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DESIGN OF A COMPACT Ka-BAND MODE LAUNCHER FOR HIGH-GRADIENT ACCELERATORS

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Abstract

In this work, we present the RF design of a table-top Ka-Band mode launcher operating at 35.98 GHz. The structure consists of a symmetrical 4-port WR28 rectangular-TE10-to-circular-TM01 mode converter that is used to couple a peak output RF power of 5 MW (pulse length up to 50 ns and repetition rate up to 100 Hz) in Ka-Band linear accelerator able to achieve very high accelerating gradients (up to 200 MV/m). Numerical simulations have been carried out with the 3D full-wave commercial simulator Ansys HFSS in order to obtain a preliminary tuning of the accelerating field flatness at the operating frequency $f_0 \simeq 35.98$ GHz. The main RF parameters, such as reflection coefficient, transmission losses, and conversion efficiency are given together with a verification of the field azimuthal symmetry which avoids dipole and quadrupole deflecting modes. To simplify future manufacturing, reduce fabrication costs, and also reduce the probability of RF breakdown, the proposed new geometry has "open" configuration. This geometry eliminates the flow of RF currents through critical joints and allows this device to be milled from metal blocks.

INTRODUCTION AND MOTIVATION

Investigations are in progress for using short accelerating structures in the Ka-band regime since ultra-high gradient higher harmonic RF accelerating structure is needed for the linearization of the longitudinal phase space [1]. Moreover there is a strong demand for accelerating structures able to achieve higher gradients and more compact dimensions. In this work we report the numerical design of a compact Ka-band standing wave (SW) accelerating structure composed of a 4-port rectangular waveguide coupler and an elliptical cavity comprising a predefined number of accelerating cells. In order to compensate the non-linearity distortions due to the RF curvature of the accelerating cavities, the use of a compact third harmonic accelerating structure working at f = 35.98 GHz is required (mode at the third RF harmonic with respect to the main Linac RF frequency ($f_0 \sim$ 11.99 GHz) at a 200 MV/m accelerating gradient) [2]. The electric field distribution inside the 3D model of one-eighth of half a SW structure simulated with the HFSS software is shown in Fig. 1.

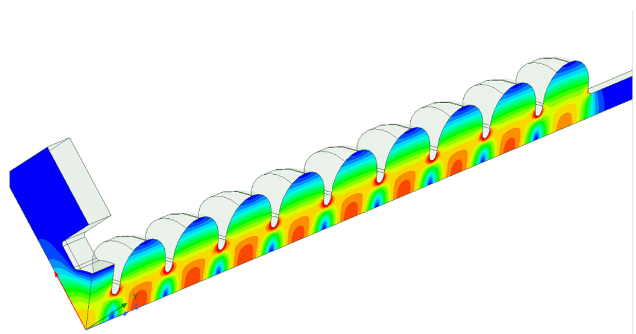

Figure 1: E-field in the structure (Ka-Band linac 19 cells) with coupler simulated by HFSS. Thanks to the cavity symmetry, only 1/16 of the structure has been simulated.

RF DESIGN

Geometry

The full structure is visible in Fig. 2. It is composed by a symmetrical 4-port WR28 rectangular-TE10-to-circular-TM01 mode converter [3,4] , which is used to feed a 19-cells elliptical cavity (18 accelerating cells plus one central coupling cell). The numerical optimization has been performed in the case of iris radius a = 1 mm and a = 1.333 mm. The total structure length along the longitudinal z direction, comprising accelerating cells, couping cell and the I/O beam pipes, is equal to 99.1926 mm.

Numerical Results

The normal conducting structure works on the TM_{010} mode, where the longitudinal momentum is provided by on axis longitudinal electric field, with π phase advance in the accelerating cells. The operating frequency is $f_0 \simeq$ 35.98 GHz. A peak RF power of 5 MW (pulse length up to 50 ns and repetition rate up to 100 Hz) has

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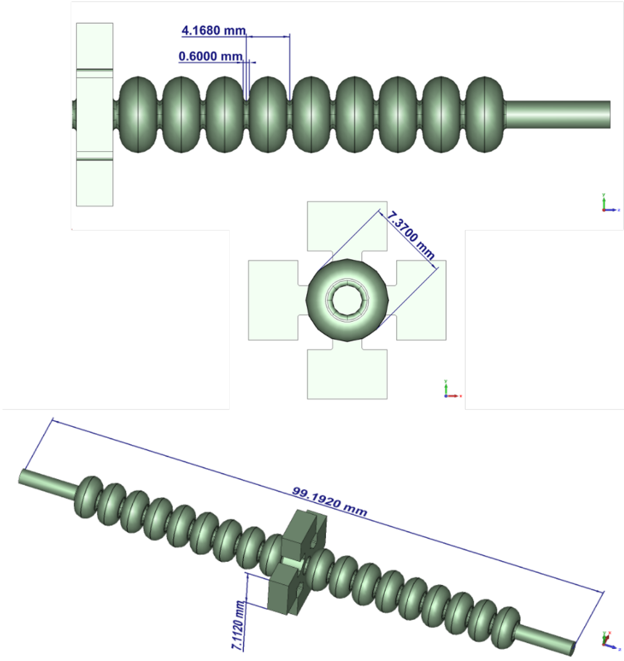

Figure 2: Geometry:The structure comprises four WR28 rectangular-TE10-to-circular-TM01 transitions.

been considered in simulations at the input ports. By exploiting transversal and longitudinal symmetries, only 1/16 of the complete structure has been considered for the numerical simulations, as seen in Fig. 3. In order to quantify the influence of the iris radius and of its geometry on the fundamental RF parameters, the $|S_{11}|$ and electric field module along the cavity axis have been evaluated in simulation for a = 1.333 mm and for a = 1 mm. In the latter case, in order to evaluate the effect of the cell number on adjacent (undesired) mode distance, also a version composed of 12 accelerating cells has been studied.

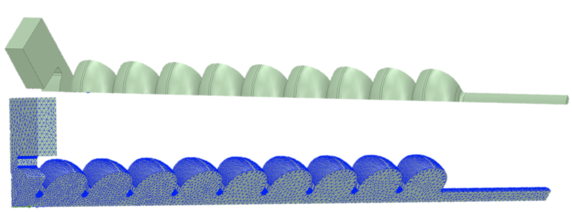

Figure 3: Geometry and mesh for a = 1 mm, 9-cells structure.

Figures 4 and 5 show the $|S_{11}|$ and |E| field along the cavity axis for the optimal parameter R_c = 3.126 mm, w_{slot} =1 mm and h_{slot} = 0.533 mm being R_c, w_{slot} and h_{slot} the coupling cell radius, the coupling aperture width and height. It can be seen that, in the case of a = 1 mm, the π-mode is well adapted at the frequency f_0 = 35.98 GHz. However, the lower adjacent is only Δf = 10 MHz distant from the accelerating one. The lower mode distance can be increased by making the cavity shorter (i. e. by employing less accelerating cells), as seen in Fig. 6, where the cell number has been decreased from 18 to 12 cells and the distance Δf between the π-mode and the lower one is now equal to $\simeq$ 20 MHz. Note that the 12-cells cavity version has not been tuned to the final f_0 yet. Finally, Figs. 7 and 8 show the RF parameters for the iris radius a = 1.333 mm and for the parameters R_c = 3.103 mm, w_{slot} = 1.3 mm and h_{slot} = 1.24 mm. It can be seen that, in the latter case, the π-mode (f_0 = 35.98 GHz) and the lower adjacent one are distanced of about 30 MHz. The maximum accelerating gradient value is $\simeq$ 115 MV/m for the case a = 1 mm and $\simeq$ 102 MV/m for the case a = 1.333 mm. The radii of the accelerating cells have been tuned in order to obtain the desired field flatness.

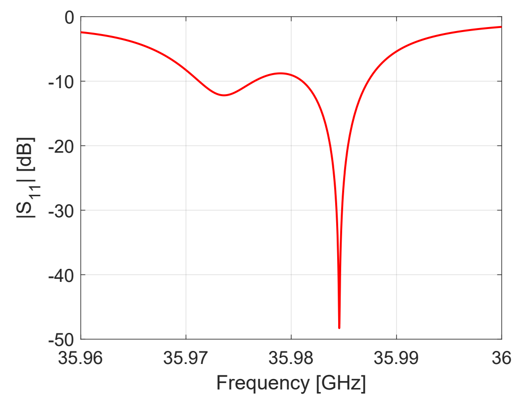

Figure 4: $|S_{11}|$ for a = 1 mm, 9-cells structure.

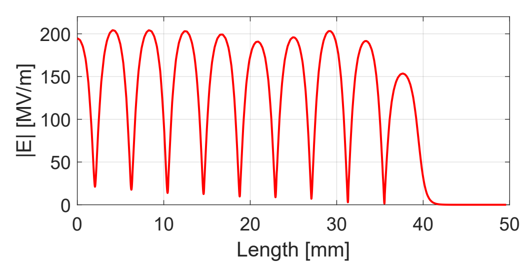

Figure 5: |E| along cavity axis for a = 1 mm, 9-cells structure.

For both cases (a = 1 mm and a = 1.33 mm) the flatness is about $\pm$4%, therefore it shall be decreased by slightly adjusting the dimensions of the coupler and the waveguide (window) end reducing the coupling cell radius.

RF PULSED HEATING

The RF Pulsed Heating (PH) [5,6] is a fundamental parameter to be taken into account when evaluating the Breakdown Rate (BDR). It has been computed for the presented structures considering an input power of 5 MW and a RF pulse length (flat top) t_p = 50 ns. The RF pulsed heating, estimated on the surface of the accelerating cells, results ΔT = 17.55 ° for the case a = 1 mm and ΔT = 20.86 ° for the case a = 1.333 mm. Since on the input coupling cell,

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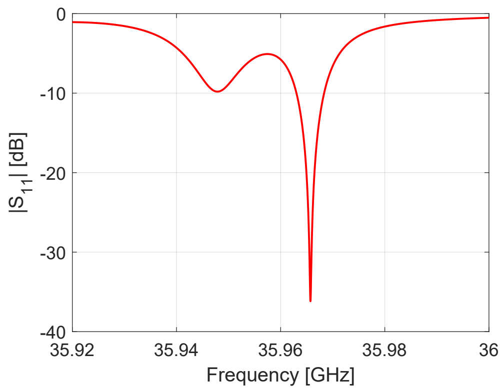

Figure 6: $|S_{11}|$ for a = 1 mm, 6-cells structure.

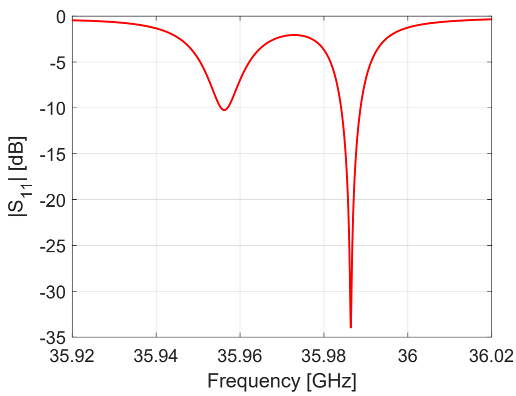

Figure 7: $|S_{11}|$ for a = 1.333 mm, 9-cells structure.

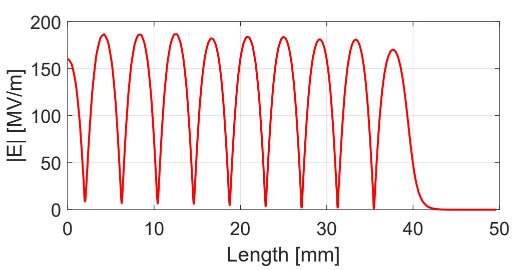

Figure 8: |E| along cavity axis for a = 1.333 mm, 9-cells structure.

these values rise to about 80 °C further optimization are needed to improve the flatness and reduce the pulse heating below 50 °C in order to avoid breakdown phenomena. The computed modified Poynting vector is S_c = 3.78 MW/mm^2 at 102 MV/m.

CONCLUSION

In this work, we present the RF design of a table-top Ka-Band mode launcher operating at 35.98 GHz. The structure consists of a symmetrical 4-port WR28 rectangular-TE10-to-circular-TM01 mode converter. Numerical simulations have been carried out with the 3D full-wave commercial simulator Ansys HFSS. We obtained a RF matching below -30 dB at the operating frequency $f_0 \simeq$ 35.98 GHz. Further optimization are needed to improve the flatness and reduce the pulse heating in order to avoid breakdown phenomena. A verification of the field azimuthal symmetry by considering the quadrupole component of the magnetic field will be performed.

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