COMPONENT QUALIFICATION AND FINAL ASSEMBLY OF THE S-DALINAC INJECTOR UPGRADE MODULE*

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Abstract

The injector of the S-DALINAC delivers currently electron beams of up to 10 MeV with a current of up to 60 µA. With the new cryostat-module an increase of both parameters, energies ranging to 14 MeV and currents up to 150 µA, are expected. For acceleration, the module houses two 20 cell elliptical niobium cavities which are used at a frequency of 3 GHz in liquid helium at 2 K. The RF power is delivered to the cavities through the different temperature stages by a WR-284 transition line which is connected to the resonator by a new waveguide-to-coax power coupler (being one of the major changes compared to the design of the existing module). We review on the design of the module and present the final component qualifications prior to cool-down. Also, a report on additional new design features, e.g. piezo actuators for tuning at 2 K, and the production of the cavities will be given.

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.

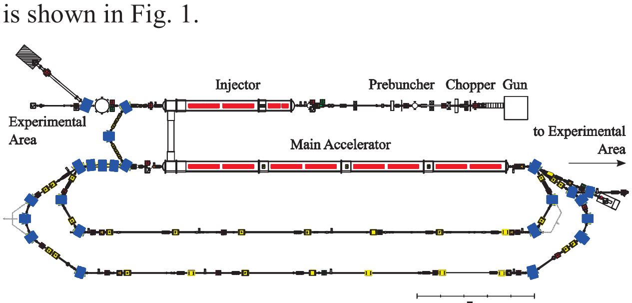

Figure 1: Floor plan of the S-DALINAC.

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 an 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 beam energies.

For future astrophysical experiments behind the injector, beam currents of 250 µA and above and energies up to 14 MeV are demanded. While a previous paper described the design issues [2] we will here focus on the results obtained so far.

NEW POWER COUPLERS

In contrast to the existing design the concept of the RF transition line to the power coupler had to be changed. While the current feed-through uses a coaxial line (being limited to 500 W) a waveguide approach had to be chosen for the new injector module in order to providing the necessary RF power of up to 2 kW to one cavity. The design of this waveguide-to-coax power coupler is described in [3]. Meanwhile, the coupler had been fabricated and tested at room temperature. Figure 2 gives the external quality factor as a function of the gap length, measured with a dummy pill-box cavity. The design feature of the old couplers, namely minimized transversal fields, was kept by the new couplers.

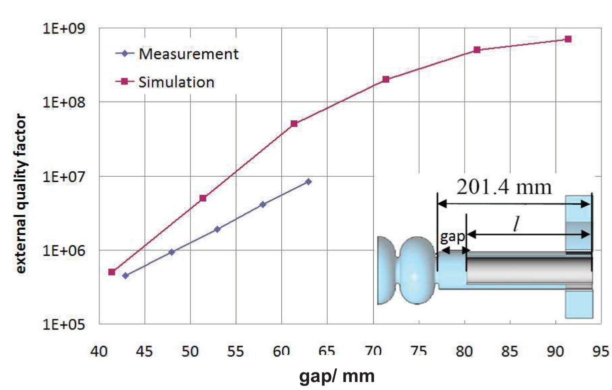

Figure 2: External Q as a function of the distance between the intermediate coaxial coupling tube and the first iris, calculated and simulated. The design value is $5*10^6$.

REDESIGN OF THE NEW CRYOSTAT

The cryostat design for the new injector module was mainly guided by copying as many features of the existing modules as possible [4]. Nevertheless, some

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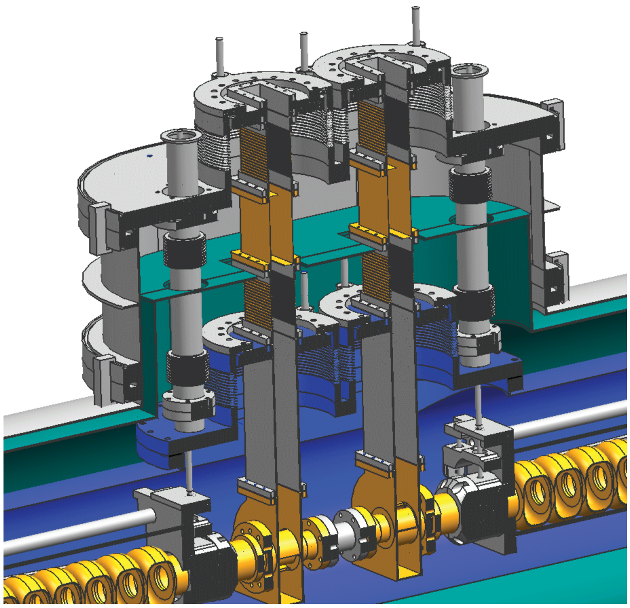

Figure 3: New injector module for the S-DALINAC showing the RF waveguide transition in detail.

major changes had to be made due to the increased specious requirements of the RF transition line (see Fig. 3). One essential design feature is the waveguide bellow (a copper plated, rectangular stainless steel bellow), which is a custom-made product. This bellow before and after copper plating is shown in Fig. 4.

Figure 4: Custom-made flexible WR-284 waveguides made from stainless, copper plated.

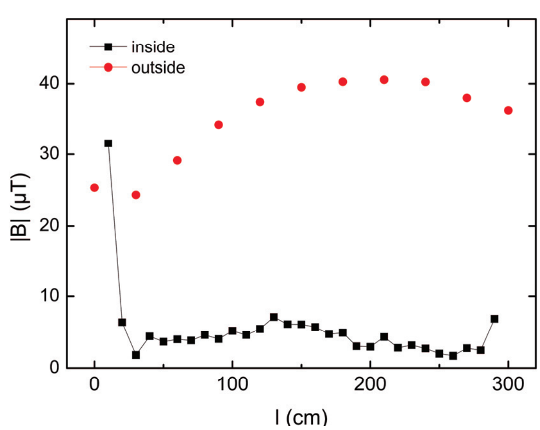

Figure 5: Measured magnetic field outside the cryo-module and along the cavity axis.

In between the two bellows, a orificed waveguide (described in detail in [5]) is used to thermally intercept at nitrogen temperature. The sealing against atmosphere is done with a warm window being a commercial product. In order to have compact flange transition between the two power couplers, a Quick-CF® connection has been qualified for the cryogenic environment [6]. To shield the earth's magnetic field, a 2 mm thick layer of CRYOPERM®, clamped around the helium vessel (@2K) was installed. The shielding effect along the cavity axis shown in Fig. 5, where we measured the magnetic field in the laboratory (red curve) and inside the cryostat (located at the same space). The measurements were taken at ambient using a hall probe, indicating a shielding factor of approx. 10.

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 were reached. For the injector upgrade it was decided to design for a gradient of 7 MV/m without changing the cavity shape but using state-of-the-art technology during production. Unlike the first series where single cells were built and measured before being welded to a full 20 cell cavity, dumb-bells were produced this time, being the common way to fabricate multi-cell cavities today. Details of these measurements and the trimming procedure have been reported in [4].

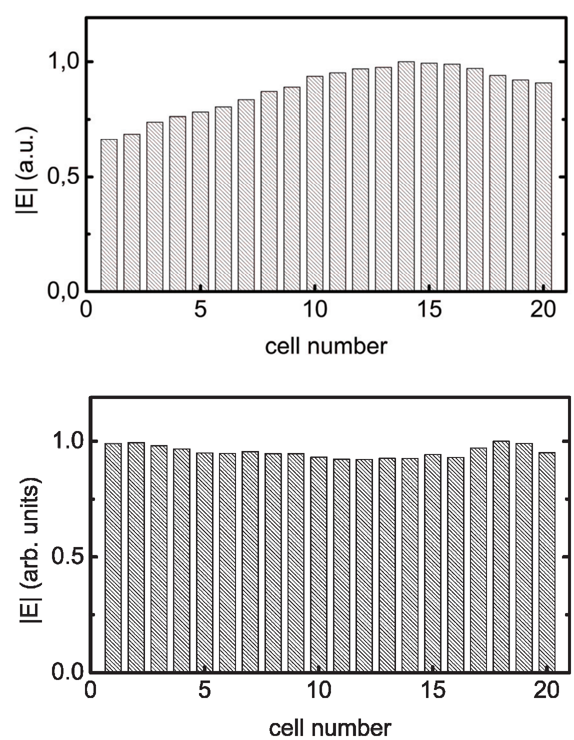

Figure 6: Field profile of the new injector cavity directly after the final EB welding (above) and after flatness tuning using an iterative algorithm (below).

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After the final welding of the cavity a three-stage chemical polishing was performed. First, the cavity was BCP treated to remove the damage-layer of 100 µm. After another frequency measurement, the second BCP removed an additional layer of 80 µm in order to reach the correct final frequency. The production steps up to this point were performed at Research Instruments while the frequency measurements and the following preparation steps were done in house. The final cavity was short only by 300 µm at the desired frequency, while ±2 mm was targeted. The field-distribution, measured by a beat-pull set-up of the first cavity is shown in Fig. 6. The field distribution after the final welding without any corrections is shown in the upper plot while the diagram below gives the field flatness after performing an iterative tuning. In-between, the cavity was heat-treated [7] in our UHV furnace at 650 °C.

PIEZO-ELECTRIC FINE TUNER

The tuning system for the superconducting accelerating cavities of the S-DALINAC consists of a lever mechanism that changes the length of the cavity in order to change its eigenfrequency. The length adjustment is done in two ways. With a motor it is possible to change the π-mode frequency within a range of ±500 kHz. In addition, there is a fast fine tuner with a tuning rage of ±1 kHz. In the standard modules, a magneto-strictive element is used. Due to the change in technology in piezo fabrication, we tested a commercial element in our bath cryostat. The stroke at room temperature, being 90 µm with a voltage of 100 V applied, reduces during cool-down. However, we measured at 2 K a frequency shift of 950 Hz, corresponding to a remaining stroke of 5 µm (see Fig. 7). In contrast to the magneto-strictive system, the piezo system showed a rather linear relation between voltage and frequency shift, which simplifies the operation of the RF control system.

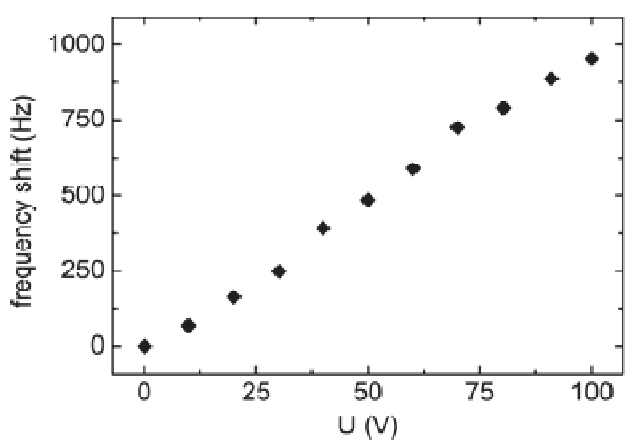

Figure 7: Frequency change induced by the action of a piezo tuner at 2 K. The corresponding stroke is 5 µm.

As one piezoelectric element has a length of 135 mm (compared to 900 mm of the magneto-strictive rod), three piezos, machanically in a row but electrically seperated will form the fine tuner for the new injector module. This gives an increased tuning range and a redundancy in case of failure of a single element.

OUTLOOK

The whole module is currently under assembly. There had been some issues during the complex leak testing procedure, all being resolved now. Due to these delays, the cool-down was rescheduled to end of May 2012.

REFERENCES

[1] A. Richter, "Operational experience at the S-DALINAC", EPAC'96, Sitges (1996) 110.
[2] 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, W. Ackermann, W.F.O. Müller, B. Steiner, T. Weiland, J. Fuerst, "Injector Upgrade for the S-DALINAC", EPAC2008, Genova (2008) 2731.
[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] T. Kuerzeder, J. Conrad, R. Eichhorn, F. Hug, A. Richter, S. Sievers, „New injector cryostat-module based on 3 GHz srf cavities for the S-DALINAC", Advances in Cryogenic Engineering, in press.
[5] R. Eichhorn, J. Conrad, F. Hug, M. Kleinmann, T. Kuerzeder, S. Sievers, "The Upgraded Injector Cryostat Module and Upcoming Improvements at the S-DALINAC", SRF2011, Chicago (2011), in press
[6] S. Sievers, J. Conrad, R. Eichhorn, R. Grewe, F. Hug, T. Kuerzeder, N. Pietralla, A. Richter, "Test of Components for the S-DALINAC Injector Upgrade" SRF2011, Chicago (2011), in press
[7] 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).