FUNDAMENTAL POWER COUPLER DEVELOPMENT FOR THE SNS SUPERCONDUCTING LINAC CAVITIES*

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Abstract

The H^- ion accelerator based Spallation Neutron Source (SNS) is being built in Oak Ridge, Tennessee, in collaboration with six DOE laboratories. TJNAF is responsible for building the superconducting linac (SCL) section of the SNS linac [1]. A total 81 6-cell cavities will be used in the SCL section that delivers the energy 210-1030MeV. Each cavity is fed through a coaxial type fundamental power coupler (FPC) to deliver RF to the beam from a klystron. For this purpose, a new coupler that employs 50 Ω coaxial line sections, a planar ceramic disk window, and a coaxial to waveguide transition has been developed. Latest result shows that the couplers can pass RF power well above the specified levels: 750 kW with 60 Hz 1.3 ms pulses and 2 MW with 60 Hz 0.65 ms pulses for traveling waves, and 600 kW forward power with 60 Hz 1.3 ms pulses for standing waves [9].

1 INTRODUCTION

In radio frequency (RF) particle accelerators, the fundamental power coupler is an expensive component and required to have high reliability and robustness. For the SNS linac, the superconducting cavities will be fed through coaxial couplers at 805 MHz. The design of the 508 MHz KEK-B type coupler that performed reliably at high power was scaled down for 805 MHz [2][3]. The SCL section of the SNS linac employs 33 beta=0.61 cavities and 48 beta=0.81 cavities in 23 cryomodules. Each 6-cell cavity requires a maximum 550 kW peak power in 60 Hz 1.3 msec pulses at 805 MHz. The development for cavities (including fundamental power coupler) was performed at the TJNAF since the institution's superconducting RF (SRF) expertise [1]. TJNAF is responsible for building all cryomodules for the complete SCL section. Initially, the FPC prototypes have been high power tested and conditioned at LANL facility with the readily available high power installations. Later, the testing has been performed at TJNAF using 805 MHz 1 MW test facility.

This paper summarizes the processes of design, simulations, measurements, conditioning, and testing of the prototype couplers along with the results obtained at room temperature high power conditioning and testing.

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2 DESIGN

2.1 Simulations

Various 3-D RF simulations have been made on the coupler design using HFSS code [4]. Figure 1 shows the field distribution and intensity inside the coupler transition assembly. The inner conductor and the copper-plated double-walled outer conductor form a 50 Ω coaxial line section. The coaxial structure is connected to the klystron through a coax-to-waveguide doorknob transition in standard WR-975 waveguide.

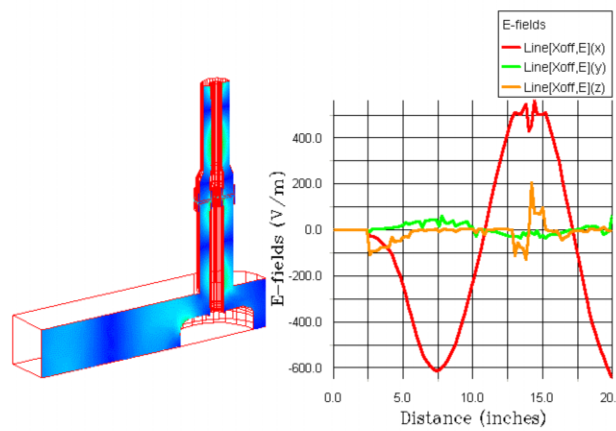
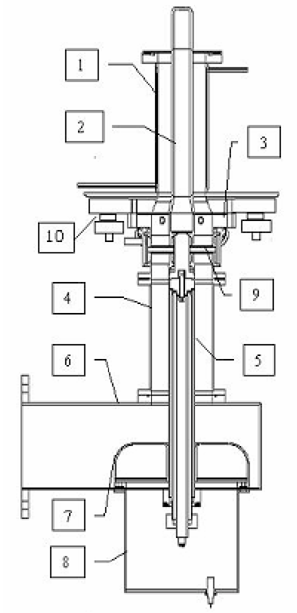


Figure 1 – Field distribution inside the coupler-transition assembly and the field strength along the coaxial structure. Fields are normalized to 1W input. Only the half section of the structure model is shown.

The simulations were made to confirm the properties of the scaled coupler design for the manufacturing and high power testing setup. The room temperature test setup uses two FPC's joined through a bridge waveguide [7].

2.2 Construction

Fig.2 shows the construction of the FPC for SNS SCL. The vacuum side of the alumina ceramic disk window is *TiN* coated. On vacuum side, the outer conductor is cooled with He gas and on the air side, the inner conductor extension is water-cooled. The contact area between the inner conductor extension and the doorknob was separated with 6mil thick Kapton® layer used as d.c. bias capacitor. Ports for vacuum, electron pick-up probe, and arc detectors are located around the vacuum side housing of the ceramic (Figure 2). More details of design of the SNS FPC can be found elsewhere [4][5][6].



1 – Outer Conductor
2 – Inner Conductor
3 – Window Assembly
4 – Outer Extension
5 – Inner Extension
6 – Waveguide
7 – Doorknob
8 – Waveguide Cover
9 – Ceramic Window
10 – Vacuum Gauge

Figure 2 - The SNS fundamental power coupler construction and its parts are illustrated.

Bench measurements were performed with the prototypes to ensure the specifications on the fundamental RF properties are met. Figure 3 shows the vacuum side components of the coupler. All RF surfaces are copper plated.

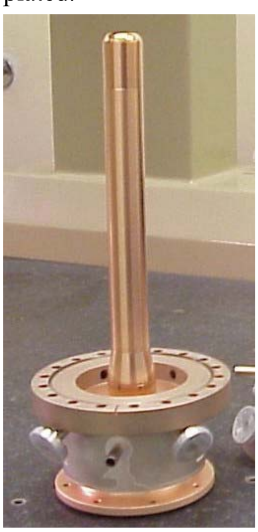


Figure 3 - Vacuum side components of the coupler. The coupler antenna and the ceramic window are shown (left) with the vacuum side coaxial outer conductor (top).

3 HIGH POWER RF CONDITIONING

3.1 Preparation

For high power conditioning without the accelerating cavities, two coaxial couplers were joined together with a bridge waveguide cavity [7] that allows baking and RF conditioning of two couplers under ultra high vacuum. The two couplers and the bridge waveguide were matched to provide maximum RF transmission power, to ensure uniform RF conditioning made at power levels well over the nominal operation specification. Before RF conditioning and testing, the components of the couplers were cleaned, assembled and baked using procedures developed at JLAB [7]. Extensive interlocks were provided for arcing, multipacting, temperature, and vacuum to protect the coupler during the high power operation without damaging. A fast vacuum interlock was used on the controller's analog output to switches the RF off if the coupler vacuum exceeds $5x10^{-7}$ mbar. RF permit is obtained after the vacuum pressure is below $2x10^{-7}$ mbar. In addition, RF conditioning was assisted by a fast RF feedback loop that controls the RF pulse amplitude as function of vacuum events [7][8]. The conditioning went fairly well without big problem that has been reported elsewhere [2][3][6]. In this setup, the RF power is transmitted from one coupler, through the stainless steel bridge waveguide to the other coupler and then to a high-power water load or to a variable waveguide short.

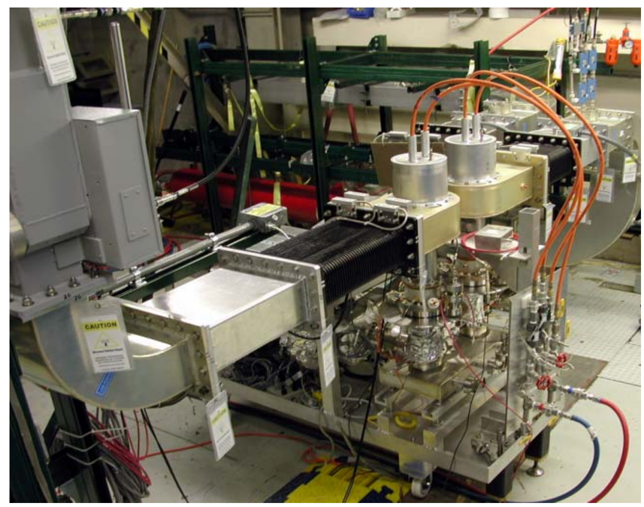


Figure 4 – High power RF conditioning and test setup. Two couplers are joined through a bridge waveguide.

The first six SNS FPC prototypes have been high power RF conditioned and extensively tested at LANL [7][8][9]. A recently completed 1 MW 805-MHz pulsed RF power station (Figure 4) allows performing high RF power tests with traveling or standing waves in JLAB [9]. Four other pairs of couplers have been tested there and qualified for assembly on a cavity.

These settings allow for optimum RF conditioning and minimizing arcing events. Computer control is made using LabView codes that provide operator interface and data acquisition for changing RF pulse settings and control of RF conditioning or testing. Calorimetry of absorbed RF power in the terminating load was made with 1.3 ms pulse width, 30 Hz repetition rate for accuracy of the power measurement [9].

3.2 Traveling wave mode

RF power was transmitted through the couplers into the RF water load for conditioning in traveling wave mode. The vacuum pressure was kept below 3 10^{-7} mbar while power levels above 2 MW were reached after about 30 hours of RF processing without arcing, vacuum, or high electron activities (Figure 5) [9].

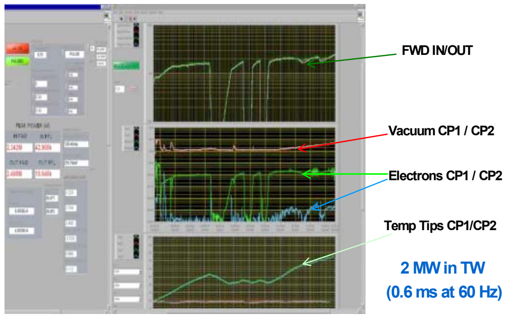


Figure 5 – Over 2 MW reached with no special vacuum or electron events

The effectiveness of using the d.c bias in controlling multipacting at different RF power levels was demonstrated while cycling the power between 10 kW and 700 kW as shown in Figure 6.

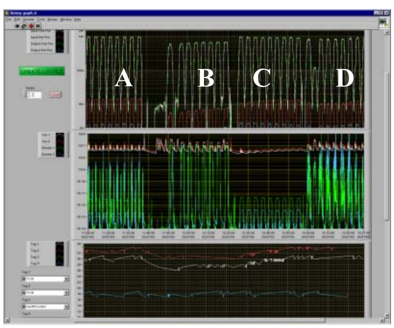


Figure 6 – Effectiveness of d.c biasing: a) vacuum and electron spikes while cycling pulse amplitude, b) same conditions of cycling but with–2.5 kV, c) vacuum and electron activities suppressed with +2.5 kV, d) cycling again without bias

3.3 Standing wave mode

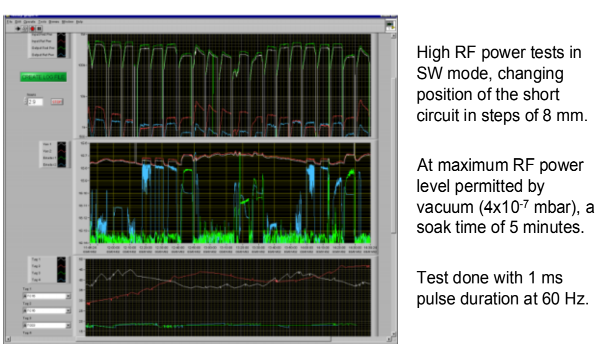


Figure 7 – 2.5 MW range in standing wave mode for different short circuit positions.

Tests were performed in standing wave mode at forward power levels in excess of 600 kW for different positions of the short circuit. The short was moved in steps of 8 mm over $\lambda_g/2$. For some positions of the short circuit, vacuum and electron events triggered by high local peak power occurred (Figure 7).

4 DISCUSSION

Result of the SNS FPC high power conditioning and testing sessions at LANL and at JLAB showed that the design can perform well at the RF power level exceeding the anticipated operating condition. Major concerns on the coupler development were answered through the development work of the SNS SRF coupler: robustness and simplified design at lower cost. Recently, three high power conditioned couplers have been assembled on a SNS medium-beta prototype cryomodule that employs three cavities successfully transferred the RF power for over 15 MV/m accelerating field with 350 kW input power [6]. High power conditioning and testing of the SNS FPC at room temperature will continue along with the prototype cryomodule testing.

5 ACKNOWLEDGEMENT

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6 REFERENCES

[1] C. Rode, "The SNS Superconducting Linac System", PAC'01, Chicago, June 18 – 22, 2001.
[2] S. Noguchi et. al., "Couplers – Experience at KEK", Proc. 4th Workshop on RF Superconductivity, KEK, Tsukuba, August 14-18, 1989.
[3] Y. Kijima et. al., "Input Coupler of Superconducting Cavity for KEKB", EPAC 2000, Vienna, Austria, June 26 – 30, 2000.
[4] Y. Kang et. al, "Electromagnetic simulations and properties of the fundamental power couplers for the SNS superconducting cavities", PAC'01, Chicago, June 18 – 22, 2001.
[5] E. Campisi et. al., "The Fundamental Power Coupler Prototype for the Spallation Neutron Source (SNS) superconducting cavities," PAC'01, Chicago, June 18 – 22, 2001.
[6] I.E. Campisi, "State of the Art Power Couplers for Superconducting RF Cavities", EPAC 2002, Paris, France, June 3 – 7, 2002.
[7] M. Stirbet et. al., "Testing Procedures and Results on the of the Prototype Fundamental Power Couplers for the Spallation Neutron Source.", PAC'01, Chicago, June 18 – 22, 2001.
[8] K.M. Wilson et. al., "The Prototype Fundamental Power Coupler for the Spallation Neutron Source Superconducting Cavities: Design and Initial Test," SRF Workshop, KEK, Tsukuba, Japan, September 6-11, 2001
[9] M. Stirbet et. al., "High power RF tests on Fundamental Power Couplers for the SNS project", EPAC 2002, Paris, France, 3 – 7 June 2002.