DESIGN OF A LINAC WITH THE NEW GASKETS CLAMPING FABRICATION TECHNIQUE

F. Cardelli[1*], M. Magi, L. Palumbo[1], F. Pellegrino, V. Pettinacci, INFN-Roma1, Roma, Italy
D. Alesini, INFN-LNF, Frascati, Italy
[1] also at Universitá di Roma "La Sapienza", Roma, Italy

Abstract

Recently, a new technique for the realization of high gradient accelerating structures based on the use of gaskets without brazing processes has been successfully tested at high power on a 1.6 cells RF gun (D. Alesini, et al, PRST 18, 02001, 2015). The new technique developed at the Laboratories of Frascati of the INFN (Italy) in the framework of the SPARC_LAB project has been also adopted for the ELI-NP RF gun. The use of special gaskets that simultaneously guarantee the vacuum seal and a perfect RF contact, allow to avoid the brazing process, strongly reducing the cost, the realization time and the risk of failure. Moreover, without copper annealing due to the brazing process, it is possible, in principle, to decrease the breakdown rate increasing, at the same time, the maximum achievable gradient. The extension of this new fabrication process to complex LINAC structures is the next step on the application of this new technique on particle accelerators. In the paper, we discuss how to extend this process to S-band and C-band Travelling Wave accelerating structures illustrating their electromagnetic design and their mechanical realization.

INTRODUCTION

There is a growing demand from the research and industrial communities for compact and high gradient RF accelerating structures. These structures are, in general, fabricated by a brazing process of pre-machined parts. The brazing process requires a large vacuum furnace so it is very expensive and implies a not negligible risk of failure. Furthermore, breakdown-rate studies [1] indicated that, avoiding the copper annealing associated with the brazing, the BDR probability can be reduced. For these reasons it has been developped a new technique that avoid this process using special RF-vacuum gaskets [2, 3] between the different machined parts that are clamped together by screws. This technique has been successfully applied for the realization of both the new SPARC_LAB 1.6 cells RF gun [3] and the ELI-NP-GBS one. The results obtained for these devices in term of reached cathode peak field open the possibility to apply this technique to other rf structures. In this paper we discuss the application of this technique to the realization of a linac section. To this purpose an S-band prototype with a reduced number of cells has been designed and will be fabricated and tested in the next months to demonstrate the feasibility of such approach. The prototype is a 10 cell S-band TW disk loaded accelerating structure, constant impedance with $2\pi/3$ field phase advance per cell. In the following sections the design of this prototype is presented both from the electromagnetic than from the mechanical point of view.

* fabio.cardelli@roma1.infn.it

ELECTROMAGNETIC DESIGN

The electromagnetic design of the S-band TW prototype has been done using the 3D electromagnetic code HFSS [4] and can be summarized in two main steps: single cell design and input/output coupler design. In the overall design a continuous feedback between the electromagnetic design and the mechanical model has been necessary.

Cell design

The main RF parameters of the single cell such as shunt impedance, group velocity and attenuation, have been studied as a function of the iris diameter, retuning the cell outer radius in order to have the $\frac{2\pi}{3}$ phase advance at the 2.856 GHz working frequency. One of the internal edges of the cell has been rounded both to increase the quality factor (of about a factor 10%) than to simplify the mechanical realization of the cell cups.

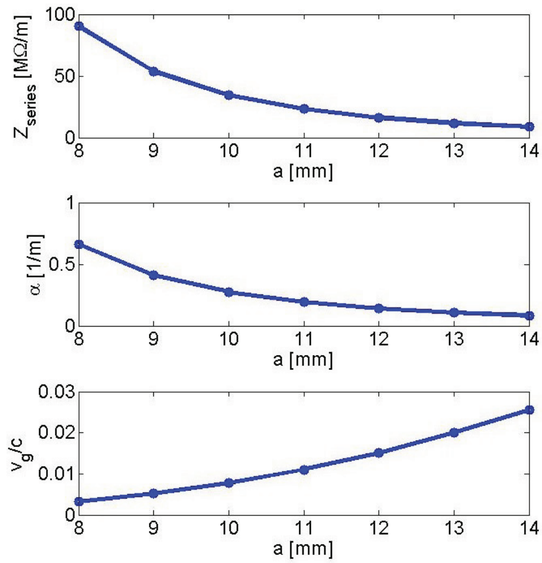

Figure 1: Main structure figures of merit as a function of the iris aperture.

Figure 1 shows the main cell parameters as a function of the iris half aperture. Since the prototype is a constant impedance (CI) section with equal cell irises an half aperture of 13 mm has been chosen as the best compromise between a good pumping speed and structure efficiency, while the cell

ISBN 978-3-95450-147-2

to cell iris thickness has been fixed to 6 mm. The frequency sensitivity with respect to the cell dimensions are reported in Table 1.

Table 1: Frequency sensitivity with respect to the cell main parameters.

Parameter	Sensitivity
Cell radius	−80 kHz/μm
Iris half aperture	22 kHz/μm
Cell length	−5 kHz/μm
Iris thickness	10 kHz/μm

To decrease the peak surface electric field on the irises an elliptical cross-section with an aspect ratio 4/3 has been chosen. This guarantees a reduction of the surface field of the order of 10% with respect to the round profile, which is desiderable for high gradient application.

Couplers design

The input and output couplers have been designed in order to implement the clamping technique on the several coupler parts and adjacent cells. In particular it was not possible, obviously, to adopt a standard z-coupling coupler [5] but we had to design the coupler with a coupling aperture (see Figure 2). Moreover one of the constraint in the design was to keep as small as possible the transverse dimension *w* of the coupling aperture to reduce the distance between the clamping screws with the adjacent cell.

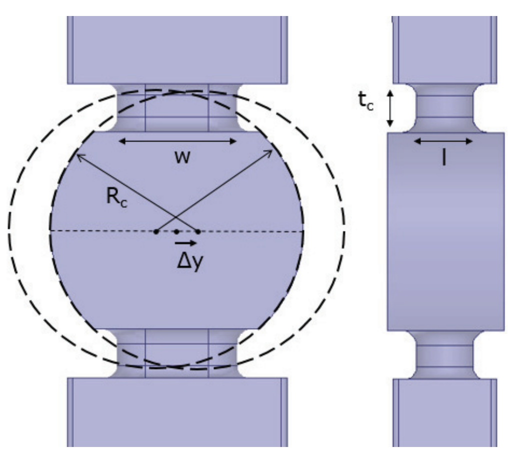

Figure 2: Sketch of the front view (left) and lateral view (right) of the input/output coupler.

For easier machining, the coupler cell has been designed with a racetrack shape and with a dual feed to cancel the dipole field components as given in Fig. 2 where it is possible to see the geometry of the couplers and its main parameters. In the final implementation of the system a splitter will be inserted on the input coupler to guarantee the correct phase between the two ports while the output one will be connected to two RF loads. The dimensions Rc, w and l have been optimized to match the waveguide mode TE10 to the accelerating one TM01-like. The design has been done

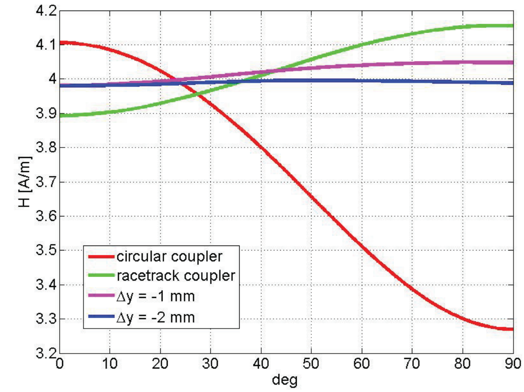

Figure 3: Azimuthal magnetic field at 5 mm from the center of the coupler cell for different geometries of the cell.

using the 3D electromagnetic code HFSS and the technique discussed in [6].

To compensate the quadrupole field components induced by the presence of the hole apertures a further modification of the coupler profile has been instroduced. In particular the two rounded parts of the coupler cell have been compressed displacing their center by a quantity equal to Δy. With a $\Delta y = -2mm$ the quadrupolar component has been completely compensated, as given in Figure 3, where the magnetic field on a circle of 5 mm radius in the center of the coupler has been reported for different Δy and the coupling hole has been also strongly rounded to reduce pulsed heating on the surfaces [7].

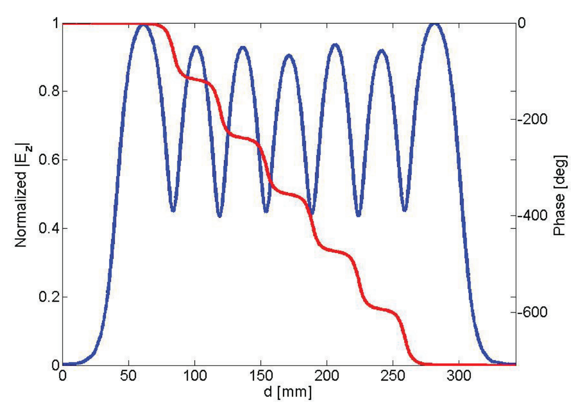

Figure 4: Amplitude and phase of the accelerating field along a 5 cells, plus in/out couplers, prototype.

Finally, Table 2 reports the main parameters for the 10-cell prototype.

MECHANICAL DESIGN

The entire accelerating section will be fabricated with the use of special RF-vacuum gaskets without brazing but simply clamping all machined components by screws. The special gaskets guarantee at the same time the RF contact

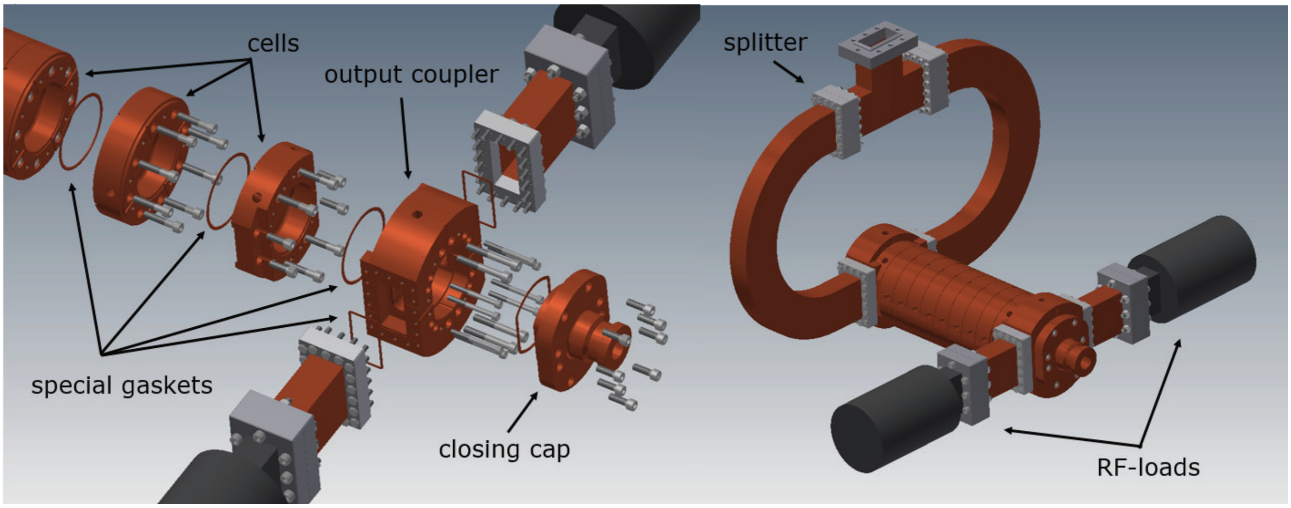

Figure 5: Mechanical drawings of the assembly procedure (left) and of the entire prototype in its final configuration (right). Designed with [8].

Table 2: Prototype RF parameter

Freq.	2856 MHz
Phase advance per cell	$2\pi/3$
Number of cells	10
Period	34.99 mm
Iris radius	13 mm
Unloaded quality factor Q	14 133
Group velocity (v_g/c)	0.02
Field attenuation	0.11 m^{-1}
Shunt impedance	11.61 $M\Omega/m$
Series impedance	55 $M\Omega/m$
$E_{acc}/\sqrt{P_{in}}$	3.4 $\frac{MV/m}{\sqrt{MW}}$
Pulsed heating (1 μs pulselength)	5 °C

and a perfect vacuum sealing between each part of the structure. The main challenge for this design was to find the better compromise between electromagnetic performances and mechanical constraints. Figure 5 shows the details of the structure assembly. The prototype structure is composed by an input coupler, ten accelerating cells and an output coupler with the final closing cap. All the cells are mechanically identical except those adjacent to the couplers that have a different profile to allow the connection with the couplers themselves. The structure will be assembled starting from the input coupler stacking up one cell after the other, inserting the gaskets between them and fixing each part with the previous one through screws, up to the output coupler and closing cap. Figure 6 shows the detail of a single cell that has through-holes and threaded holes for the connection with the two adjacent cells. Each cell has eight screw holes disposed at 45 degree to one another to provide an homogeneous force on the gasket when the cells are clamped together. Two opposite bi-directional tuners are inserted on each cell and on the couplers. All cell gaskets have the same dimensions and the same profile as given in [3], while the gaskets connected to the input and output couplers have a different geometry to follow the coupler cells profiles. Each part will be fabricated from cilinders of Oxygen Free High Conductivity (OFHC) copper. The single cell will be machined as a cup using a high precision lathe. The input and output coupler instead will be realized with a computer controlled milling machine.

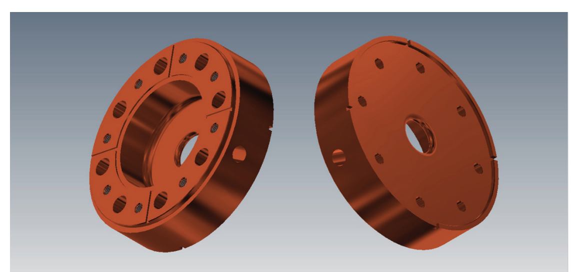

Figure 6: Mechanical drawings of the single cell.

CONCLUSION

In the paper we have presented the electromagnetic and mechanical design of a 10 cells S-band TW structure implementing the gasket-clamping technique. The manufacturing will be done at the mechanical workshop of INFN-Roma1. After the vacuum leak test and the low power measurements and tuning, high power test will be performed to verify the effectiveness of this technique in the realization of an entire accelerating structure. This preliminary test open new perspectives to further extensions of this technique to the realization of C/X-band structures.

ACKNOWLEDGEMENT

I would like to aknowledge F. Cioeta and V. Lollo for the usefull suggestions on the mechanical design.

REFERENCES

[1] V.A. Dolgashev , *et al.*, Proceedings of the 21st Particle accelerator conference, Knoxville, TN, 2005 (IEEE, Piscataway,NJ, 2005).

[2] Int'l patent application PCT/IB2016/051464, D. Alesini *et al.*,*"Process for manufacturing a vacuum and radio-frequency metal gasket and structure incorporating it"* assigned to INFN.

[3] D. Alesini,*et al.*, Physical Review Accelerators and Beams 18, 02001, 2015.

[4] ANSYS HFSS, `http://www.ansys.com`

[5] *The Stanford Two-Mile Accelerator*, Neal R.B. (ed), W.A. Benjamin, Inc., New York, 1968.

[6] D. Alesini,*et al.*, Nuclear Instrumentation Methods Physics Results A 580 (2007) 1176-83.

[7] D. Alesini, Power Coupling, CERN Yellow Report CERN-2011-007 [arXiv:1112.3201] (2007).

[8] Autodesk Inventor `http://www.autodesk.com`