CONSTRUCTION AND TESTING OF THE β=0.31, 352 MHZ SUPERCONDUCTING HALF WAVE RESONATOR FOR THE SPES PROJECT

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Abstract

The interest in low- and medium- beta superconducting cavities is presently focused to future high intensity proton, deuteron and heavy ion linacs. A particular application is acceleration of cw and pulsed beams of variable q/A, which requires cavities with a small number of gaps and excellent mechanical stability. We have designed and constructed a β_0=0.31, 352 MHz SC half-wave cavity aiming to similar characteristics and fitting the requirements of the intermediate-beta section of the LNL-SPES driver. The status of the project and the first test results are presented.

INTRODUCTION

The SPES project at Laboratori Nazionali di Legnaro includes a superconducting linac for high intensity proton, deuteron and A/q=3 beams which requires 2-gap, β_0=0.31 cavities at 352 MHz [1]. LNL is participating also to the EURISOL radioactive beam facility program, where similar cavities have been proposed both for the Driver and for the Post-accelerator linacs [2]. We developed a Half-Wave (HW) resonator prototype that could be used in all these applications, suitable also for pulsed operation. We started from the characteristics of the LNL coaxial QWRs to design this HWR; the concept can be easily extended to different values of β_0 and frequency required for SPES.

RESONATOR CHARACTERISTICS

The cavity design was described in ref [3]; attention was paid to the construction of a very stiff structure, having in mind also time dependent Lorentz force detuning in pulsed operation. The rf parameters are shown in table 1. The cavity (figure 1) is characterized by a double wall coaxial structure with integrated He tank. The 2 mm thick cavity walls and the 10 mm thick end plates are made in RRR>200 Nb. The outer shell is made of a normal grade Nb tube, terminated by a Ti disk and closed on the top with a removable stainless steel flange. A tuning cup is welded in the equator plane, in a high electric field, low rf current region. The tuning cup is cooled by thermal conduction and not exposed to liquid helium; this makes it insensitive to helium pressure changes. Fine tuning can be achieved by moving a 1 mm thick Nb wall without the necessity of moving the beam ports, which are usually connected to adjacent cavities and could transmit mechanical vibrations. The tuner strength requirements, moreover, are much more relaxed than in the usual beam port tuning of HWRs. The 30 mm diameter beam ports have DN40 type flanges to allow separation beam vacuum from thermal isolation vacuum, if required. The resonator includes a ϕ=42 mm port to host a capacitive coupler and two ϕ=15 mm ports for rf pickups. The beam port and the rf ports flanges are made of NbTi, as well as the outer flange of the tuning cup, where a tuning mechanism can be easily mounted. The tuning plate has a threaded insert in the center to allow easy connection with a mechanical actuator.

Figure 1. The β_0=0.31, 352 MHz HWR mounted in the test cryostat.

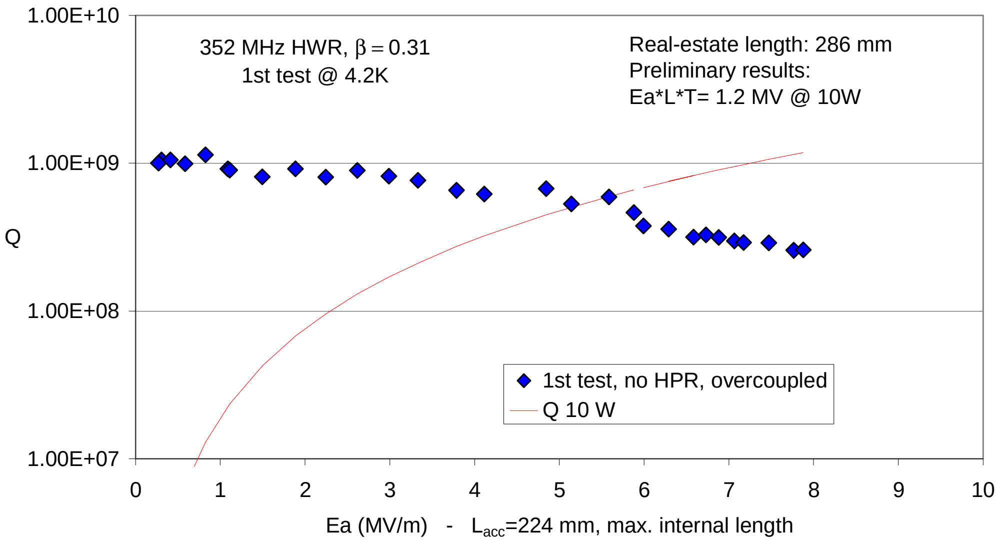

Figure 2. Q vs. E_a curve of the 1^{st} rf test. The accelerating field is defined using the maximum inner length of the cavity. The E_a value expressed with the iris-to-iris length definition, used by other authors, is 1.28 times larger.

The inner conductor of this prototype has a cylindrical shape; this enhances the quadrupolar asymmetry of EM field typical of HWRs. This is sometimes suspected to cause emittance growth in lattices with solenoid lenses; SPES, however, will use quadrupole lenses. The importance of this asymmetry in beam transport decreases rapidly with increasing beam velocity, and it is not very large in the β range of the resonator (fig. 4). Proper shaping of the drift tube region, however, can significantly reduce this asymmetry without substantial changes of cavity performance; this will be done if further beam dynamics simulations will reveal this necessity in SPES.

Another source of asymmetry is the side tuner. Calculations show that this could cause beam steering. An effect qualitatively similar is given by the rf coupler in the opposite side. In the useful velocity range (β>0.2) the amount of this deflection is rather low (<0.08 mrad at 6 MV/m) and can be compensated to 0.006 mrad by displacing the resonator axis 0.4 mm aside (Figure 3).

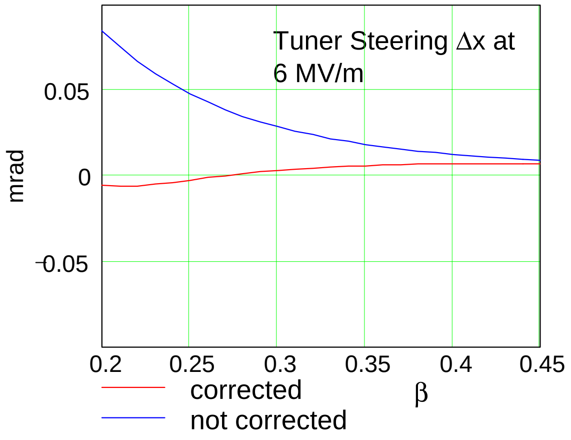

Figure 3. Tuner horizontal steering vs. β (mrad). Blue line: on axis; red line: 0.4 mm off axis.

The cavity active length is 78% of its "real estate" one (286 mm) and the resonator, for this β value, is rather short.

CAVITY CONSTRUCTION

The cavity was constructed in Italy by Zanon SpA [4].

The construction included a first preliminary tuning by means of cavity length adjustment; the final tuning, after welding of all resonator parts exposed to rf, was done by welding the tuning cup in the proper position. The critical operation of welding the inner and outer conductors to the top rf plate, thus closing the resonator, makes further visual inspections difficult. However, the rather large aperture (100 mm) left for inserting the tuning cup allows access to the inner surface and, if necessary, further surface finishing.

The final chemical polishing was done at CERN, paying attention to preventing long permanence of vapour bubbles on the Nb surface of the closed resonator.

Frequency	f_0	352	*MHz*
Optimum velocity	β_0	0.31	
Stored energy	U/E_a^2	0.086	$J/(MV/m)^2$
Peak magnetic field	B_p/E_a	10.4	*mT/(MV/m)*
Peak electric field	E_p/E_a	3.9	
Shunt impedance	R_{sh}/Q_0	1180	*Ω/m*
Geometrical factor	$R_s \times Q_0$	66.5	*Ω*
Tuner sensitivity	$\Delta f/\Delta h$	107	*KHz/mm*
Active length	L	224	*mm*
Real-estate length	L_{re}	286	*mm*
Aperture diameter	a	30	*mm*

Table 1. Resonator rf parameters.

FIRST TESTING AT 4.2 K

The resonator, after CP, was sent back to Legnaro and installed in a test cryostat without any high pressure rinsing (HPR). A low power, movable test coupler was mounted at the coupler port. To detect possible temperature changes determined by insufficient cooling, a thermometer was connected to the center of the tuner. The resonator did not show multipacting (MP) at room temperature or at liquid nitrogen temperature. After cool down at 4.2K we found MP around E_a=0.17 MV/m, that could be conditioned in about 30' with a few watts rf power.

Due to improper coupler dimensioning, it was not possible to reach critical coupling during the test; the minimum achievable coupling coefficient at low field was β_c ~12. This prevented us to apply sufficient rf and helium conditioning, since most of the power was reflected back to the rf source.

The 1st test results are shown in figure 3. The maximum peak fields reached were 31 MV/m and 82 mT, limited by quench.

Figure 3. Final frequency adjustment: tuning cup position adjustment before final welding.

The maximum gradient was 7.9 MV/m (10.1 MV/m with the Iris-to-iris E_a definition). The accelerating voltage (including transit time factor) obtained at 10 W was about 1.2 MV. Although satisfactory in general terms, this is 10% lower than our design goal, that we will try to reach in the next test after readjustment of the rf coupler and some more conditioning.

The thermometer at the tuning cup (see figure 1) did not show detectable changes of temperature with different rf power level, suggesting that cooling is sufficient in accordance with the calculations results.

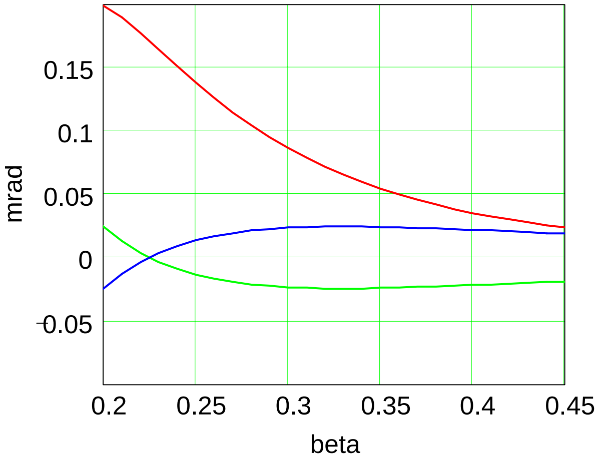

Figure 4. Green and blue lines: quadrupole steering *x* and *y* components vs. β, at 6 MV/m and ϕ=-30 deg synchronous phase. Red line: the normal rf defocusing.

CONCLUSIONS

We have constructed a β=0.31, 352 MHz superconducting HWR prototype, characterized by compact and stiff structure suitable for both cw and pulsed operation. We did the first test at 4.2 K after CP, reaching 5.4 MV/m with 10 W, corresponding to 1.2 MV acceleration. Maximum peak fields of 31 MV/m and 82 mT have been reached after little conditioning. The special tuning cup, which allows frequency adjustment without acting on the beam ports, has shown no overheating, in agreement with calculations. Further testing is planned after coupler modification and high pressure rinsing.

REFERENCES

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[3] A. Facco and V. Zviagintsev, "A 352 MHz, β=0.31 Superconducting Half Wave Resonator for High Intensity Beams", Proceedings of the 11th Workshop 12 Sept. 2003.

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