THE SUMMARIZED FINDINGS FROM THE JUELICH HALFWAVE RESONATORS

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Abstract

The operation of a superconductive cavity is mainly influenced by the ancillary subsystems. Within the design of a superconducting linac, a cryomodule based on superconducting Half-Wave Resonators (HWR) was designed and prototyped. This paper will report the results of all the ancillary parts of the module: The RF coupler will be described and the measurements will be reported, the tuner design will be reviewed and the results will be summarized and finally, a status report on the cryomodule fabrication and assembly will be given.

RF MAIN COUPLER

The layout of the Juelich HWR (described in more detail in [1]) and the mounting conditions in the compact cryostat favoured a coupler design according fig. 1. A capacitive coupler at the used access port is not possible because of the high power losses (about 100W) by the magnetic field in that cavity-region. Thus an inductive coupling was chosen. The design of the inductive loop coupler was mainly dominated by cryogenic aspects and a broadband construction to use the coupler at both accelerating frequencies (160 MHz and 320 MHz) and as output coupler of higher-harmonic components induced by the beam bunches. The coupling is designed to be variable and can be changed to give an external Q_{ext} ranging from $1*10^6$ to $1*10^{10}$ at a pulsed RF-power of at least 4 kW with a pulse length of 10 ms at a repetition rate of 2 Hz. The basic parameters of the main coupler are summarized in tab. 1.

Table 1: RF and mechanical parameters of the main coupler

Loaded Cavity Q	Adjustable 1E6-1E9
Length	600mm
Adjustable length	+/- 25mm
Ceramic material	F99.7 (HF)
Vase tang. E field at B_p	310kV/m
Vase rad. E field at B_p	250kV/m
Vase tang. B field at B_p	35mT
RF pk. power, 100% refl.	4kW
Aver. power, 100% refl.	80W
Char. Impedance	50 Ohm
RF attenuation, 0% refl.	0,005 dB
RF loss at 300K	~ 1.5W
RF loss at 80K	~ 0.7W
RF loss at 4K	~ 0.1W

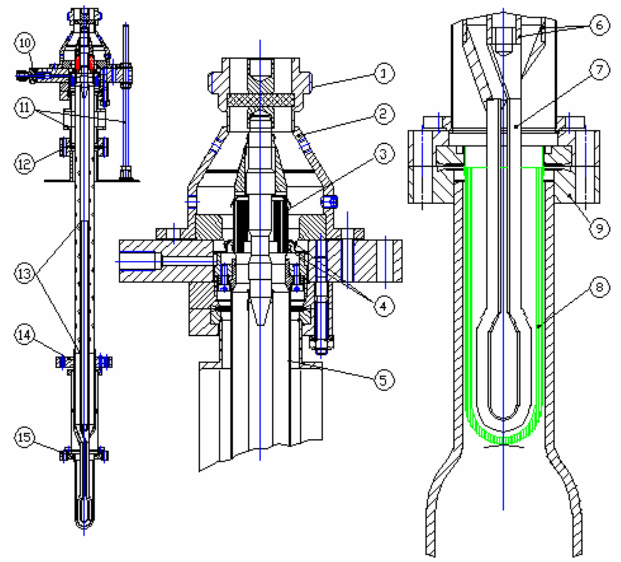

Figure 1: RF coupler (complete view on the left, warm part in the middle and the cold end on the right), (1) rf connector (2) conical line with tuning screws, (3) coaxial ceramics (warm), (4) contact springs transition lines, (5) Cu plated steel-tube, (6) OFHC Cu coax line, (7) OFHC Cu loop and (8) ceramic vase (cold), (9) cavity flange, (10) air rinsing, (11) bellows and arresting unit, (12) cyrostat flange (CF35), (13) Cu/steel interfaces, (14) thermal intercept, (15) vase flange

As a special design feature, a cold ceramic window is used in order to preserve the cavity from entering dust while changing the coupling strength, which could spoil the superconducting surface. This window – installed in the clean room - separates the cavity vacuum from the

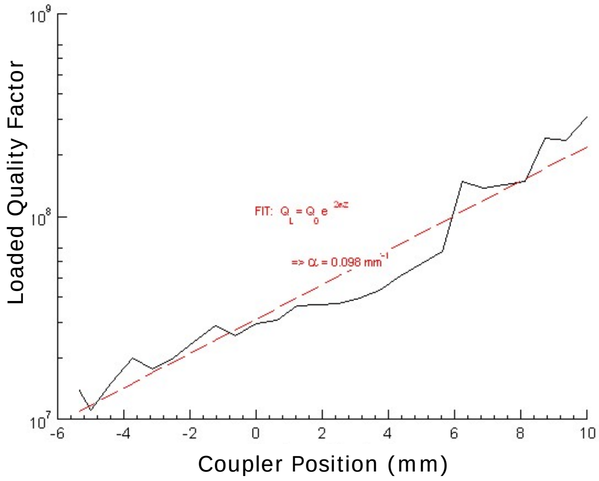

Figure 2: Measured loaded Q-value as a function of the coupler position.

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insulation vacuum of the cryostat and splits up the coupler mechanism from the prepared cavity.

During the commissioning, only small changes at a spring contact were necessary to reach a routinely failure free operation at the design values. Beside the proof of power operation at the design level, the variability of the coupler has been measured (see fig 2).

CAVITY TUNER

For the successful operation of a sc cavity, a tuning system is required to bring the cavity on resonance after installation and cool-down. Usually, the tuner deforms the cavity within the elastic regime. Once the cavity is on resonance, the tuner has to compensate for the changes in frequency due to pressure and temperature fluctuations of the helium bath. Furthermore, due to the pulsed operation of the resonator, the cavity deforms itself under the action of the rf fields (this effect is known as Lorentz force detuning), which is compensated for by a fast-tuning mechanism [1]. The concept is shown in fig. 3.

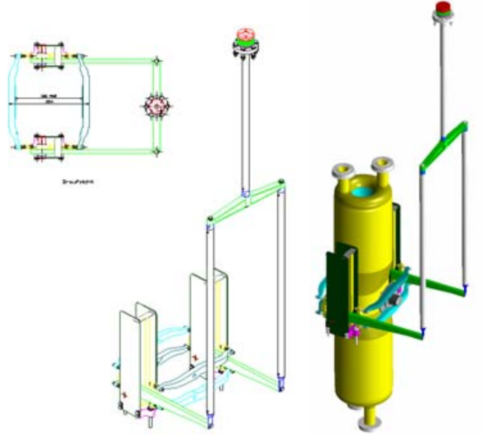

Figure 3: The cavity tuner in different views. The mechanism without cavity is on the right, the sketch to the left shows one cavity equipped with its tuner.

The system is composed of two parts: (1) the stepping motor including the gear unit and (2) three piezoelectric elements and the mechanical lever mechanism. While the whole drive unit is located outside the cryostat at ambient temperature, which is favourable for maintenance purposes, the mechanical part is located inside the cryostat at cold temperatures. The tuning motion is imparted to the cavity through an arrangement of rods vertical to the beam axis from the top flange of the cryostat. These rods lead to two levers, one on each side of the cavity, transforming the vertical motion into a motion parallel to the beam axis using only elastic deformations of the components.

Table 2: Parameters of the cavity tuner

mechanical pre-adjustment	± 2 mm
gear ratio	1:6
slow tuning range (stepping motor)	±0,3 … ±0,6mm
stepping motor sensitivity	1.2 Hz/step
stepping motor tuning speed	2.4 kHz/sec
fast tuning range (piezo actuators)	15µm
Material	Titanium & Stainless
Motor and Piezos	At ambient
Tuning sensitifity of the cavity	120 kHz/mm

The main strain is then located in a torsion tube leading to a squeezing of the cavity at both beam ports (see fig. 2). The parameters of the tuner can be found in tab. 2.

The tuning range is defined to be ±0.3mm … ±0.6mm (slow-tuning) and 15µm (fast-tuning), respectively. Due to the extremely different requirements for the two tuning ranges the tuning system itself consists of two parts: a stepping motor including a gear unit represents the slow-tuning system whereas the fast-tuning system is realized by three piezoelectric actuator elements. To make sure that the tuning system performs accordingly several tests were made.

In a room temperature test set-up, the operation of the slow and the fast-tuning system was checked. Special displacement transducers with a precision better than µm were used. To simulate the effect of the cavity, a spring is used as a dummy with a value of the spring stiffness twice as high as the stiffness of the cavity. Figure 3 and 4 report

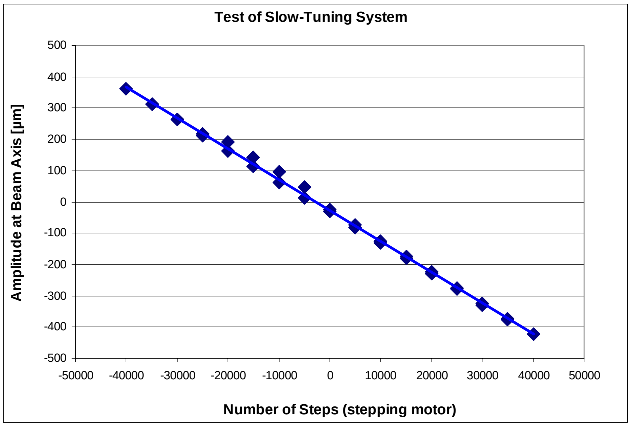

Figure 4: Performance of the slow tuner (stepper-motor) at room temperature

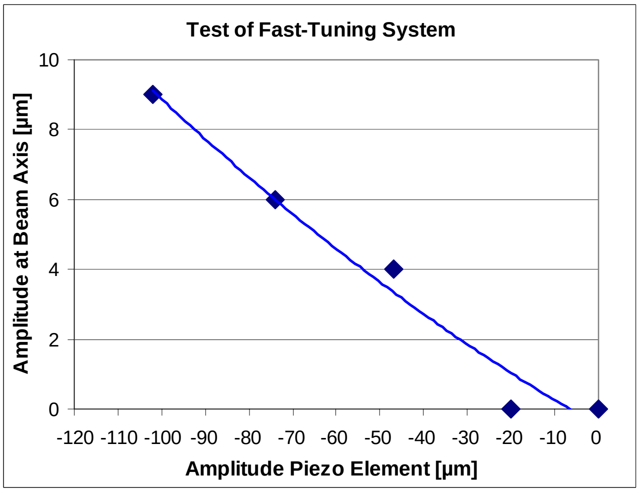

Figure 5: Performance of the fast tuner (piezo actuators) at room temperature

the test results indicating clearly that the tuner fulfils all requirements perfectly.

However, when cooled down to 4 K an operated with the cavity, the behaviour of the tuner mechanism shows a small hysteresis loop indicating a non backlash free operation (fig. 5).

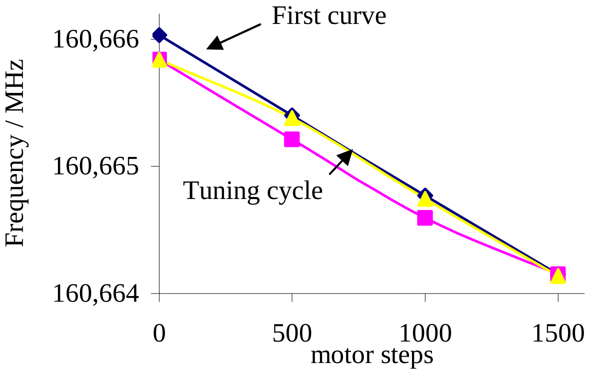

Figure 5: Hysteresis of tuner measured at 4 K with the cavity as detector

CRYOSTAT

The major concern during the development of an optimized cryostat was to meet the main parameters fixed by the beam dynamics and by the requirements of cavity operation. This mainly influenced the choice of designing a separated vacuum system (beam and insulating vacuum not connected), having many consequences on the cryostat layout. Due to beam dynamics, the cryostat had furthermore to be very compact. This restricted space together with the need for separated vacuum systems lead to an unconventional design in the beam port region, where the outer vacuum vessel has a round shape, while the diameter changes to an angled surface in the region of the beam tube. Like other accelerator modules a top-loading design approach was chosen to allow for easy and clean mounting. The spacing between the resonators was kept to a minimum value of 56 mm. The length of the cold-warm transition at the beam tube amounts to only 70 mm, leading to a high real-estate gradient of about 2.7 MV/m within a unit cell. The cooling of the cavities is done via an open-cycle thermosyphon.

To keep the system as simple as possible and to allow a stand alone operation, the cooling of the radiation shield and the thermal intercepts is done by using gaseous helium evaporated from the liquid helium reservoir. The temperature of the gas leaving the cryostat is expected to be 50 K during normal operation. Figure 6 gives an impression of the whole cryomodule, for a more detailed description see [3].

OUTLOOK

Even so the project [4] once triggered the design of the cryomodule was discontinued, the development of a cryostat itself turned out to be a scientific challenge, keeping the people involved, busy and motivated and the funding at least for prototypes of all components alive.

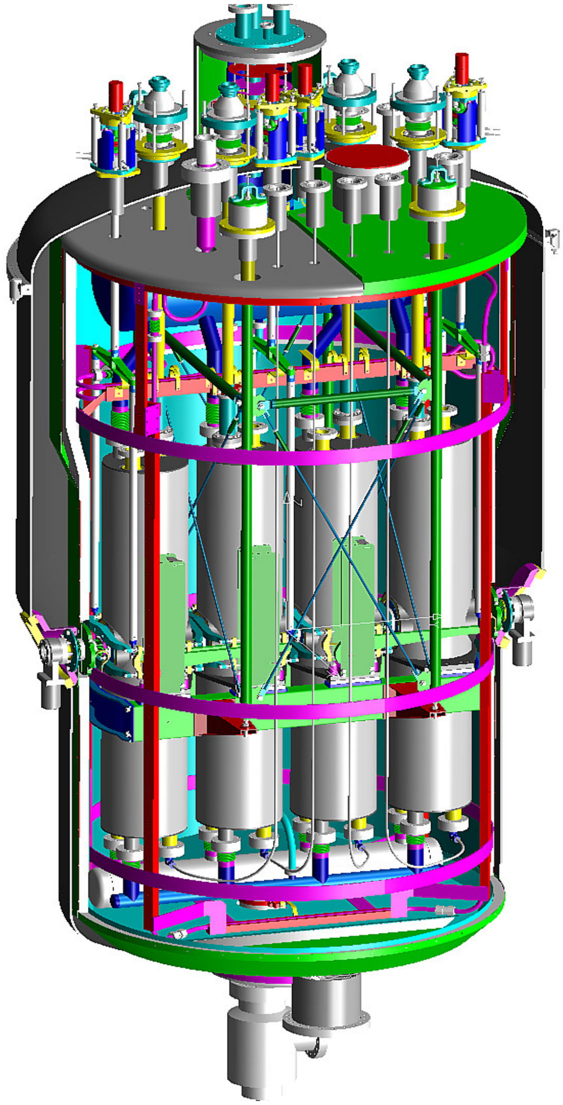

Figure 6: The cryomodule housing 4 resonators. Its diameter is 1.3 m, the height 3.3 m.

Most components have been built and were successfully tested up to now. The fabrication of the cryostat is underway, almost all sub-assemblies are finished. The global assembly will start in October and should be finished by November. After some testing at ambient a first cool-down, probably without the cavities for security reasons is envisaged to take place shortly after New Year 2006.

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