# Design, multipacting simulations and conditioning of 500 kW FPCs for the BNL ERL SRF Gun

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# Outline

- Brief introduction of the BNL R&D ERL project
- Design of the FPCs for the SRF gun
- Multipacting simulation of the FPCs
- The FPC conditioning test and comparison with test results
- Summary

# High current ERL-prototype: 500mA



- The assembly of ERL beamline is in progress.
- Commissioning of the SRF gun is scheduled for Aug. 2012.

### High current ERL-prototype: SRF gun



# High Power CW FPCs Design



The design was done by collaboration of AES and BNL

✤1 MW transmitted power was used in simulations. Water cooling (9.6psi for window) make sure the temperature rise less than 0.1°C.

\*The maximum stress at the window is 6144 psi from the heat load and ambient pressure, which is approximately one third of the tensile strength of BeO.

# BNL ERL prototype: high power CW FPCs

2.4



- 1 MW transmitted power was used in simulations.
- I GPM water flowing around the inner corner of the doorknob to keep the temperature (72°C) increase <1°C.</p>





# High Power CW FPCs



- Pringle tip at the inner conductor to increase the Qext: 40,000~50,000.
- Water cooling for the inner conductor and air side, 5 K hellium gas cooling at the vacuum side outer conductor.

## Multipacting simulations by ACE3P





S3P calculates the field distribution; Track3P simulates the electron behavior /trajectories.
 The simulations were carried out for the FPC conditioning setup: standing wave, full reflection at different phases, different frequencies .

### Multipacting simulation: Results





Multipacting simulation at different frequencies: left - 703.9 MHz, right - 703.75 MHz  $\rightarrow$  not much frequency sensitivity for MP zone, but time consuming is different for different frequency

#### Multipacting simulation: Results







# FPC conditioning

Prior to installation on the gun the couplers must be RF processed at high power. The goals of the processing are:

- 1. To help remove any surface contaminations 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.

# FPC conditioning setup





#### FPC conditioning control system



#### Watching the signals









## FPC conditioning: Multipacting observed



watt.

- The FPC conditioning began in various pulse modes, from 100 μs / 10 ms to 2 ms / 10 ms pulse. length / period, followed by CW mode with gradual increase of RF power to the maximum value.
- Multipacting zones at 8 to 10 kW, 16 to 25 kW, 40 to 70 kW, 85 to 120 kW and about 165 to 185 kW. Above 185 kW, there was a lot of out gassing.
- For different RF phases (every 10°), the processing went similar and the conditioning time was close except for the very first run, which took most of the test time to ramp up the RF power and it was much shorter time for the later runs.

#### Comparison of simulation and test



- ✓ Simulation shows multipacting will happen at the RF power level about are 8 to 10 kW, 16 to 25 kW, 40 to 70 kW, 85 to 120 kW and about 165 to 185 kW. All these featuresd were observed in the experiments
- ✓ The simulation also shows that multipacting zone is not sensitive to frequency.
   However, the strength of multipacting changes with frequency.
- ✓ The multipacting is not sensitivity to the phase, since the multipacting mainly happens in the vacuum side.

# Summary

- High power fundamental power was designed for the SRF gun.
- We have successfully tested 500 kW FPCs for the R&D ERL SRF gun with standing wave up to 250kW in pulse mode(limited by klystron collector) and 125 kW in CW (administrative limit).
- Observed MP barriers were in very good agreement with those predicted by simulations with Track3P.

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### Thank you for your attention!

#### Backup slide

### ERL-prototype parameters

Parameters	High Current	High charge
Bunch charge [nC]	0.7	5
Passes	1	1
Energy max/injection, [MeV]	20/2.0	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 $\varepsilon_x/\varepsilon_y$ [mm*mrad]	1.4/1.4	4.8/5.3
RMS ∆E/E	3.5x10 <sup>-3</sup>	1x10 <sup>-2</sup>
RMS Bunch length [ps]	18	31

# Power and cooling requirement for the FPC

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Heat load and temperature rise are based on 1MW through power.
For all water circuits the system pressure should not exceed 70. psia
Vacuum side inner conductor: 567 watts, 1.3 GPM, DP = 33.4 psid temp rise = 1.7K
Inlet and outlet tubes are 3/16" O.D.
Window O.D.: 160 watts, 6.9 GPM, DP= 9.6 psid temp rise = .08K
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#### Air Side of the FPC

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Air side inner conductor: 346 watts, 3.0 GPM, DP = 10.8 psid temp rise = .44 K
Air side outer conductor: 86 watts, 3.0 GPM, DP = 10.5 psid temp rise = .11 K
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Waveguide & Doorknob: 174 watts, 1.0 GPM, DP = 1.73 psid temp rise = .66K

Waveguide temperature near short and doorknob calculated as 72. °C. Protective cage or other safety feature may be required.

#### Transition section and cold flange

#### The helium requirement is .075 g/sec.

Helium flows through the cold flange then into the transition section.