BNL-94097-2011-CP

FPC conditioning cart at BNL

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Presented at the 2011 Particle Accelerator Conference (PAC'11)
New York, N.Y.
March 28 – April 1, 2011

Collider-Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy
Office of Science

DISCLAIMER

FPC CONDITIONING CART AT BNL*

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Abstract

The 703 MHz superconducting gun for the BNL Energy Recovery Linac (ERL) prototype has two fundamental power couplers (FPCs), and each of them will deliver up to 500 kW of CW RF power. In order to prepare the couplers for high power RF service and process multipacting, the FPCs should be conditioned prior to installation into the gun cryomodule. A conditioning cart based test stand, which includes a vacuum pumping system, controllable bake-out system, diagnostics, interlocks and data log system has been designed, constructed and commissioned by collaboration of BNL and AES. This paper presents FPC conditioning cart systems and the conditioning process.

INTRODUCTION

The BNL ERL prototype makes use of half-cell superconducting RF gun resonating at 703.75 MHz in fundamental TM010 mode to provide 2 MeV electron beam for main linac [1]. The half-cell superconducting cavity is powered by two coaxial fundamental power couplers (FPCs). Each FPC must be able to withstand half of the maximum power delivered by 1 MW klystron, which is 500 kW in a CW mode.

In order to ensure that the FPCs will be able to perform properly in operation, they must be cleaned, assembled, baked and then conditioned with RF power at levels about twice the operating power level. A room temperature test stand has been designed and built by AES in collaboration with BNL for testing and conditioning of the FPCs before they are assembled onto the superconducting gun. The goals for the testing and conditioning include: (1) to help remove any surface imperfections from the fabrication step; (2) to check for, and process through, any multipacting barriers that may be encountered; (3) to ensure the copper plating on the outer conductor is well adhered; (4) to help outgas the UHV components prior to installation on the gun; (5) to ensure the parts are capable of handling the designed power level prior to installation on the gun; (6) to verify the cooling circuits function properly and provide adequate cooling to the respective parts.

According to the goals, the test stand allows for simultaneous processing of the two FPCs and has the capabilities of mobility, in situ baking, monitoring of critical RF and vacuum parameters, diagnostics and control equipment for baking and RF conditioning, and interface with data acquisition and retrieval systems. This paper presents the design and operation of the test stand.

FUNDAMENTAL POWER COUPLER

Figure 1 shows the scheme of 50 Ω coaxial-line-based fundamental power coupler for the gun cavity. The FPC is separated by a planar alumina window to vacuum side and air side. On the vacuum side, the copper-plated stainless-steel-made outer conductor is cooled by helium gas and the OFE copper made inner conductor is cooled by water with a double-wall design. On the air side, both the copper-plated stainless steel outer extension and copper inner extension are water cooled with a double-wall design. The planar ceramic window assembly has five instrumentation ports on vacuum side: two for vacuum gauges, two for arc detectors and one spare blank flange. The transition between the coaxial line of the FPCs and WG1500 waveguide is provided by a doorknob configuration. To enhance the coupling of the FPCs to the cavity, a pringle-shaped tip, confirming to a profile of the beam pipe, is attached at the end of the inner conductor.

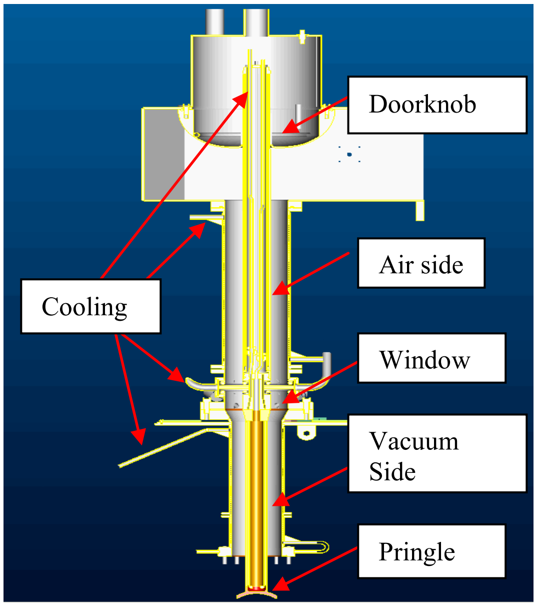

Figure 1: Scheme of the BNL fundamental power coupler.

*Work is supported by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. DOE.
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FPC CONDITIONING CART

General Layout

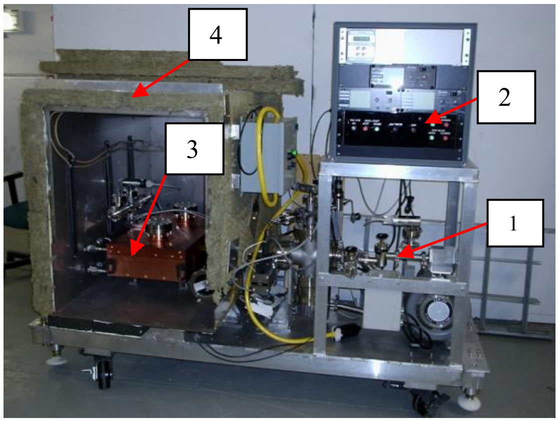

Figure 2: Layout of the FPC conditioning cart.

1- Pumping system,
2- Control panel,
3- Connecting waveguide,
4- Thermal box

The FPC conditioning stand shown in Figure 2 is based on a robust, mobile aluminum cart. It houses the vacuum pump system and connecting waveguide. RF conditioning of the couplers is performed under ultrahigh vacuum (UHV). The UHV is maintained using a turbomolecular pump, which is backed by a dry mechanical pump. Vacuum near the ceramic window is measured with two MKS magnetron gauges, which provide the vacuum signal for RF power level control during the conditioning. In addition, a residual gas analyzer is mounted on the vacuum system. A fast-response vacuum controller is used to protect the system by shutting off the klystron.

Bake-out

Before RF processing, the FPCs and the connecting waveguide are baked out at 200°C. With a thermal-insulation box, it takes 7 hours to ramp the temperature up to 200°C (window temperature). The stand stays at this temperature for 20 hours. Then the temperature is ramped down at a rate of 15°C/hr. The vacuum reached to 7.3E-9 Torr immediately after baking and to 3E-9 Torr after several days of pumping.

RF system

Two FPCs are mounted on the connecting waveguide to be conditioned simultaneously. One FPC is connected to a waveguide from the 703.75 MHz, 1 MW CW klystron, the other one is connected to a 90-degree phase shifter and a short plate, so the conditioning is carried out with a standing wave. Four sets of directional couplers (one before the circulator, one before the water load, two connected to the FPCs) are used to measure RF power levels. The RF diagram is shown in Figure 3. The PASS (Personal Alert Safety System) permission sums the arc detector, vacuum, water flow signals.

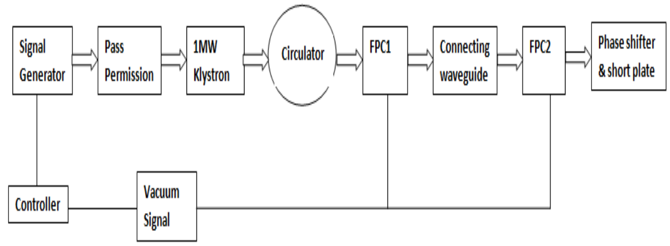

Figure 3: BNL FPC conditioning block diagram.

S-parameter measurement

Two AES/CPI Mark 1 FPCs fabricated by CPI FPCs were mounted on the connecting waveguide and S parameters were measured as the phase shifter position was being changed, according to the diagram shown in Figure 4. From the VSWR measurements presented in Table 1, one can see that the phase shifter travel is only good up to 2 inches, which corresponds to 45 degrees of the RF phase. Short pieces of waveguide will have to be added to cover 135 degrees for complete conditioning of the FPCs.

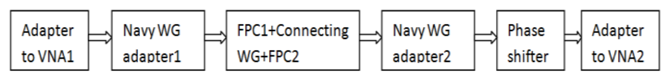

Figure 4: S-parameter measurement diagram.

Table 1: VSWR of the phase shifter

Phase Shifter travel (inch)	VSWR
0	1.2
0.5	1.26
1	1.28
1.5	1.30
2	1.25
2.5	10.78

ASSEMBLY AND CONDITIONING

Assembly

The FPC conditioning cart and FPCs were assembled at AES. Before assembly, all components (bellows, vacuum manifolds, connecting waveguide) were cleaned by immersion in an ultrasonic bath and dried with dust-free nitrogen gas. Additionally, prior to drying, the window assemblies were also rinsed with DI-water to reduce concentration of dust particles and contaminants trapped in the window.

The FPCs and connecting waveguide are assembled in a class-10 clean room at AES. Then they are connected to the vacuum system on the conditioning cart. The entire assembly was checked for a vacuum leak. Finally, the conditioning cart was delivered to BNL for the bake-out and the RF processing.

The first step after the conditioning cart delivered to BNL was to bake-out the vacuum system at 200 ℃ for about 20 hours. Another vacuum leak check was performed again after bake-out to ensure the system is still leak free.

Then, the air sides of FPCs including the inner and outer conductor extensions and waveguide/doorknob transitions were assembled. The S-parameter measurements were also carried out with two adapters connecting to the doorknob/waveguide. Finally, the FPCs were connected to the klystron output at one end, and the phase shifter at the other end. Figure 5 shows the setup for FPC conditioning.

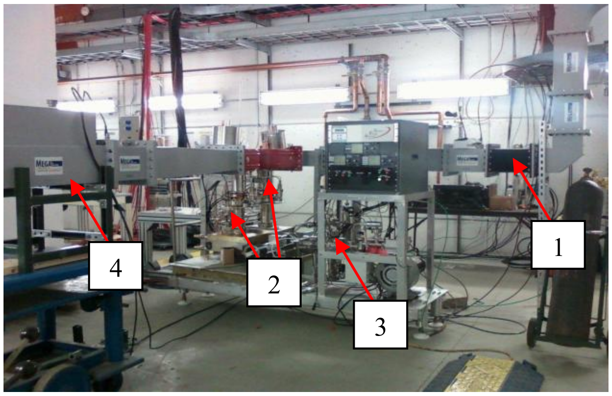

Figure 5: Assembly of the FPCs for conditioning.

1- Waveguide connecting to 1MW klystron
2- Two FPCs
3- FPC conditioning cart
4- Phase shifter and short plate

Conditioning procedure for FPCs

The FPC conditioning begins in the pulse mode (for example, 1 ms pulse length and 100 ms repetition period), followed by the CW mode with gradual increase of RF power to the maximum value. This repeats every 10 degrees of RF phase by adjusting the phase shifter and adding 45-degree pieces of waveguide. The output of the klystron is controlled either manually or by a computer program with a feedback on a vacuum signal. Figure 6 shows a typical vacuum trip during the conditioning. The phase shifting up to 45 degrees is performed from the ERL control room by a remote motor control.

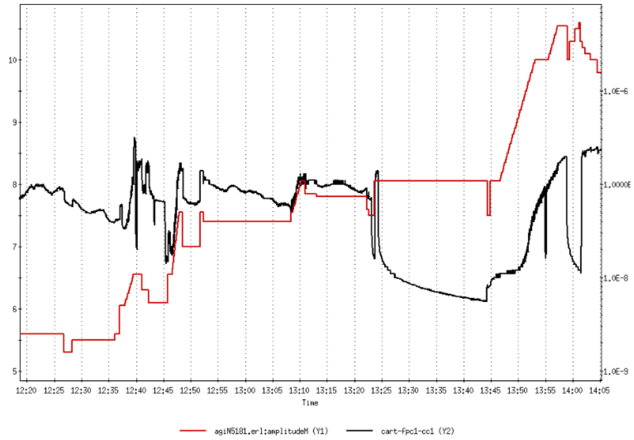

Figure 6: Typical vacuum trip during conditioning

SUMMARY

A RF processing test stand was designed and fabricated by a collaboration between AES and BNL. The first two couplers tested on this stand were AES/CPI Mark 1 FPCs fabricated by CPI. The experience gained during the first test will be applied to processing of the BNL gun Mark 2 FPCs.

ACKNOWLEDGEMENT

The author would like thank Eric Montesinos from CERN for his great help for providing the automatic control system and sharing his experience about FPC conditioning.

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