RIDGE WAVEGUIDE HOM DAMPING SCHEME FOR HIGH CURRENT SRF CAVITY*

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Abstract

FFAG based eRHIC SRF linac generates up to 6.8 kW of HOM power per 647 MHz 5-cell BNL4 cavity, presenting a big challenge for the machine design. A ridge waveguide is a natural high pass filter and has a smaller size than the regular waveguide. A HOM damping with combination of ridge waveguide for low frequency HOM and two room temperature HOM damper (between cryomodules) for high frequency HOM was proposed to damp the high power, full spectrum HOM in eRHIC. The eRHIC SRF linac configuration and the results of ridge waveguide design will be presented in this paper. The prototype waveguide HOM damper and its measurement plan are described as well.

INTRODUCTION

The future electron-ion collider proposed at Collider-Accelerator Department at BNL is an FFAG based electron-ion collider, eRHIC [1]. eRHIC is designed to collide polarized electron beams with an energy range from 5 to 20 GeV with the existing polarized proton beams. The new electron accelerator will be placed in the existing RHIC tunnel. The SRF linac will be at IP2, where the available straight section is 200m long. The accelerator design for producing electrons with energies up to 20 GeV is based on up to 12 passes energy recovery linac (ERL), as shown in Figure 1.

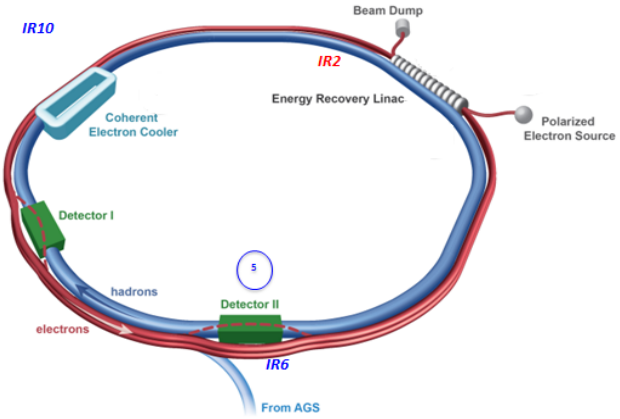

Figure 1: Layout of FFAG based eRHIC. Existing "Blue" hadron ring (center); Two electron NS-FFAG beam lines (Red) and SRF linac at IP2.

The SRF linac, consisting of 80 5-cell 647 MHz SRF cavities with gradient of 18 MV/m, will provide 1.667 GeV of energy gain. As the total available length for linac is 200 m, a compact, efficient, reliable HOM damping scheme for the linac has to be designed. The SRF linac configuration and a practical HOM damping scheme for eRHIC will be presented in this paper.

LINAC CONFIGURATION

The main eRHIC SRF linac frequency is 647 MHz, the 69th harmonic of RHIC bunch repetition frequency, 9.38 MHz. The linac has 80 5-cell BNL4 cavities in 20 cryomodules (4 cavity per cryomodule). The cavity design is describe in reference[2, 3]. The total linac length is 176 m with a filling factor of 0.53, resulting a real-estate gradient of 9.48 MV/m. Figure 2 shows the configuration of one main linac cryomodule. There are four 647 MHz 5-cell cavities in one cryomodule to provide 83 MeV of energy gain and two types of HOM dampers are used: ridge waveguides placed at each side of cavity for low frequency HOM damping, room temperature beamline absorbers at each side of the cryomodule to further absorb the HOM between the two cryomodules. The cryomodule's parameters are listed in Table 1.

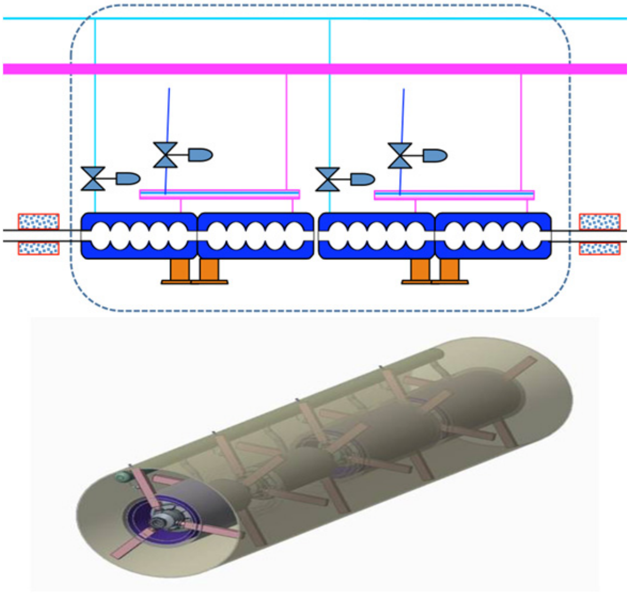

Figure 2: Sketch of eRHIC SRF linac configuration: Cryomodule (top) and ridge waveguide HOM damper (bottom).

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* Work supported by BNL LDRD program
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Table 1: eRHIC cryomodule's parameters

Parameters	One Cryomodule
Energy gain [MeV]	83
Cavity frequency [MHz]	647.4
Number of cavity	4
Accelerating gradient [MV/m]	18
RF coupler per cavity	1
Operating temperature [k]	1.9
Cavity intrinsic Q factor at operating gradient	2E10
Peak resonant frequency detuning due to microphonics [Hz]	12
Qext of FPC	2.0 E7
RF power per cavity [kW]	16
Number of ridge waveguide per cavity	6
Number of RT beam line absorber	2
Maximum HOM power per cavity for nominal design [kW]	2.8
Maximum HOM power per cavity for ultimate design [kW]	6.8
Length of cryomodule with RT absorber [m]	8.78

DESIGN OF RIDGE WG HOM DAMPER AND BBU SIMULATION RESULTS

The coupling of a waveguide to a cavity or beampipe is approximately proportional to intersecting area of the waveguide and beampipe. As shown in Figure 3, there are two design concepts to apply ridge waveguides for the HOM damping. The first one is to place dual ridge waveguide at the cavity's taper area, so that the whole tapered beampipe will be covered by the waveguides. The second design is to have a rectangular waveguide place on the enlarged beampipe and then the rectangular waveguide transitions to a ridge waveguide. Except for the larger coverage on the beampipe, the other advantage of the first scheme is there will no additional reflection that is caused by the transition in the second scheme. Additionally, the transition from rectangular waveguide to ridge waveguide will cause resonant waveguide modes, which affect the damping, depending on the frequency, impedance and types of modes. The worst case is when this frequency lines up with the beam spectrum.

The impedance of monopole and dipole components of the HOMs of these two HOM damping schemes are shown in Figure 4. For the most monopole modes, the pure ridge waveguide damping scheme performs better than the composite scheme. Similarly for the dipole components, the uniform ridge waveguide damping scheme (Blue Diamond) damps much better than the rectangular transition to ridge waveguide scheme at low frequency, where beam-break-up (BBU) is more critical. BBU simulation results with GBBU [4] also proved this: with eRHIC's parameters and 12-pass FFAG based ERL lattice, the BBU threshold current for the uniform ridge waveguide damper case is 18. mA, which is 30% higher than the case with rectangular to ridge transition waveguide scheme, where the threshold current of 12.7 mA.

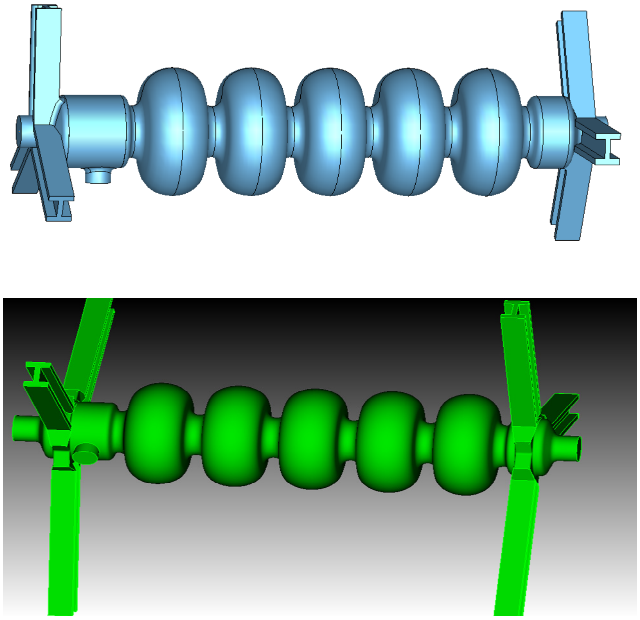

Figure 3: Two concepts of HOM damping: ridge waveguide placed on the taper (top); rectangular waveguide placed on the enlarged beampipe and tapered to ridge waveguide.

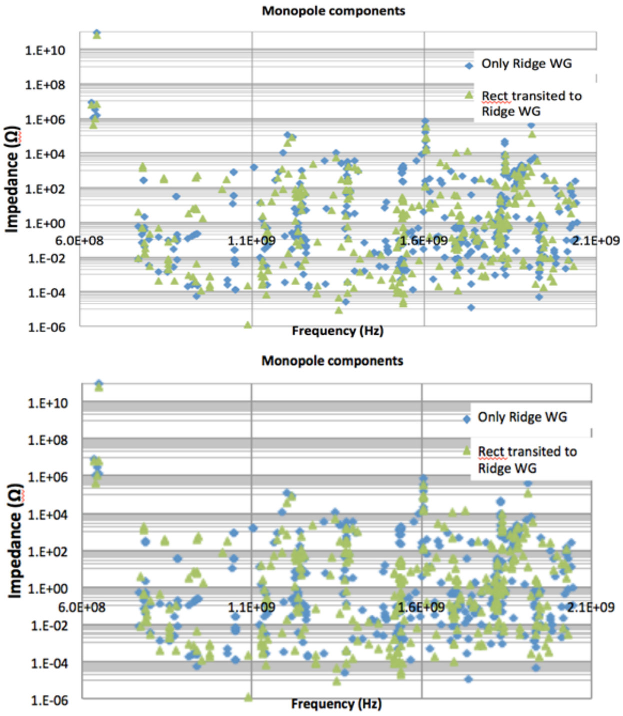

Figure 4: Monopole and dipole damping results with only ridge waveguide on the cavity's taper (Blue Diamond) and rectangular WG transited to ridge waveguide (Green triangle).

RIDGE WAVEGUIDE PROTOTYPE AND MEASUREMENT PLAN

The ridge waveguide HOM damper will be fabricated and we will measure the S-Parameters using the setup shown in Figure 5 to verify the RF design. When the 647 MHz 5-cell copper BNL4 cavity is delivered in early 2017, the setup will be attached to the cavity's beam pipe (in Figure 5 Bottom), so that the HOM damping will be measured.

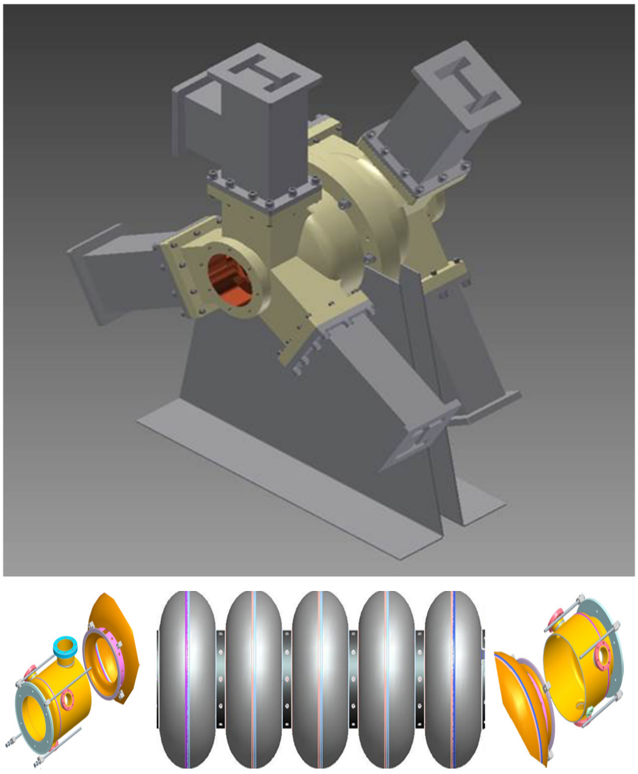

Figure 5: Ridge waveguide prototype measurement setup (top) and detachable copper BNL4 cavity.

Two broadband (0.5 - 8 GHz and 7-40 GHz) transitions from the ridge waveguide to coaxial line were ordered from Mega [5] for RF measurements. A dog-leg structure, shown in Figure 6, will be needed if there is RF window (a challenge) has been designed to shield radiation from beam, although we try to avoid the RF window as it may cause unwanted reflection.

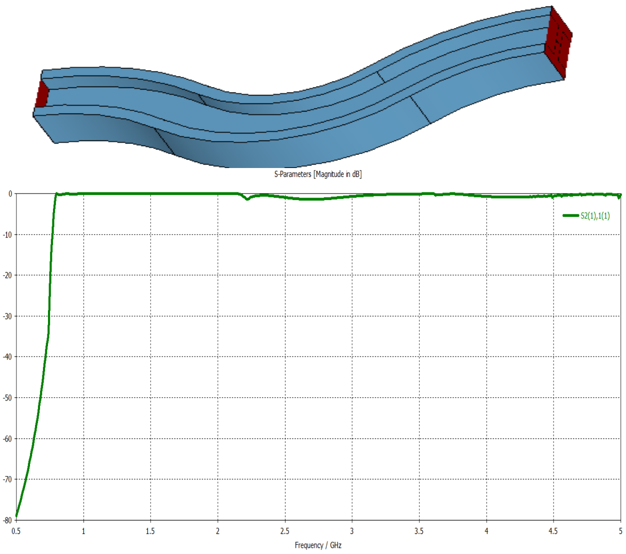

Figure 6: Dog-leg structure design and its S-parameter.

SUMMARY AND PLAN

HOM damping for eRHIC SRF linac is a challenge due to its high power and broad sprectrum. Using a ridge waveguide to damp the low frequency modes has been simulated in frequency domain. The next step will use time domain simulation to calculate the damping results over the whole spectrum. A ridge waveguide prototype will be fabricated to verity the RF design, fabrication process and HOM damping on the copper BNL4 cavity.

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