

ENGINEERING DESIGN OF THE RF INPUT COUPLERS FOR C-ADS RFQ

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Abstract

A new special coupler with a kind of bowl-shape ceramic window for a proton linear accelerator named as C-ADS at IMP (Institute of Modern Physics) has been simulated and constructed and a beam commissioning through a prototype RFQ was done by the end of May, 2013. At the beginning of the design in the original prototype cavity, a 30kW coupler are placed at a one-meter prototype RFQ cavity with four-vane structure. In the experiments of conditioning and beam, some problems were promoted gradually such as sparking or thermal issues. Finally, two new couplers are developed and fabricated since the valuable experiences from the prototype RFQ experiments, the couplers were passed almost 110kW CW power and 120kW pulsed mode, respectively. The detailed design and simulation was presented in the paper.

INTRODUCTION

Since 2011 Chinese Accelerator Driven System (C-ADS) project has been carried out in order to solve the nuclear waste disposition and energy shortage crisis [1]. According to the plan the goal of the project is to build a 25-50MeV proton LINAC by 2015 whose upstream is a 2.1MeV four-vane RFQ operating in CW mode [2].

The new RFQ couplers for C-ADS project with a quarter-wave cooling port for the thermal consideration, based on a 6 1/8 inch coaxial waveguide, is designed for the CW operation. The cooling channels are installed into the loop antenna, inner and outer conductor. The optimized S parameter is better than -30dB and the effect from ceramic window are suppressed to the minimum. The ceramic window was designed according to the RF and brazing situation.

Considering lack of experiences for CW RFQ, a full-scale one-meter prototype cavity was fabricated and measured in the last two years. Simultaneously, a matching 30kW coupler was also simulated and tested on the prototype cavity. The results of conditioning or commissioning can help us to promote the coupler design and complete its fabrication for real four-meter cavity of C-ADS project.

RF INPUT COUPLER FOR PROTOTYPE

Original design of prototype cavity was only 25kW dissipation power and 560keV output energy from one-meter structure other than real cavity with the higher power and energy. In order to accelerate proton beam better, the over-coupling configuration [3] is very

necessary to handle with beam loading. Thus the specification of coupler are as follows:

Table 1: Target Performance

Requirement	Target value	Comment
Nominal frequency	162.5MHz	
Duty cycle	100%	Pulsed mode possible
Max. transmitted power	30kW	Full reflection to be withstood on solid-state AMP.
Max. reflected power in operation	5.6kW	Over-coupling (beam power)
Line impedance	50.0 ohm	RF network impedance

The simulation was mainly optimized on S parameter at the first time design resulted from the special structure of ceramic window which can minimize the line impedance effect of ceramic into the coaxial line and ease difficulty of brazing. And the observation port and ARC monitor port were also placed in the coupler whose structure is shown in Fig. 1.

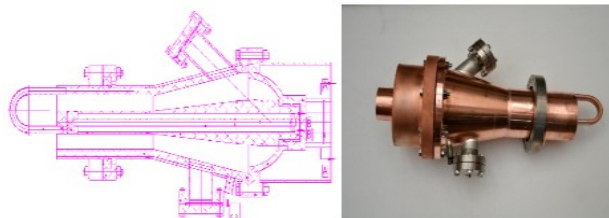


Figure 1: The structure of prototype coupler.

According to the input power scale of 30kW, the standard EIA 6 1/8" coaxial transmission line was chosen to connect the solid-state amplifier with RFQ cavity. A water-cooling port of quarter wave length was also optimized to promote S parameter and add separate cooling channels from CST software [4]. The structure was shown in the Fig. 2.

All the simulated and measured results show in the Figure 3 and 4, respectively.

Unfortunately, the ceramic window inside the coupler was broken during the high power conditioning or beam commissioning. According to the software simulation and material analysis, the most probable reason should be shortage of multipacting protector and high tangent loss of alumina.

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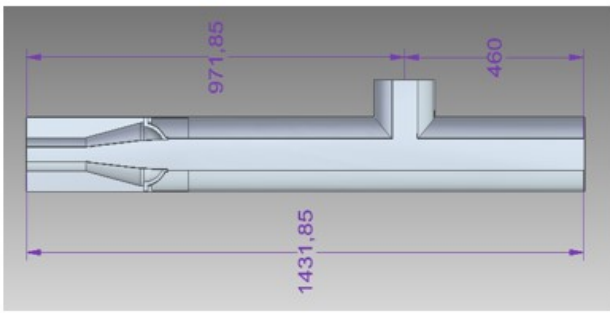


Figure 2: The structure of quarter-wave part.

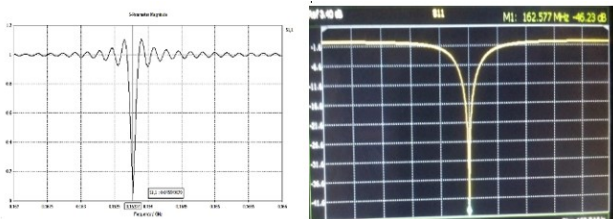


Figure 3: The simulated and measured S parameter.

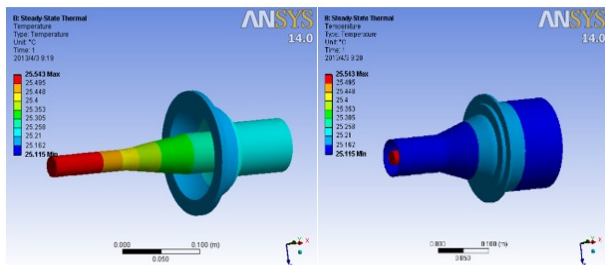


Figure 4: The simulated thermal result from ans.

NEW COUPLERS FOR RFQ CAVITY

Since the many experiences from previous design and power experiments, the new two couplers were also optimized in S parameter several times.

Table 2: Specifications of Real Couplers

Requirement	Target value	Comment
Nominal frequency	162.5MHz	
Duty cycle	100%	Pulsed mode possible
Max. transmitted power	60kW	Full reflection to be withstood on tetrodes AMP.
Max. reflected power in operation	31.5kW	Over-coupling (beam power)
Line impedance	50.0 ohm	RF network impedance

Simultaneously, the sufficient cooling channels were added to the inner conductor to decrease the copper deformation from the higher power (the design power reach up to 120kW which means more than 60kW on every coupler). The Fig. 5 shows the structure of the new 60kW coupler.

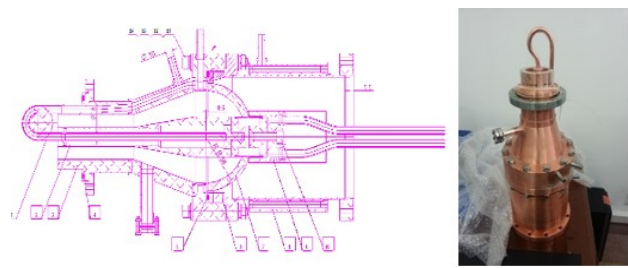


Figure 5: The structure of the real 60kW coupler.

A extra quarter wave part of EIA 6 1/8'' waveguide was designed to connect with the coupler to improve thermal situation [5], the length of it can be confirmed by CST software or something else, the S parameter reached up to close -40dB. The sizes and calculation are presented in Fig. 6.

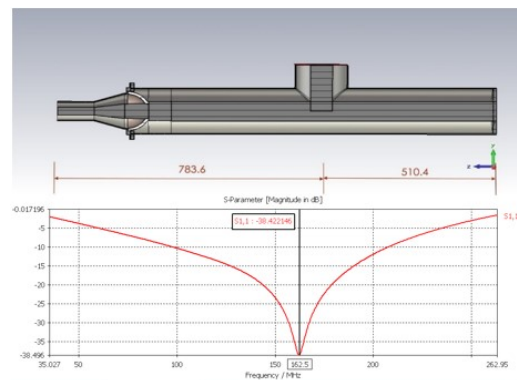


Figure 6: The S11 result from the matching port.

The antenna loop was also simulated in the RF analysis software whose thermal distribution was presented in Fig. 7 (the shape of loop was not the same with the design one because of the bending difficulty).

Since RF system has some special aspects, the coupling coefficient and reflected power are also different from the other facilities. According to the original design, the special power divider and phase shifter were considered as the necessary devices to distribute and balance power on two identical couplers inside the cavity whose connection is presented in Fig. 8.

Until now, the conditioning with CW mode is very close from the success (shown in Fig. 9) and the basic beam experiments with the pulsed mode are also in progress whose results meet the requirements of the dynamics calculation, such as output energy and transmission efficiency.

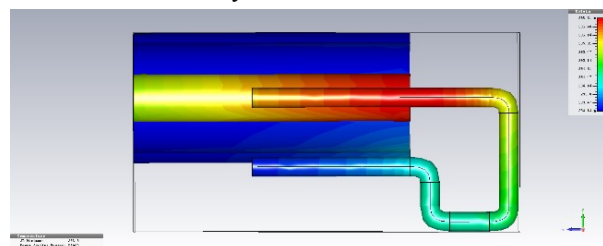


Figure 7: The temperature of the antenna loop.

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Figure 8: The connection from the amplifier to the cavity (two coupler ports).



Figure 9: The measurement platform and test results.

SUMMARY

As the newest development of couplers in IMP, two sets of couplers with the bowl-shape ceramic windows are designed by the RFQ group with complete intellectual property rights. The conditioning and beam commissioning process have already proved that the RF and structural design meets the requirements of the LINAC operation. About the main problems of the injured windows, although many specific factors have no efficient measures to check, the situation has been improved greatly, especially, the CW mode power close to 120kW will be a promising result for a four-vane CW RFQ.

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