THE ADVANCED PHOTON SOURCE 352-MHz HIGH-POWER RF TEST STAND*

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Abstract

A high-power rf test stand was designed and constructed at the Advanced Photon Source for testing of 352-MHz rf components. A shielded test bunker with a controlled-access monitoring system provides personnel protection. A water manifold system accommodates single-cell and five-cell rf cavities to provide rapid connections to cooling water lines. A patchbay-style low-level rf system allows for rapid configuration of rf monitoring and control electronics, including two cavity tuner control systems. A programmable controller is utilized to provide complete flow and temperature monitoring and interlock functions for the device being tested. Full EPICS monitoring of all test parameters is provided.

1 INTRODUCTION

The Advanced Photon Source (APS) 352-MHz High-Power RF Test Stand (see Fig. 1) is designed to provide a test and conditioning platform for accelerating cavities and cavity accessories such as tuners, couplers, HOM dampers, and waveguide components, and for testing 352 MHz, 1.1 MW klystrons into a 1 MW continuous-wave (CW) rf load. It consists of a test bunker, which provides shielding from x-ray radiation produced by the device being tested, cooling water distribution manifolds to provide easy connection to supply and return cooling water lines, a complete equipment interlock system designed to measure test parameters and protect the device under test, an ultra-high vacuum pumping system to achieve, maintain, and measure vacuum levels down to $5\times10\ E^{-10}$ Torr, and a personnel safety interlock system which prevents personnel entry to the test bunker while rf power is applied to the device under test. The test stand also includes a complete VXI-based low-level rf system, which provides amplitude and phase monitoring and control, including cavity-tuning functions. The test stand can be monitored and controlled locally or from remote locations utilizing the network-based Experimental Physics and Industrial Control System (EPICS).

The rf power source for the test stand is the APS RF1 storage-ring rf station, which serves as the test stand driver when not needed for storage-ring service. It is capable of 1.1 MW CW rf output at 352 MHz, and is switched between test-stand and storage-ring service using a four-port, WR2300 waveguide switch. Dual 1-MW WR2300 waveguide shutters isolate the rf input to the test stand when access to the device under test is desired while the storage-ring rf systems are operating. The waveguide shutters each provides a minimum of 80 dB isolation when closed.

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Figure 1: rf test stand operator console.

2 STRUCTURAL DESIGN

The structural design of the test stand accommodates a very complicated personnel safety specification. The test stand bunker building has been constructed to protect against x-ray emission produced by high-vacuum rf structures under test (see Fig. 2). The bunker walls are 32-inches thick, with a 2-inch air gap between two discrete concrete-composition layers. The inner walls are standard 18-inch-thick dense concrete shielding block, dry-laid. The outer walls are 12-inch-thick solid concrete building blocks, laid with mortar. An 8-inch solid cast concrete ceiling, supported by the outer walls, is utilized to reduce x-ray sky-shine radiation from the bunker. Shielding thickness calculations assume that personnel could work up to 8-hours per day outside the test stand bunker without needing an additional controlled area. During the commissioning, Argonne's Environment, Safety and Health Division will monitor radiation dose rates and compare them to calculated values. Personnel access to the test cell is through a labyrinth with doors that are controlled by an Access Controlled Interlock System (ACIS).

3 LOW-LEVEL RF SYSTEM

The low-level rf system consists of VXI-based, 352-MHz envelope and phase detectors, 352-MHz phase shifters, and dc-to-100 kHz proportional-integral-

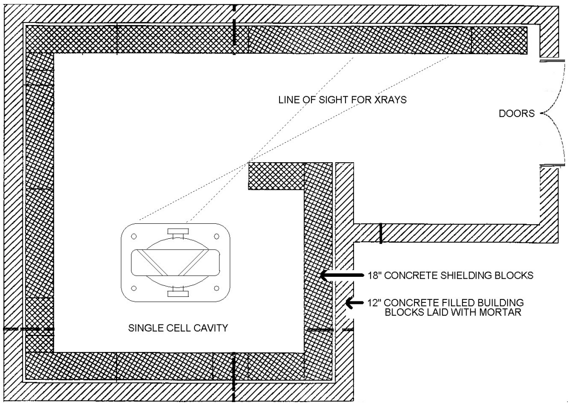

Figure 2: Test bunker top view.

differential (PID) amplifiers. The "patchbay and tie-trunk design of the system (see Fig. 3) provides for rapid configuration of low-level rf (LLRF) components to achieve a variety of rf control and monitoring functions. The LLRF system also includes two complete motor-driven, piston-type cavity-tuning systems, which can be used individually to tune single-cell rf cavities or together to tune five-cell rf cavities for optimum field flatness. EPICS is utilized to monitor and control the LLRF system VXI modules. A dedicated frequency synthesizer is used as an rf source for test stand operations. A 100-w broadband solid-state rf amplifier is patchable into the LLRF system to allow low-power excitation of the test cavity for field probe coupling measurements and cavity-tuning system adjustment.

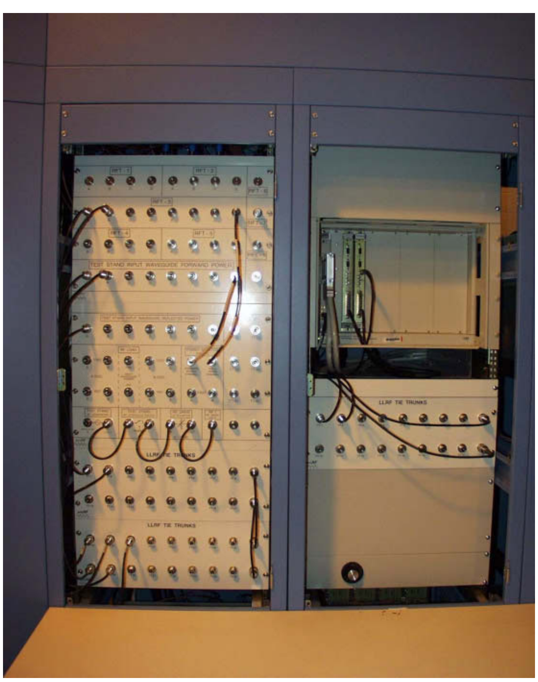

Figure 3: Low-level rf patchbay.

4 WATER COOLING SYSTEM

A filtered (0.5 μm) 300-GPM, de-ionized water system provides cooling to the rf cavity and associated components (see Fig. 4). Supply/return line differential pressure is maintained at 100 psi, and a three-way mixing valve achieves temperature control. The main line is a 6-inch 304 stainless-steel header that branches off into five 2-inch auxiliary headers that supply the cavity under test, a possible second cavity under test, and three cavities in storage. Flow-regulating valves regulate the flow to individual cavities to 75 GPM. Each 2-inch header has numerous 1-inch and 0.75-inch National Pipe Thread ports for use as drop lines to the cavity and associated components. Each port is equipped with a stainless-steel ball valve for easy cavity and component replacement, with extra ports and valves supplied on all auxiliary headers for future use.

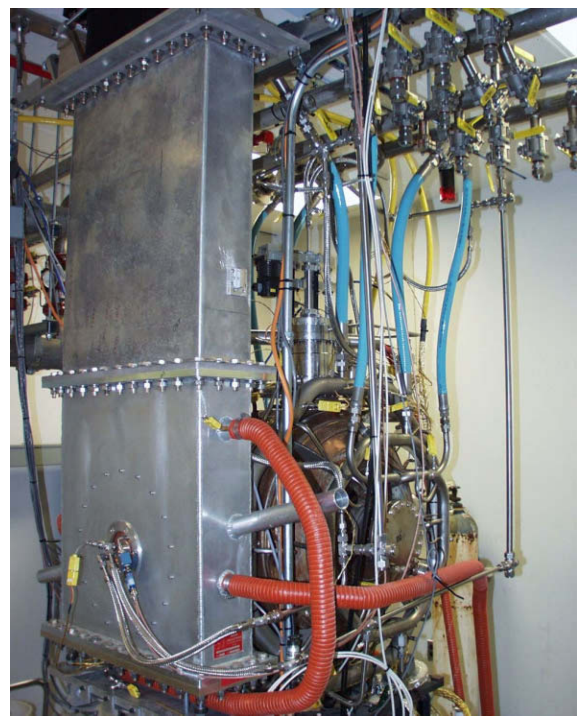

Figure 4: rf test cavity assembly.

5 VACUUM SYSTEM

The ultra-high vacuum system consists of a 520-ℓ/second turbo pump in tandem with a 400-ℓ/second ion pump/nonevaporative getter combination. Initial system rough pumping and subsequent turbo pump backing is achieved with an oil-free high vacuum pump. An 8-inch gate valve provides turbo and roughing system isolation. A vacuum valve interlock chassis monitors ac power, foreline pressure, and roughing pump and turbo pump speed, and provides for automatic gate valve closure in the event any of these parameters exceed safe limits. A manual override is provided to bypass these parameters during initial pump-down. Vacuum readbacks and vacuum warning rf interlock contacts are provided by the main ion pump controller, and a tungsten-filament Bayard-Albert nude ion gauge with a separate controller.

6 EQUIPMENT SAFETY INTERLOCK SYSTEM

A local programmable logic controller is dedicated to provide continuous status monitoring of the device under test, the 1-MW rf test load, and the waveguide switches and shutters in-line with the test stand rf input (see Fig. 5). It also provides an rf interlock with a response time of approximately 25 ms in the event critical operating parameters are exceeded. The PLC also provides a touch-screen operator interface for monitor and control functions, which displays the status of the operator keyswitch, rf drive control, and positions of waveguide switches and shutters in line with the test stand rf input waveguide. The PLC has the capacity to monitor up to forty 4-20 mA analog instrumentation signals and 20 dry-contact status inputs, and is programmed to interrupt the klystron rf drive signal and shut down the RF1 high-voltage power supply unit in the event system conditions are exceeding safe levels, or if a waveguide component is detected to be in an incorrect position. The rf drive inhibit function is achieved by electro-mechanical coaxial relays in series with the output of the test stand rf source. The PLC is monitored and controlled locally by a touch-screen monitor, and remotely by EPICS.

Figure 5: PLC and fast rf interlock.

Fast rf interlocking (10-100 μs) is provided by an rf power monitor that detects the levels of forward and reflected rf power at the input of the test stand, as well as the field probe output signal of the cavity under test. If the rf power level at any of these points exceeds preset limits, the rf drive signal from the test stand rf source is muted within 100 μs. The power monitor also detects alarm signals from up to four waveguide arc detectors, six cavity vacuum monitors, and two cavity coupler temperature monitors, and will mute the rf source signal within 10 μs of an alarm signal from any of these devices.

7 PERSONNEL SAFETY INTERLOCK SYSTEM

Personnel safety in the vicinity of the rf test stand is achieved by local-area rf and ionizing radiation monitors and access control to the test bunker interior, provided by an extension of the APS Access Control Interlock System (ACIS). This system prevents entrance to the test bunker during rf-permit periods, such as when rf power could be applied to the device under test, and also allows for emergency exit from the interior of the bunker in the event the test stand is placed in rf-permit mode while personnel are inside. During rf-permit periods, the bunker access doors are secured in the closed position by means of an electromagnetic lock, and a permissive signal is generated that allows the RF1 rf station to provide rf power to the test stand input. If the bunker doors should be opened while in rf-permit state, the ACIS will immediately remove the permissive signal to the RF1 station, preventing it from operating. A bunker search procedure using sequential search buttons is utilized to insure that the bunker interior is thoroughly inspected for the presence of personnel before the doors are closed and the test stand is placed in rf-permit mode. The ACIS system also monitors the position of two WR2300 waveguide shutters in-line with the test stand input waveguide, and will allow entry into the bunker interior only when both shutters are in the closed position.

8 SUMMARY AND FUTURE PLAN

The construction of the APS 352-MHz High-Power RF Test Stand is nearly complete, with the first operation of the system scheduled for late June 2001. After commissioning, the test stand will be utilized for the rf processing and conditioning of the APS storage-ring cavity high-power couplers and tuners in support of APS operation. RF preconditioning of these critical components in the test stand will reduce the rf conditioning period needed after the components are installed in the storage-ring beam line, and will enhance the overall operational reliability of the APS storage ring. The test stand will also serve as a facility for development, testing, and characterization of different types of high-power rf hardware such as cavity higher-order mode (HOM) dampers, waveguide components, and ceramic windows.

9 ACKNOWLEDGEMENTS

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