MULTIPACTING ANALYSIS FOR JLAB AMPERE CLASS CAVITIES*

G. Wu[#], M. Stirbet, H. Wang, R. Rimmer, E. Donoghue, Jefferson Lab, Newport News, VA 23606, U.S.A.

Abstract

JLAB's Ampere class 5-cell cavities require a moderate accelerating gradient (16.7~20MV/m), but electron multipacting activity in the cavity could degrade the expected performance. A survey of multipacting behavior for β=1 electron cavity shapes, including options for the new high current cavity shape. The results provided useful guidance to the selection of the final cavity shape adoption and to its expected performance.

INTRODUCTION

Five-cell cavities were proposed for a JLAB Ampere-class FEL cryomodule [1] for a good packing factor to maintain a high real-estate gradient. Heavy High Order Mode (HOM) damping and low cryogenic loss are basic requirements for cavity shape optimization [6]. A Round Nose, Elliptical Equator (RN-EE) cell shape with waveguide dampers gives a reasonable fundamental mode efficiency, strong HOM damping and places HOM frequencies safely between dangerous harmonic resonances of the bunch frequency. Many different cell shapes have been studied. While several shapes offer similar advantages in fundamental mode efficiency and HOM damping effectiveness, we also need to consider the possibility of multipacting in the final shape. The multipacting analysis in this case becomes a guide to the final design between a couple of good final choices.

The FishPact code [2] was used to simulate the electron impact energies during the cavity shape optimization process.

IMPACT ENERGY AND CAVITY SHAPE

Previously the multipacting analysis was carried out as a post-design. Cavity shape optimization was first conducted for either HOM behavior (for high beam current), shunt impedance (for acceleration efficiency) or peak magnetic surface field (for low cryogenic loss). Then a numerical simulation was conducted to assess the potential multipacting behavior of a particular cavity shape. While multipacting itself is a very complicated physical process, it is well known that the electron impact energy of the electrons with stable trajectories should be kept as low as one can achieve, where the Secondary Electron Yield (SEY) should be less than 1, which is a physical-chemical process difficult to control in a typical niobium cavity.

The equator section is a common place where two-point multipacting occurs [3]. The curvature of the equator section is by far the most influential factor in terms of the electron impact energy where there exist stable electron trajectories.

During cavity shape optimization process, one can vary the cavity equator shape "significantly" without compromising the basic cavity parameters like shunt impedance, peak surface field and HOM behavior.

Table 1 lists several major cavity shapes. The proposed ILC reentrant [4] and low loss [5] are also included as references.

Table 1: Selected cavity center-cell shapes and their parameters [6]. The A/B and a/b are ellipses' axis length ratios refers to the beam axial over transverse direction.

Name ID	Freq. [MHz]	E_{peak}/E_{acc}	R/(Qβ^2)G [Ω^2/cell]	Equator R/λ and A/B	Iris r/λ and a/b
SNS β=0.61	805	2.71	22375	0.440 1.0	0.115 0.588
SNS β=0.81	805	2.19	27939	0.440 1.0	0.131 0.556
JLab-OC	1497	2.56	26285	0.468 0.504	0.175 0.5
JLab-HG	1497	1.89	29709	0.451 1.0	0.153 0.571
JLab-LL	1497	2.17	36103	0.434 1.290	0.132 0.7
ILC-RE	1300	2.19	35250	0.428 1.414	0.152 0.789
ILC-LL	1300	2.51	37971	0.428 1.403	0.130 1.0
Rounded Pillbox	748.5	2.40	28949	0.449 1.0	0.175 1.0
Re-entrant	748.5	2.66	21832	0.422 1.778	0.175 1.0
RN-EE	748.5	2.44	29141	0.422 1.344	0.175 1.0
JLAB-LL-modified	748.5	2.91	29518	0.442 1.344	0.175 0.7

Cavities from different projects have different beta and frequency. Nevertheless their geometries can be normalized to wavelength as shown in Figure 1.

MultiPac [7], FishPact, and other multipacting codes predict that two point multipacting is the most common electron activity within the elliptical cavities' equator region. The impact energy for those electrons with stable trajectories is shown in Figure 2.

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[#] genfa@jlab.org

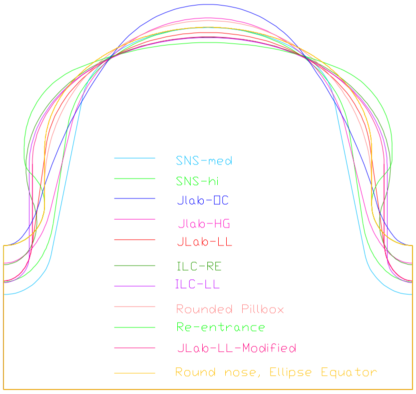
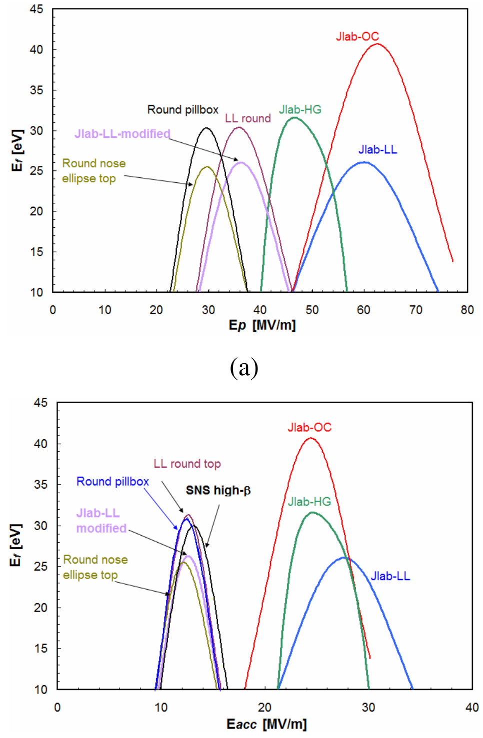


Figure 1: Normalized cavity shapes comparison.

With varied equator shapes, such as those in JLAB-OC, JLAB-HG and JLAB-LL, the simulation shows the impact energy can be reduced from 42 eV to 25 eV. This suggests among those cavities satisfying the Ampere-class cryomodule requirements, the shape with relatively flat equator is preferable.

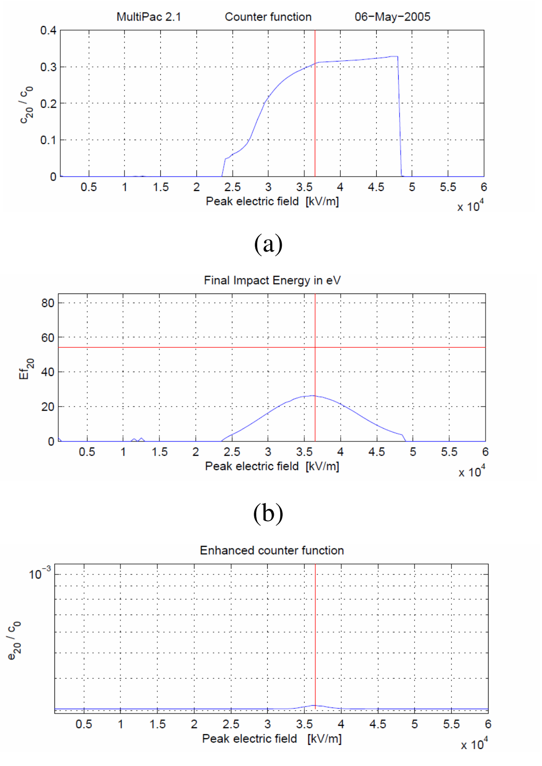


(a)

(b)

Figure 2: (a) Electron impact energy versus peak surface electrical field. (b) Electron impact energy versus accelerating gradient.

One Ampere-class cavity shape with round iris and flat elliptical equator was considered as a preferable shape. The MultiPac code was used to calculate the enhanced counter functions using the default SEY model provided by this code as shown in Figure 3. The designed operating accelerating gradient was far away from the range where stable electron trajectories for potential multipacting activities exist.



(a)

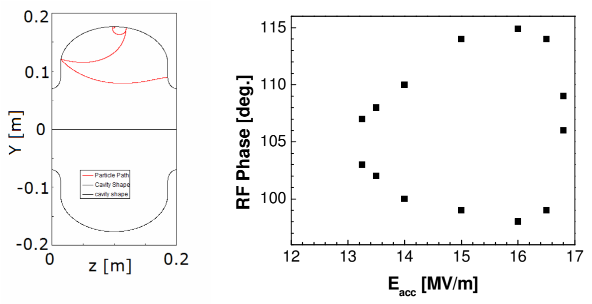
(b)

(c)

Figure 3: MultiPac simulation of Round Nose/Ellipse Equator shape cavity center-cell: counter function (a), final impact energy (b), enhanced counter function (c).

MULTIPACTING ENHANCED BY FIELD EMITTED ELECTRONS

During SNS cavity production when a particular multicell cavity was not processed to ideal surface condition, field emission usually became an issue: field emitted electrons may become captured around the equator and constantly feed into the non-self-amplifying multipacting activity [2]. One such electron trajectory is shown in Figure 4a.



(a) (b)

Figure 4: (a) A typical field emitted electron being captured around the equator. (b) Range of RF phase and field amplitude where multipacting enhanced by field emitted electrons can happen.

For each RF cycle, such electron activity happens in a range of RF phases and cavity field levels as shown in Figure 4b. Since the electron impact energy peak falls around the edge of the field range, and also the SEY is smaller than 1 at this impact energy level, the electron activity will be less important compared to that of SNS high-β cavities [2].

CONCLUSION

By surveying the multipacting behavior of the β=1 electron cavities, we conclude that elliptical cavity's equator shape may affect the electron final impact energy by several electron volts, which may contribute to possible different cavity multipacting phenomena. In particular, the analysis for JLAB Ampere-class cavity shapes shows that flattened equator cavity shape such as Round Nose/Ellipse Equator shape RN-EE cavity can fulfill the cryomodule design goal and smaller multipacting possibility. However, the similarity between these cavities and SNS high-β cavities suggests possible "persistent" multipacting behavior [2] at certain field levels.

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