PROGRESS IN THE ALPI-PIAVE LOW-BETA SECTION UPGRADE

D.Zenere, A.Facco, F.Scarpa, INFN Laboratori Nazionali di Legnaro, Padova, Italy

Abstract

The low-β section of the PIAVE-ALPI superconducting linac is being upgraded in order to increase its energy gain from approximately 10 to about 20 MeV/q. This large increase of the accelerating voltage will be obtained by increasing by 20% the number of low-beta bulk niobium quarter-wave resonators and by upgrading the old rf system, underdimensioned in comparison with the resonator performance. This will lead to a significant enhancement of the linac capabilities, including the possibility of acceleration well above the Coulomb barrier heavy ions with any mass number. Status and technical details of the upgrade program will be described.

INTRODUCTION

The low-β section of the superconducting linac PIAVE-ALPI consists of 20, 80 MHz superconducting quarter wave resonators [1], working at 3 MV/m and giving a total voltage gain of about 10 MV. The required rf system was built according to the old specifications, assessed in 1988. Since the resonators performance would allow operation at a significantly higher gradient, an upgrade program started [2] that include refurbishing the old rf system and installation of 4 new low-β cavities bringing their total number to 24. The new gradient specifications for the resonators are 5 MV/m at 7 W in operation; this will allow to double the acceleration voltage of the low-β line with a relatively modest cost. The main interventions on the system are the following: 1) Construction of 4, β=0.047 resonators and their installation in a cryostat of the low-β line that was left empty; 2) replacement of the 24, 150 W rf amplifiers with 1 kW ones; 3) replacement of the rf couplers with new ones that allow cooling with liquid nitrogen, required to handle the increased rf power; 4) upgrade of the cryostats to host the new couplers; 5) installation of a new liquid nitrogen supply line along the low-β cyostats. We decided also to develop new tuners in order to increase the resonators tuning range.

UPGRADE STATUS

Quarter-wave resonators

We have built 4 β=0.047 cavities with flattened inner conductor. Their design was silghtly modified in order to allow removal of the mechanical damper without the necessity of opening the indium seal. A new, slotted tuning plate allows a tuning range about three times larger than the present one. The first cavity has been tested

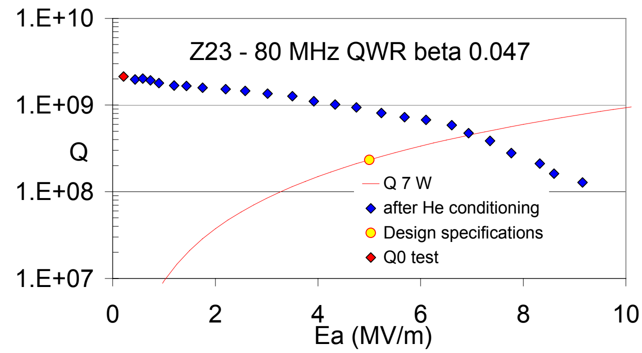

Figure 1. Results of the 1st cavity test.

and more than fulfilled the new design specifications (Fig. 1). The measured Helium pressure and Lorentz force detuning were 0.9 Hz/mbar and 1.24 Hz/(MV/m)^2, respectively. The testing of the remaining cavities is in preparation.

Figure 2: Low-β cavity equipped with new tuner and cooled coupler

Rf system

The acquisition and testing of the new 1 kW amplifiers was completed. These solid-state amplifiers include a built-in circulator and rf load; they can deliver a maximum power of 1 kW and allow operation in any matching conditions up to an average power of 500 W. We plan to operate the cavities at 5 MV/m with 200 W forward power. Even if the cavity power consumption is below 7 W, this power is required in order to guarantee sufficient rf bandwidth to phase- and amplitude-lock the cavity to the reference signal.

New rf coupler

The first prototype of our cooled coupler [2], inspired by the TRIUMF-ISAC 2 one [3], was tested with a forward power up to 200W. Although we used a copper braid to provide thermal contact between the rf coupler and a rigid liquid nitrogen pipe, the test results were encouraging. The coupler met the rf requirements, the pinion-rack moving mechanism proved to be reliable and the cooling system was able to prevent overheating. However, after experiencing unexpected problems presented by this system during mounting and maintenance and in terms of dust contamination, we decided to go back to a TRIUMF-like direct cooling by using stainless steel bellows liquid Nitrogen lines.

Some of the rf coupler components underwent revision in order to optimize its performance. The rf connector was modified to improve the electrical contact and mechanical reliability. The PTFE sliding rings were modified in order to reduce yawing and to improve mechanical stability in operation. A new driving mechanism with three wheels and a reduced ratio allowed to increase the coupler stroke and thus its coupling range, with a smooth movement and motion reversal at both ends even with the additional load of the cooling bellows.

To reduce the thermal load to liquid Helium, the contact surface between the resonator the coupler holding flange was reduced, and the stainless steel housing was shaped with a thinner section near the cavity.

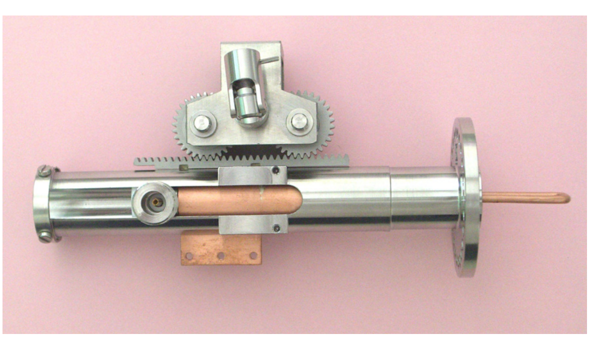

Figure 3: View of the new cooled coupler

This new version of the coupler was tested in a QWR, with and without coupler cooling. The cooling system was able to keep the copper coupler body and the stainless steel housing at a stable temperature with a forward power up to 400W (tab.1). When the cooling was off the temperature values tended to run out of control already with 100 W and, at the required rf power of 200W, the coupler temperature increased at more than 100 K/h. At 400W the liquid nitrogen flow was started, the outer conductor temperature stabilized in few minutes to about 90K and the stainless steel housing temperature decreased to 65K. These results show that the new coupler is adequate to our upgrade plans. Further tests are foreseen with higher rf power, to better check the final limits of the present design.

Forward power W	Outer conductor T [K]	Stainless Steel housing T [K]
100	>230*	>110*
200	86	65
400	89	65
* without cooling		

Tab.1: RF coupler temperature vs. forward power

New tuning plate

After the preliminary tests on a dummy Cu model [2], 4 bulk Niobium plates with radial slots to increase their flexibility were made from an annealed sheet of RRR>150 material and underwent surface preparation and chemical treatment before being mounted and tested. Each plate, which design is a modification of the TRIUMF-ISAC 2 one, is coupled to an aluminium cover which facilitates a clean mounting procedure. During the rf test at 4.2K, neither Q degradation nor field emission enhancement were observed, while the tuning range was increased to 25 kHz, about 3 times larger than the one obtained with the old flat plates.

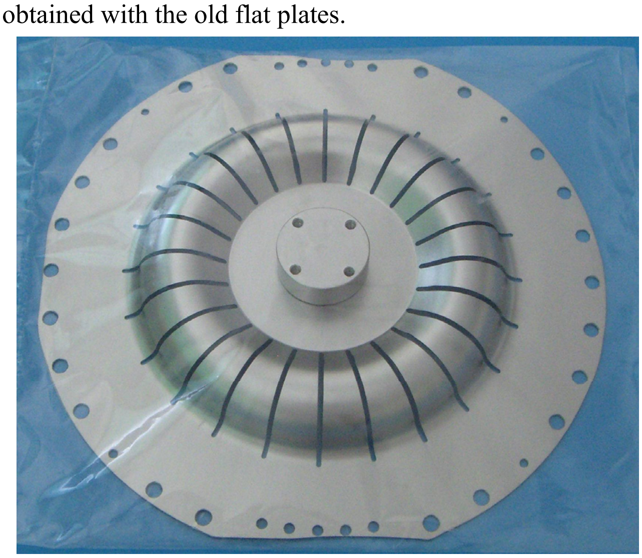

Figure 4: Bulk Nb slotted tuning plate (in a protective plastic bag).

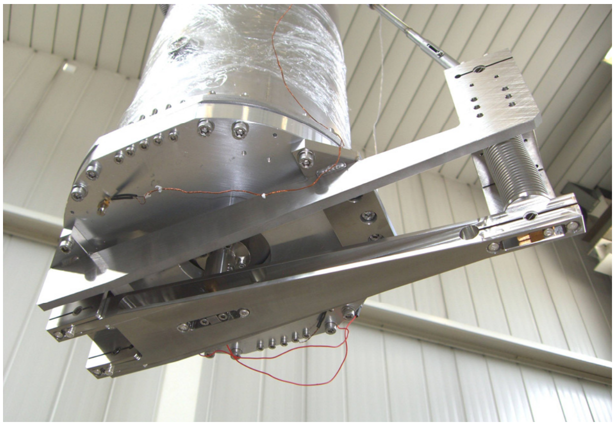

Figure 5: New tuner assembly

Cryostat upgrade

The low-β cryostat upgrade includes new flexible cooling pipes bringing liquid nitrogen to the couplers, insulated fittings on top flange, and a thermal shield to prevent heat radiation from the rf lines to the Helium reservoir.

The liquid Nitrogen cooling line concept and components have been tested together with the new coupler in the test cryostat. The liquid nitrogen flows through a Cu block in tight contact (maintained by three screws) with the coupler body, very near to the heat generating surfaces. This gives a fast and effective response to temperature variations due to rf power.
Two bayonnet-type commercial fittings, located on the cryostat top cover, provide an easy and removable connection between the liquid Nitrogen supply line and the flexible line inside the cryostat.

The additional thermal shield, made of aluminum, is connected to the existing 80K shield cooled by He gas, and cooled by this by thermal conduction. Direct cooling of the shield with liquid Nitrogen might be easily implemented if necessary. This possibility will be evaluated in the first complete cryostat test.

CONCLUSIONS

The ALPI-PIAVE low-β section upgrade is proceeding. Most critical components have been acquired and validated. The next step will be the assembly and operation of the new cryostat, expected within this year. After cryostat validation, during 2009 the remaining 5 cryostats will be upgraded one by one with new couplers and cooling pipes without interfering significantly with accelerator operation. The performance of the low-β line will be gradually increased up to the 20 MV design goal, which is expected to be reached by the end of 2009.

ACKNOWLEDGMENTS

We thank V. Zvyagintsev and R. Laxdal of TRIUMF, Vancouver, for their precious suggestions about coupler and tuner development.

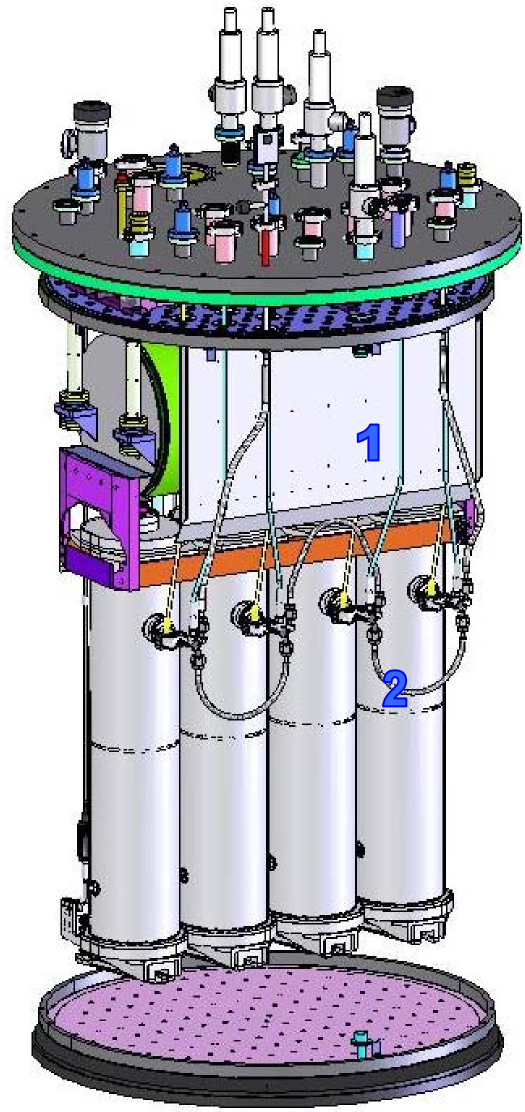

Figure 6: Sketch of the modified cryostat internal part. (1) Aluminum sheet shielding the He reservoir from the rf cables heat irradiation. (2) Flexible cooling pipes bringing lN_2 to couplers.

REFERENCES

[1] A. Facco, F. Scarpa and V. Zviagintsev, “The non-rfq resonators of the PIAVE project”, Proc. of the 8th International Conference on Heavy Ion Accelerator Technology, Argonne (Chicago), USA, 1998.

[2] D.Zenere, A.Facco, F.Scarpa, “Upgrade of the low-β section of the Piave-Alpi Linac at lnl”, Proceedings of SCRF work shop, Beijing, China,2007

[3] R. Poirier, K. Fong, P. Harmer, R. Laxdal, A. Mitra, I. Sekatchev, B. Waraich, V. Zvyiagintsev, “Rf coupler design for the TRIUMF ISAC-II superconducting quarter wave resonator Proc. of LINAC 2004, Lubeck, Germany, p. 228.