RF CONDITIONING AND TESTING OF FUNDAMENTAL POWER COUPLERS FOR THE RIA PROJECT

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Abstract

The Rare Isotope Accelerator (RIA) is the highest priority of the nuclear physics community in the United States for a major new accelerator facility. A principal element of RIA will be a superconducting 1.4 GeV superconducting ion linac, accelerating ions of isotopes from hydrogen to uranium onto production targets or for further acceleration by a second superconducting linac. The superconducting linac technology is closely related to that used at existing accelerators and the Spallation Neutron Source. Taking advantage of JLAB's SRF Institute facilities and expertise for the SNS project, preparation of couplers, RF conditioning and high power tests have been performed on fundamental power couplers for the RIA project. The fundamental power couplers for the RIA project are 50-ohm coaxial lines with planar ceramic windows similar in design to the SNS fundamental power couplers. SNS's pulsed 805 MHz 1 MW room temperature test stand was used for RF tests. After RF conditioning, the first two RIA fundamental power couplers have sustained in traveling wave mode power levels up to 200 kW (1 ms 60 Hz) well above the specifications (intended CW operation up to 10 kW). An overview of the RIA fundamental power couplers, procedures applied and RF tests results will be given in this paper.

INTRODUCTION

The Rare Isotope Accelerator (RIA) driver linac is designed to accelerate heavy ions to 400 MeV/u (beta=v/c=0.72) with a beam power up to 400 kW [1].

The superconducting cavities, under development at Jefferson Lab [2], must produce accelerating gradients consistent with peak surface electric fields of 27.5 MV/m, or better. In order to power the cavities, coaxial couplers were chosen. In operation the couplers must be able to withstand 10 kW CW delivered by an 805 MHz RF source. The input coupler for the 6-cell, β=0.47 RIA cavity has been designed with a Qext~2x10^7 using a smaller beam pipe and coupling port than SNS which allows equal end cell and beam pipe diameters on both ends of the cavity [2].

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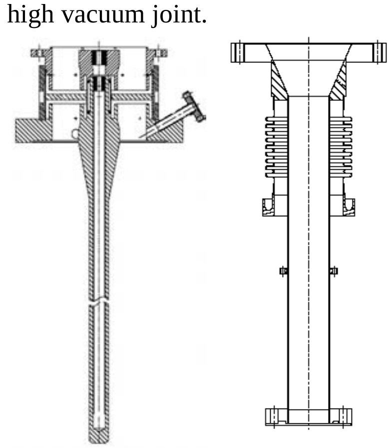
PREPARATION OF THE RIA FPCs FOR RF CONDITIONIG

General Layout of the Fundamental Power Coupler

The fundamental power coupler consists of a tapered 50-ohm coaxial line with a planar ceramic window [2]. On the vacuum side of the coupler, the outer conductor is made from a stainless steel tube with an 8 μm thick copper-plated layer and the inner conductor is made from an OFE copper bar. The outer conductor is provided with a bellows for assembly onto insulating cavity vacuum envelope and no active cooling of the outer conductor is intended during machine operation. The window assembly houses a planar ceramic window with impedance matching elements chosen as is described in [3]. TiN anti-multipacting layer was sputtered on the vacuum side of the ceramic. Drawings for RIA's window assembly and outer conductor are shown in Figure No.1.

The window assemble has three instrumentation ports: one for a vacuum gauge, one port for an electron pick up antenna and one sapphire optical view port for arc detector. A modified Conflat gasket is used on the vacuum side to provide good RF contact and, at the same time an ultra high vacuum joint.



a) b)

Figure 1: Basic components for RIA's fundamental power coupler: a) window assembly with planar ceramic and three instrumentation ports (for vacuum gauge, electron pick up antenna and optical view port) and b) outer conductor.

We can choose between two options to RF power this coupler: one using a taper coaxial cable transition and another one involving a waveguide/doorknob transition. In the high RF power tests performed on prototypes, transition between WR975 waveguide and coupler's coaxial line was provided by a waveguide/doorknob configuration.

Connecting Waveguide

A custom made-connecting waveguide with four ports was dimensioned and built for RF testing the RIA fundamental power couplers [4]. It consists of a stainless steel box with internal dimensions equivalent with a half height WR975 waveguide. As the distance between the two couplers is constant as well as the distance between the antennae's tip and the bottom box plate, the matching is realized by the position of the end plate short-circuits. No copper plating was made of the surfaces exposed to UHV and RF.

Incoming Inspection

All components have undergone incoming inspection including a check of dimensions on a coordinate-measuring machine, a visual examination of the surface finish and vacuum leak checks. Due to the small diameter of the outer conductor, the adherence of the copper plating was not checked by high pressure water rinsing.

Qexternal Measurements

Using the RIA prototype cavity equipped with a fundamental power coupler and a driven antenna at the opposite beam port, the following values for the Qexternal at room temperature were measured in transmission: a) with a taper coaxial line transition 1.414×10^7 and b) with a waveguide/doorknob transition 1.986×10^7.

Components Cleaning and Clean Room Assembly

Before assembly, all coupler components were carefully cleaned. The outer conductors and all the stainless steel components were cleaned by 15 minutes of immersion in an ultrasonic bath filled with a 10% solution of Micro-clean detergent, followed by rinsing with de-ionized water (DI) and drying with dust-free nitrogen gas. The window assemblies were cleaned for 15 minutes in DI water filled ultrasonic bath. The transfer from the cleaning area to the clean room class 100 was done in double wall plastic bags filled with dry nitrogen.

Mechanical Assembly and Vacuum Tests

The window assemblies were inserted into the pre-assembled outer conductors and connecting waveguide in the clean room. Aluminum-Magnesium gaskets were used as vacuum seals between the outer conductor and the connecting waveguide ports. In addition, the instrumentation ports were equipped with: a Balzers cold cathode vacuum gauge, an electron pick up antenna and one sapphire optical view port.

Vacuum leak tests were performed on the assembled couplers using the test stand's Residual Gas Analyzer. Helium leak detection sensitivity of the system was better than 2×10^{-10} Torr l/s.

Baking

The assembled FPCs and connecting waveguide were baked under vacuum, using a modified heating box with hot air blower operated via a computer and a Programmable Logic Controller. Our usual baking procedure was applied: ramping up the temperature with a gradient of 10 ˚C /h, soaking for 24 hours at 200 ˚C then cooling down to room temperature with a controlled gradient of 10 ˚C /h [4] [5].

Low RF Power Measurements

The airside of the RIA couplers was assembled after baking, using zero length adaptors as outer conductor extensions modified inner conductor extensions and waveguide/doorknobs from the SNS project. The subsequent low RF power measurements had lead to poor S11, S22 parameter values, hence higher expected reflected power and local peak power in the transmission line during RF conditioning and testing were expected.

CONDITIONING AND POWER TESTS

High Power RF Setup

SNS's 1 MW 805 MHz pulsed RF power stand [5] (Fig. 2) has been used to perform RF conditioning and power tests of the RIA prototype couplers. The two couplers have been assembled to the test stand, the RF power delivered by the klystron being transferred from the input coupler to the output one via the connecting waveguide and dumped into an RF 5 MW terminating load.

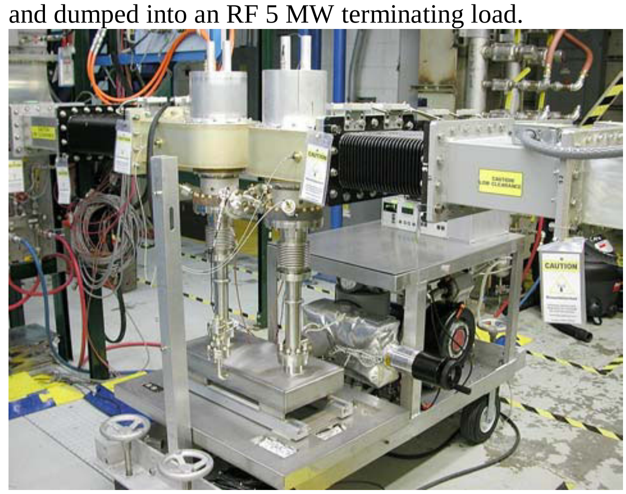


Figure 2: RF layout used in testing RIA couplers

Three sets of directional couplers (two between the klystron and the test cart and one between the test cart and the terminating load) were used to independently control the transmitted RF power levels. The RF conditioning was assisted by a fast RF feedback loop, which controls the RF pulse amplitude if vacuum events exceed a predetermined threshold (Fig. No 3).

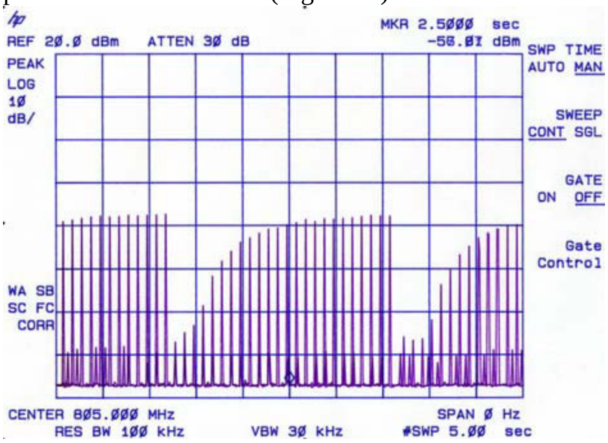


Figure 3: RF amplitude modulation as a function of vacuum in RIA coupler

A fast interlock system on the vacuum controller’s analog output switched RF OFF if the coupler vacuum is worse than 5 10^{-7} mbar. The RF permit is obtained after the vacuum pressure is better than 2 10^{-7} mbar [5]. Real-time LabView software provides the operator interface to data acquisition system that allows changing the RF pulse characteristics and control of RF conditioning or testing.

During the RF tests, in addition to the vacuum signals, information regarding the electron activity near to the ceramic window is obtained with electrometric instrumentation. A fast photodiode based arc detector is hard interlocked and switches the RF OFF if arcing events occur on the vacuum side or on the airside (doorknob area) of the coupler.

RF Testing Results

RF conditioning as a function of vacuum has been done after baking. It took about six hours of RF conditioning without RF switches OFF or arcing in the coupler to reach 50 kW as is shown in Figure No. 4.

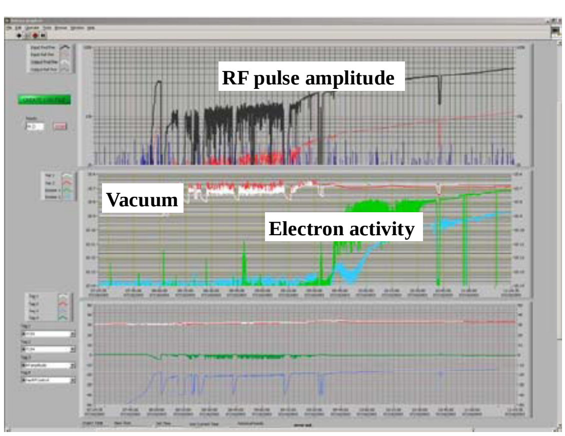


Figure 4: 4 hours of RF conditioning to reach 50 kW.

In the next 5 hours RF conditioning has allowed the transfer of 150 kW (1 ms 60 Hz) through the two windows to the terminating RF load. During long-term tests, the RF power was cycled from 1 kW up to 200 kW (1 ms, 60 Hz, 30 sec at maximum power) or the RF amplitude was kept constant (8 hours) at 150 kW. At the end of the constant power test, coupler vacuum was in the range of 6 - 8 10-9 mbar, electron activity 1 – 12 nA and temperatures of the ceramic windows 30 – 32 ˚C. No arcing events have been recorded during a total of about 40 hours of RF conditioning and testing. After several weeks of storage under vacuum the RF conditioning memory was tested – the RF power was ramped directly to 200 kW, with outgassing 2 10^{-8} mbar and electron activity 100 nA.

CONCLUSIONS

The first two RIA prototype fundamental power couplers have been tested on a room temperature RF test stand and transferred an average RF power of 9 – 12 kW, in excess of the initial specifications

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