TIARA-REP-WP8-2014-003

Test Infrastructure and Accelerator Research Area

Status Report

Installation, commissioning and test of the C-band Linac at SPARC

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This work is part of TIARA Work Package **8: HGA R&D Infrastructure**.

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Test Infrastructure and Accelerator Research Area

Installation, commissioning and test of the C-band Linac at SPARC

Deliverable 8.2

February 2014

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WP8: High Gradient Acceleration

The goal of the Work Package 8 is the energy upgrade of the Frascati SPARC test-facility linac by designing, constructing and commissioning two C-band (f=5712 MHz) TW high-gradient accelerating structures. The construction of the two accelerating sections was accomplished as Deliverable D8.1 of WP8. This report summarizes the results of the installation, commissioning and test of the C-band Linac at SPARC, as Deliverable 8.2.

The new C-band structures are fed by a 50 MW klystron Toshiba E37202. The high voltage pulsed modulator and the 400 W solid state driver for the klystron have been manufactured respectively by ScandiNova (S) and MitecTelecom (CDN). The new system will also include a pulse compressor provided by the Institute of High Energy Physics (IHEP, Beijing).

The C-band structures are travelling wave constant-impedance (CI) sections. A detailed illustration of their design criteria can be found in [1]. Each structure has 71 accelerating cells. The mechanical drawing of the prototype is given in Figure 1 (a). The input coupler includes the splitter while, for the output one, two symmetric ports to be connected to two RF loads have been chosen. Table I reports the main structure parameters. The mechanical drawings of the single cell are shown in Figure 2. Each cell has been machined as a “cup” and includes one iris. The cooling system has been integrated in each cell with 6 cooling pipes. Three tuners at 120 deg have been inserted. They allow deforming the outer wall of each cell in both directions.

Previous to the realization of the final devices, a prototype with a reduced number of cells has been realized and high power tests have been carried out at KEK by the Frascati INFN group in collaboration with the Japanese KEK laboratory. The details of the high power test results on the prototype are reported in [1]. The mechanical drawing of the prototype is given in Figure 1 (b). Experimental results on this first prototype confirmed the reliability of its operation at 50 MV/m accelerating gradient with about 10^{-6} breakdowns per pulse per meter, as shown in the Figure 3, where the breakdown rates (BDR) measured at different field values before and after conditioning are given.

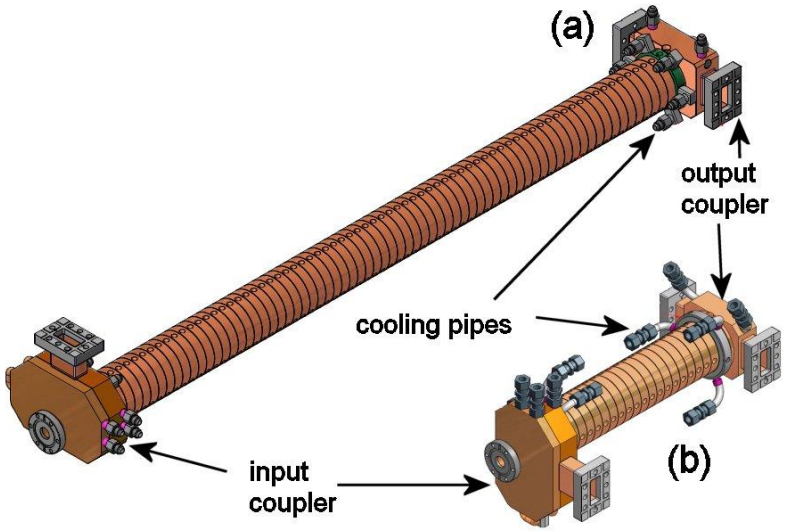

Fig 1: Mechanical drawing of the C-Band Structure (a) and prototype (b). Picture taken from [1].

TABLE I: Main C-Band structure parameters

PARAMETER	Value
Frequency (f_{RF})	5.712 [GHz]
Phase advance per cell	$2\pi/3$
Number of accelerating cells (N)	71
Structure length including couplers (L)	1.4 [m]
Cell length (d)	17.495 [mm]
Iris radius (a)	7 [mm]
Group velocity (v_g/c):	0.0283
Field attenuation (α)	0.206 [1/m]
Shunt impedance (r)	82.8 [MΩ/m]
Filling time (τ_F)	150 [ns]
Accelerating gradient	>35 [MV/m]
Output power	$0.60 \cdot P_{in}$
Average dissipated power @ 10 Hz	59.6 [W]

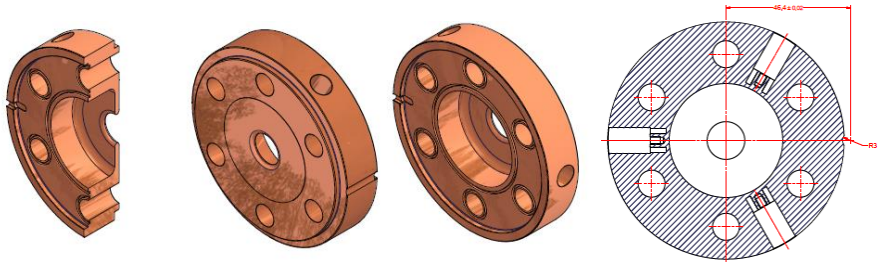

Fig. 2: Mechanical drawings of the single cell.

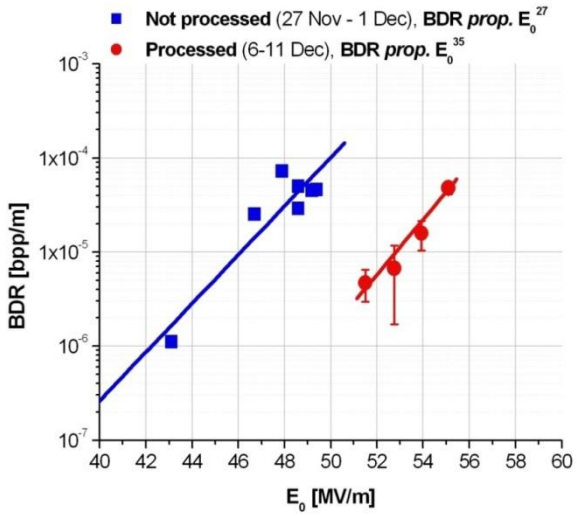

Fig. 3: Breakdown rates as measured at different field values before and after conditioning of the SPARC C-Band prototype (plots taken from [1]). After processing, about 50MV/m accelerating field has been reached, with a BDR per meter of the order of 10^{-6}.

The fabrication of the RF cells of the accelerating structure was performed at LNF; the critical issues of the fabrication phase are the mechanical tolerances and the internal surface finishing. Details of this work can be found in the Deliverable D8.1 Report [2].

The cells of the first structure have been joined in two stacks and brazed in two halves at LNF, since the dimensions of the LNF oven do not allow for brazing the whole accelerating cavity (Figure 4). Also IN-OUT couplers of the structure were fabricated and brazing of stainless steel flanges was performed. Then brazing of the stacks of cells with the in/out couplers for the first structure was done.

Fig. 4: Preparation of the cells. Stacking the cells (left), inserting alloy rings for brazing (right).

The procedure for brazing together the two stacks of cells was very delicate, since a problem occurred in the final brazing between the two halves of the structure that caused a field reflection and a consequent reduction of the accelerating field. The mechanical drawing of the central junction has been then modified and this new design was implemented also in the second structure. Figure 5 shows the prototype of the two central cells of the new junction successfully realized, brazed and tested.

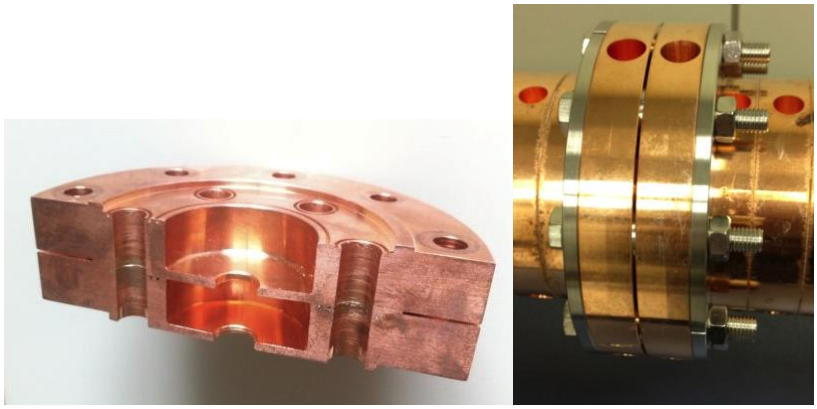

Fig. 5: Prototype of the new junction between the two half structures (left) and the two new central cells ready for brazing (right).

A special support was built to be able to braze horizontally the final structure with the new cells for the central junction. This time the brazing was successful, and the same procedure was then repeated for the second accelerating structure. On bench RF measurements were done (Figure 6) on both structures and tuning of the electrical field was performed. The structure has been successfully tuned after the brazing process (using the procedure developed in [3, 4], performed in collaboration

with a group from Rome La Sapienza University as sub-contractor. The measured electric field before and after the tuning with the phase advance per cell are given in Figure 7. Similar results have been obtained for the second structure.

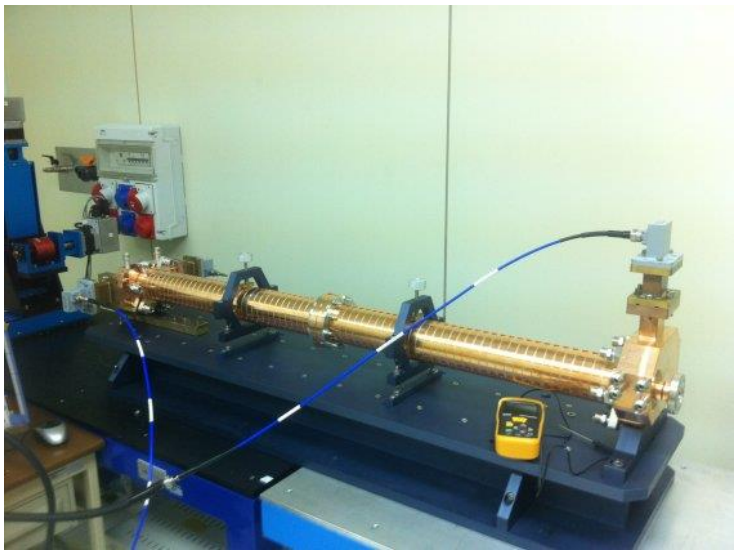

Fig. 6: Final C-band complete accelerating structure on bench.

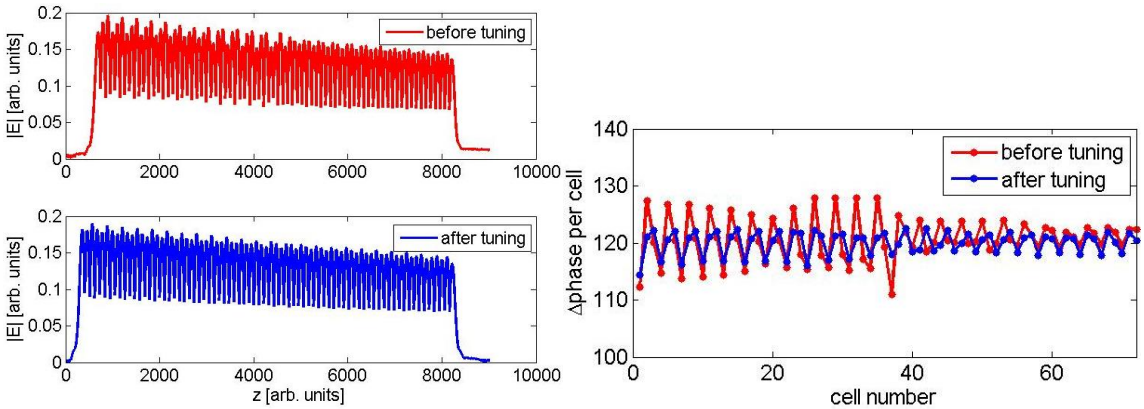

Fig. 7: Measured field and phase advance per cell before and after the tuning [3, 4].

The first structure has been installed in the SPARC hall for high power test on October 2013 (see Figure 8). The waveguide line from the klystron to the structure (including T-pumping units and RF pickups) has been connected and tested.

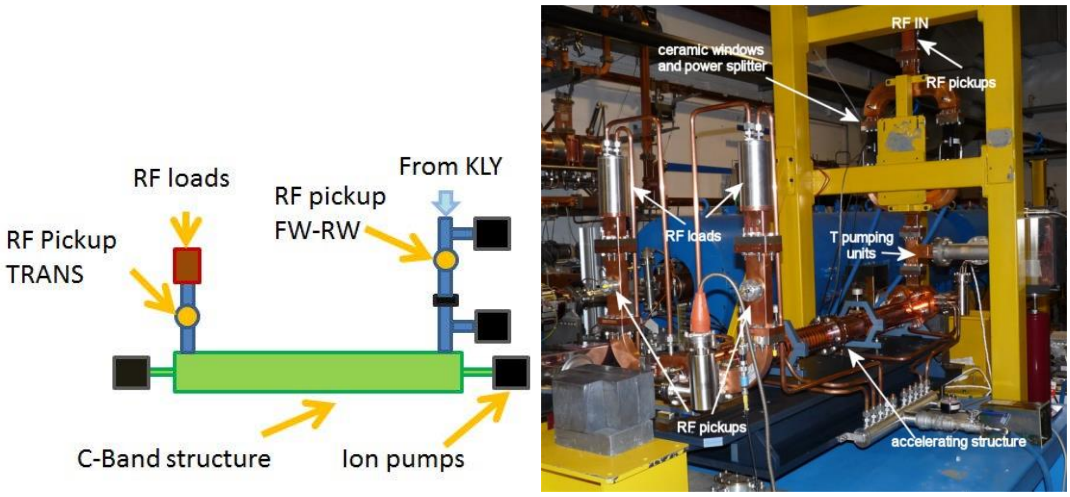

Fig. 8: C-Band structure installed in SPARC for high power tests.

The RF conditioning has been done in three steps:

a) test of the Klystron system terminated to a dummy load;
b) test of the waveguide system up to the SPARC hall terminated to a dummy load;
c) test of the accelerating structure.

The high power test on the first C-band structure started on November 2013. Operation was at 10 Hz with the nominal pulse width of 165 ns (slightly longer than the filling time of the structure). The power from the klystron was progressively increased (by increasing the HV of the modulator) at the same time monitoring the current absorption of the 4 ion pumps (3 connected to the structure and 1 to the waveguide before the splitter) and the RF signals from pickups.

A picture of the control panel is given in Figure 9. A typical event of discharge monitored by the increase in vacuum pressure is given in Figure 10 while the picture of the RF monitored signals is given in Figure 11. Normal operation conditions were a vacuum level in the structure between $5 \cdot 10^{-10}$ mbar and $2 \cdot 10^{-9}$ mbar.

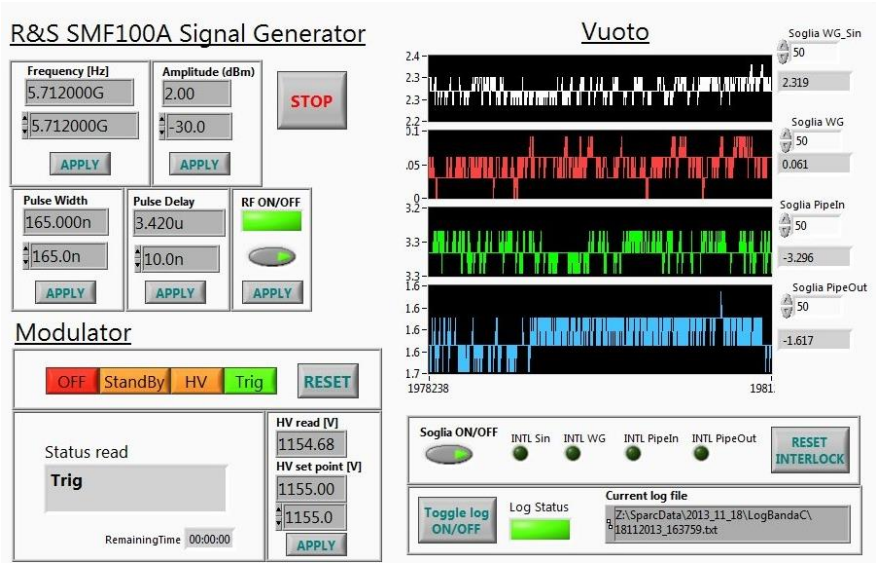

Fig. 9: Control panel for high power test.

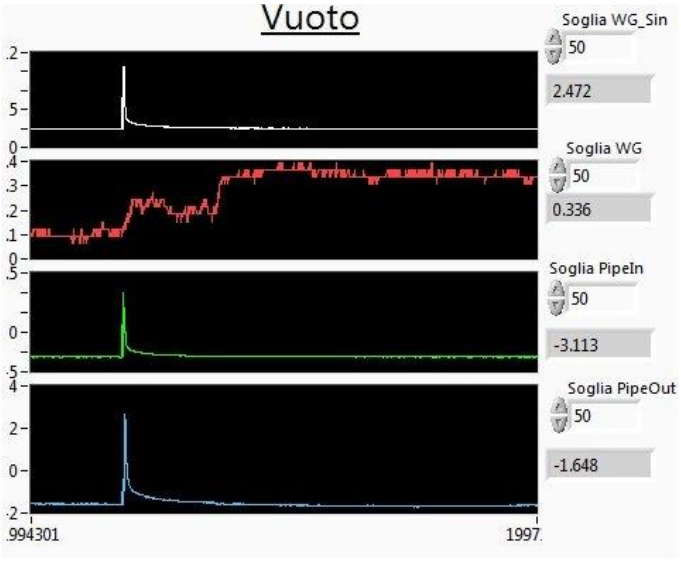

Fig. 10: Typical event of discharge monitored by the increase in vacuum pressure.

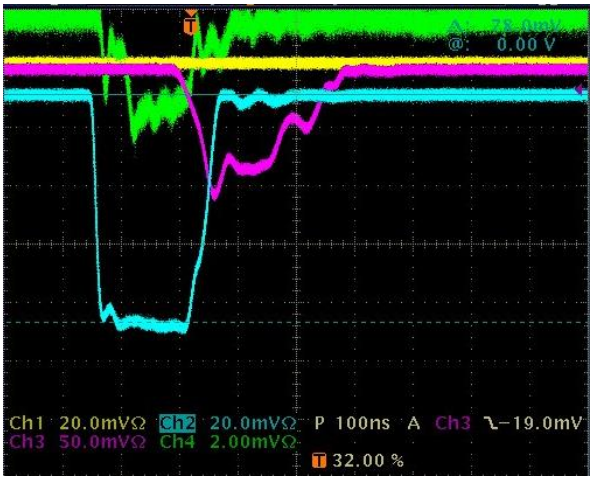

Fig. 11: Picture of the RF monitored signals: cyan is forward input power, green is reflected power, magenta is transmitted power.

The LLRF system that controls the structures has been provided by PSI [5] with a GUI application for remote control. At LNF it has been developed a custom console, using the EPICS CA drivers in LabVIEW programming environment that is fully compatible with the SPARC_LAB control system. The conditioning of the second C band accelerating structure is being performed by means of that interface, integrated in a "conditioning console" application that also includes vacuum reading and RF power station control. Figure 12 shows the initial PSI GUI (on the right side) running together with the SPARC_LAB console application that is controlling the LLRF during the conditioning (read signals from linac, control amplitude and phase of the RF driving pulse).

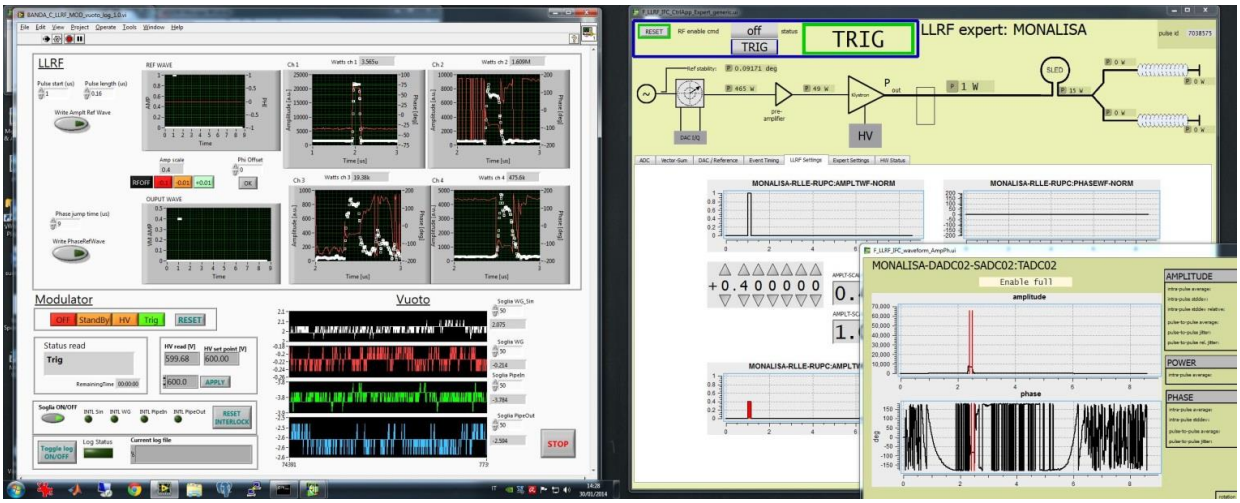

Figure 12 : PSI GUI (right) running together with the SPARC_LAB console application that is controlling the LLRF during the conditioning

The duration of the RF conditioning for the first RF structure was about 10-15 full equivalent days. As a result, it was reached:

a) a 38 MW input power in the structure (44 MW from the klystron), nominal repetition rate and pulse length;
b) the corresponding accelerating field was 36 MV/m peak and 32 MV/m average;
c) a BDR <10^{-5} or less, not measured yet since a correct measurement of the BDR requires a long time;
d) a 340 kV modulator voltage.

A picture of the C-band modulator control panel at the maximum input power is given in Figure 13.

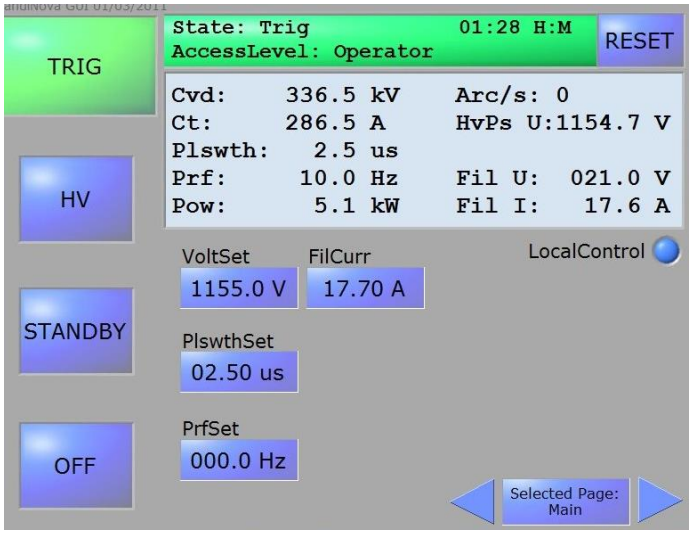

Fig. 13: Picture of the C-band modulator control panel.

The RF conditioning of the second RF structure started on late December 2013 and was concluded on February 2014. Similar results have been obtained, confirming the achievement of the WP8 Deliverable 8.2.

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