TEST OF COMPONENTS FOR THE S-DALINAC INJECTOR UPGRADE*

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Abstract

In 2009 a vertical bath cryostat was commissioned at the S-DALINAC. Since then, components for the new cryostat module within the framework of the injector upgrade have been tested. Measurements have been performed to check the leak rate of "Quick-CF" UHV flanges. Furthermore, the performance of piezo actuators in superfluid helium has been investigated. To extend the range of possible measurements at the vertical bath cryostat, systems for measureing the quality factor via the decay-time method and for quench localisation via second sound will be implemented this year.

INTRODUCTION

The superconducting Darmstadt linear accelerator S-DALINAC [1] is a recirculating electron 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 S-DALINAC uses cryostat modules containing two cavities per module. The first module is used in the injector section of the machine. Behind this section, the beam can be transported into an experimental area where nuclear physics experiments at a maximum energy of 10 MeV are performed, or transferred to the main linac for further acceleration.

The injector upgrade project [2] aims at a beam-energy and current increase from 10 MeV with 60 μA up to 14 MeV with 250 μA in the injector section. Therefore, it was necessary to construct a modified cryostat module to replace the existing one. Furthermore, new cavities had to be built, providing a good quality factor to achieve the higher accelerating gradient of 7 MV/m with acceptable power transfer to the helium bath. A vertical bath cryostat was used to test the components for the new cryostat module and is still being improved to provide a larger range of measurements for new test projects.

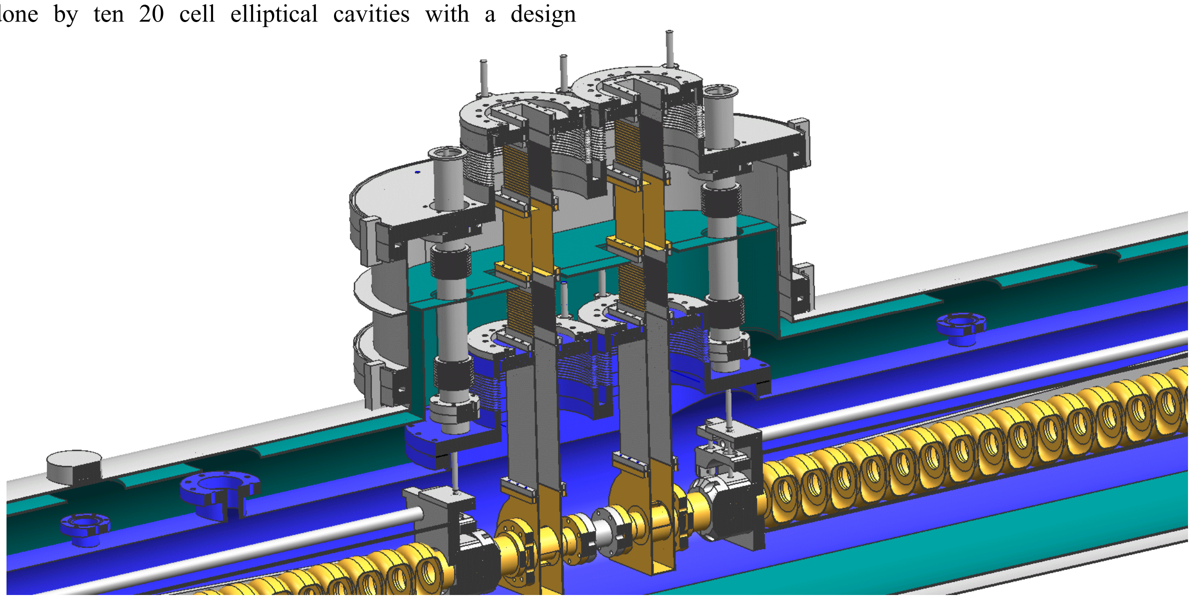

Figure 1: 3-D design of the new injector module. RF input and output couplers, together with the 20 cell cavities and their frequency tuners are shown inside the helium vessel. These inner parts are surrounded by a thermal shielding made of aluminium and cooled with liquid nitrogen. The outer pressure vessel is made of stainless steel. In the center, the waveguides and their transitions through the different vacuum/pressure stages in the so-called tower section are shown. Each transition line consists of two custom-made flexible waveguides with a special waveguide in between to intercept heat radiation. For a better view the carriage which supports the tuners and the beam line, several lines for nitrogen and helium, the magnetic shielding and the multi-layer-insulation are hidden.

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PIEZOELECTRIC ACTUATORS AT 2 K

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 different ways. With a motor it is possible to change the π-mode frequency within a range of ±500 kHz. Because this method is slow and the resonant frequencies cannot be adjusted with high precision it is called the coarse tuner. After the cooling-down of the accelerator the cavities are tuned to the operating frequency using this motor gear. For fine tuning an one meter long rod made of pure nickel is used. The rod is surrounded by a superconducting solenoid to produce high magnetic fields making the rod elongate under this field (known as magnetostrictive effect). Placed close to the cavity and shielded with some layers of CRYOPERM® it is possible to change the eigenfrequency by approximately ±1 kHz. It is used to tune the cavity to the reference frequency of the RF control system and for compensating frequency changes due to pressure variations in the helium vessel. These magnetostrictive nickel rods were chosen when the accelerator was built, because the stroke of piezoelectric actuators was to small at the temperature of liquid helium.

In 2009 the magnetic field distribution at the accelerating cavities of the S-DALINAC was investigated in more detail [3]. It turned out that the magnetostrictive elements used in our fine tuning system increase the magnetic flux at the position of the cavities of up to 100 µT if not degaussed properly. This value is nearly three times the unshielded earth's magnetic field. As shown in fig. 1 our cavity tuners are located inside the helium vessel close to the cavity. As magnetic fields can freeze-in into superconducting cavities during the cooling-down process (or re-cooling after a quench) and hence decrease the quality factor of the cavity, we started testing piezoelectric actuators to replace the magnetostrictive elements.

As new materials are available today and first measurements elsewhere [4] were promising, we decided to test those piezoelectric actuators in liquid helium inside a vertical bath cryostat [5]. This cryostat can be connected to the pumping stations of the main helium plant in order to reach 2 K at 35 mbar. A cavity with frequency tuner was brought into the vertical bath cryostat after replacing the magnetostrictive rod by a piezo actuator. The result of the measurement is shown in fig. 2. By applying a voltage of up to 100 V to the piezo, it was possible to tune the frequency of the π-mode by 950 Hz. In contrast to the magnetostrictive system [6], the piezo system showed a rather linear relation between voltage and frequency shift, which simplifies the operation of the RF control system.

One piezoelectric element has a length of 135 mm. Therefore, putting several piezos in a row is an option to increase the tuneable frequency range and to have redundancy in case of failure of a single element. The measurements indicate a maximum stroke of the piezo

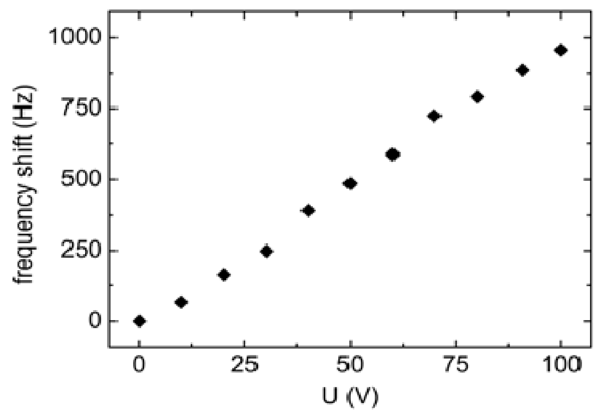

Figure 2: Measurement of the resonant frequency of a S-DALINAC cavity using a piezo tuner at 2 K. The plot shows the shift of the resonance frequency as function of the piezo voltage.

actuator of about 5 µm at 2 K compared to 90 µm at room temperature. Low quality factors due to remanent magnetic fields will be excluded in the future by replacing magnetostrictive elements by piezo actuators. In combination with the better surface preparation of the new S-DALINAC cavities we expect higher Q values as needed for the injector upgrade.

QUICK-CF IN SUPERFLUID HE

For vacuum connections in positions that are difficult to reach, the German company VACOM developed the Quick CF (QCF) system, shown in fig. 4. The manufacturer states that "The new QCF flanges combine the sealing principle of ConFlat® flanges with the simple mounting principle of KF connections. They fully comply with the UHV demands such as a leak rate <1.0E-11 mbar l/s and bakeability to 350 °C. Standard CF copper gaskets can be used for all dimensions." [7]

VACOM provided us with one QCF flange set for testing purposes. In a set-up consisting of a turbo-molecular pumping station, a DYCOR LC-D mass spectrometer and the QCF connection as device under test, we examined the characteristics of the QCF connection.

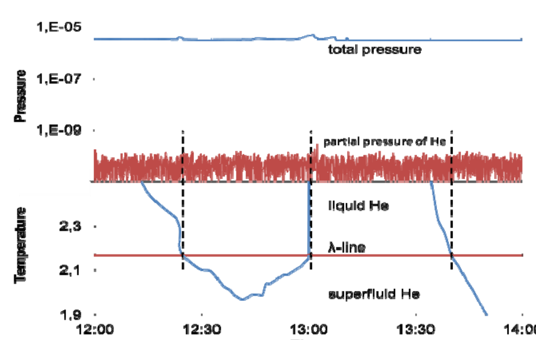

Figure 3: Temperature cycles through the lambda-point of liquid helium did not increase the leak rate.

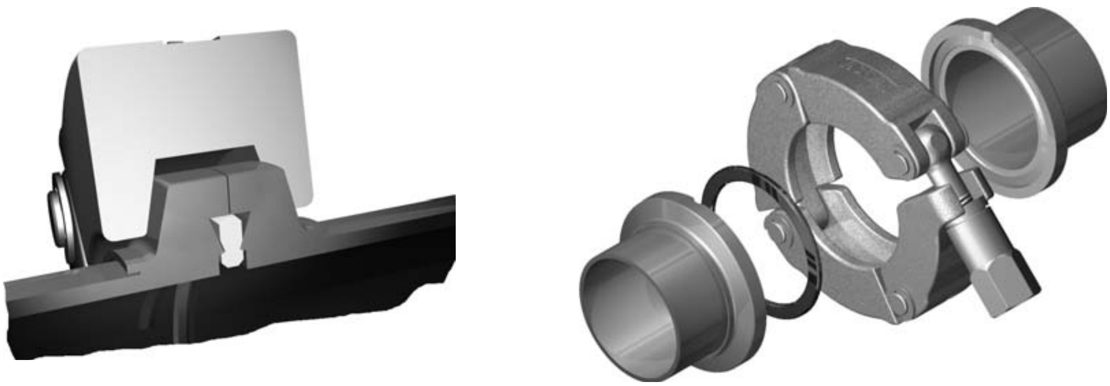

Figure 4: Sealing principle of QCF flanges with clamp chain and exploded drawing of assembly parts [7].

In several cycles of cooling-down and warming-up to the temperature of liquid nitrogen (77 K), the connection did not show any signs of leakage. Even cycles at cryogenic temperatures through the lambda-point of liquid helium did not increase the leak rate (fig. 3). This means that we can verify that the QCF connection in principle is leak-proof for superfluid helium.

We want to use these very compact vacuum connections between the two rf input couplers shown in fig 1.

NEW EQUIPMENT FOR THE VERTICAL BATH CRYOSTAT

To enlarge the range of possible measurements at the vertical bath cryostat a quality factor measurement system via decay time and an Oscillating Superleak Transducer (OST) array for quench detection via second sound is being constructed and will be implemented by the end of the year.

As has been shown in [8], Oscillating Superleak Transducers (OST) can be used to locate the quench spot of superconducting cavities. The quench causes a second sound wave in the superfluid helium that propagates at about 20 m/s. So it is easy to triangulate the quench location if enough OSTs "hear" the quench.

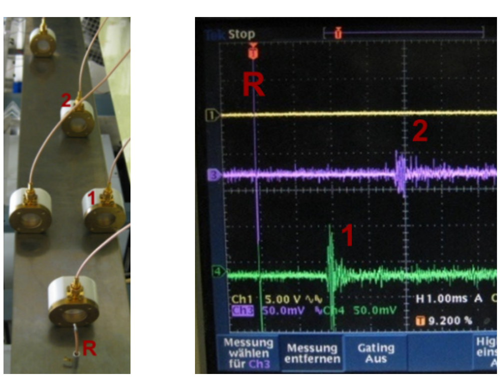

Figure 5: In house developed and built OSTs in a test set-up and oszilloscope screenshot of successful test. R labels the electrically pulsed resistor exciting the second sound wave and 1 and 2 the corresponding OSTs and their electrical response signals.

In house developed, built, and tested OSTs shown in fig. 5 will be used to build an array within which a cavity can be mounted. The newly produced cavities presented in [9] will be the first to be examined with this system.

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