STUDY AND DESIGN FOR TRASCO RFQ HIGH POWER COUPLER

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Abstract

TRASCO RFQ needs an overall RF power of about 800 kW at 352 MHz in order to accelerate a 30 mA CW proton beam up to a final energy of 5 MeV. For such purpose eight couplers based on the use of a loop have been conceived to be used. In this paper the study and design of such coupler, including RF optimization and thermal analysis is presented.

1 INTRODUCTION

At LNL is under construction a high intensity RFQ (Radio Frequency Quadrupole) funded within TRASCO project [1], the Italian feasibility study an ADS (Accelerator Driven System). This accelerator will be the front-end of a high-energy proton driver. The same RFQ has been proposed as the first step of a proton linac to be used as the driver accelerator of an ISOL facility for the production of exotic beams (SPES project [2]). The 5 MeV beam of the RFQ will also be used for the production of the neutrons necessary for the BNCT (Boron Neutron Capture Therapy).

In table 1 the main RFQ RF parameters are listed.

Table 1: RFQ RF parameters

Energy Range	0.08-5	MeV
Frequency	352.2	MHz
Proton current	30	mA
Duty cycle	100	%
Maximum Surf. Field	33	MV/m
RFQ length	7.13	m (8.4 λ)
Intervane voltage	68	kV
Average Aperture R_0	2.9-3.2	mm
Synchronous Phase	-90÷-29	deg
Dissipated Power (SF·1.2)	0.579	MW
Q_0 (SF/1.2)	8261	
Beam Loading	0.1476	MW
RF Power	0.726	MW

The RF power will be supplied by one klystron (already used for LEP, and whose maximum output power is 1.3 MW) and split in eight ways (Fig.1) via three splitting stages making use of magic tee power dividers. Each high power coupler (Fig.2) consists of a WR2300 half-height waveguide input, a waveguide to coaxial transition, a RF ceramic window (LEP kind) and a drive loop protruding into the RFQ. From Fig.1 it is possible to see that the couplers are located in opposite quadrants in segments 2nd, 3rd, 5th and 6th. Since the power is split among eight couplers, the power level for each coupler is about 100 kW. It has been already tested at CERN that the RF windows safe power limit is 140 kW.

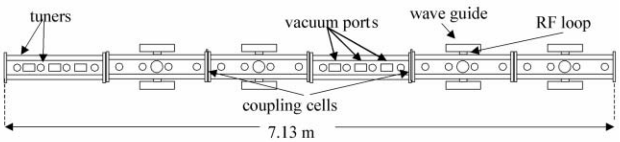

Fig.1 Schematic layout of TRASCO RFQ in which the feeds are indicated

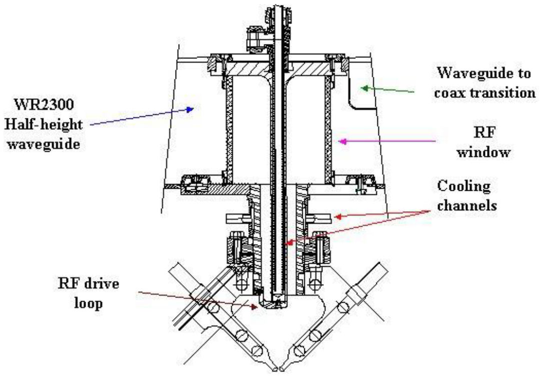

Fig.2 The high power coupler

2 DESIGN OF THE WAVEGUIDE TO COAX TRANSITION

The transition has been optimized in order to achieve the impedance matching between the WR2300 waveguide (a=58.4 cm, b=14.6 cm) and the 50 Ω coaxial waveguide (inner radius=0.87cm, outer radius=2.00cm), and the minimum return loss. Its structure is an aluminium doorknob like transition (See Fig.3); the matching device is semicircular instead of circular, as in the traditional doorknob. Such a shape has been chosen since the simulations results show a high power transmission at the operation frequency with a reliable structure. The ceramic RF window is included in the model. The shorting plane is located at a distance equal to $\lambda_z/4$ (λ_z is the guide wavelength) from the axis of the coaxial line. This is an arrangement already used for LEP NC couplers.

The transition has been simulated with HFSS 8.0. In these simulations the parameters h and R_{ext} (see Fig.3) have been varied in order to find the optimum value for the return loss at the operating frequency (Fig.4). For symmetry reasons only half of the structure has been taken into account.

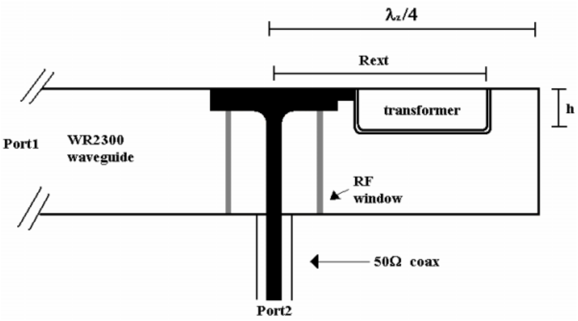

Fig.3 The transition model used for simulations

In Fig.4 we report the values of the return loss as a function of the transition height h. With h=60.5 mm a return loss of -41 dB has been obtained, that corresponds to a VSWR=1.016:1.

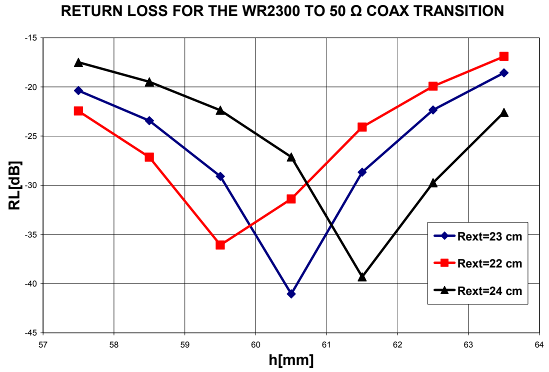

Fig.4 Return loss for various heights and radii of the transition

In Fig.5 the electric field intensity in the symmetry plane, for an input power of 100 kW at Port 1 is shown.

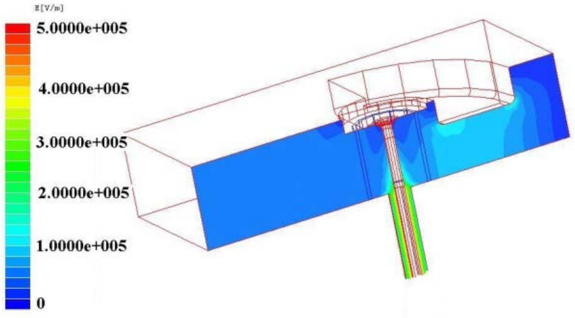

Fig.5 Electric field magnitude for the transition

The sensitivity of the transition to mechanical errors has been also evaluated. This analysis has shown that with an error up to 0.04 mm on h and 0.3 mm on R_{ext}, RL keeps below -40 dB.

3 DESIGN OF THE DRIVE LOOP

The design of the final part of the coupler has been carried out with the aim of providing the necessary matching condition between the loop and the cavity (i.e., VSWR<1.05:1) under beam load conditions.

The drive loop coupled with the RFQ has been simulated with HFSS 8.0 too. In our simulations all details of the cavity (tuners, coupling cells and end cells) have been included. We have varied the loop penetration into the RFQ up to find the necessary coupling conditions ($0.95<\beta=1.05$, β being the coupling coefficient) [3]. We have considered a 20% safe margin on Q_0 and that the matched conditions need to be achieved under beam loading. This leads us to assume in our simulations a target value of $\beta=1.5$.

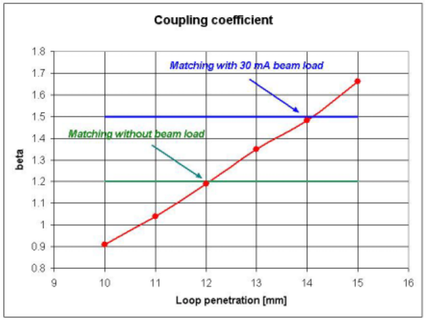

Fig.6 Coupling coefficient as a function of loop intrusion

In the following figures the electric field magnitude distribution of the overall structure (RFQ + coupler) is shown. The corresponding input power is 100 kW (corresponding to 800 kW of total RF power).

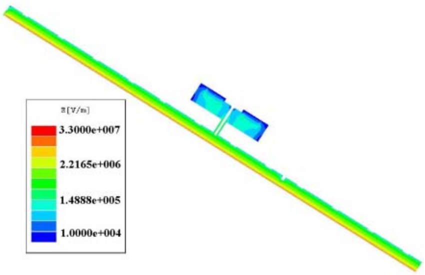

Fig 7 Electric field magnitude in the RFQ and coupler (longitudinal plane)

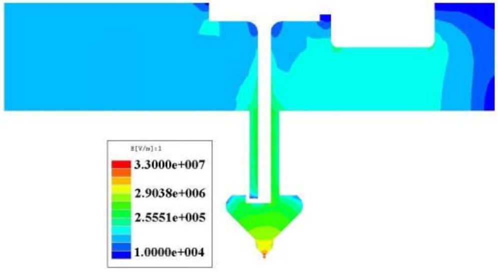

Fig 8 Electric field magnitude in the RFQ and coupler (transverse plane)

The input coupler will be made of OFE copper and it will be cooled by two coaxial channels into the inner conductor and by a cooling channel surrounding the outer conductor. The arrangement of the channels is inspired by the LEP NC design. Spring contacts are foreseen in order to guarantee RF contact between the coupler and the body of the RFQ. Indeed, it is possible to rotate the drive loop in order to modify the coupling conditions, if requested.

4 THERMAL ANALYSIS

We have performed a thermo-structural analysis (ANSYS code) in order to investigate the temperature distribution inside the copper bulk of the coupler and the related mechanical deformations. This is particularly important, because, at the present stage, the lower part of the drive loop is not foreseen to be cooled. The RF power dissipated on the coupler walls (provided by HFSS) is the thermal load in the structure. We have overestimated of a factor 2 these data in order to take into account any possible critical situation that may occur. This means that we are assuming 400W of power dissipation in the inner conductor (250W in the loop) and 100W in the outer conductor. The cooling channels temperature is fixed at 20°C (as in the RFQ).

In the following figures we show the temperature distribution under such conditions.

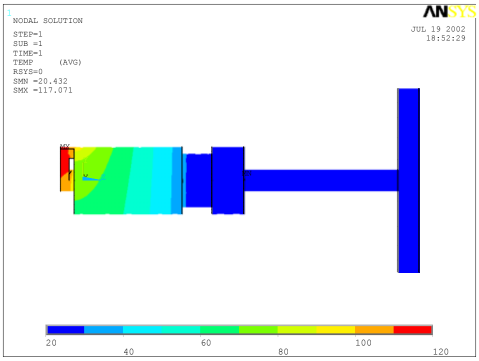

Fig 9. Temperature distribution in the bulk of the coupler

From the above figure it is possible to notice that, as expected, the hottest region of the coupler is on the loop. As a consequence of such thermal distribution, the deformations obtained are shown in the Fig.10. Notice that the loop is bond at the inner and outer conductor of the 50Ω coaxial line by means of screws.

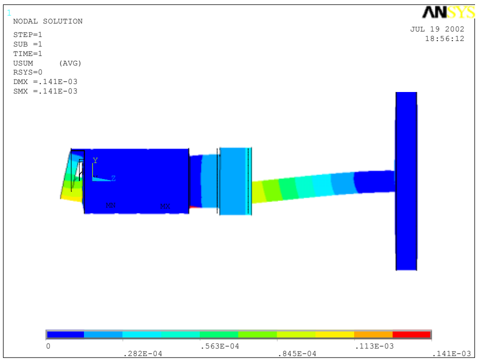

Fig.10 Behaviour of the structural deformation

Looking at Fig.10 we can deduce that the deformation induces a variation of 2% in loop area. The coupling coefficient β, shifts from the target value1.5 to 1.45, leading to a VSWR under beam load equal to 1.03, which still fulfils the requirements already fixed.

5 PERSPECTIVES

The overall study of the coupler is almost completed. As a last step the multipacting studies will be carried out. The engineering and the construction of the coupler is foreseen for the beginning of 2003.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] STATUS OF TRASCO INFN-TC-00-23 21
[2] LNL-INFN (REP)-181/2002
[3] T.P. Wangler “RF Linear Accelerators”, Wiley & Sons (1998) Ch. 5