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Author(s):

M. Stirbet, I. E. Campisi, E. F. Daly, G. K. Davis, M. Drury, P. Kneisel, G. Myneni, T. Powers, W. J. Schneider, K. M. Wilson, TJNAF, Newport News, VA 23606, USA
Y. Kang, Spallation Neutron Source, Oak Ridge, TN 37830, USA
K. A. Cummings, T. Hardek, LANL, Los Alamos, NM 87545, USA

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TESTING PROCEDURES AND RESULTS OF THE PROTOTYPE FUNDAMENTAL POWER COUPLER FOR THE SPALLATION NEUTRON SOURCE*#

M. Stirbet†, I. E. Campisi, E. F. Daly, G. K. Davis, M. Drury, P. Kneisel, G. Myneni, T. Powers, W. J. Schneider, K. M. Wilson, TJNAF, Newport News, VA 23606, USA
Y. Kang, Spallation Neutron Source, Oak Ridge, TN 37830, USA
K. A. Cummings, T. Hardek, LANL, Los Alamos, NM 87545, USA

Abstract

High-power RF testing with peak power in excess of 500 kW has been performed on prototype Fundamental Power Couplers (FPC) for the Spallation Neutron Source superconducting (SNS) cavities. The testing followed the development of procedures for cleaning, assembling and preparing the FPC for installation in the test stand. The qualification of the couplers has occurred for the time being only in a limited set of conditions (travelling wave, 20 pps) as the available RF system and control instrumentation are under improvement.

1 INTRODUCTION

The fundamental power coupler for the SNS superconducting cavities must be able to transfer up to 550 kW peak power over 1.3 ms pulse width at a repetition rate of 60 pps during machine operation [1].

Two prototype couplers have been manufactured and preliminary testing has occurred at Los Alamos National Laboratory (LANL) using a test stand specifically developed for this purpose [4]. The testing was done using a LANL 2.5 MW, 805 MHz RF source, with vacuum, arc, infrared interlocks and electron current monitors provided for window protection [2].

In this paper we present the methods used in assembling the FPC in preparation for testing and the results of the initial series of tests.

2 ASSEMBLY PROCEDURES AND EXPERIENCE

2.1 General Layout of the FPC for SNS

The FPC consists of a tapered 50-Ω coaxial line with a planar ceramic window [2]. On the vacuum side of the assembly, the outer conductor is double-walled, helium-cooled, copper-plated stainless steel, and the inner conductor is OFE copper. The coaxial alumina window assembly has four instrumentation ports on the vacuum side: one for a vacuum gauge, one for an electron pick-up antenna and two sapphire optical view ports for infrared and arc detectors. On the air side, the outer extension is made from copper-plated stainless steel and the water-cooled inner extension is made of OFE copper. The FPC is matched to a rectangular WR975 waveguide via a doorknob/waveguide coaxial transition.

Modified Conflat® gaskets are used on the vacuum side of the window to provide good RF contact and, at the same time an ultra high vacuum joint [4]. To insure FPCs safe operation after RF conditioning [5], a capacitor for DC bias is provided.

2.2 Incoming Inspection

All components have undergone incoming inspections, including a check of dimensions on a coordinate-measuring machine, a visual examination of the surface finish and vacuum leak checks.

Occasional marks and stains on the vacuum side of the window assemblies were observed. Also, the copper-plating adherence to the stainless steel outer conductor jacket was checked by high-pressure water rinsing at 100 Bar for about 30 minutes.

2.3 Components Cleaning and Clean Room Assembly

Before assembly in a Class 100 clean room, the components were carefully cleaned. The outer conductors and all the stainless steel components (bellows, vacuum manifolds, connecting waveguide) were cleaned by a 15 minute immersion in an ultrasonic bath filled with a 10% solution of Micro-clean® detergent, followed by rinsing with de-ionized (DI) water and drying with dust free nitrogen gas. The window assemblies were also cleaned for 15 minutes in a DI water-filled ultrasonic bath before being transferred to the clean room where, additional cleaning with DI water jets was performed to reduce concentration of dust particles and contaminants trapped in the windows' RF chokes. Dust-free nitrogen was used to dry the window assembly after cleaning.

2.4 Mechanical Assembly and Vacuum Tests

The window assemblies were inserted into the pre-assembled outer conductors and connecting waveguide in the clean room. In addition the instrumentation ports were equipped with: a Balzers vacuum gauge, an electron pick

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†stirbet@jlab.org

up antenna and two sapphires optical view ports for IR and arc detectors.

The assembled connecting waveguide with the two couplers was transferred to the test cart and connected to the vacuum system. Vacuum leak test was performed with the test stand RGA [4] and additional integral leak checks were performed on each coupler using helium-filled plastic bags. Helium leak detection sensitivity of the system was better than $2x10^{-10}$ Torr l/s.

2.5 Baking

The FPC couplers and the waveguide were baked out at 200ºC for 24 hours for removing the adsorbed water [4]. RGA spectra were continuously recorded during baking.

No additional baking was performed after the original Conflat® seals were replaced with modified ones, which insure good RF contacts.

2.6 Electrical and RF Power Measurements

The couplers' extensions were assembled after baking. A reinforcement bolting ring was used on the waveguide transition, which slightly modified the reflection coefficient. The biasing capacitor (insulated by a two-layer Kapton® foil, each with a thickness of 0.12 mm) was inserted between the inner conductor extension and the doorknob and its DC and RF integrity was verified.

3 TESTING APPARATUS

An RF system consisting of a 805 MHz 2.5 MW pulsed klystron connected via WR975 waveguide to a water-cooled high-power load was used to transfer the RF power through the FPCs as shown in Figure 1. 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. Additionally, the transmitted power was measured calorimetrically at the load [6].

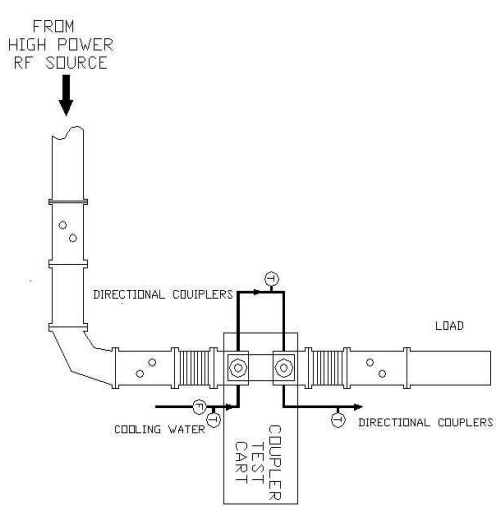

Figure 1: RF layout used in testing SNS couplers.

4 TEST RESULTS

4.1 Initial Results

RF conditioning at high power was performed at LANL. Starting with pulse duration of 1 ms at 1 pps repetition rate, over 100 kW peak power was reached without any vacuum activity. A vacuum outburst occurred at about 125 kW. After vacuum recovery the normal conditioning process (with vacuum and electron activity) was restarted from 35 kW. In less than 24 hours of RF conditioning with different pulse durations and repetition rates (from 100 µs to 1 ms and at 1, 10 and 20 pps), 500 kW peak power was reached (Figure 2).

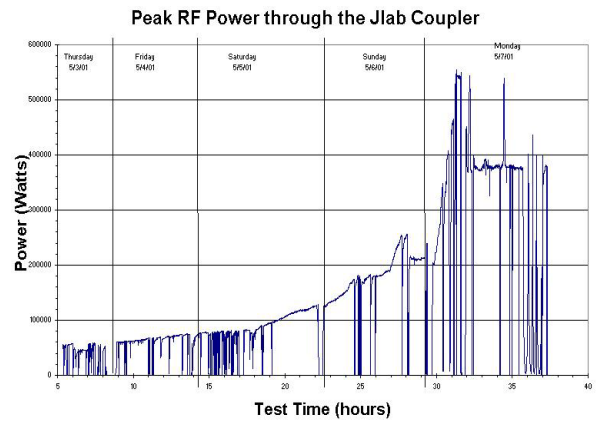

Figure 2: RF conditioning and power tests as recorded on an independent power meter at LANL.

The amplitude of the klystron drive was maintained for different period of times at various levels and at 500 kW for more than 30 minutes (Figure 3). During those tests the vacuum was better than 10^{-8} mbar, and the electron activity in the picoAmpere range.

Even if arcing events on the air side of one of the couplers occurred at 300 kW, tests at 350 kW were continued for several hours, without being affected by vacuum or electron activity.

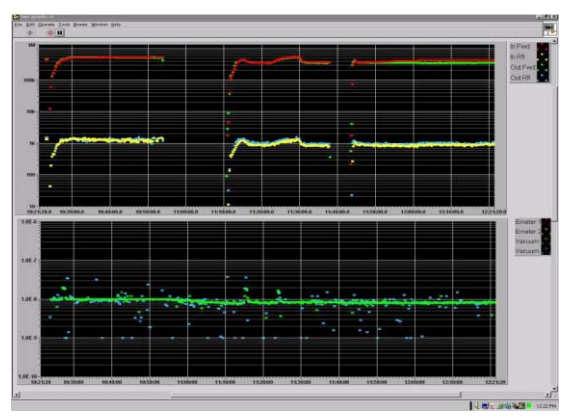

Figure 3: 500 kW of RF on the FPC. Vacuum levels on both couplers were better than 10^{-8} mbar.

After RF conditioning, no evidence was observed of multipacting up to 550 kW. Also, no appreciable temperature increase was observed during RF processing.

4.2 Reconditioning

The test cart and the SNS FPCs were kept under vacuum for a period of two weeks and then exposed again to RF (pulse duration 1 ms and repetition rate 20 pps).

Less than two hours RF reconditioning was necessary before reaching 300 kW.

Vacuum and electron activity and some non vacuum-related arcing events were recorded by photomultiplier tubes only on the vacuum side of the output coupler (Figure 4).

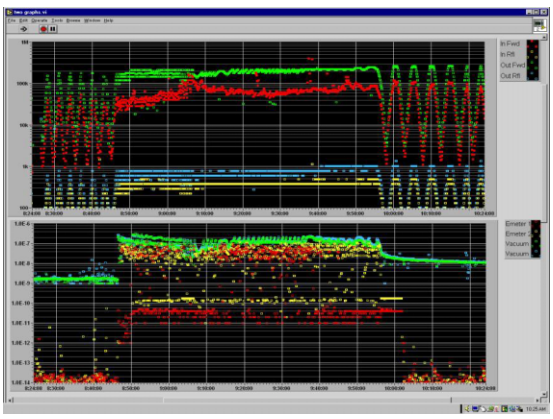

Figure 4: Less than two hours conditioning with controlled vacuum at about $3x10^{-7}$ mbar were needed after two weeks of RF off.

During this RF conditioning hydrogen was noted to be the dominant desorbing gas specie (Figure 5).

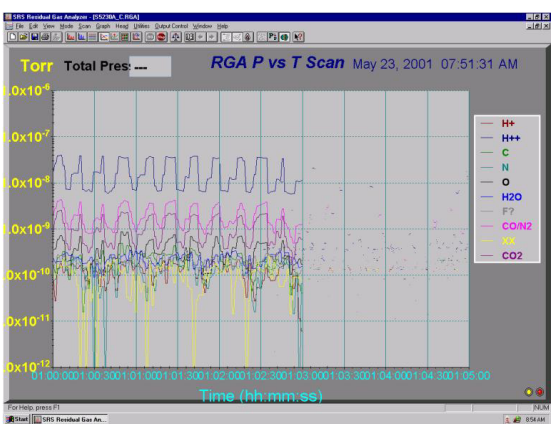

Figure 5: Partial pressure of residual gas species during RF conditioning at 160 – 180 kW.

After reconditioning, (Figure 6) no more spurious arcing or vacuum events were observed and the RF power could be cycled and maintained constant at 300 kW, then cycled again and increased to over 550 kW.

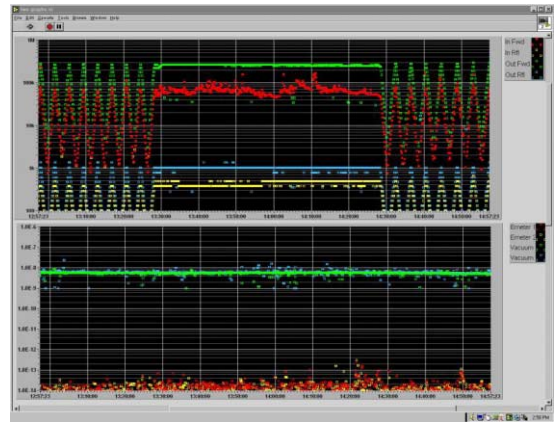

Figure 6: Power test up to 300 kW after RF conditioning, showing no more vacuum or electron activity.

5 CONCLUSIONS

A series of tests were performed on the prototype SNS fundamental power couplers. Peak power levels in excess of 500 kW were achieved without strong evidence of multipacting problems or average heating problems. The work will continue to extend the tests to full 1 MW standing wave power at 60 pps as soon as the RF power source will be ready for this mode of operation.

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