SUPERCONDUCTING RF ACTIVITIES AT FZ-JUELICH

R. Stassen, H. Singer, F.M. Esser, Forschungszentrum Juelich, Germany, R. Eichhorn, TU Darmstadt, Germany

Abstract

For many years sc cavities have been designed and tested in Juelich: The 5-cell elliptical prototype cavity for the ESS was measured in a horizontal bath cryostat. A vertical test cryostat was installed to characterize the Halve Wave Resonators (HWRs) for the COSY linac project and several spoke-type cavities. During the measurements of the 352 MHz triple-spoke cavity (designed and built within the HIPPI collaboration) a 2K operation was established using some refurbished pumps from the University of Wuppertal. First experiences with the 2 K operation, sometimes hindered by thermo-acoustic oscillations, and the final results of the 352 MHz spoke-cavity will be presented. Furthermore, we will report on the cryomodule performance, built for the Half Wave Resonators. Currently, one prototype cavity was completed with a titanium helium cover and installed into the cryostat. The whole system with one cavity is now ready for first RF tests.

ESS 500MHz Test-Cavity

First experience with superconductive cavities at Forschungszentrum Juelich was made during the studies of a superconductive alternative for the ESS linac [1]. A complete test module (a horizontal bath cryostat including a 5-cell elliptical medium-beta β=0.75 cavity) was realized in co-operation with industry [2] in order to supplement the design work by experimental investigations (Fig. 1). The 500MHz elliptical cavity was operated for tests with RF-power up to 40 kW in the proposed pulse scheme of the ESS long pulse and short pulse version. The cavity reached the design value of E_{acc_cw}=5MV/m in CW and about E_{acc_pulsed}=11MV/m in pulsed mode operation.

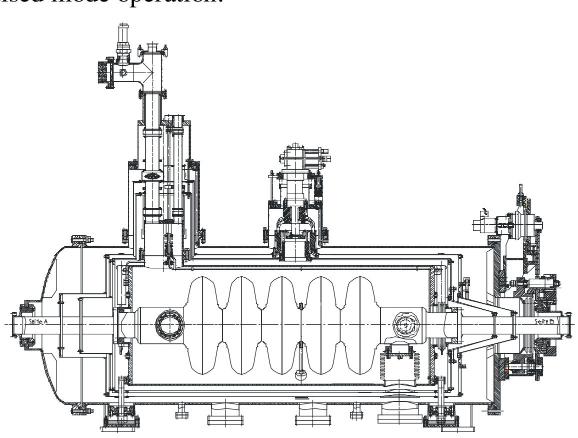

Figure 1: ESS test-module.

The Lorentz-force detuning was successfully compensated by feed-forward operation of the fast piezo tuning-elements [3].

760MHz Triple Spoke Cavity

Within the frame of the ESS project the design of this cavity started already in 2000. Details of the design, fabrication, and tests results of this compact cavity can be found in [4] and [5].

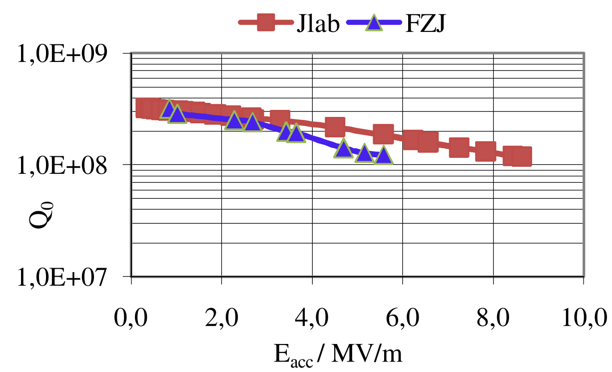

Figure 2: Q_0-E_{acc} curve at 4.2K of the 760MHz triple spoke cavity, measured at Jlab and FZJ.

During the first tests in Juelich the cavity quenched at about 5.5 MV/m. The cavity was shipped to Jlab and an additional chemical preparation was performed. The test 2 results at Jlab agree very well with the measurements at FZJ (Fig.2) and due to the additional preparation the cavity reached now a field of about 9MV/m limited by a quench. By contrast, at 2K, a field-level of E_{acc}~ 12.5MV/m was reached without any quench [4].

352 MHz HIPPI Triple Spoke Cavity

This spoke cavity (Fig. 3)was designed, fabricated and tested at the Forschungszentrum Juelich [6] within the framework of the High Intensity Pulsed Proton Injector (HIPPI) [7]. Intense cavity RF and structural analyses were carried out to optimise the medium beta cavity (β=0.48) with respect to high gradients and mechanical aspects like eigen modes and Lorentz-force detuning.

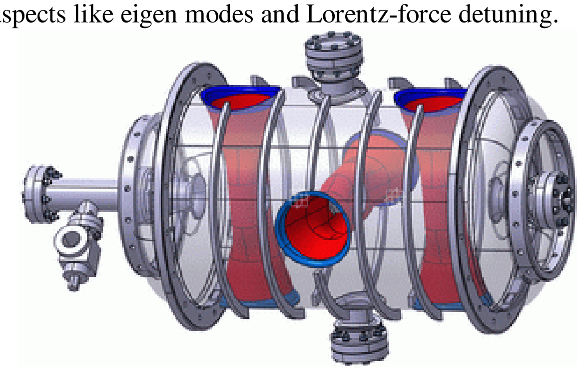

Figure 3: 3d-sketch of HIPPI triple spoke cavity.

The chemical treatment was done at Saclay in a closed acid circulation. After the removal of about 60 to 90µm of niobium the cavity was high pressure water rinsed at IPN-Orsay.

First cold tests were carried out using the vertical bath cryostat. Even with beam-tubes this cavity fits into the 70cm diameter of the cryostat. During the evacuation the resonance frequency changed from 353.2046 MHz to 353.475 MHz. At about 1MV/m some multipacting levels appeared, which were conditioned within some minutes.

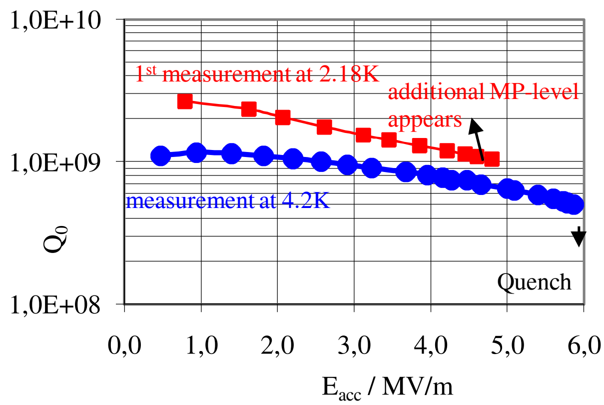

Figure 4: Q_0-E_{acc} curve of the HIPPI cavity.

A field value of E_{acc}~6MV/m was reached easily at 4.2K limited by a quench (Fig. 4). During the measurements of the HIPPI spoke cavity the installation of the refurbished old pumps came into operation. A temperature of about T_{end}=2.18K was reached, limited by the more than 30m long transferline from the cryostat to the pumps located in the cellar. Thermal acoustic oscillations appeared during the cool-down. Within some minutes the Helium pressure inside the cryostat rose to a value higher than the threshold of the safety valve, although the bypass to the refrigerator line was opened immediately after the appearance of the resonance. This effect was reproducible. It always appears when the difference pressure at the 2K-pumps exceeds 20mbar.

The Lorentz-force detuning (LFD) was measured at 4.2K and at 2K. Both measurements give the same LFD constant of K_{lfd_exp}=-5.5 Hz/(MV/m)². This value agrees very well with the calculated one (K_{calc}=-4.1Hz/(MV/m)².).

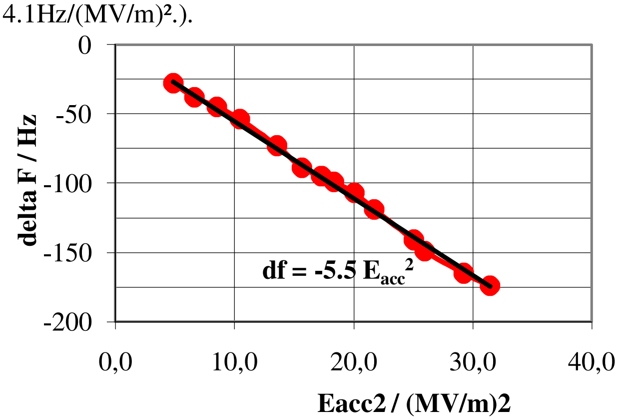

Figure 5: Lorentz-force detuning of the HIPPI cavity.

A similar good correlation was found concerning the cavity frequency and the helium bath pressure. After closing the helium flue gas valve the helium bath pressure increased while the frequency of the cavity decreased. This was directly measured with the frequency control loop (Fig. 6). The result of the measurement was df/dp_exp = -31.9 Hz/mbar whereas the calculation gives a value of df/dp_calc = -21.4 Hz/mbar.

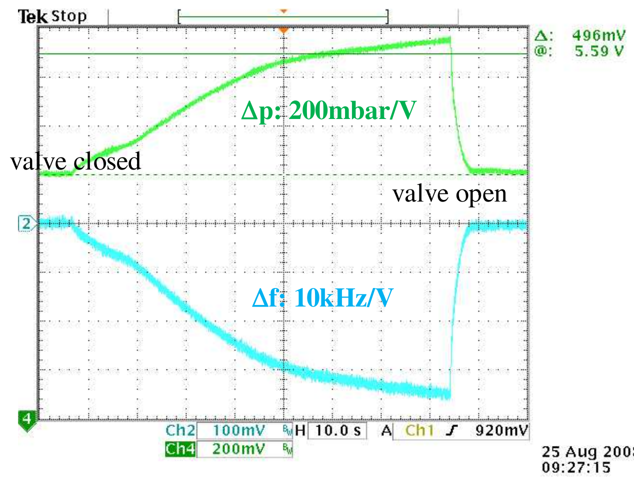

Figure 6: Sensitivity of cavity frequency of the HIPPI cavity.

A first estimation of mechanical eigen modes was done by using the tuner-system of the half-wave-resonators which was fixed at the upper end-cup stiffening ring of the cavity. The sinusoidale excitation with the piezos and the response measurement with the frequency control loop shows much higher amplitudes in the resonator frequency change at the following frequencies: 211 Hz, 282 Hz, 347 Hz and 391 Hz.

Linac Cryostat

The cryostat of the proposed COSY linac project [8] was designed to house 4 HW resonators [9] mounted on a common girder. The operating temperature is 4.2 K and the cryostat requires only liquid helium, neither secondary cold gas nor liquid nitrogen are required.

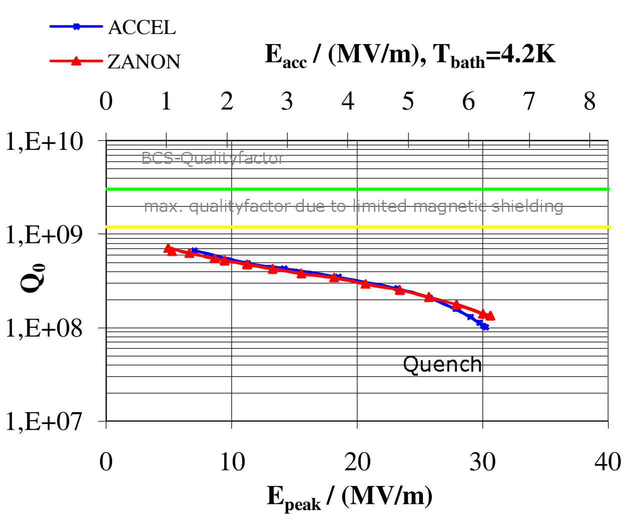

Figure 7: Q-E curve of the two 160MHz HWR-prototypes.

Two prototypes of the HW resonators were already manufactured by two different companies and tested in the vertical test cryostat several years ago.

The cryostat will provide a separated vacuum for the beam to ensure a low dust concentration. For easy mounting, a top loading design was selected. The longitudinal space of the cryostat was restricted to 1152mm, therefore, the cold-warm transitions at the beam ports must be kept as short as possible.

A first cooling down test was done using LN2 as pre-cooling medium. It was not possible to exchange all nitrogen into helium, even with four heaters located at the lowest point of the thermo-siphon. Thus, the temperature of the girder stayed constant at 77K. Even without pre-cooling the remaining air in the thermo-siphon is frozen out before the siphon is filled with helium. The next cooling down test started with a pre-pumping of the helium-system [4]. Now all temperatures decreased and within 200 minutes the expected liquid helium level was reached.

The static heat loss of the cryostat was measured to about 1W, mainly influenced by the short cold-warm transitions and the pumping line of the dummy cavities. Taking into account the missing RF-Couplers and tuners the static heat loss is lower than the estimated 3W.

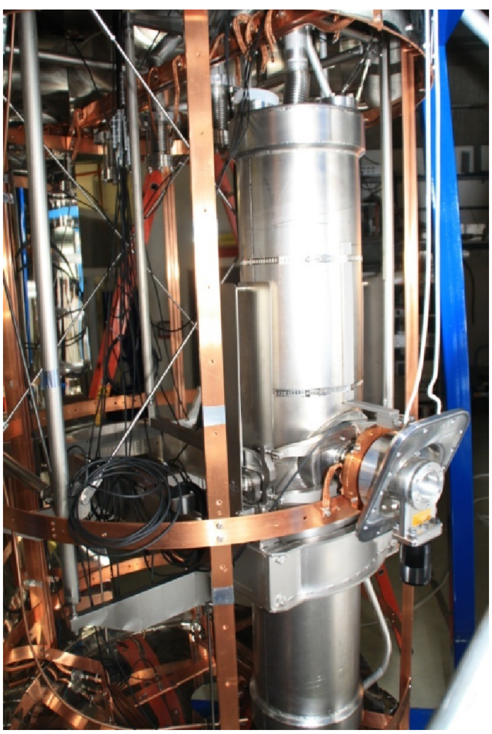

Figure 8: One prototype cavity installed in the cryostat before shield cooling MLI and magnetic shielding were added.

One of the two HWR-prototypes was already prepared by the manufacturer to install a lHe cover. The titanium cover was electron beam welded at the central workshop of the FZJ. During the installation of the cavity into the cryostat the disadvantage of the compact cryostat design became obvious (Fig. 8). Magnetic shielding, multilayer insulation (MLI) and thermal shield had to be dismantled piece by piece before any cavity can be exchanged.

The system is now prepared as having been in the COSY-Linac concept, with the exception of the medium power coupler [12], which is substituted by a simple but movable coupling loop. A first cold test is scheduled this year.

REFERENCES

[1] W.Braeutigam, et al., Design Considerations for a Superconducting Linac as an Option for the ESS, PAC99, New York, USA, 1999.
[2] M.Peiniger, H.Vogel, P.v.Stein, W.Bräutigam et al, Engineering and Fabrication of a low β Prototype SC Accelerator Module, SRF Workshop, 1999, Santa Fe, USA.
[3] R. Stassen, et al., Superconductive activities at COSY FZJ, SRF Workshop 2001, Tsukuba, Japan.
[4] E.Zaplatin, W.Braeutigam, M.Pap, M.Skrobucha, P.Kneisel, FZJ smallest SC Triple-Spoke Cavity, proceedings of EPAC08, Genoa, Italy
[5] E.Zaplatin, et al., Triple-Spoke Cavities at FZJ, proceedings of EPAC04, Lucerne, Switzerland, 2004
[6] E.Zaplatin, W.Behr, H.Glueckler, W.Guenther, R. Maier, M.Pap, R.Stassen, R.Toelle, J.Wolters, FZJ HIPPI sc triple-spoke cavity, proceedings PAC09, Vancouver, Canada.
[7] http://care.lal.in2p3.fr/
[8] R.Toelle et al., COSY-SCL, The superconducting injector linac for COSY, proceedings PAC03, Portland USA, 2003.
[9] F.M.Esser, B.Laatsch, H.Singer, R.Stassen, R.Eichhorn Development of a pulsed light-ion accelerator module based on half-wave resonators.
[10] R.Stassen, R.Eichhorn, F.M.Esser, B.Laatsch, G.Schug, H.Singer, The HW resonators in Jülich, Physica C 441, p. 179-184, Elsevier, 2006
[11] F.M.Esser, R.Eichhorn, B.Laatsch, H.Singer, R.Stassen, First cool down of the Juelich accelerator module based on superconducting half-wave resonators, proceedings EPAC06, Edinburgh, Scotland.
[12] G.Schug et al., The adjustable RF main coupler for the superconducting COSY Linac cavities, IKP Annual report 2002.