



**FABRICATION AND TESTING OF A NOVEL S-BAND BACKWARD
TRAVELLING WAVE ACCELERATING STRUCTURE FOR PROTON
THERAPY LINACS**

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Abstract

Compact and more affordable, facilities for proton therapy are now entering the market of commercial medical accelerators. At CERN, a joint collaboration between CLIC and TERA Foundation led to the design, fabrication and testing of a high gradient accelerating structure prototype, capable of halving the length of state-of-art light ion therapy linacs. This paper focuses on the mechanical design, fabrication and testing of a first prototype. CLIC standardized bead-pull measurement setup was used, leading to a quick and successful tuning of the prototype. The high power tests will soon start in order to prove that the structure can withstand a very high accelerating gradient while suffering no more than 10^{-6} breakdown per pulse per meter (bpp/m), resulting in less than one breakdown per treatment session.

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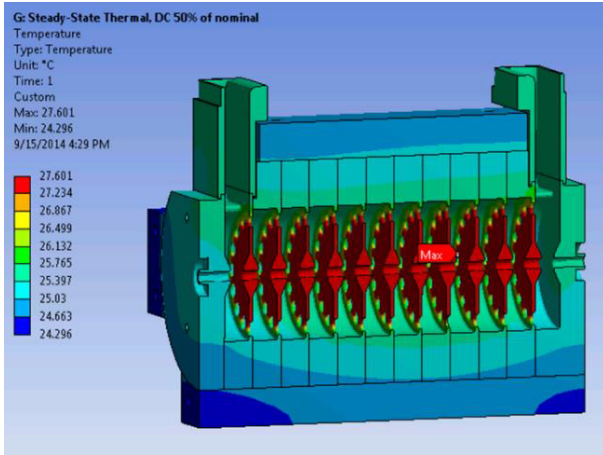


Figure 2: Temperature distribution in the structure in case of a load of 0.75 kW, and cooling water at 22 deg.

The full structure design is presented in Fig. 3. It is possible to notice the details of the cooling plates and pipes, dimple tuners and waveguides transition to standard WR284.

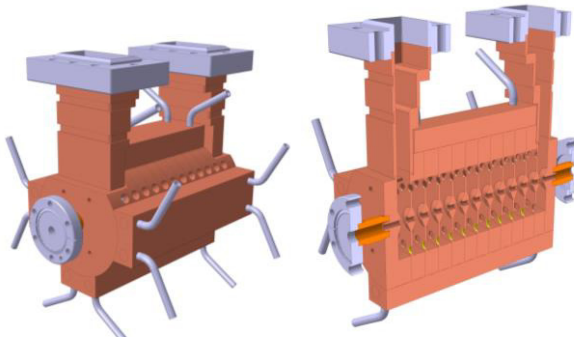


Figure 3: Mechanical design of the prototype.

FABRICATION

Once the ultra-precision machined disks arrived at CERN, they underwent visual and metrological inspection to check the presence of eventual surface defects and compliance with the nominal values indicated in the drawings (Fig. 4).



Figure 4: Regular and input cell of the prototype.

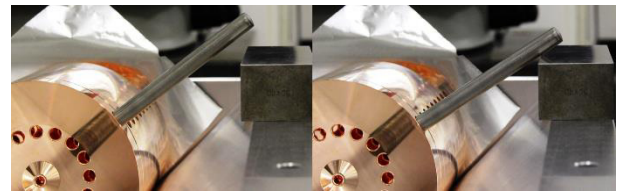


Figure 5: Disks alignment procedure.

A low power RF test was performed on the structure prior to bonding, in order to verify that the prototype was within the tuning range. The stack of disks was joined by diffusion bonding in a partial hydrogen atmosphere following the CLIC baseline fabrication procedure. The fabrication technique was chosen so that the high-gradient test results can be most easily compared to the structures tested in the CLIC high-gradient program. The axial alignment of the disks was ensured thanks to a precise V-shape support whereas azimuthal alignment was performed using the tuning holes as seen in Fig. 5.

After the structure was assembled by brazing the cooling blocks and vacuum tubes and input waveguides, it was returned to CERN for the final tuning. A summary of the tests performed on the prototype is shown in Fig. 6.

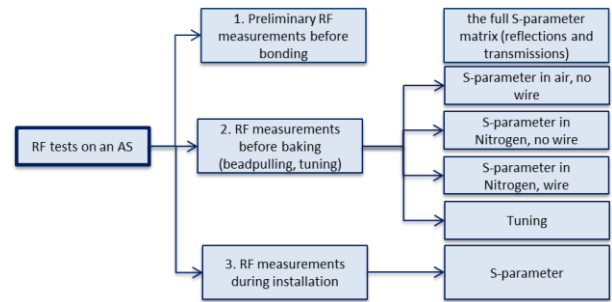


Figure 6: Scheme of the RF tests performed on the accelerating structure.

TUNING

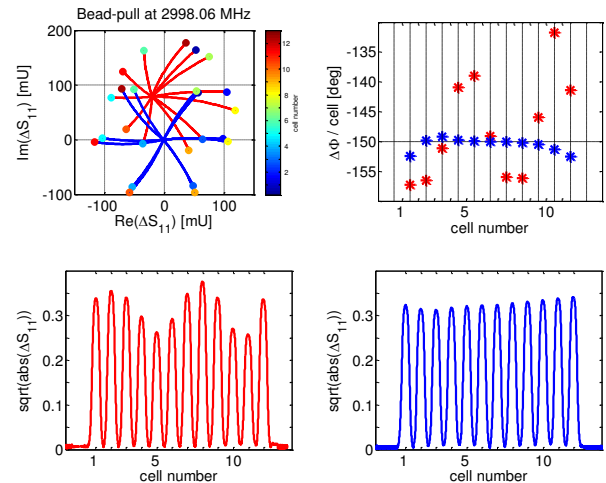


Figure 7: Electric field pattern along the structure for all 12 cells, before (in red) and after tuning (in blue). Top left: in the complex plane; top right: in phase advance per cell; bottom: in magnitude.

All 12 cells (10 regular and 2 coupling cells) of the structure were adjusted in frequency by pulling or pushing up to 4 tuning pins in each cell. The available tuning range per cell is about ± 3 MHz. Bead-pull measurements were used to determine the electric field profile along the axis. The standing wave pattern was minimised and the desired phase advance of $150 \pm 1.5^\circ$ for regular cells was adjusted for the operating frequency of 2.9985 GHz under vacuum at a temperature of 32° . The frequency of the output coupling cell was increased by 2.2 MHz, the frequency of the 10 regular cells was increased between 0.1 and 0.8 MHz (average 0.3 MHz, std 0.2 MHz) while the frequency of the input coupling cell was decreased by 0.6 MHz. Fig. 7 shows the electric field pattern along the structure and Fig. 8 the measured S-Parameters after tuning.

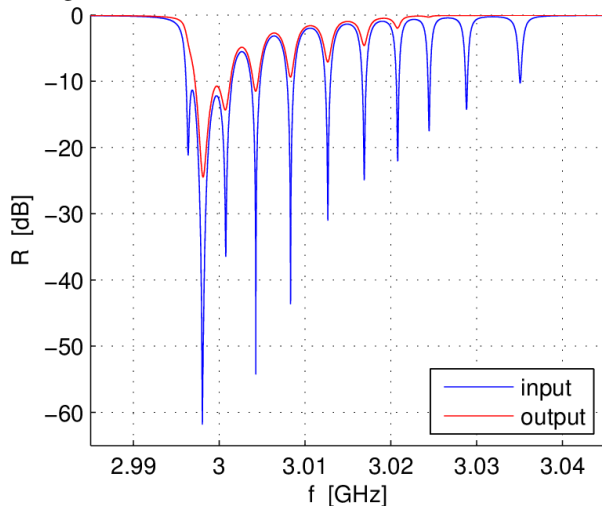


Figure 8: Input and output S-parameters of the tuned structure, measured at a temperature of 23°C in a dry nitrogen atmosphere.

HIGH POWER TEST SET-UP

A high power test of the prototype is under preparation using a bunker and infrastructure of the CLIC Test Facility (CTF3) to evaluate its breakdown performance. An S-band klystron unit is connected to the accelerating structure, located in the CTF2 bunker room, via WR284 waveguides (Fig. 9).

To ensure the ultra-high vacuum in the structure, below 10^{-8} mbar, an ion pump is installed next to the prototype through an RF pumping. In addition, a vacuum leak test of the prototype has been made in situ at the testing place.

The control and acquisition system are based on National Instrument electronics, a largely direct copy of the configuration of the Xbox-2 test stand [4]. The structure is equipped with a complete experimental set-up for breakdown diagnostics. Two Faraday cups are attached to both ends of the prototype for breakdown detection and dark current measurements. Incident, reflected and transmitted RF power is extracted by bi-directional couplers inserted before and after the structure. The amplitude and phase of these 3 GHz signals will be

processed by down-mixing to 62.5 MHz and digitizing in 250 Msps ADCs. The analysis of these signals will allow the longitudinal localization of vacuum arcs in the structure [5].

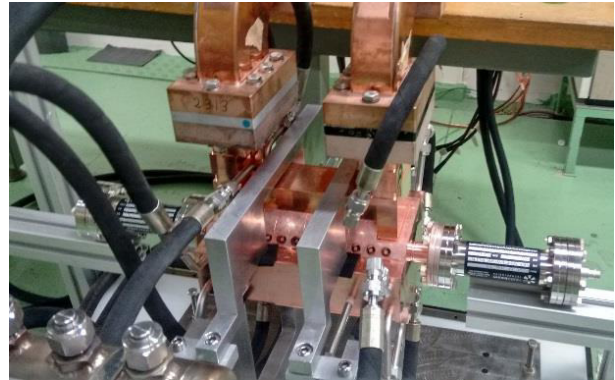


Figure 9: Picture of the prototype under test in CTF2.

SUMMARY AND FUTURE STEPS

A 3 GHz Backward Travelling Wave (BTW) accelerating structure with geometric beta of 0.38 was recently designed and built at CERN. The main goal of the project is to investigate the accelerating gradient limits of the S-band regime. In this paper, the mechanical design, fabrication and tuning of the prototype is discussed, together with the high power test set-up. The prototype is currently installed in CLIC CTF2. The start of high – gradient testing is imminent.

ACKNOWLEDGMENT

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