [9]
Piezo resolution	-	≤0.2 Hz [9]
Piezo voltage	-	0 kV to 1 kV [9]
Piezo movement	-	2 μm V^{-1} [13]

Typical response times of coarse tuning are around several 10 Hz [14], while piezo tuner elements are much faster with several 10 kHz [15]. The tuning range for warm pre-tuning (at 300 K) is for the XFEL/Saclay tuner $\Delta f = \pm 2$ MHz.

Higher Order Mode (HOM) Damper

Considering the c.w. mode in ERL operation, every bucket in the cavity is filled with two bunches. This causes many interactions between the electrons and the RF field and leads to HOMs. To stabilize the system, the HOMs have to be taken out of the system by an antenna.

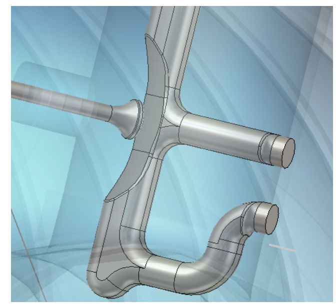

Figure 4: Assembly of the f-part and HOM antenna. The cavities and HOM coupler container are shown in transparent blue. F-part designed by DESY [16].

The f-part and HOM antenna will not be modified, as shown in Fig. 4, but the feedthrough will.

In order to avoid heating up the cold niobium mass around the HOM antenna and risking a quench, the HOM antenna will have a feedthrough made of sapphire to increase the thermal conductivity. The outer part of the electrical feedthrough is made of massive copper. This system is commercially available and made by Kyocera Corp. In Fig. 5 a sketch of the HOM antenna and flange is shown.

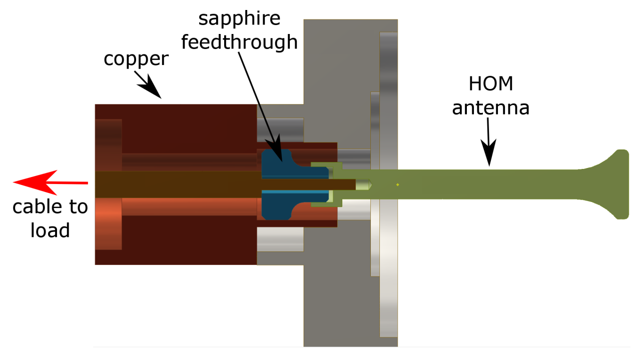

Figure 5: HOM antenna (green) and feedthrough (blue) based on Kyocera design. Sapphire feedthrough was chosen for a better thermal conductivity.

Because of the RF losses in the HOM antenna, it will heat up. The high thermal conductivity of sapphire will guarantee a good thermal connection between the HOM antenna and the copper piece. The copper piece is coupled to parts of the cold mass. The connection to the 2 K helium vessel has an excellent heat transfer and is used as a heat-sink.

To optimize the coupling between the copper and the cold mass and to calculate the heating of the HOM antenna, simulations using CST are ongoing. First simulations of thermal heat transmission are done, but further investigations are still required.

Integrated 4 K/2 K *Joule-Thomson Expansion*

To garantuee the 2 K helium supply, the Joule-Thomson expansion will be build, as shown in Fig. 6 The cryomodule will be extended with a combination of a 4 K phase separator, a 4 K/2 K heat exchanger, Joule-Thomson valves, a 2 K phase separator and valves for the 4 K operation to guarantee the supply of 2 K liquid helium and to increase the stability of the cryogenic system. Nevertheless, microphonics are an issue which cannot be ignored. Therefore, mechanical decoupling between cavities and croygenic supply has to be done.

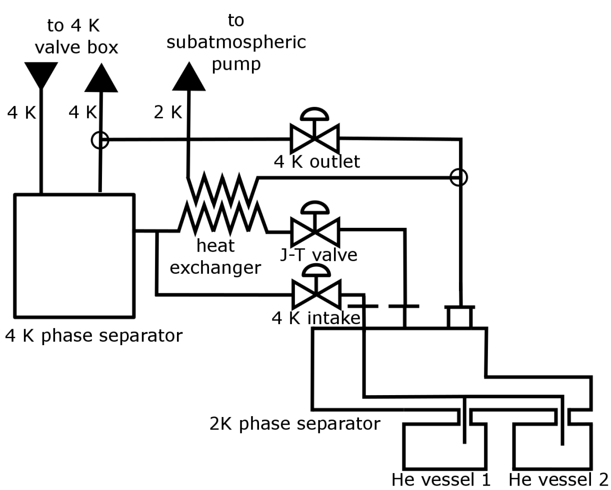

Figure 6: Basic principle of the integrated 4 K/2 K Joule Thomson expansion.

To produce the 2 K helium, the pressure of He in the vessel has to be decreased. So the 4 K helium has to be expanded to sub-atmospheric pressure by a Joule-Thomson valve. Therefore, it is necessary to suppress gas bubbles in the 4 K helium by adding a phase separator.

The efficiency of the system will be increased by pre-cooling the 4 K helium in a heat exchanger with the back-flowing 2 K helium.

For shielding the cold parts from room temperature, a thermal shield at 77 K will be installed. This shield is cooled by liquid nitrogen and wrapped into several layers of superinsulation.

As a connection point between liquid gas supply and cryomodule, a valve box has to be installed.

The design and technical realization of the stage will be done within the next year.

EDDY CURRENT SCAN OF THE NIOBIUM SHEETS

The niobium sheets are manufactured by Tokyo Denkai Co., Ltd. with a RRR > 300. To do quality control, they were tested by eddy current scan at DESY, Hamburg, Germany [17]. As result of the eddy current scan, 59 % of the sheets do not show any impurities or damaging in optical or eddy current analysis. 36 % of the niobium sheets show damaging or eddy current signals on one of both sides. 5 % of the niobium sheets had suspicious results on both sides. Those 5 % are not considered to be used for cavity building. Plans for a further analysis of these sheets with eddy current signals are ongoing.

STATUS OF THE PROJECT

The production of the cryomodules is in the design phase. Most of the long term delivery material is ordered. The niobium sheets to build the resonators have been already delivered. The begin of building the cavities will be in october 2015. The cryomodules will be delivered mid 2017 and first beam tests will be within the same year.

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