STATUS OF THE NON-RFQ RESONATORS OF THE PIAVE HEAVY ION LINAC

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Abstract

Three different types of non-rfq resonators[1] are included in the PIAVE[2] low beta linac under construction at LNL, i.e. 8 superconducting, β=0.047 quarter wave cavities, a room temperature β=0.0089 triple harmonic buncher and two, β=0.05 room temperature quarter wave rebunchers. The construction and testing of the superconducting cavities has been successfully completed, the design goal of 5 MV/m at 7 W was more than fulfilled with a measured average gradient of 6.7 MV/m; the triple harmonic buncher was successfully tested and installed in the beam line; the 10 kW, high energy rebunchers are under construction and their completion is expected within 2000. The installation is proceeding according to the PIAVE schedule.

1 THE SUPERCONDUCTING LOW-β CAVITIES

The 8 superconducting low beta cavities of PIAVE are 80 MHz bulk niobium quarter wave resonators that must accelerate the beam from the second rfq (0.58 MeV/A) to ALPI (1.3 MeV/A). They differ from the ALPI low beta cavities only in the shape of drift tube region, optimised for the velocity of β=0.047. All these cavities are equipped with the LNL mechanical dissipator to damp mechanical vibrations of the inner conductor[3]. The cavity construction and chemical treatment was completed in 1998; the initial design goal of 3 MV/m at 7 W was moved to 5 MV/m after the promising results of the first prototype. During 1999 all cavities could be tested in superconducting regime to assess their performance.

Figure 1: View of a PIAVE type bulk niobium cavity.

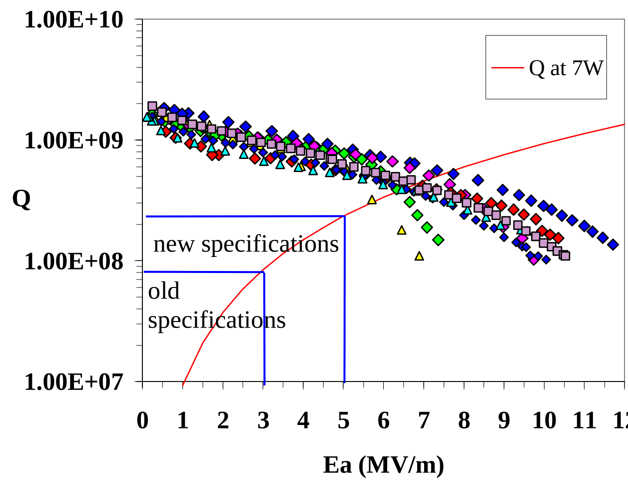

Figure 2: Rf test results of the 80 MHz, low-β superconducting cavities. Only cavity n. 8 (square marker) underwent high pressure rinsing.

The results are far above the last, more severe requirements (see table 1). It should be noted that the average performance of 6.7 MV/m at 7 W, although rather satisfactory, are expected to further increase after high pressure water rinsing (HPR) that we will apply routinely just before the final installation of the cavities in the linac cryostats. Until now, we did HPR only in the last cavity (see fig. 3), moving the 7 W accelerating field from 5.6 to 6.8 MV/m. These results are very similar to the ones obtained with the ALPI bulk niobium cavities, in spite of a slightly unfavourable geometry due to the lower beam velocity in PIAVE which required the shortening of the drift tube and the prolongation of the beam ports.

Table1: Statistical representation of the PIAVE low beta resonators performance.

	<Ea> @ 7W (MV/m)	Low power Q_0 (×10^9)	$\langle R_{res} \rangle$ nΩ
Design requirements	> 3 old > 5 new	0.23	65
8 cavities average	6.7	1.56	8
Best result	7.7	1.91	6
Worst result	5.8	1.17	10

Most of the PIAVE tuning disks are covered with sputtered niobium, while the ALPI ones are plated with lead. Even if it is difficult to observe any difference in cavity performance that could be related to the two treatments (the losses on the disks are of the order of microwatts), the second solution is preferable: the niobium is not prone to oxidation as much as lead, and this makes the storage and mounting operations much simpler and more reliable.

All cavities are ready for installation in their cryostats.

Table 2: The PIAVE low beta resonators rf parameters.

Frequency	f	80	MHz
Optimum velocity	β	0.047	
Acceleration length	l	0.18	m
Stored energy	U/E_a^2	0.13	J/(MV/m)
Max H field	H_p/E_a	≈ 100	G/(MV/m)
Max E field	E_p/E_a	≈ 5	
Norm. shunt res.	R'_{sh}	17.7	MΩ/m
Geom. Factor	$\Gamma = Q \times R_s$	15.4	Ω

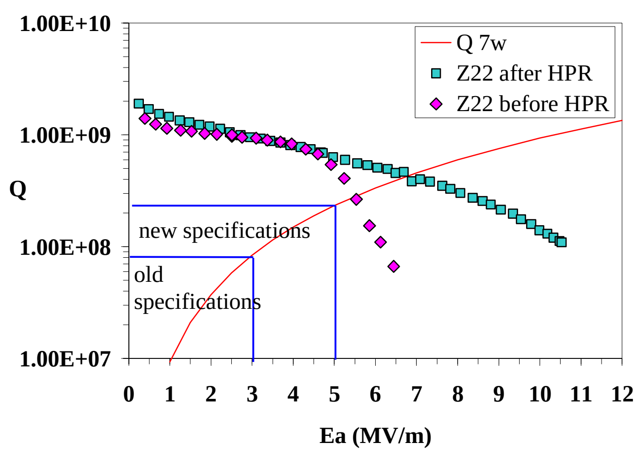

Figure 3: Effect of high pressure water rinsing in the last cavity tested.

2 THE TRIPLE HARMONIC BUNCHER

The triple harmonic buncher[4] consists of 2 quarter wave resonators working at 40-120 MHz and at 80 MHz, respectively, terminated by 2-gap structures with optimum velocity β=0.0089 (fig. 4). The function of this device is bunching at 40 MHz, with high efficiency due to the triple harmonic, the dc beam produced by the ECR source and accelerated by the PIAVE high voltage platform. This unusual structure presents some features that are difficult to be obtained simultaneously with double-drift bunchers or by single gap, gridded ones. The short spacing and the location of the buncher in a transverse beam waist, as well as the absence of grids, will allow us to obtain a high efficiency (about 68 %) and a good output emittance (3.75 *MeV deg*)[5]. The buncher, after the construction, was mounted in the beam line together with its rf equipment, and tested at the operating field levels. The two resonators reached the design voltage at the required power (3900 V at 34 W for the 40 MHz harmonic, 380 V at 2 W for the 120 MHz one and, finally, 1400 V at 10 W for the 80 MHz harmonic); all three harmonics could be locked and tuned at the same time. The inner conductor of the 40-120 MHz resonator required air cooling to improve thermal stability, while the 80 MHz one could be cooled by natural air convection. The tuning of the 1[st] and 3[rd] harmonics of the longer resonator is obtained by means of two tuners: the first one is a piston tuner facing the drift tube, which changes the frequency by the same fraction and the same sign in both modes. The second tuner acts mainly on the 120 MHz frequency. This was obtained by locating the piston in a position where the electric-to-magnetic energy density ratio is high for the 120 MHz mode, while being approximately 1 for the 40 MHz mode, making it almost insensitive to the tuner motion.

The triple harmonic buncher and its electronics are in their final location and ready for beam commissioning.

Figure 4: The PIAVE triple harmonic buncher

3 THE REBUNCHERS

The longitudinal matching between PIAVE and the superconducting booster ALPI is provided by two rebunchers working at 80 MHz. These are quarter wave resonators (see fig. 5) with optimum velocity β=0.05; the maximum required voltage on the gap is 100 kV.

The design characteristics are listed in tab. 3; some of the construction features have been suggested by the local expertise in vacuum brazing and in spinning. The resonators are made of stainless steel; the rf surfaces of the inner conductor and the top plate are covered by a 2 mm copper sheet brazed to the stainless steel; the water cooling is obtained by means of a groove between the stainless steel core and the copper sheet. The outer conductor is a copper plated cylinder with a double wall to allow for water cooling. The outer conductor is connected to the top plate by means of screws and an rf joint. An o-ring provides the vacuum tightness. A flange for connecting a 250 l/s turbomolecular pump is available in the bottom plate, in a field free region. The frequency adjustment is done by means of two tuners, one movable and one fixed, facing the drift tube.

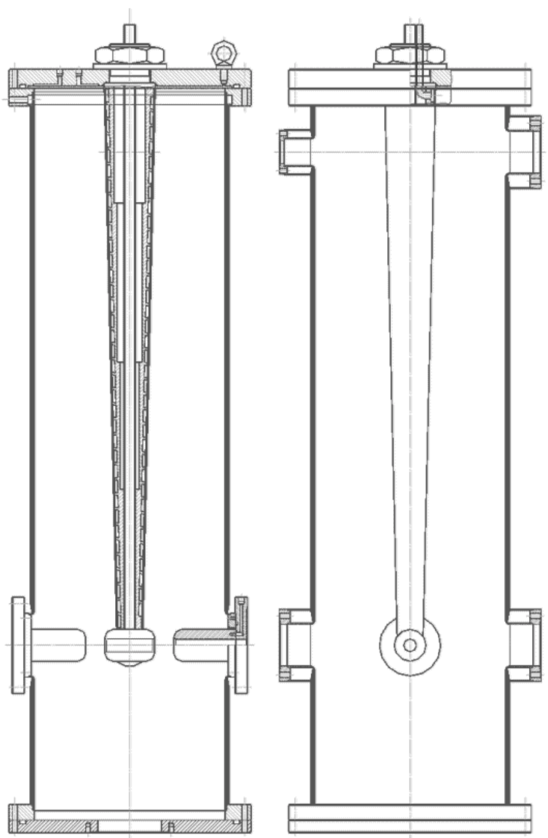

Figure 5: Schematic drawing of the 80 MHz rebunchers.

Table 3: PIAVE rebunchers characteristics

Frequency	f	80	MHz
Quality factor	Q_o	10500	
Max voltage on the gap	V_g	100	kV
Shunt impedance $V_g^2/(2P)$	R_{sh}	1.28	MΩ
RF power at V_g=100 kV	P	3.9	kW
Peak-to-Kilpatrick ratio	E_p/E_k	0.58	
Acceleration length	l	0.3	m
Cavity diameter	D	0.3	m
Cavity length	h	1.16	m

The rf power will be fed by a class AB, 10 kW triode amplifier, through a 1 5/8” coaxial line and a water cooled inductive coupler.

The rebuncher resonators are presently under construction at the LNL mechanical workshop.

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