INJECTOR UPGRADE FOR THE S-DALINAC*

T. Kuerzeder#, A. Araz, M. Brunken, J. Conrad, R. Eichhorn, H.-D. Graef, M. Hertling, F. Hug, M. Konrad, M. Platz, A. Richter, S. Sievers, T. Weilbach, IKP, TU Darmstadt, Darmstadt, Germany
W. Ackermann, W.F.O. Müller, B. Steiner, T. Weiland, TEMF, TU Darmstadt, Darmstadt, Germany
J. Fuerst, ANL, Argonne, IL 60439, U.S.A.

Abstract

The injector section of the S-DALINAC currently delivers beams of up to 10 MeV with a current of up to 60 µA. The upgrade aims to increase both parameters to 14 MeV and 150 µA in order to allow more demanding experiments. Therefore, a modified cryostat module equipped with two new cavities is required. Due to an increase in rf power to 2 kW the old coaxial rf input couplers, being designed for a maximum power of 500 W, have to be replaced by new waveguide couplers. We review the design principles and report on the fabrication of the coupler and the whole module.

INTRODUCTION

The superconducting Darmstadt electron linear accelerator S-DALINAC [1] is a recirculating linac, using twelve superconducting niobium cavities at a frequency of 2.9975 GHz. It was first put into operation in 1987. Running at a temperature of 2 K the main acceleration is done by ten 20 cell elliptical cavities with a design accelerating gradient of 5 MV/m. The first pair of those cavities is used in the injector section of the machine. Behind this section it is possible to use the beam for nuclear physics experiments with a maximum energy of 10 MeV or the beam can be bent into the main linac. With its two recirculations and an energy gain of 40 MeV per pass the maximum design energy of the S-DALINAC is 130 MeV which can be used for several experiments in the adjacent experimental hall. The layout of the machine is shown in Fig. 1.

The S-DALINAC uses cryostat-modules with two cavities per module. Each cavity has an RF input coupler, which is capable of a maximum power of 500 W. Assuming a 5 MV/m gradient the beam current is limited to 60 µA for the injector and 20 µA for the main linac, which might be higher for lower the beam energies.

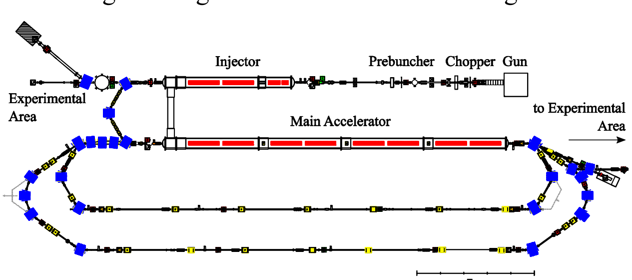

Figure 1: Floor plan of the S-DALINAC.

*Work supported by the DFG through SFB 634

#kuerzeder@ikp.tu-darmstadt.de

For future astrophysical experiments behind the injector, beam currents of 150 µA and above and energies up to 14 MeV are demanded. This paper describes the plans for a new cryostat-module in order to reach the requested parameters.

NEW POWER COUPLERS

The first step was to build a new power coupler which is capable of providing the necessary rf power of up to 2 kW to the cavity. In order to replace the old coax-to-coax couplers [2] a new waveguide-to-coax power coupler [3] was designed.

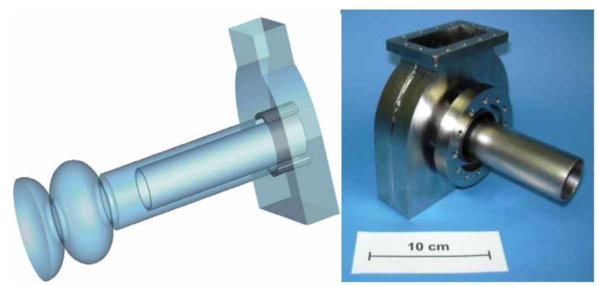

Figure 2: The design and the finally fabricated waveguide-to-coax coupler for the injector upgrade.

The design feature of the old couplers, namely minimized transversal fields, was kept by the new couplers. Using 2 two diaphragms the excitations of the transverse electromagnetic fields in the beam tube are reduced to less than -40 dB, which is essential in the low energy part of the accelerator. Fig. 2 shows how the coupling from waveguide to coax can be realized in combination with the cut-off tube of a S-DALINAC cavity. The length of the tube of the coupler is adjusted to guarantee an external quality factor of $5 \cdot 10^6$ which ensures acceleration of beam currents ranging from 150 to 250 µA. The whole coupler was made out of bulk niobium to make it superconducting. The fabrication of the couplers including the EB-welding was done by the FZ Juelich. Currently, the chemical cleaning of the couplers is underway.

DESIGN OF THE NEW CRYOSTAT

The current power couplers are using a coax-to-coax coupling, where the transition line has a diameter of only 21 mm. For the new couplers a WR-284 waveguide transition (cross area 72×34 mm^2) through the cryo-module was chosen. Accordingly the existing cryostat-module has to be modified.

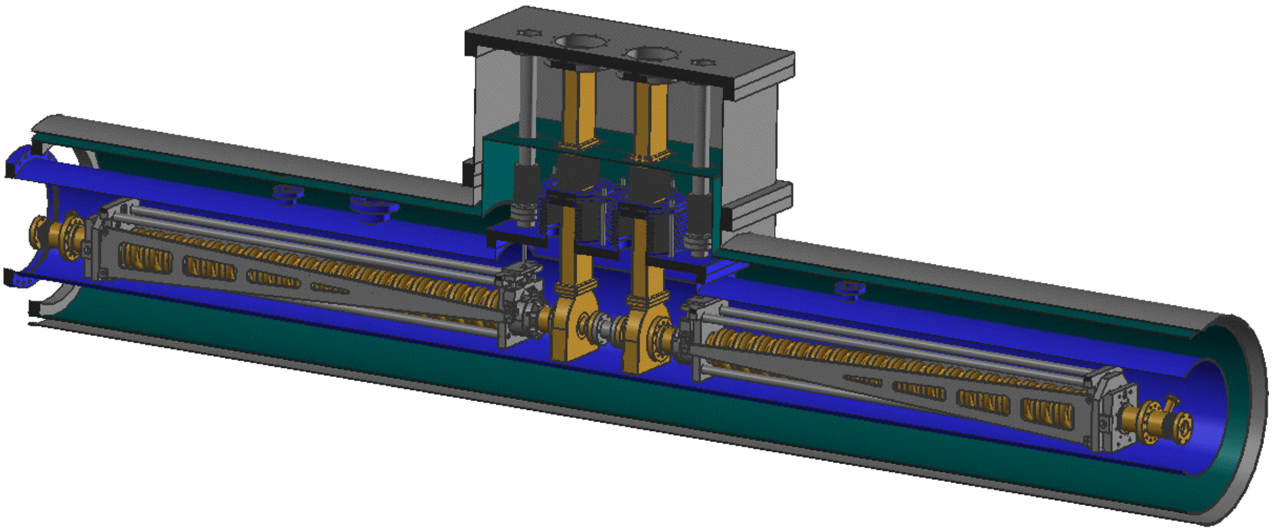

Figure 3: Design of the new injector module. The rf components like waveguides, coupler and cavities are shown in yellow, the helium vessel in blue, the nitrogen-shield in green and other parts like the outer vessel and the frequency tuner of the cavities are grey. For a better view the bench supporting the tuners and the beampipe is not shown.

Fig. 3 shows the 3-D view of the design. The cavities together with their tuners and the couplers are located inside the helium vessel. During 2 K operation the vacuum inside the beamline is about 10^{-8} mbar, while the pressure in the liquid helium is at 35 mbar. Between the helium vessel and the outer vessel a cylinder of aluminium is cooled by liquid nitrogen. The insulating vacuum of 10^{-5} mbar and some 20 layers of super-insulation ensure a minimum heat transfer.

The design had to solve, how to accommodate the bigger rf waveguide (compared to the small coaxial line), while keeping all sections leaktight and still mountable. Furthermore, the vacuum forces on the materials had to be compensated, especially the transition between the waveguide and the new coupler must be force-free. This was not critical in the old design, where the coax-to-coax coupler was supported by a shell out of stainless steel around it.

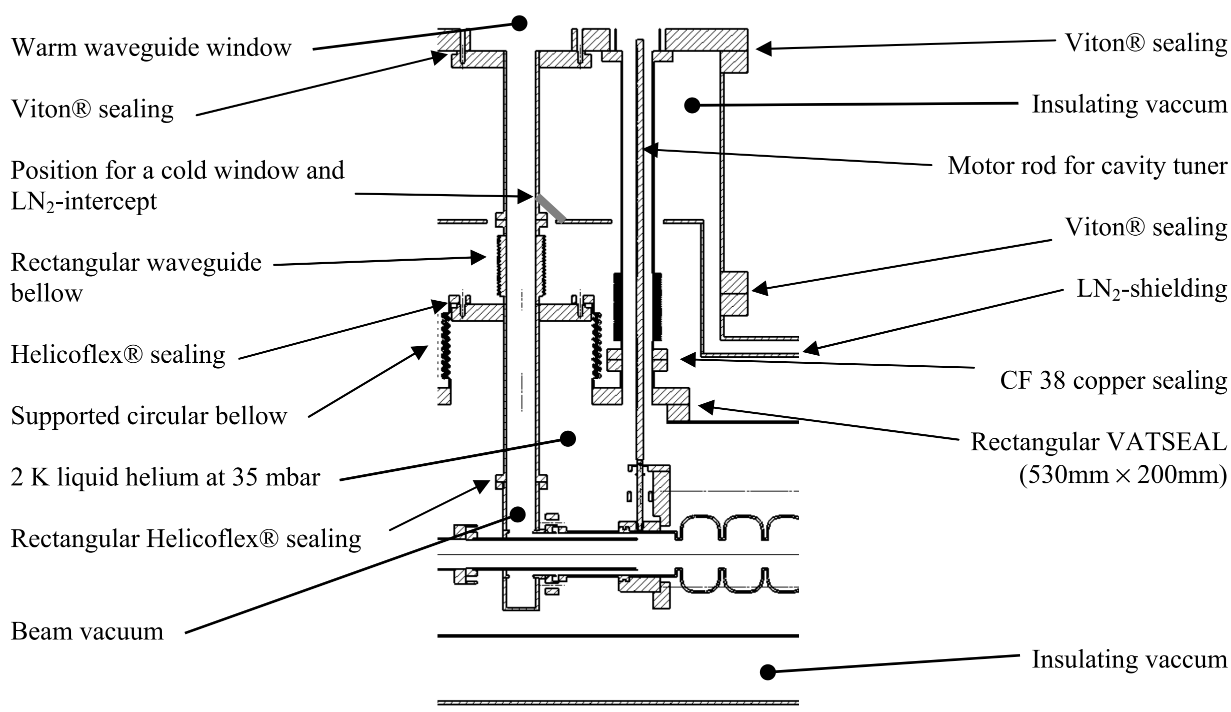

Figure 4: 2-D cut of the cross-section of the waveguide transition line surrounding from the helium vessel through the whole module. The different pressure stages and the position of sealings and other elements are shown.

The actual design consists of a complex waveguide, which will be connected to the coupler. Welded to this waveguide is a circular flange to be connected to an adequate counterpart sealing the helium vessel. This counterpart holds a bellow to compensate small misplacements in height and angle, oversized holes are planned for offsets in horizontal directions. To avoid strong forces on the input coupler this bellow can be fixed in its position by thread rods.

The rectangular waveguide bellow compensates the uncertainties in position and angle in the transition line. For the sealing between insulating vacuum and atmospheric pressure Viton® sealings are intended.

To keep the static heat losses per transition line below 0.4 W it has a thermal intercept to the nitrogen-shield behind the waveguide bellow. Furthermore, a cold waveguide window could be installed at this position to minimize losses from heat radiation. A warm waveguide pressure window will be installed outside the cryo-module. The static heat transfer from the warm into the nitrogen will be kept below 5 W per transition line.

Fig. 4 shows the cross-section of the module around the so called tower, where the positions of the sealings and bellows as well as the different pressure stages can be seen. The big opening of the helium vessel will be sealed with a special Vatseal gasket. A tube going from the helium vessel through all vacuum stages holds the motor rod of the cavity frequency tuner, where the motor is placed outside the cryo-module. This concept is the same as with the current modules and will not be changed. Also cables for the magneto-restriction and other parts like temperature sensors or a heat load will be located in that tube.

NEW SRF CAVITIES

The actual S-DALINAC cavities were built almost 20 years ago for an accelerating field of 5 MV/m, which was reasonable at that time. During operation gradients of 6 MV/m and more [4] were reached. So a beam energy of 14 MeV of the injector is possible without changing the cavity shape. Unfortunately, the design value of the quality factor of $3 \cdot 10^9$ was never reached [5], which sometimes limits the accelerator operation.

Besides our efforts to improve the quality factor of our existing cavities with chemical and heat treatments [6], it was decided to manufacture three new cavities to get a higher quality factor with today's best available technology. The fabrication will be done by Accel company, the delivery and first results are expected by the end of this year.

OUTLOOK

Currently, the design is finalized. Smaller components like bellows, flanges and special sealings must be fabricated in the next months. The vessel for the cryo-module has already been delivered and is shown in fig. 5. Like already mentioned the specifications for a cold waveguide window have to be made. Also chemical treatments for the new couplers and cavities have to be planned and accomplished. Additional projects are the construction of an improved magnetic shielding for the cavities as well as an external Q-tuner.

Including tests of all components and completion of construction, the timetable aims for a first test in operation in the first half of the year 2009.

Figure 5: New injector module for the S-DALINAC.

REFERENCES

[1] A. Richter, "Operational experience at the S-DALINAC", EPAC'96, Sitges (1996) 110.

[2] J. Auerhammer, R. Eichhorn, H. Genz, H.-D. Graef, R. Hahn, T. Hampel, C. Hofmann, J. Horn, C. Luettge, A. Richter, T. Rietdorf, K. Ruehl, P. Schardt, V. Schlott, E. Spamer, A. Stascheck, A. Stiller, F. Thomas, O. Titze, J. Topper, T. Wesp, H. Weise, M. Wiencken, T. Winkler, "Progress and status of the S-DALINAC", SRF'93, Newport News (1993) 1203.

[3] M. Kunze, W.F.O. Müller, T. Weiland, M. Brunken, H.-D. Graef, A. Richter, "Electromagnetic design of new rf power couplers for the S-DALINAC", LINAC '04, Luebeck (2004) 736.

[4] J. Auerhammer, H. Genz, H.-D. Graef, V. Huck, C. Luettge, A. Richter, T. Rietdorf, P. Schardt, E. Spamer, K. Rühl, A. Stascheck, F. Thomas, O. Titze, J. Toepper, H. Weise, "Latest of the Superconducting Darmstadt Electron Accelerator S-DALINAC", SRF'91, Hamburg (1191) 110.

[5] A. Araz, M. Brunken, M. Gopych, H.-D. Graef, J. Hasper, M. Hertling, M. Platz, A.Richter, S. Watzlawik, H. Kunze, W. Müller, S. Setzer, T. Weiland, W. Bayer and U. Laier, "Recent Results and Develpoments from the S-DALINAC", SRF'05, Ithaca (2005).

[6] R. Eichhorn, A. Araz, M. Brunken, J. Conrad, H.-D. Graef, M. Hertling, F. Hug, M. Konrad, T. Kuerzeder, M. Platz, A. Richter, S. Sievers, T. Weilbach, "Results from a 850°C heat treatment and operational findings from the 3 GHz srf cavities at the S-DALINAC", SRF'07, Beijing (2007).