DEVELOPMENT OF AN RFQ INPUT POWER COUPLING SYSTEM *

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Abstract

Development of RF power coupling system for a radio frequency quadrupole (RFQ) accelerating structure for operation at 402.5 MHz is presented. The system employs two coaxial loop couplers for reliable operation. Each coupler has a coaxial loop antenna that is fed through a coaxial alumina ceramic window. The two coaxial couplers are fed through a waveguide magic-T hybrid junction used as an in-phase power splitter with isolation. The coaxial ceramic window design is virtually identical to the design of the windows used in the SNS superconducting RF (SRF) cavities operating at 805 MHz that have shown superb performance. Results of RF simulations, electrical and mechanical designs, manufacturing, and high power testing are discussed

INTRODUCTION

Many RFQ structures employ either waveguide or coaxial couplers [1][2] in their RF coupling systems. Present coupling system of the SNS RFQ has eight coaxial couplers that could cause certain operation and maintenance problems. For this reason, an RF power coupling system is being developed at the SNS for future upgrade installation. The RFQ coupling system presented in this paper employs two loop couplers using coaxial ceramic windows as the vacuum barrier operating at 402.5 MHz. To deliver equal power split to the loops, a magic-T waveguide hybrid is used for good isolation between the ports as shown in Figure 1. The alumina ceramic coaxial windows employed in this system are almost identical to the windows presently used in the SNS SRF cavities operating at 805 MHz. [3][4]. Previously, the windows were successfully conditioned and tested for 650 kW peak power at 8% duty cycle at 805 MHz. The windows have shown an excellent mechanical reliability along with their high RF power handling capability. The plan is to use the existing RFQ accelerating structure. This requires the dimensions of the coupling ports on the wall of the cavity structure to be specified. Using coaxial ceramic windows with a greater diameter than the coupling port needed a tapered coaxial transmission line section to be used on the vacuum side of the coupler assembly as shown Figure 2.

The SNS RFQ requires maximum 800 kW, 8% duty cycle pulsed RF power at 402.5 MHz. One coupler needs to handle 400 kW. Modifying the inner and outer conductors of the coaxial transitions and sections was needed for employing the ceramic window with an increased diameter. In the following paper, the design, manufacturing, and RF power testing of the couplers of the RFQ coupling system are described.

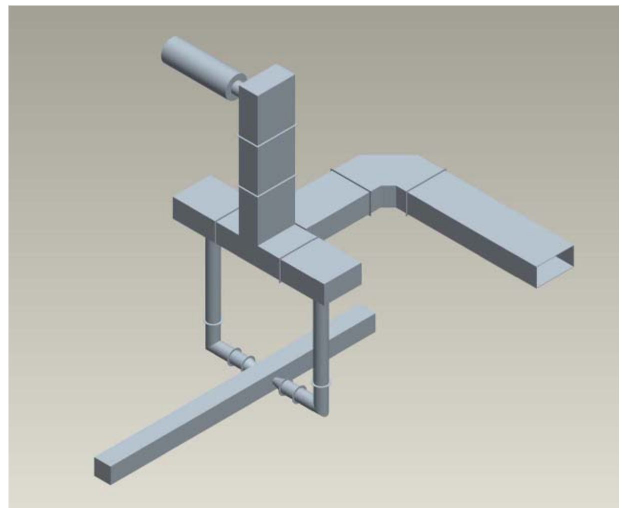

Figure 1: RF power coupling with two coaxial loop couplers mounted to an RFQ. Magic-T waveguide power splitter is used to have isolation between the two ports.

DESIGN AND MANUFACTURING

Figure 2 shows the two coaxial loop couplers feeding an RFQ. A coaxial transmission system has been chosen for constructing the RFQ couplers that is connected to the main waveguide transmission system.

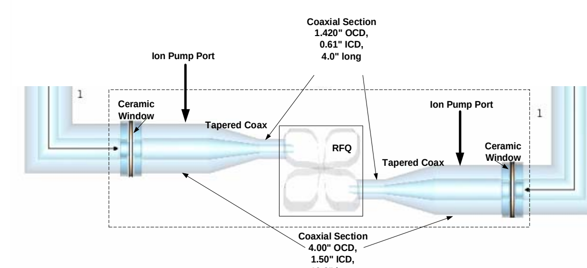

Figure 2: Two coaxial loop couplers feeding the RFQ.

The size of the ports on the RFQ is limited due to the small cross-sectional construction of the RFQ structure. The waveguide to coaxial transitions have standard 6-1/8” EIA flange connections. 6-1/8” EIA to 4-1/16” coaxial reducers are used for the connection to the flanges of the coupler windows. A short 4-1/16” coaxial section is modified for precisely matching the flange of 4.0” ceramic window to the 4-1/16” flange of the reducer.

Computer simulations of the coaxial ceramic window showed that the window characteristic is good for a wide

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range of RF frequencies. The window has return loss > 30 dB and insertion loss < 0.02 dB at 402.5 MHz. Figure 3 shows the computed transmission and insertion losses. It seems the design is completely useful for frequencies roughly up to 1000 MHz.

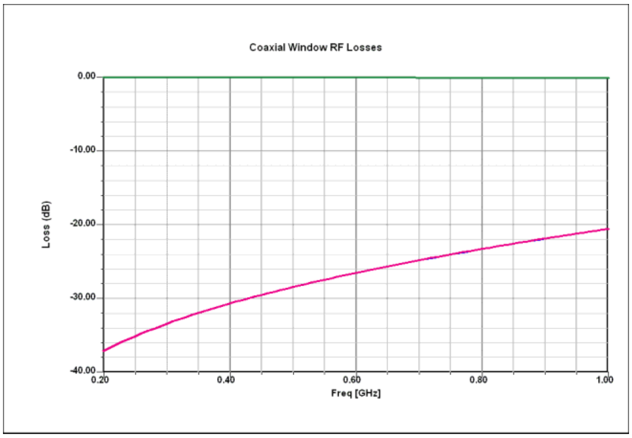

Figure 3: Computed transmission and return losses of the coaxial window

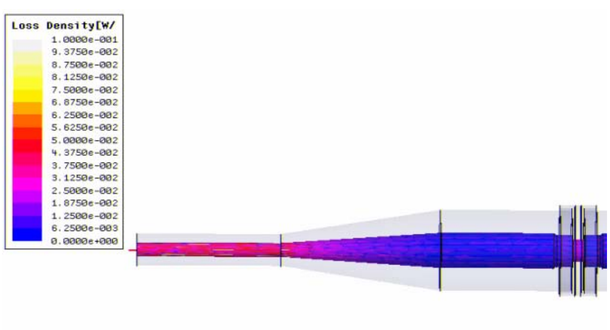

Figure 4: RF heating on the center conductor surface.

The center conductor of the loop antenna is integrated with the center conductor of the ceramic window as a single piece structure. Figure 4 shows the RF heating on the center conductor through the vacuum side coaxial coupler structure without cooling. The RF heating on the center conductor is estimated to be 0.37 W for 1kW average input power. The center conductor is cooled by a 1gpm water circuit that is formed through the loop antenna at the coupler tip. The outside conductor is dissipating only 0.15 W for 1kW average input power. Since the outer conductor is connected to the cavity body, the cooling requirement for the heating in the coupling system is considered light.

Figure 5 shows the design of the coupler assembly. The loop connects the center conductor and the outer conductor at the end of the reduced diameter coaxial section. The loop carries the 1/8" cooling tube circuit that is connected to the water source on the outer conductor. Two 2.4" diameter vacuum ports are located right in front of the ceramic window and are RF shielded with axial slots on the outer conductor.

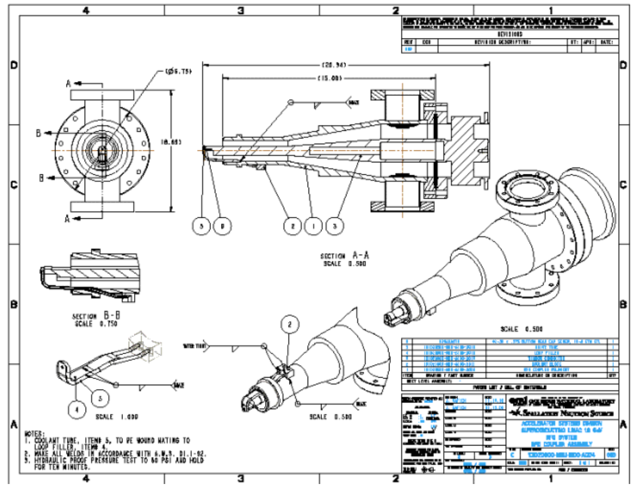

Figure 5: Coaxial loop coupler assembly.

Maintaining a good vacuum around the vacuum side of the window is critical for reliable operation of the coupler system. Two vacuum ports are placed in front of the ceramic window for protection. Either one or both of the ports can be used for efficient vacuum pumping.

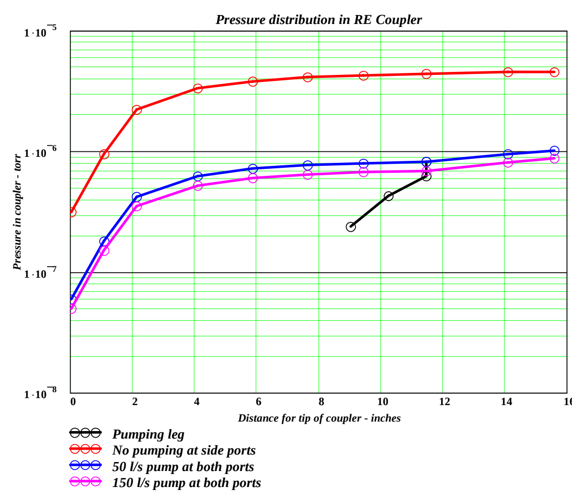

Figure 6: Vacuum pressure distribution in the coupler.

The pressure distribution in the coupler was analyzed using a multi node model with 10 nodes distributed along the length of the coupler and two additional modes for each of the 2 pumping ports located at approximately 3/4 of the coupler's depth. The model assumed that the pumping provided from the RFQ was infinite but limited by the inlet conductance to the coupler. Figure 6 shows the pressure distribution along the coupler with and without pumping at the side pumping ports with outgassing rates of $1*10^{-10}$ T-l/s-cm^2 for the coupler body and $1*10^{-7}$ T-l/s-cm^2 for the window being assumed.

RF PROCESSING AND TESTING

Figure 7 shows the coupler conditioning setup with two couplers connected back to back through the bridge waveguide. WR-2100 waveguide run is transformed to 6-1/8" coaxial system to feed the two couplers and then transformed back to waveguide which is terminated with a matched water load at the end. Figure 8 shows the RF response of two couplers connected through the bridge waveguide. Figure 9 shows the bridge waveguide made of stainless steel.

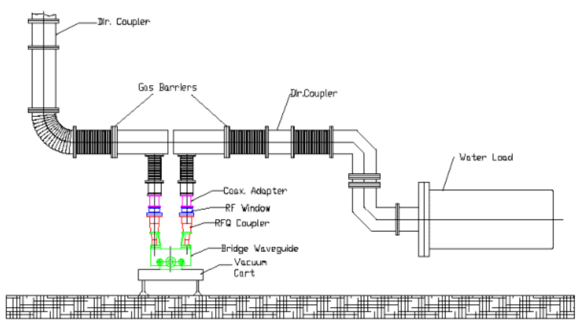

Figure 7: Coupler conditioning setup with two couplers connected back to back through the bridge waveguide.

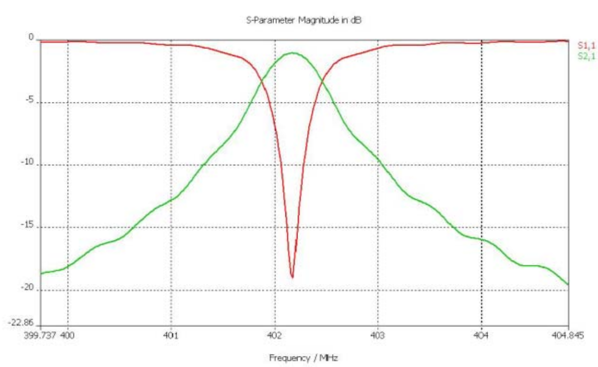

Figure 8: RF response of two couplers connected back to back through the bridge waveguide.

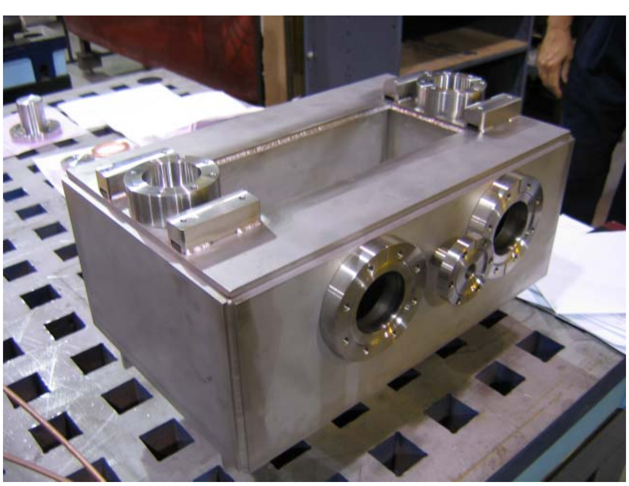

Figure 9: Capacitively loaded bridge waveguide for 402.5 MHz operation. Reduction of footprint is achieved.

All parts have been manufactured and being delivered. Some vendor deliveries of the parts were delayed which resulted in a delay of the high power testing and conditioning. The bridge waveguide has been successfully manufactured and tuned. Additional tuning mechanisms can deliver ± 2 MHz tuning range. The capacitively loaded waveguide or ridge waveguide design allows significant reduction of structure footprint: only 18" x 11" compared to 22" x 21" with a regular rectangular waveguide.

DISCUSSION

The goal of work is to achieve a simpler and electrically and mechanically dependable coupling system to be used with the existing RFQ accelerating structure. Good vacuum pumping around the windows has been emphasized. The test setup including the klystron amplifier and RF controls has been readied.

An arc detector and an electron probe are to be placed near the windows to monitor the vacuum activity and to interlock the RF with vacuum pressure to protect the ceramic windows.

High power RF processing of the system is being prepared in the RF test facility at the SNS using 2.5 MW, 402.5 MHz klystron system that can run up to 8% duty cycle. The output of the klystron is reduced through an unequal output power splitter to have a -7 dB output that can deliver maximum 500 kW of power for the testing. The high power RF conditioning of the couplers has been postponed due to delayed delivery of some parts, but is expected to be performed in a few months.

ACKNOWLEDGEMENT

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