A 352 MHZ, β=0.31 SUPERCONDUCTING HALF WAVE RESONATOR FOR HIGH INTENSITY BEAMS

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Abstract

A 352 MHz, β=0.31 superconducting Half Wave resonator was designed at LNL and the prototype is presently under construction. The cavity is aimed at the intermediate energy section of the SPES driver, a wide-β linac for high intensity protons and deuterons; it could also fit the requirements of superconducting linacs for radioactive beams, like the EURISOL post-accelerator. The resonator is designed with a double wall structure similar to the LNL 80 MHz low-β quarter-wave resonators. Compared to Spoke-type resonators with similar optimum velocity, the SPES HWR aims to be more compact in order to obtain a higher real-estate gradient and a better mechanical stability, at the expenses of a slightly lower shunt impedance. This could make it particularly suitable to pulsed operation. The cavity rf and mechanical design will be presented and discussed, as well as the status of the prototype construction.

INTRODUCTION

The large radioactive beam facilities [1][2] and the high intensity proton accelerators projects [3] presented during the last decade have triggered an increasing interest in intermediate-velocity accelerating structures (β~0.2÷0.5). The field, dominated for a long time by normal conducting structures, is now shifting to superconducting resonators for their high gradient, efficiency and reliability demonstrated in heavy ion linacs; the impressive evolution of superconducting technology allows designing and constructing low- and intermediate-β resonators with very good performance and low cost.

The preferred frequency, to obtain the required longitudinal and transversal acceptance for this velocity range, is about 350 MHz, which allows the use of compact cavities with good rf parameters. The preferred cavity geometry is the Half-Wave one, either “Spoke” or “Coaxial” (see, e.g. ref. [4]).

The main difference between Coaxial and Spoke HWR is the symmetry axis of the outer conductor. This is parallel to the beam axis in the Spoke, leading to a larger cavity volume that benefits shunt impedance. Below 350 MHz, Spoke cavities (for their large size) start losing part of their interest. On the other hand, the Quarter-Wave geometry, very attractive below about ~160 MHz, at higher frequency presents an unfavourable aspect ratio that introduces intolerable beam steering [5]. Coaxial HWRs are very well suited in the ~160÷350 MHz range: their high symmetry and their short physical length make them steering-free and mechanically stable; in spite of their somehow lower shunt impedance, they can allow a high real estate gradient and a very compact lattice.

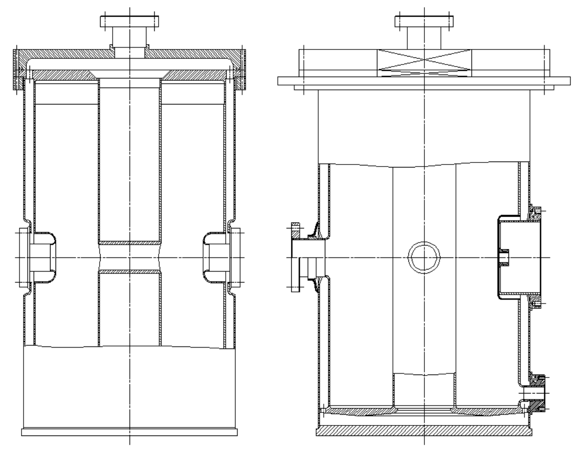

Figure 1: Schematic of the LNL, β=0.31 HWR.

The SPES project at Laboratori Nazionali di Legnaro [6] requires 2-gap, β_0=0.31 cavities at 352 MHz for high intensity proton, deuteron and A/q=3 beams. LNL is participating also to the EURISOL radioactive beam facility program, where similar cavities are being proposed both for the Driver and for the Post-accelerator linacs. We decided to develop a HW resonator prototype that could be used in all these applications and also for pulsed operation. Our experience with coaxial QWRs suggested us to keep similar design characteristics, that could be easily extended to different values of β_0 and frequency required for SPES.

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/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		30	*mm*

Table 1. Resonator rf parameters.

* from August 1st, 2003 at TRIUMF, Vancouver, Canada

CAVITY DESIGN AND CONSTRUCTION

The cavity has a coaxial structure similar to the LNL 80 MHz niobium resonators one, where the double wall has the double function of mechanical reinforcement and helium container. The beam ports, terminated with a CF 35 type flange to allow beam vacuum separation in the cryostat, are welded to the outer conductor without modifying its cylindrical shape, in order to keep the structure stiff against helium pressure changes. The tuning mechanism, which in HWRs usually acts on the beam ports, has been moved aside on a dedicated tuning cup cooled by thermal conduction. This will avoid, during tuning operation, mechanical cross-talk between adjacent cavities connected together by means of bellows. The HWR end plates, 10 mm thick disks, have a similar design as in 80 MHz QWRs; compared to a thin toroidal sheet design, they require a larger amount of Nb material but they are mechanically stiffer and easier to construct. To avoid dangerous magnetic field enhancement, no aperture is located on the end plates.

The cavity rf parameters (see Table 1) have been calculated by means of the codes HFSS, and the mechanical ones by means of the code I-DEAS (see Table 2). A ϕ=42 mm rf port, located at the cavity equator 90° from the beam ports, will host a capacitive coupler. Two more ϕ=15 mm ports, required for rf pickups, will be used also for chemical treatment and will allow high pressure water rinsing in the whole inner cavity surface.

He pressure detuning	$\Delta f/\Delta p$	1.53	*Hz/mbar*
Lorenz force detun.	$\Delta f/E_a^2$	0.9	$Hz/(MV/m)^2$
Max. stress 1 Bar		$2.37 \cdot 10^4$	$mN/(mm^2 Bar)$
1st mechanical mode	$f1_{mech}$	321	*Hz*
2nd mechanical mode	$f2_{mech}$	851	*Hz*

Table 2: Resonator mechanical parameters.

The beam port aperture is 30 mm, as specified for the SPES beam dynamics. The inner conductor is cylindrical, including the drift tube region. This seems to produce an acceptable field distribution up to now; if more accurate beam dynamics simulation will reveal significant negative effects on the beam, the tube shape will be flattened. The cavity active length is 78% of its real-estate one (286 mm) and the resonator, for this β value, is rather short.

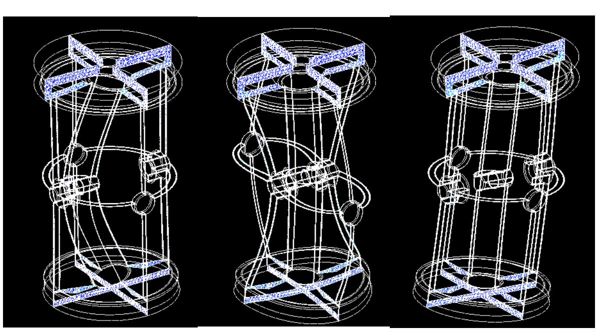

Figure 2: I-DEAS representation of the lower mechanical modes.

Figure 3: Resonator parts before welding.

The energy gain at optimum velocity, at the design gradient of 6 MV/m, is 1.34 MV; the peak electric and magnetic fields are 23.4 MV/m and 62 mT, respectively.

The construction technique is similar to the Legnaro Niobium QWRs one. The most critical step is welding of the second end plate to the outer and inner conductor, to close the cavity. The final weld is the tuning cup; this allows the final frequency regulation. The resonator is presently under construction at Zanon S.pA., Schio, Italy. First results are expected within 2003.

Figure 4: Intermediate rf testing.

REFERENCES

[1] S. Schriber, "Rare Isotope Heavy Ion Accelerators", these proceedings.

[2] http://www.ganil.fr/eurisol/

[3] A.Facco, "High Intensity Proton Sources", these proceedings.

[4] J. Delayen, "Low and intermediate beta cavity design", these proceedings.

[5] A.Facco and V. Zviagintsev, "Study of Beam Steering in Intermediate-β Superconducting Quarter-wave Resonators" Proc. of PAC 2001 Particle Accelerator Conference, Chicago, USA, June 18-22, 2001, p. 1095.

[6] "SPES- Technical Design for an Advanced Exotic Ion Beam Facility at LNL", LNL-INFN (REP) 181/02, edited by A. Bracco and A. Pisent, INFN- Laboratori Nazionali di Legnaro, I-35020 Legnaro (Padova) Italy.