FIRST RESULTS OF PULSED SUPERCONDUCTING HALF-WAVE RESONATORS

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Abstract

A pulsed linac for the cooler synchrotron COSY was projected based on superconductive half-wave resonators (HWRs)[1]. The concept of single phased resonators is a great challenge related to the requirement of accelerating protons and deuterons up to a similar energy. A cryomodule, which houses four cavities was designed taing into account the restricted space and the special requirements of a linear accelerator.

Two prototypes of the 160MHz, niobium made Half-Wave Resonators (HWRs) were built at different companies. The fabrication methods differ slightly concerning the top and bottom parts of the cavities as well as the welding of the inner and outer conductors. First results of warm and cold measurements will be presented. The behaviour of the adjustable 4kW main coupler as well as the mechanical tuner can be tested together with the HWR in a new vertical test-cryostat.

HALF-WAVE RESONATORS

The design of the HWRs was dominated by the parameters of a Linac concept to fill the synchrotron COSY at FZ-Juelich with polarized protons and deuterons up to the space charge limit.

The first prototype of the 160 MHz HWRs was tested at room-temperature (RT) prior to any chemical preparation. Figure 1 shows the good conformity between the field profile measurements in comparison to the calculated accelerating field by the simulation tool MicrowaveStudio [2].

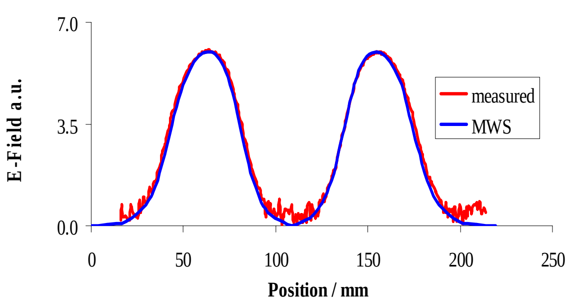

Figure 1: Field profiles: measured and calculated by MicrowaveStudio (MWS)

Due to the fact of a strong RF-Transmitter at 80 MHz inside our research centre the working frequency of the HWR have been shifted to a little higher operating-frequency for undisturbed measurements.

The resonant frequency measurements during the production process and each step towards operation (like pumping and cool-down) are compared with the calculated values in tab. 1.

Table 1: calculated and measured frequency changes

	Calculated	Measured
f_o at RT	--	160,4 MHz
Δf after pumping	- 32 kHz	- 50 kHz
Δf after cool down	+ 270 kHz	+ 260 kHz
Tuning sensitivity	140 kHz / mm	120 kHz / mm

The control of the resonant frequency after each step during manufacturing and preparation allows a good estimation of the final frequency range during a series production. Figure 2 shows the cavity test set-up before the final welding was done.

Figure 2: Frequency check of the unwelded parts at ZANON

COUPLER AND TUNER

First tests of the adjustable RF coupler as well as the tuning system had been carried out after cooling down the untreated cavity. Even though the cavity did not reach high gradients, the achievable low field levels were sufficient to test the behaviour of the tuner and the tuning control system. The layout of the mechanical tuner is shown in fig. 3. The construction with a small horizontal dislocation allows an installation into the cryostat combining two cavities [3]. No additional length in longitudinal direction is required keeping the design compact.

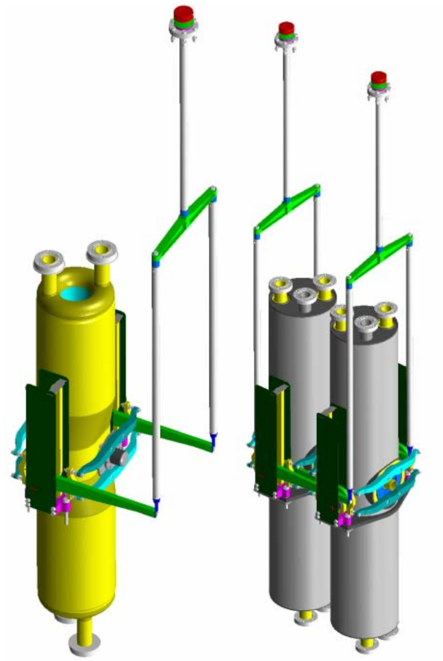

Figure 3: Tuning System and mounting position of a pair of cavities inside the cryostat.

The actuating mechanical part of the tuner for each HWR consists of two parts: a stepper motor driving the coarse tuner and a piezo fine tuner both mounted outside the cryostat, allowing easy access for maintenance. The possible change in length of the piezos is about +120µm. A gear of 1:7 minimizes the microphonics effects of the long tuning rods and lowers the tuning forces. The resulting movement on the cavity is sufficient to compensate for the Lorentz-force detuning during the pulsed operation.

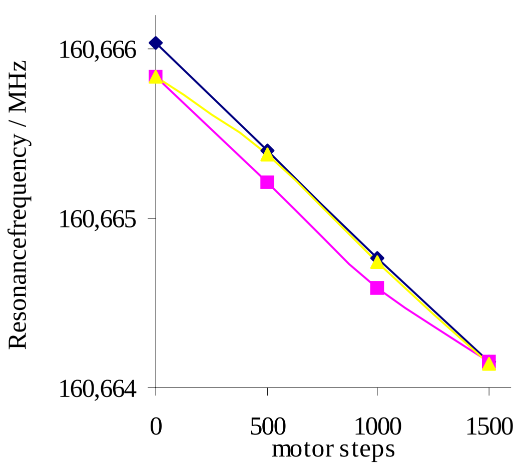

Figure 4: Hysteresis of steppermotor-driven tuner

The high sensitivity of the stepper motor system of about 1.2 Hz / step allows a frequency control based only on this stepper motor, corresponding to a frequency change rate of 2.4 kHz / s.

The behaviour of the tuner mechanism shows a small hysteresis loop (see fig. 4). This hysteresis does not affect the reaction of the resonant frequency control system, but can evoke a mechanical resonance when changing the direction of movement. Further investigations have to be done to analyse this mechanical resonance in the final cryostat.

The RF-coupler had been designed to allow an adjustable coupling from $1*10^6$ to $1*10^{10}$ at a power level of at least 4 kW [4]. The mounting condition of the inductive loop-coupler using one of the access ports foreseen for chemical treatments minimized the heat transfer to the liquid helium. The first multi-pacting barrier of the coupler had been found at about 30 W of RF power operating the coupler fully mismatched without any cavity. This very “soft” barrier had been easily exceeded after some minutes of conditioning.

A cold window will be used to separate the cavity vacuum from the insulation vacuum of the cryostat. It also preserves the cavity from entering dust during the change of the coupling strength [5].

Figure 5: Cold window before (right) and after Ge plating (left)

This cold window is installed in the clean-room and separates the coupler mechanism from the prepared cavity.

Table 2: Basic parameters of the cold window

Film material	Amorphous Ge
@ substrate temp.	300K
Rest-gas press.	2-3 E-6 mbar
Evapor.. rate	30nm/s
Evapor. Angle	90-45 degree
Film thickness	80nm
DC square resist. (300K)	52-8000 MOhm
Estimated DC sq. resist. 4.2K, 1MV/m	1E18 Ohm
4.2K, 20MV/m	1E9 Ohm
Estimated RF sq. resist. 4.2K, 160MHz	3E8 Ohm

A thin Ge-layer has been plated to protect the window from static discharges and lowers the multi-pacting effects at the ceramic surface due to the fact that Ge has a very low secondary emission coefficient. The basic parameters of the Ge-film are summarized in tab. 2.

FIRST COLD TEST

So far the prototype tests have been started only with one cavity due to delays in the production process of the second competitor. A commercially available standard procedure has been used to get a chemical preparation of this prototype. The special high pressure water-rinsing through the access ports at the bottom and top flange of the HWR-prototype guaranteed an optimized cleaning of the surfaces. Details of the preparation are summarized in the following list:

- 60µm BCP chemical etching in a temperature controlled closed loop operation
- 60µm BCP after a 180° rotation of the cavity
- HPR through all of the four access-ports
- Drying by pumping
- Baking at 100° C for 4 hours
- Pumping to $1*10^{-5}$ mbar

The cavity, prepared in this manner, was cooled down to 4 K in a vertical bath cryostat without further pumping of the cavity vacuum. A first multi-pacting (MP) level occurred at the low RF-level of about 2mW and a loaded Q-value of $1.3*10^{6}$. Even after conditioning for some days close to the MP-level the MP-barrier did not disappear.

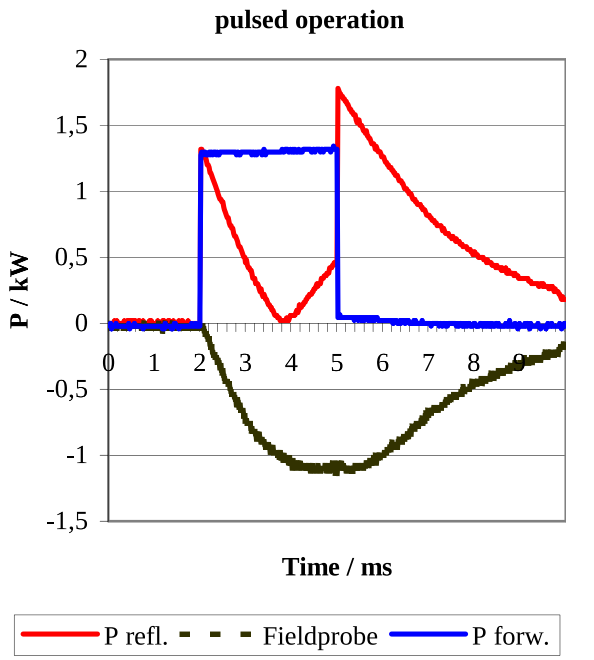

Figure 6: RF Power balance during pulsed operation of the MP limited HWR

Operating the resonator in a pulsed operation mode with RF-levels of about 1kW showed that this MP-barrier can be exceed.

The forward and reflected RF-power signals as well as the corresponding field-level, measured with a negative RF-diode are shown in fig. 6. More than half of the pulses at a repetition-rate of 5Hz exceed the MP-barrier while the other half are dominated by the MP. At 16:00, 01.07.2004 the MP barrier has been exceeded. The first field-measurement are presented in fig. 7. The cavity was operated in cw. Due to insufficient cooling (low liquid helium level inside the bath cryostat), a thermal breakdown was observed at 2.3 MV/m. In pulsed operation (40 ms, 0.2 Hz), the cavity reached more than 6 MV/m. As the testing continues more results are expected within the next weeks.

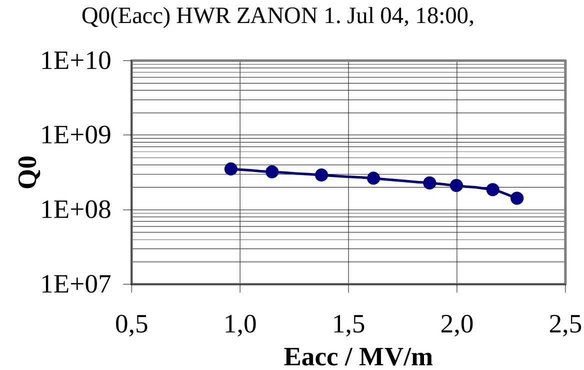

Figure 7: First Q_0-E_{acc} measurement with low lHe-level

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OUTLOOK

Testing the first cavity will go on during the next weeks. In order to reach higher gradients, several measures are foreseen:

- Baking of the cavity for a longer period (>24 h at 150 C)
- Improved vacuum pumping on the cavity to achieve a residual gas pressure below $1*10^{-8}$ mbar prior to cool down
- Surface improvement by means of He-processing

The second prototype cavity is expected to be delivered by late summer, the testing will take place in fall. Comparable results, relating the different behaviours to the slightly different geometries and fabrication processes will be available by the end of the year.

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