CONDITIONING THE FUNDAMENTAL POWER COUPLER FOR ERL SRF GUN*

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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 for the BNL GUN FPCs.

INTRODUCTION

The 703 MHz photo-injector is used to produce high current, high brightness electron beam for BNL high current Energy Recovery Linac (ERL) prototype, shown in Figure 1 [1], whose design parameters are listed in Table 1. The 704MHz half-cell superconducting gun requires a total of 1 MW of RF power in order to meet the high current specification (0.5 A, 2 MeV), necessitating two 500 kW fundamental power couplers.

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. 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. This paper presents the conditioning test stand and procedures of conditioning for BNL gun FPCs.

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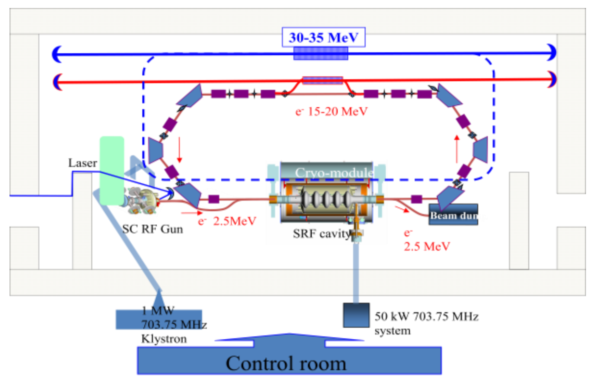

Figure 1: Layout of BNL ERL prototype.

Table 1: BNL ERL prototype parameters

Parameters	High Current	High charge
Bunch charge[nC]	0.7	5
Passes	1	1
Energy max/injection, [MeV]	20/2.5	20/3.0
Bunch rep-rate[MHz]	700	9.383
Average current[mA]	500	50
Injected/ejected beam power[MW]	1.0	0.15
RMS emittances ex/ey, [mm*mrad]	1.4/1.4	4.8/5.3
RMS $\Delta E/E$	$3.5x10^{-3}$	$1x10^{-2}$
RMS Bunch length[ps]	18	31

FUNDAMENTAL POWER COUPLER

Figure 2 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.

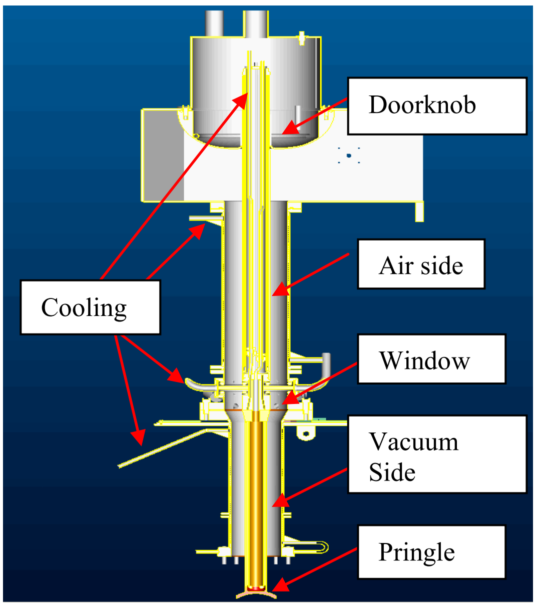

Figure 2: Scheme of the BNL fundamental power coupler.

FPC CONDITIONING CART

General Layout

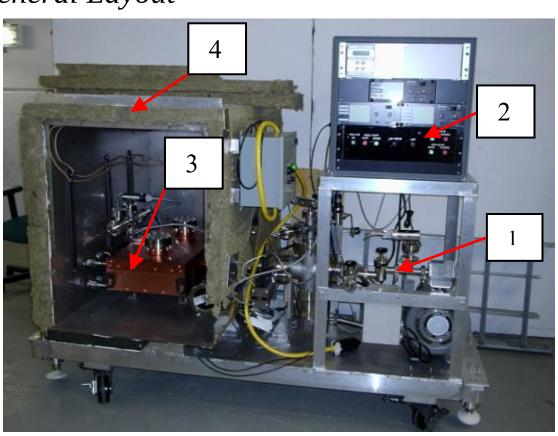

Figure 3: Layout of the FPC conditioning cart.

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

The FPC conditioning stand shown in Figure 3 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 4. The PASS (Personal Alert Safety System) permission sums the arc detector, vacuum, water flow signals.

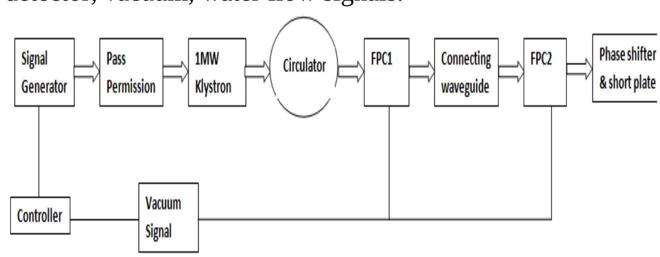

Figure 4: BNL FPC conditioning block diagram.

Control Panel

Figure 5 shows the control panel of the conditioning. The control panel is to control the RF signal generator, which goes to 200w amplifier to excite the 1MW klystron. The increasing or decreasing of amplitude is decided by the vacuum at the two RF windows comparing with the set point. If the vacuum is worse than setpoint2, then the amplitude is constant; if it is worse than setpoint3, then the amplitude will be decrease by the rate of increment. Unless the vacuum is better than setpoint1, the RF power will not increase again.

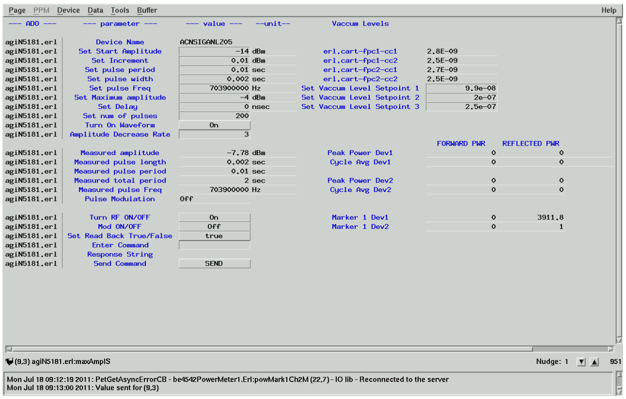

Figure 5: BNL FPC conditioning control panel.

ASSEMBLY AND CONDITIONING

Assembly

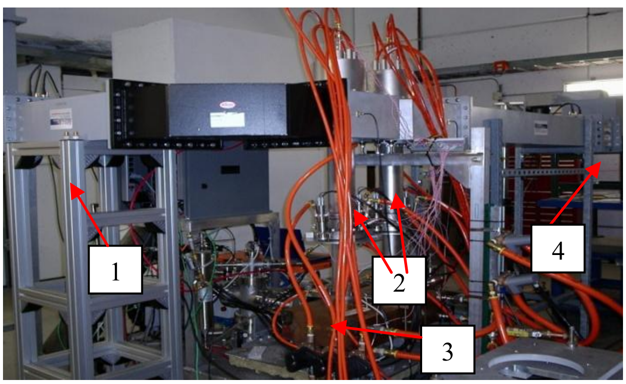

Figure 6: Assembly of the FPCs for conditioning.

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

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°C 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 6 shows the setup for FPC conditioning.

Conditioning Procedure for FPCs

The FPC conditioning begins in various pulse modes, from 100µs/10ms to 2ms/10ms, up to 250kW and followed by the CW mode up to 125kW. 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 7 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.

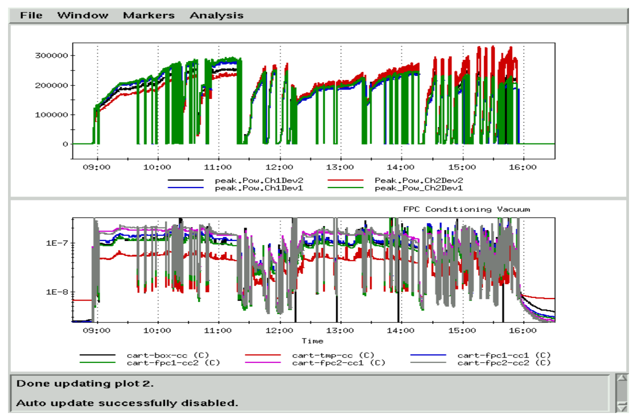

Figure 7: Typical vacuum trip during conditioning.

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[2]. The conditioning for the BNL FPCs for ERL GUN has been done and moved to the clean room for installation.

REFERENCES

[1] V.N. Litvinenko et al, "High current energy recovery linac at BNL", Proceedings of the 2004 FEL Conference, 570-573

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