REALIZATION AND HIGH POWER TESTS OF DAMPED C-BAND ACCELERATING STRUCTURES FOR THE ELI-NP LINAC

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Abstract

The ELI-NP C-Band structures are 1.8 m long travelling wave (TW) accelerating cavities, quasi-constant gradient, with a field phase advance per cell of 2π/3. They operate at a repetition rate of 100 Hz and, because of the multi-bunch operation, they have been designed with a dipole HOM damping system to avoid beam break-up (BBU). The structures have symmetric input and output couplers and integrate, in each cell, a waveguide HOM damping system with silicon carbide (SiC) RF absorbers. An optimization of the electromagnetic and mechanical design has been done to simplify the fabrication and to reduce the cost. After the first full scale prototype successfully tested at the nominal gradient of 33 MV/m, the production of the twelve structures started. In the paper we illustrate the realization process and the low and high power test results.

INTRODUCTION

The linac booster of the ELI-NP Gamma beam system [1] consists of 12 TW C-Band disk loaded accelerating structures, 1.8 m long, quasi-constant gradient with 2π/3 field phase advance per cell. Since the linac operation is multi-bunch (32 bunches spaced by 16 ns), the structures have been designed with an effective damping of the HOM dipoles modes based on waveguide coupled to SiC absorbers. The design criteria have been illustrated elsewhere [2,3] and the main structures parameters are given in Table 1. In the paper we illustrate the realization process and the low and high power test results.

FABRICATION PROCEDURE

Each C-band structure has been divided in 10 modules: the input and output coupler (with the two adjacent cells) and eight modules, each one consisting of 12 cells. All modules have been fabricated, brazed and tested separately and have been then brazed all together. The fabrication of all components has been done at COMEB [4].

The manufacturing of the cells required several steps. After a rough machining, the cells underwent a stress relieving treatment in a vacuum furnace at 500°C for one hour. Such treatment allowed the relief of any internal stress caused by unwanted deformations due to machining and/or brazing procedures. They have been then milled (with the Vertical Work Center Hass VF 3 SS) while the final machining of the irises has been performed by means of the ultra-precise lathe Schaublin 225 TM-CNC that guarantees a precision ±5 µm and a surface roughness lower than 50 nm.

Table 1: Main Parameters of the ELI-NP Structures

Structure type	Quasi-Constant gradient
Working frequency (f_{RF})	5.712 [GHz]
Number of cells	102
Structure length	1.8 m
Iris half aperture radius	6.8 mm-5.78 mm
RF input power	40 MW
Average accelerating field	33 MV/m
Acc. field struct. in/out	37-27 MV/m
Average quality factor	8850
Shunt impedance	67-73 MΩ/m
group velocity (v_g/c)	0.025-0.014
Filling time	310 ns
Rep. Rate (f_{rep})	100 Hz
Average dissipated power	2.3 kW

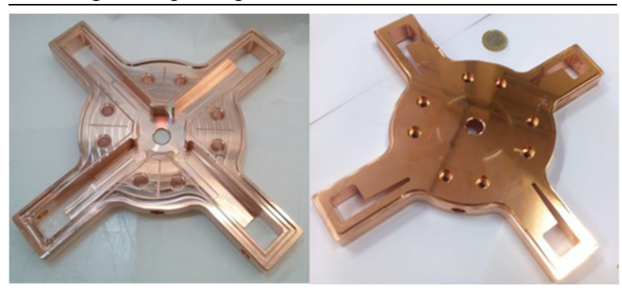

Figure 1: Picture of machined cell.

The picture of a machined cell is given in Fig. 1. Each cell has been checked with an automatic 3D measuring machine to verify all internal dimensions.

The manufacturing of the input and output couplers followed a similar procedure. They have been roughly machined (with the Vertical Work Center Doosan DNM 750 L) and underwent a stress relieving treatment in the vacuum furnace. The final machining has been done with the Vertical Work Center Mikron UCP 600 Vario with a precision on the internal dimensions lower than ±10 µm and with a surface roughness lower than 150 nm. Pictures of the couplers are given in Fig. 2. All components have been then cleaned in several steps: by neutral soaps, weak acid (citric) andby Almeco 19 and NGL soap in an ultrasound bath.

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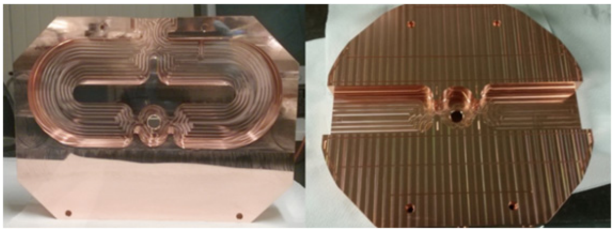

Figure 2: Machined input and output couplers.

The modules of 12 cells have been brazed at 850 ° C with Palcusil 10 alloy [5]. All external module dimensions have been verified with a 3D measuring machine (before and after the brazing process) and have been vacuum tested with a sensitivity lower than $5x10^{-10}$ mbar·l/s. The SiC (Ekasic-P) absorbers tiles (pre-machined) have then been inserted in the cells and fixed with special screws. A brazed module is shown on Fig. 3 with a detail of the SiC absorber fixed inside the module itself.

The two couplers have been brazed similarly. The picture of the input coupler is given on Fig. 3.

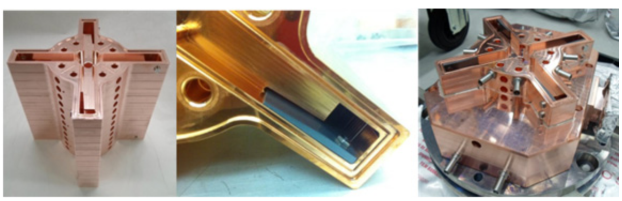

Figure 3: From the left: Twelve cell module, detail of the SiC absorber fixed inside the module, input coupler.

The last two brazing steps have been performed in the INFN LNL-Legnaro laboratories where a large vacuum furnace is available. The first sub-assembly was composed of six modules plus the output coupler while the second one was made up of the remaining two modules with the input coupler. The pictures of the two half structures before brazing are given in Fig. 4 (left). Palcusil 5 alloy at 810 ° C was used in this brazing phase. In the last oven cycle the two sub-assemblies have been joined by the Cusil alloy at 780° C. The picture of the full assembled structure in the LNL-INFN oven is given in Fig 4 (right).

The two brazing steps were necessary because the full length of 2.2 m of the vacuum furnace at LNL can be achieved with an extension not heated only.

The leak test has been done after the final brazing with a sensitivity lower than $5x10^{-10}$ mbar/l/s and, after the tuning phase described in the next paragraph, a moderate bake-out at 100 deg for 12 hours has been done reaching a pressure lower than $2x10^{-9}$ mbar under ion pumping, in perfect agreement with expectations [3]. The cooling channel distribution has then been implemented and the picture of the final structure is given in Fig. 5.

LOW POWER TESTS AND TUNING

The tuning of the structure has been done using the procedure described in [6]. Here we report the results of the first fabricated structure. The magnitude of the accelerating field and the phase advance per cell before and after the tuning are given in Figs. 5 and 6, respectively.

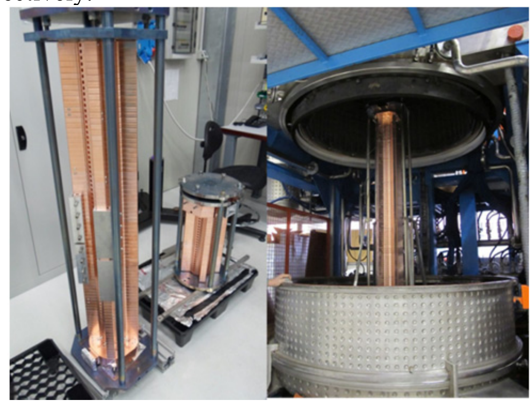

Figure 4: (Left) two half structures before brazing; (right) full assembled structure in the LNL-INFN oven.

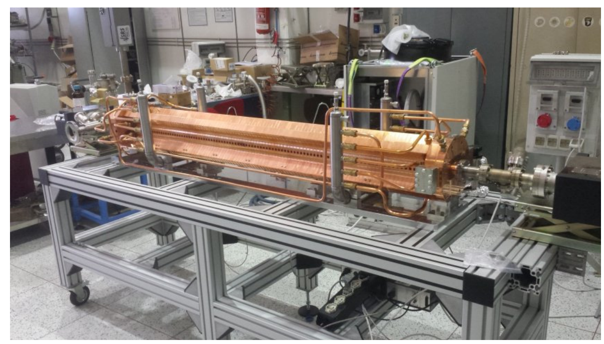

Figure 5: Full C-band structure.

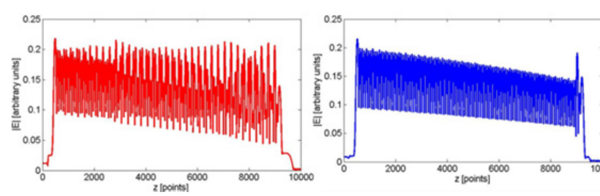

Figure 6: magnitude of the accelerating field before (left) and after (right) the tuning.

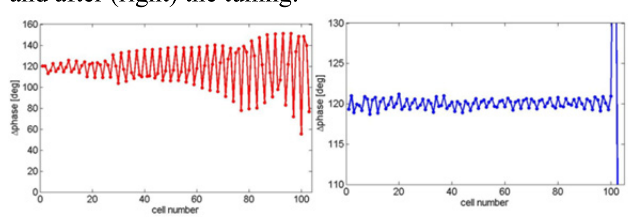

Figure 7: Phase advance per cell before (left) and after (right) tuning.

The peak in the accelerating field at the end of the structure (and the corresponding oscillation in the phase advance per cell) has been introduced during the tuning phase to compensate the reflections coming from the output coupler probably due to a deformation occurred during the brazing phase. In the following structures this deformation has been compensated changing the dimensions of the coupler itself. The final field flatness is below 1%, while the final phase advance per cell is within ±1.5 deg with respect to the nominal one. The reflection coefficient at the input port before and after the tuning is given in Fig. 8 and, at the working frequency, is ~-30 dB.

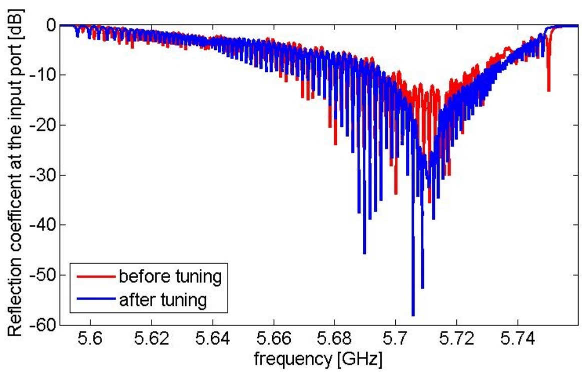

Figure 8: reflection coefficient at the input port before and after the tuning.

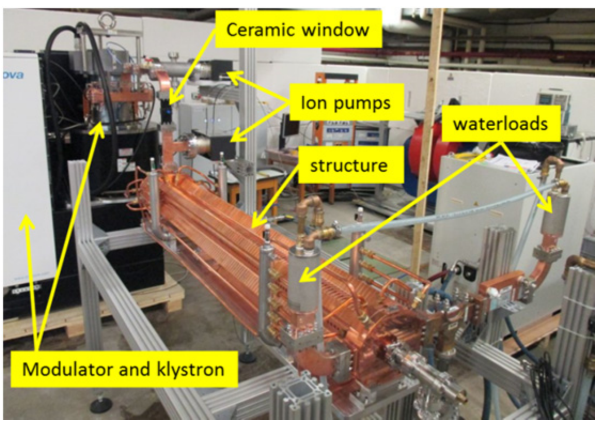

Figure 9: C-band structure under high power test.

HIGH POWER TEST RESULTS

The first structure has been also tested at high power at the Bonn University under RI responsibility [7].

A picture of the structure under high power test is given in Fig. 9. The power source was the ELI-NP nominal one: Scandinova RF Unit based on Solid State modulator K2-2 adapted for 50MW C-band Toshiba klystron E37212.

The aim of the RF conditioning was to reach 40 MW at the input coupler at a rep. rate of 100 Hz with the 820 ns pulse width (one filling time plus beam time). The forward/reflected power signals at the input and output couplers were measured using diodes and oscilloscopes. These readings were recorded by means of a Labview GUI which calculates the corresponding power levels. The klystron power, rep. rate and pulse length were progressively increased and the current of three ion pumps (connected to the input and output waveguides) and the RF signals from pickups were monitored. The conditioning procedure was semi-automatic and the switch-off on the modulator HV could be caused by: (a) operators; (b) ion pumps current absorption exceeded a threshold corresponding to a pressure of 1×10^{-7} mbar; (c) reflected power to the klystron exceeding 10%.

The RF conditioning for the first RF structure lasted about 190 hours. In Fig. 10 the behavior of the RF Pulse length, input power and repetition rate as a function of time are reported. The vacuum pressure, measured both at the beginning and at the end of the structure, was of the order of 1×10^{-8} mbar at the final nominal parameters. Figure 11 shows the vacuum pressure measured by the three ion pumps current absorption as a function of the conditioning time. The reached breakdown rate at the end of the conditioning was of the order 10^{-6} bpp/m.

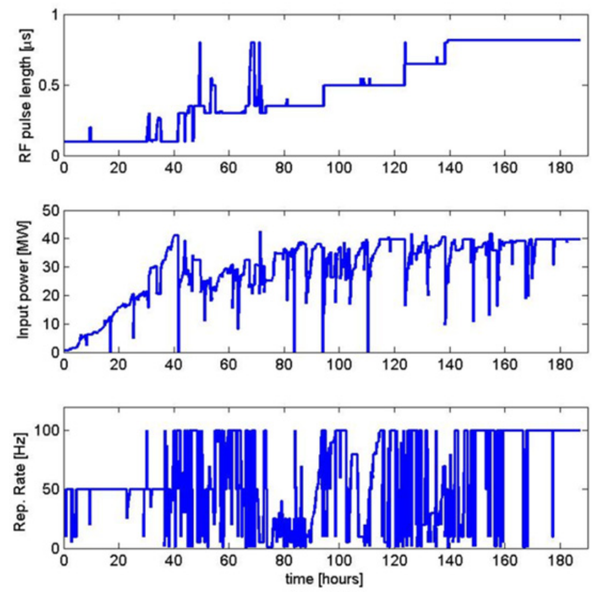

Figure 10: Behavior of the RF Pulse length, input power and repetition rate as a function of time during the high power test of the C-band structure.

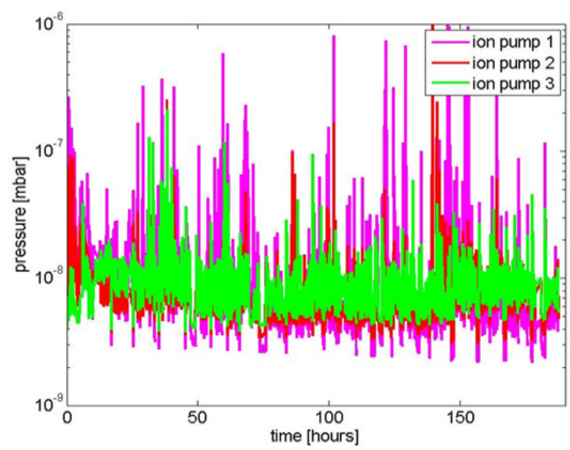

Figure 11: Vacuum pressure as a function of the conditioning time.

CONCLUSIONS

The ELI-NP C-Band structures are now under realization. In the paper we illustrated the fabrication procedure and the low and high power test results on the first fabricatedcavity. The structure has reached, in about 190 hours of RF conditioning, the nominal parameters in terms of gradient (33 MV/m), repetition rate (100 Hz) and pulse length (800 ns).

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