

A BIPERIODIC X-BAND RF CAVITY FOR SPARC

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Abstract

The Frascati photo-injector SPARC (Pulsed Self Amplified Coherent Radiation Source) will be equipped with a X-band RF cavity for linearizing emittance to enhance bunch compression and for reducing bunch longitudinal energy spread. A biperiodic cavity working on the $\pi/2$ -mode offers some advantages in comparison to a conventional (periodic) cavity despite the need of accurate machining. A copper prototype made of seventeen separated cells has been built following numerical simulation. In this paper we report on preliminary measurements of its RF properties. The main characteristics of the cooling system for the final device are also addressed.

INTRODUCTION

The proposed $\pi/2$ accelerating section represents an alternative design to the standard π -mode cavity [1] for longitudinal phase space compensation at SPARC [2], as the lower sensitivity (of the cavity field distribution and resonant frequency) to the machining error, cell-to-cell temperature variations and assembly errors. The price to be paid is a lower shunt impedance per unit length and major fabricating costs because of the presence of the coupling cells, with respect to the π -mode structure. Bead-pull measurements on a copper prototype have been done and the results are illustrated and compared with the numerical ones. The sketch of the cavity profile with dimensions is reported in Fig. 1. The X-Band structure is designed to obtain 5MV

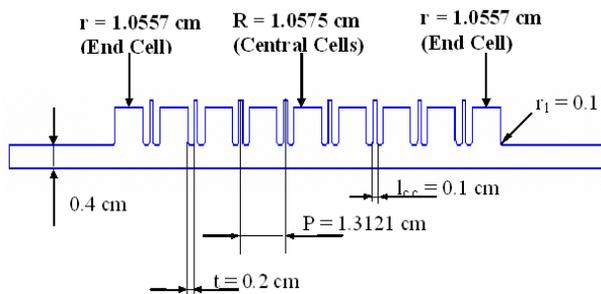


Figure 1: Longitudinal section of the cavity.

accelerating voltage with an input power of 3MW. It is a 17 cells structure fed by a central coupler.

SIMULATION RESULTS

The detailed analysis of the structure design without coupler is reported in [1]. The 2D design have been performed

using SUPERFISH code. The double periodicity of the structure operating on $\pi/2$ -mode introduces a *stop-band* in the dispersion curve with two $\pi/2$ -mode configurations (Fig. 2). There are two modes with $\pi/2$ cell-to-cell phase shift: one excites the long accelerating cavities, the other one excites the short coupling cavities. In order to close

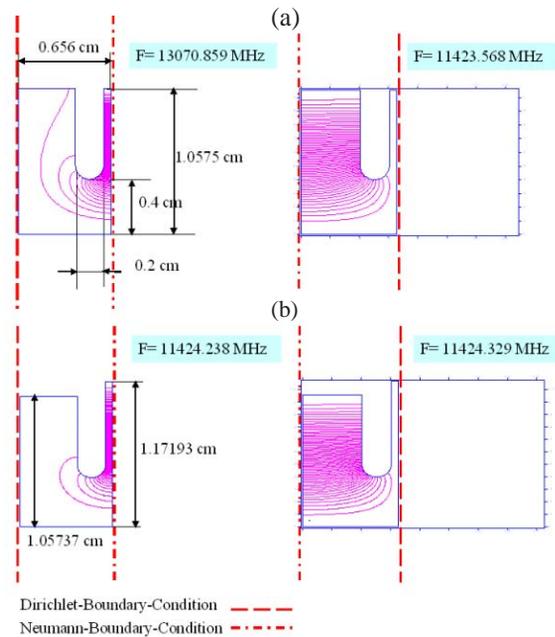


Figure 2: Half-cell simulated structure with the different configuration of the accelerating and no-accelerating electric field lines when the stop-band is open(a) or close(b).

the stop-band, the short cavity radius has been increased up to make the resonant frequencies of the two modes equal. Prototype radius of the coupling cell with open and close stop-band vary of 0.6mm. The corresponding field distributions of the accelerating and coupling cells are reported in Fig. 2. The dispersion curves obtained from HFSS and GDFIDL code, compared with the one obtained from SUPERFISH, are superimposed over same Fig. 3 for the case of stop-band open and stop-band close. 3D simulation codes (HFSS and GDFIDL) have been used to design a proper feeding system for the cavity in the central cell in order not to excite the adjacent modes that have the nearest frequency to the $\pi/2$ mode and zero field in the central cell. Therefore with central coupler we have a much greater modes separation and the working mode is less perturbed by the closest ones. The coupling cell, coupler and window dimensions are sketched in Fig. 4. The dimension

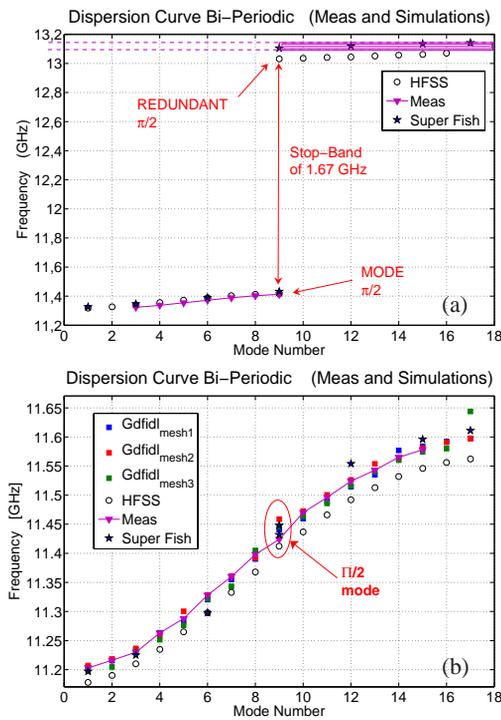


Figure 3: Measured dispersion curve in the case of: a) *stop-band open* and b) *stop-band close*, compared to simulation code results.

signed for brazing, but the RF tests refer to a mechanically joined structure. The material used to build this prototype is oxygen free copper. The structure has been realised by mechanical machining with a numerically controlled lathe and the obtained precision is below 0.01mm , while the surface roughness is not worst than $0.4\mu R_a$. The assembling procedure foresees the joining of the seventeen cells using two stainless disks used to press the structures by means of three 8mm diameter copper rods. A torque of 11N/m was applied to every rod, corresponding to a pressure of roughly 80N/mm^2 . Each accelerating cell has a tuning

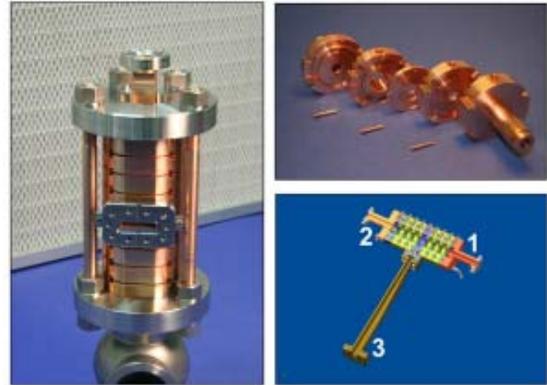


Figure 5: Copper prototype of the structure.

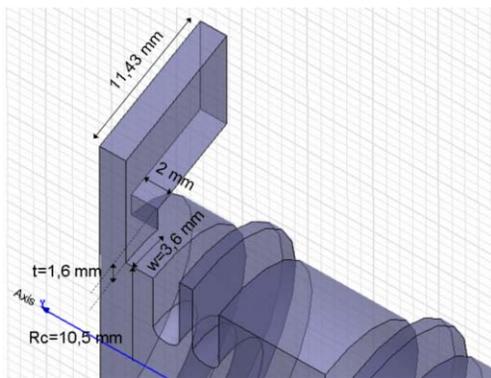


Figure 4: Sketch of the coupling cell.

of the coupler window (w) and of the central cell radius (R_c) have been tuned in order to obtain simultaneously a coupling coefficient $\beta = 1$, a resonant frequency of the whole system equal to 11.424GHz and to preserve a good field flatness. We have obtained the coupling coefficient $\beta = 0.97$ with a good field flatness, within few percent.

THE PROTOTYPE

Mechanical Characteristics

Two full scale copper prototype has been constructed and it is shown in Fig. 5. The 17 cells structure has been de-

screw (with radius of 3mm and length of 5mm , Fig. 5) to vary the cell volume and thus the resonant frequency and field distribution. The average frequency variation due to maximum elongation for each tuner is not greater than 0.5MHz . To feed the structure two lateral small antennas are also inserted (position 1, 2 of Fig. 5). Two type of different measurements have been carried out: transmission (or reflection) scattering coefficient measurements between the two antennas or between the antennas and the central coupler (port 3 in Fig. 5) and bead pull measurements.

Electromagnetic Characterisation

The transmission coefficient between the two small lateral antennas and between the antennas and the central coupler have been measured both in the stop-band open and stop-band close structures. As previously observed, we can excite only nine over seventeen possible modes by central coupler because we impose a non-zero field in the central cell. On the contrary with the two antennas we can excite all the possible modes. The quality factor of the resonance has been measured and compared with the numerical ones. The Q factor of the $\pi/2$ mode in the case of stop-band close is reported in Tab. 1; the measured Q is lower than the calculated ones since the cavities are not brazed yet. The measured dispersion curve, compared with the one obtained from HFSS, GDFIDL and SUPERFISH, is reported in Fig. 3. Showing a good agreement with the simulation

Table 1: Quality and form factors measured on the stop-band close prototype compared with the numerical results.

	HFSS	Superfish	Meas
Q_0	7412	7101	5815
$R/Q(\Omega/m)$	9452	9693	9150 ± 200

results.

With the bead pull technique we measured the electric field on axis [4]. To calculate the R/Q we have calibrated the bead form-factor comparing the perturbation induced by the perturbing object in a pill-box cavity working at $1.91GHz$ on the TM_{010} mode with analytical results. Using different resonant modes of the pillbox cavity we have also checked that the form-factor does not depend on the frequency, within our measurement uncertainty.

The measured longitudinal electric field on axis, for the stop-band close structure, is plotted in Fig. 6. The tuning procedure allow a field-flatness of the order of 3% at the nominal resonant frequency of $11.424GHz$. The mea-

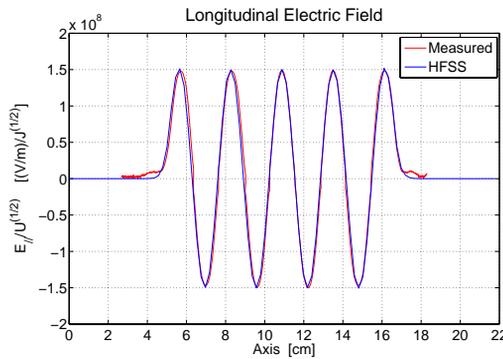


Figure 6: Measured and simulated electric field on axis at the $\pi/2$ -mode resonant frequency.

sured R/Q per unit length is reported in Tab. 1 and it is in very good agreement with the simulation results.

PRELIMINARY THERMAL ANALYSIS

To maintain the structure dimensions unchanged during operation, a close temperature control during the operation is needed. The main factors that affect the section temperature are the RF power losses, the heat transfer mechanism from the structure to the cooling tubes and the cooling water temperature variation.

The frequency shift behaviour versus the heating of the structure has been studied by the integration between ANSYS [3] and SUPERFISH. A temperature variation $\Delta T = 1^\circ C$ causes a $191kHz$ frequency shift by assuming an isotropic expansion and a $80kHz$ frequency shift if one considers the real power distribution shown in Fig. 7. The maximum dissipated power on the surface is $3.5W/cm^2$.

These results show that temperature stabilisation within

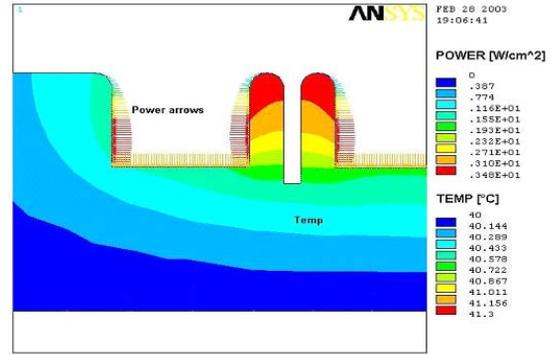


Figure 7: Thermal flux and distribution in temperature using copper, simulated by ANSYS code.

$0.1^\circ C$ has to be applied at the maximum duty cycle to keep the structure frequency within 1/100 of the frequency bandwidth.

CONCLUSIONS

A Bi-Periodic X-Band accelerating section for linearizing the longitudinal phase space in SPARC project has been proposed and the copper prototype has been realised. Resonant frequency, quality factors and electric field have been measured on the copper prototype in the open and close stop-band cases. Even if the prototype is not brazed the measurement results are very close to the expectation. Thermal analysis has been carried out using ANSYS code. Brazing tests are now in progress in the LNF for the construction of the final device.

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