CONSTRUCTION AND TESTING OF A 161 MHZ, BETA=0.16 SUPERCONDUCTING QWR WITH STEERING CORRECTION FOR RIA

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Abstract

We have built a 161 MHz, b=0.16 superconducting Quarter Wave Resonator with steering correction for the low beta section of RIA. This bulk niobium, double wall cavity, compatible with both separate vacuum between beam line and cryostats or unified one, was designed in collaboration between MSU-NSCL and LNL. The design is suitable for extension to other frequencies, e.g. to obtain the 80.5 MHz, beta=0.085 cavity required in RIA. The shaped drift tube allows correction of the residual QWR steering that can cause emittance growth especially in light ions; this could make this resonator a good alternative to Half-Wave resonators in high intensity proton-deuteron linacs, like the SPES injector project at LNL. First test results will be presented.

INTRODUCTION

The design of the RIA proton and ion driver developed at MSU is based on the 80.5 MHz frequency. This allows basing the low beta part of the linac on the reliable and cost effective Quarter Wave Resonators technology. Laboratori Nazionali di Legnaro and Michigan State University have designed and built in collaboration a 161 MHz cavity that could include all the required features for the RIA QWRs:

- high performance
- high mechanical stability
- steering correction
- modularity for extension to 80.5 MHz
- possibility to work with separate rf vacuum
- short real estate length
- design simplicity
- low cost

The resonators rf parameters are presented in Table 1.

The basic design concepts are similar to the ones of the Legnaro and TRIUMF superconducting QWRs [1], with a double wall coaxial structure that integrates the Helium reservoir. The rf and mechanical design characteristics are described in ref. [2]. The stainless steel top flange is connected to the resonator top plate to limit its deformation when Helium pressure changes are applied. Differently from the previous cavities, NbTi flanges at the beam ports and rf ports allow separation of the rf and isolation vacuum, as required in RIA. In spite of that, the active length of the resonator, 240 mm, is 84% of the real estate one giving a rather high packing factor.

Figure 1: The resonator before testing.

The modular design allow extension of design and components of this 161 MHz QWR to 80.5 MHz QWRs and 322 MHz HWRs.

In Table 1 and Table 2 are shown the rf cavity parameters, calculated by means of the code HFSS, and the main mechanical ones, calculated by means of the code I-DEAS and measured in the prototype.

The lower mechanical frequency of the inner conductor oscillation is well above the frequency range of the main environmental noise and no mechanical damper was mounted in the cavity. If required, however, this can be easily done by a simple modification of the upper stainless steel flange.

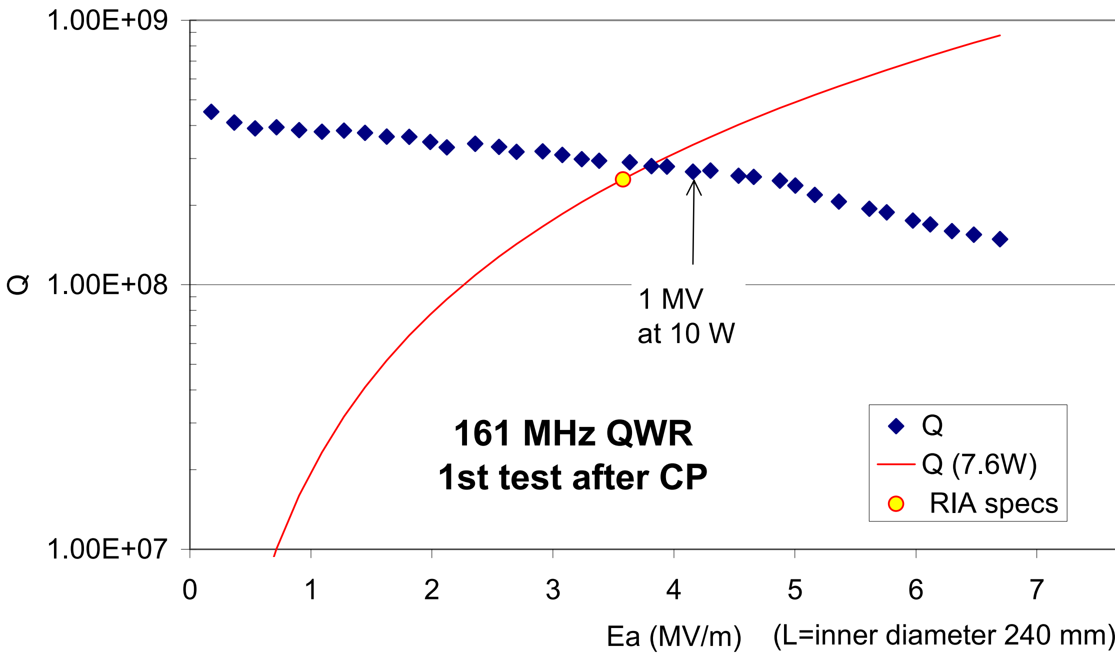

Figure 2: 1st test results.

Table 1: Resonator RF parameters calculated by means of the HFSS code

Frequency	f_0	161	MHz
Optimum velocity	β_0	0.16	
Stored energy	U/E_a^2	0.147	$J/(MV/m)^2$
Peak magnetic field	B_p/E_a	10.6	mT/(MV/m)
Peak electric field	E_p/E_a	~5	
Shunt impedance	R_{sh}/Q_0	1620	Ω/m
Geometrical factor	R_sQ_0	34.2	Ω
Tuner sensitivity	$\Delta f/\Delta h$	6	kHz/mm
Active length	L	240	mm
Real estate length	L_{re}	286	mm

The resonator prototype was built at ZANON SpA.[3]; the construction procedure is similar to that of the LNL 80 MHz QWRs and did not present particular problems.

CAVITY TESTING

After construction the resonator underwent Chemical Polishing (CP) at CERN and was sent back to LNL for testing. The cavity was mounted in the test cryostat without any further treatment. Due to space limitations in our test cryostat we had to mount a movable coupler that could provide critical coupling only at 4.2 K.

We had conditioned multipacting (MP) partly with low duty cycle 200 W rf power at room temperature and at 77 K, partly at 4.2K. We applied 30 minutes of rf conditioning and 1 hour Helium conditioning.

The results of the first Q vs. E_a test are shown in figure 2. It can be seen that the given RIA specifications have been fulfilled; the resonators already provides the required 0.86 MV with less than 7 W. The maximum peak fields achieved were E_p 33 MV/m and B_p=70.9 mT. The 10 W gradient was 4.3 MV/m, corresponding to 1 MeV/q energy gain.

Even if sufficient for our specifications, the value of Q_0= 4.5×10^8 is below our goal of 10^9 based on our previous experience. This is probably related to surface contamination during installation in the test cryostat; the next step will be High Pressure Rinsing in order to improve the surface cleanliness.

The measured frequency response to He bath pressure, +0.044 Hz/mbar, is very low and much lower than expected. The Lorentz Force detuning was –2.1 $Hz/(MV/m)^2$, larger than expected (See table 2) but well within reasonable limits for reliable operations.

Figure 3: View of the shaped beam ports and drift tube.

The measured frequency of the lowest mechanical mode was 333 Hz.

The cavity appeared very stable and easy to lock at the required gradient.

Table 2: Measured and calculated mechanical properties

Detuning	meas.	calc.	units
He P $\Delta f/\Delta p$ detuning	+0.044	-1.5	Hz/mBar
Lorentz $\Delta f/E_a^2$	-2.1	-0.66	Hz/(MV/m)^2
mech. mode 1	333	282	Hz

Figure 4: The tapered inner conductor before welding.

CONCLUSIONS

The prototype of the 161 MHz, β_0=0.16 quarter wave resonator with steering correction designed for the low-β section of the RIA driver [4] was built and preliminary tested as a collaboration between LNL and MSU-NSCL. The cavity performance was measured just after CP and fulfilled the RIA specifications. In spite of the Q_0 value, below our expectation in this first test, the cavity gave a voltage gain of 1 MV at 10 W rf power dissipation. The mechanical parameters are satisfactory for reliable operation, especially the very low pressure detuning. Further improvements Q are expected after high pressure rinsing.

REFERENCES

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