THE IPNS RCS RF SYSTEM THIRD CAVITY UPGRADE*

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Abstract

The IPNS RCS is a rapid cycling synchrotron used to accelerate protons from 50 MeV to 450 MeV, 30 times per second. Currently, two single-gap, ferrite-loaded coaxial cavities, located 180º apart, provide a total peak accelerating voltage of approximately 21 kV over the 2.2 MHz to 5.1 MHz revolution frequency band. An amplifier chain, which includes a 2 kW predriver, a 20 kW driver and a 100 kW final, drives each cavity. A third RF system, consisting of a cavity, cavity bias supply, and amplifier chain, is currently under construction. When complete, this upgrade will provide flexibility in operation that is expected to enhance reliability (i.e., three cavity operation at higher total accelerating voltage, three cavity operation at lower voltage per cavity, or two cavity operation with an on-line spare). In addition, the third cavity will provide an experimental station for second harmonic RF cavity studies. We report progress to date.

1 GENERAL DESCRIPTION

The IPNS accelerator operates at an average reliability of greater than 95%. As IPNS approaches 20 years old, facility and equipment aging have become major concerns. To address these concerns in part, and to provide a path for enhancement, an effort is currently underway to upgrade the RCS RF system with the addition of a third accelerating cavity. Figure 1 shows a schematic drawing of the IPNS RCS ring.

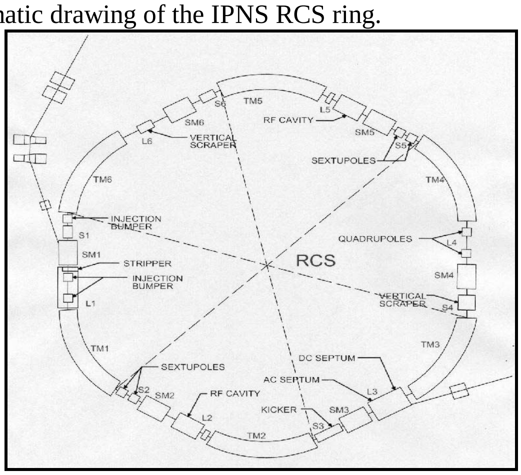

Figure 1. Schematic diagram of IPNS RCS ring.

The existing RF system consists of two single-gap, 50.75" long coaxial ferrite-loaded accelerating cavities, located opposite each other in the L2 and L5 straight sections. A power amplifier chain consisting of a 2 kW predriver, a 20 kW driver and a 100 kW final drive each cavity. The predriver and driver stages, power supplies and local controls are located above the RF stations outside the radiation shield. The final power amplifiers are located beneath the respective cavities. A single 10 kV plate supply, rated at 1 MW, provides power for both final amplifiers, and is housed in a power shed adjacent to the RCS building.

Cavity tuning is provided by 1000 A, 30 V variable DC power supplies, coupled to each cavity via a single-turn, figure-eight, water-cooled bias conductor. A variable current of ~100 A to ~800 A provides the saturating field (~1.5Oe to ~11Oe) required to tune each cavity over the 2.2 MHz to 5.1 MHz frequency band[1].

The third-cavity upgrade, when complete, will provide a third accelerating cavity and final power amplifier in the L6 straight section. The final plate supply, cavity bias supply, driver and predriver stages will be located above the L6 section outside of the radiation shield. Progress to date includes initial design of the amplifiers and plate supplies, final plate supply specifications and purchase, predriver construction and initial testing, and driver plate supply construction.

2 ACCELERATING CAVITY

The third cavity will be identical to the existing two cavities and will be constructed from spare parts. Figure 2 shows a photograph of an existing cavity with the bias choke box and top shell removed.

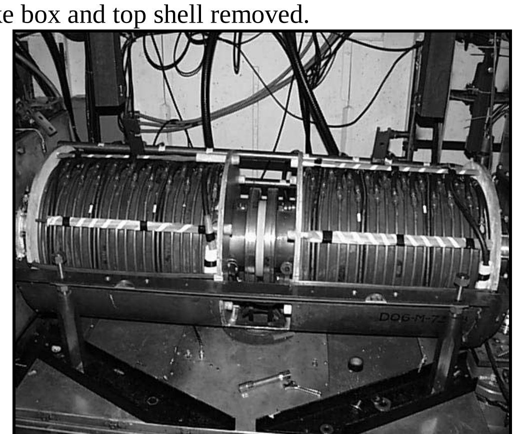

Figure 2. Existing cavity with the top shell removed.

The existing cavities are single-gap, coaxial ferrite-loaded, water-cooled structures 50.75" long. Each cavity is made up of two core stack modules that are each 20" long and 13.75" O.D. Each stack module is made up of twenty Phillips type 4H ferrite torroids, twenty-one 0.125" edge-cooled copper cooling disks, insulating end

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plates and a single-turn figure-eight, water-cooled bias conductor. The 1.11" gap is a formed by a ceramic vacuum insulator placed between two 24.82" long, 6" O.D., type 430 magnetic stainless steal beam pipes and shunted with two 75 pf glass vacuum capacitors. Cavity biasing for the third cavity will be provided by a 1000 A, 30 V variable DC power supply of the same design as the ones in current use.

3 FINAL

The third-cavity final amplifier is push-pull, grounded-grid, cathode-driven, and will employ two Eimac 3CW150000H3 water-cooled power triodes. A simplified schematic is shown in Figure 3.

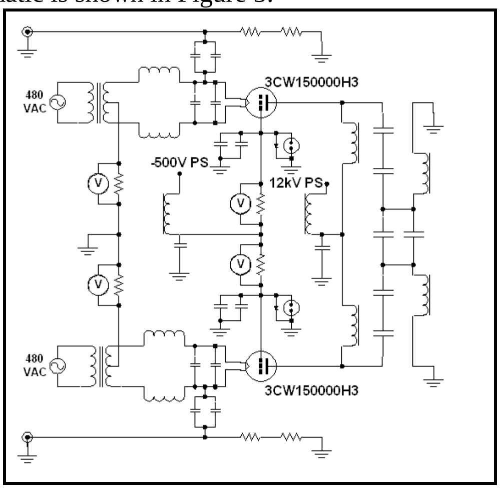

Figure 3. Simplified schematic of final amplifier.

The Eimac 3CW150000H3 tubes were chosen in part due to concern regarding the availability of the tubes currently used in the existing finals. The amplifier will be operated in class AB_1 and tube curves indicate that it will conduct ~8 A per tube of zero-signal plate current at 12 kV plate voltage and –500 V grid voltage. The 3CW150000H3 has an absolute maximum plate dissipation rating of 150 kW. With an amplifier efficiency of 55 to 65%, it is expected that these tubes can easily provide the 100 kW of RF output power necessary to drive the third cavity.

The final plate supply was obtained from an outside vendor. It was specified to provide 168 kW of unregulated DC power in either of two configurations; 24 A at 7 kV or 12 A at 14 kV. The two output configurations were specified with future second-harmonic RF[2] and cathode-follower amplifier studies in mind.

4 DRIVER

The third-cavity driver consists of a push-pull tube amplifier, 5 kV plate supply, -500 V grid supply and 2 kV screen supply. It is identical to the driver amplifiers currently in use. A simplified schematic is shown in Figure 4. The amplifier, plate supply, bias supplies and metering will be contained in a 66"x46"x34" doublewide standard equipment rack. A photograph of the rack with exterior panels removed shows progress to date in Figure 5.

The driver amplifier is push-pull, grid-driven and employs two Eimac 4CW25000A water-cooled power tetrodes. The driver is operated in class AB_1 and conducts ~4 A per tube of zero-signal plate current at 5 kV plate voltage, -350 V grid voltage and 1.5 kV screen voltage.

The driver plate supply is a three-phase transformer-rectifier set capable of providing ~10 A at 5 kV of unregulated DC power at full output.

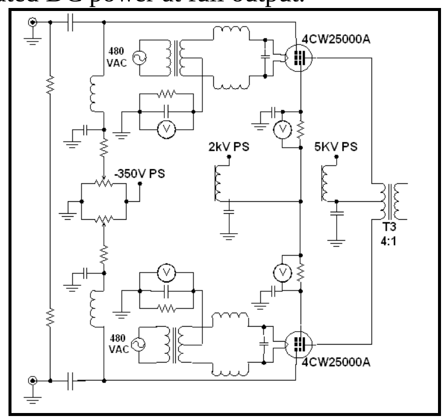

Figure 4. Simplified schematic of driver amplifier.

Figure 5. Driver with exterior panels removed.

5 PREDRIVER

The third-cavity predriver consists of a push-pull tube amplifier and 5 kV plate supply. The amplifier, plate supply, metering and interlock control relays are all contained in a 66"x29"x34" standard equipment rack. A photograph of the predriver, with the front panels removed from the amplifier section, is shown in Figure 6.

The predriver plate supply is a three-phase transformer-rectifier set capable of providing ~4 A at 5 kV of unregulated DC power at full output.

The amplifier is push-pull, grounded-grid, cathode-driven, and employs two Eimac YU-106 (mu = 160), water-cooled power triodes. A simplified schematic is shown in Figure 7. The amplifier is operated in class AB_2 and conducts ~0.4 A per tube of zero-signal plate current at 5 kV. The YU-106 has an absolute maximum plate dissipation rating of 5 kW. It is expected that the predriver will easily be capable of providing greater than 4 kW of continuous RF output power with approximately 300 W of input power, over the frequency band of 2.2 MHz to 5.1 MHz.

Figure 6. Predriver with front panels removed.

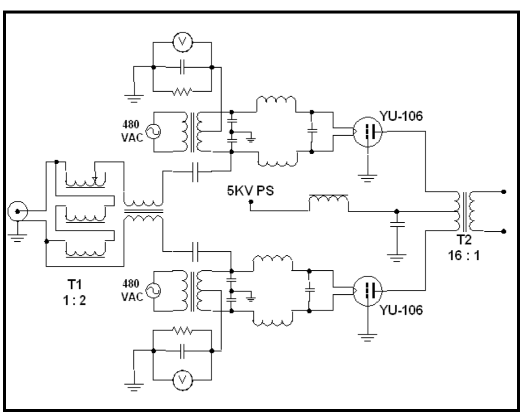

Figure 7. Simplified schematic of predriver amplifier.

Input to the predriver is transformer-coupled via a compound transmission line transformer providing an unbalanced to balanced 1:2 impedance transformation. It consists of two transmission line transformers in series. The first transformer provides an unbalanced to unbalanced 1:2 impedance transformation[3]. The second transformer provides an unbalanced to balanced 1:1 impedance transformation[4]. Each transformer is constructed on a single 6.0 cm O.D. torroid of ferrite material 43 (μ ~ 850) and wound with 14 AWG Formvar® enameled solid copper wire.

The predriver output is transformer-coupled via a conventional isolation transformer consisting of four 10.5cm x 8.9cm x 3.5cm ferrite blocks configured to provide a 10.5cm x 3.5cm winding window (μ ~ 115). The primary winding consists of 12 turns (center-tapped) of 12 AWG high-voltage insulated wire, and the secondary winding consists of 3 turns of 12 AWG high-voltage insulated wire, providing a 16:1 impedance transformation.

Output gain-versus-frequency data, for a fixed 150 W input, were measured for the input network, the output network and the amplifier. The results are presented in Figure 8. Input power was limited to 150 watts due to available equipment.

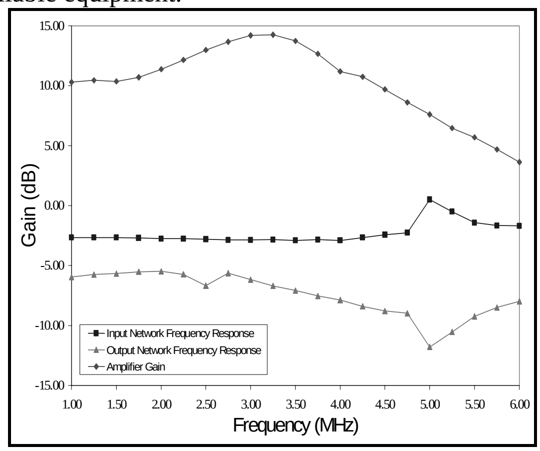

Figure 8. Predriver output gain versus frequency for 150 watts input.

A maximum amplifier gain of ~14 dB at a frequency of 3.25 MHz, with a 3 dB bandwidth of 2 MHz was obtained. The frequency response of both the input and output networks suggest areas for improvement. Modifications to the input and output transformers are underway to provide improved overall bandwidth.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

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