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MULTIPACTOR SIMULATION ON SUPERCONDUCTING SPOKE CAVITY FOR LASER COMPTON SCATTERED PHOTON SOURCES

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Abstract

Superconducting spoke cavities for laser Compton scattered (LCS) photon sources is under development. The operating frequency is 325-MHz to accelerate electron beam for the LCS sources, where the size of the spoke cavity is less than an elliptical cavities with the same frequency. Because of the complicated shape of the cavity, it may be suffered from a strong multipactor effect. A trial of multipactor analysis is described.

INTRODUCTION

Superconducting spoke cavities have been studied for acceleration of low beta particles such as low energy protons or ions [1]. Their operating frequency can be lower than those of elliptical cavities with the similar cavity diameters. When the operating frequency is low enough, the cryogenic temperature can be at 4K, not 2K and the whole system can be simplified because the requirement on the pressure-resistant vessel for liquid He can be eased. This reduces the total fabrication and operation cost in spite of the complicated cavity structure. The open structure or high electromagnetic field coupling gives good field stabilities, which relaxes the fabrication difficulty. The open structure also gives a high vacuum conductance throughout the cavity.

In addition to the above mentioned advantages, the simple cylindrical outer surface and the less electromagnetic field on the outer wall allows us to install the RF power coupler, HOM couplers and other ports such as pickups or vacuum ports on the outer wall. These components installed on the beam pipes occupy the space along the beam axis and hence the total accelerator length becomes longer [2-4]. This cavity is also applicable to electron acceleration, where the longer wavelength is preferable to the beam quality.

The Quantum Basic Research Coordinated Development Program started last year, aims at the generation and usage of the Laser Compton X –rays. The baseline design is to use the elliptical cavity, which has been well studied for electron acceleration and becomes popular in the world. Utilizing the spoke cavity to this area may reduce the requirement to the infrastructures and contribute to spread application area of the LCX system. We are planning to develop the spoke cavity for electron acceleration in the program: two major R&D items are targeted. The first one is the fabrication technique of the cavity from Nb sheets by Electron Beam Welding (EBW) technique keeping the mechanical strength. This item is described elsewhere in this conference [4]. The other one is the multipactor analysis in the cavity. The multipactor phenomena tend to happen at some specific electromagnetic field levels because of their resonant characteristics, where such field levels have to be passed at each startup time even for CW operation. When the RF power is severely sucked by the multipactor phenomenon during the filling time of the RF power, no acceleration field can be obtained even for a CW operation. Since such multipactor tends to arise at specific locations that satisfy resonant conditions for them, a careful design should be able to suppress them. In order to find a better design, we started to study the multipactor simulations.

MULTIPACTOR SIMULATION

The target cavity shape was initially designed with genetic algorithm using CST Microwave Studio [2] (see Fig.1). The main parameters used for the simulations are listed in Table 1.

Table 1: Main Parameters for MP Simulations

F0	327 MHz
Cavity length	0.92 m
Cavity diameter	0.61 m
Eacc	1.081 MV/m
Epeak	4.047 MV/m
Hpeak	6.174 KA/m
R/Q	484 Ohm
Mesh cells	~1e5
# of primary electrons	10^8~10^9
Emitting surface	Perimeter of endplate 1
Energy	0~8 eV, uniform
Angle spread	0 degree
Secondary emission	Furman model
Surfaces	All surfaces (PEC)
TRK max. steps	30000
TRK fields	Field factor: 0.2 steps Phase:0 degree

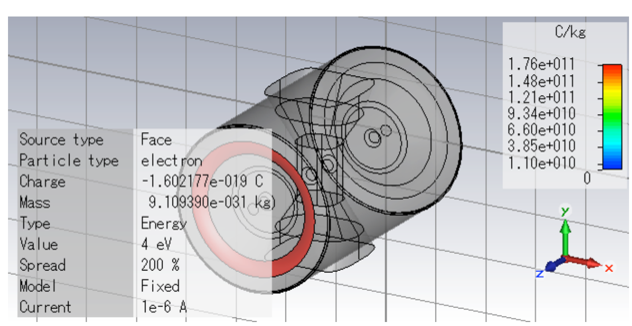

Figure 1: 325MHz single spoke cavity.

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Among some simulation codes, we picked CST Particle Studio in addition to Microwave Studio. Since the multipactor phenomena are somewhat complicated, we need to establish an analysis recipe by using the simulation code.

SIMULATIONS PERFORMED WITH DIFFERENT CORNER RADII

Since the multipactor events are often observed at the corners, some simulations were carried out changing the corner radius (see Fig. 2). The corner radii tested in the simulations are listed in Table 2. The growth rates of the secondary electrons are counted for each case changing the accelerating gradient. Figure 3 shows the resulted growth rates in the simulations. Figure 4 shows a multipactor like event, where the electrons are bouncing in the rather wide area. These events are usually observed at low gradient area and their periods are found to take one RF cycle. Figure 5-9 show the multipactor events whose periods are a half RF cycle and they are somewhat localized.

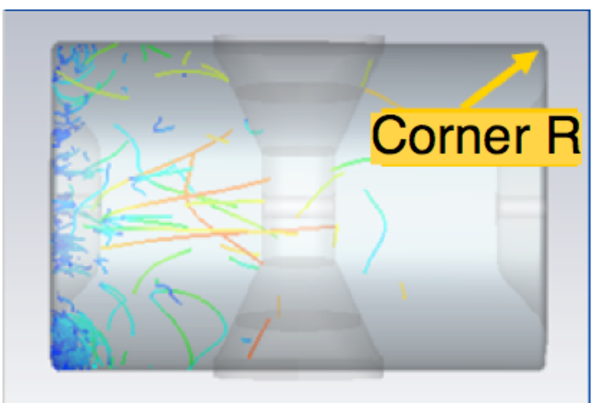

Figure 2: The single spoke model with corner radii.

Table 2: The Corner Radii for Simulated Models

Model	Corner R (mm)	f_0 (MHz)	# of primary e
#1	2.8	326.9	108
#2	10	327.0	108
#3	15	327.1	108
#4	20.1	324.5	108
#5	25.2	324.5	108

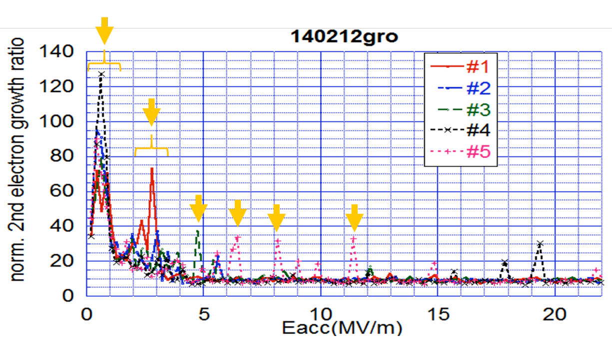

Figure 3: Growth rates of secondary electrons as functions of accelerating gradient.

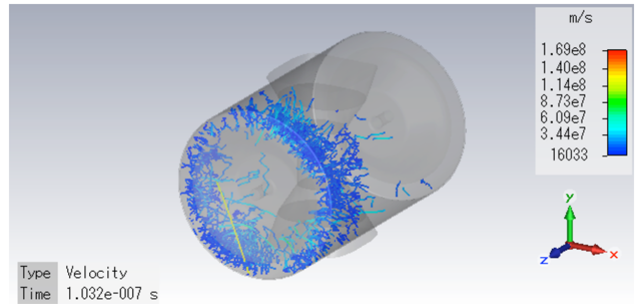

Figure 4: Multipactor like event. #1 Eacc=0.43MV/m.

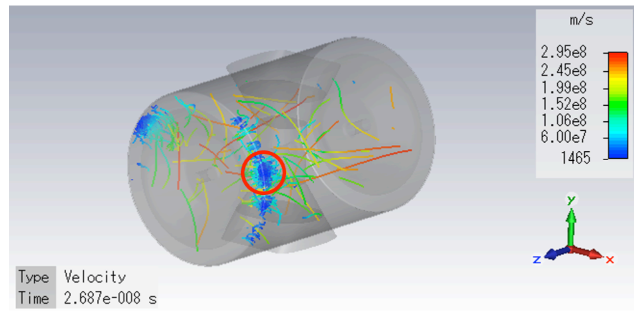

Figure 5: Multipactor event. #1 Eacc=2.8MV/m.

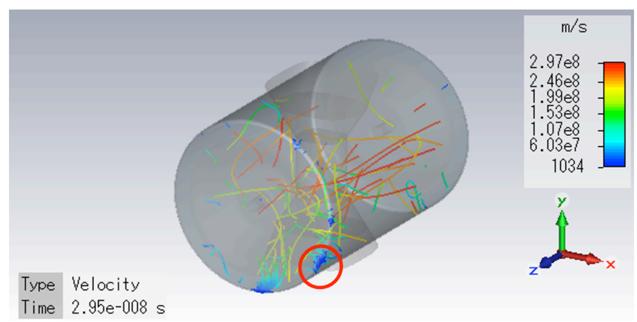

Figure 6: Multipactor event. #2 Eacc=3.0MV/m.

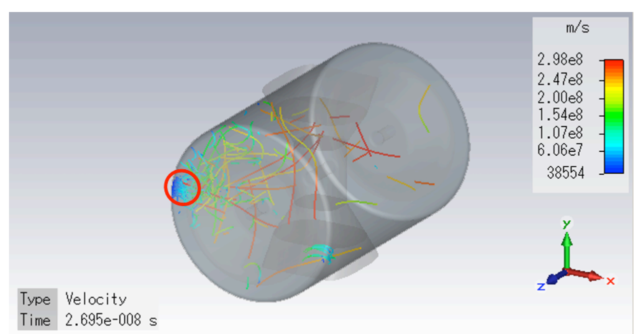

Figure 7: Multipactor event. #3 Eacc=4.8MV/m.

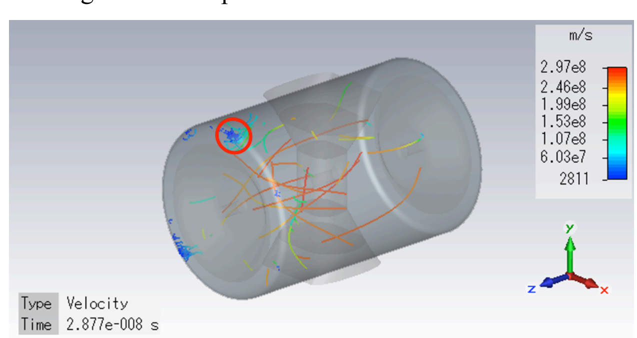

Figure 8: Multipactor event. #4 Eacc=3.0MV/m.

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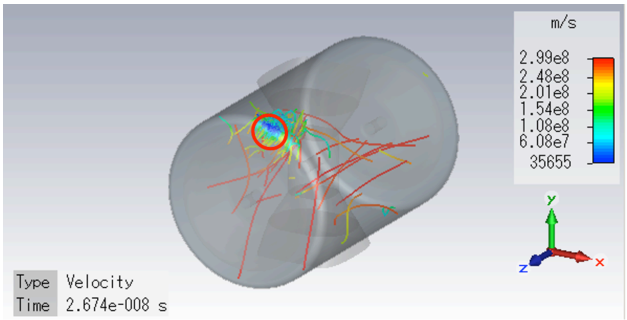

Figure 9: Multipactor event. #5 Eacc=8.2MV/m.

CONCLUDING REMARKS

Multipactor study with simulation code has started to design for fabrication of a real spoke cavity at 25MHz for LCX generation. The initial observations show that not much dependence was found on the corner radius. Simulation study with more primary electrons and with more fine mesh size has just started with powerful computer. A recipe to judge MP condition has to be established for effective design procedures.

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REFERENCES

[1] J. R. Delayen, Superconducting Spoke Cavities for Electron and High-Velocity Proton Linacs, Proc. LINAC'12, p. 758 (2012).
[2] M. Sawamura, R. Hajima, R. Nagai, N. Nishimori, Design Optimization of Spoke Cavity of Energy-Recovery Linac for Non-Destructive Assay Research, Proc. SRF'11, pp. 165-8, 2011.
[3] C.S. Hopper and J.R. Delayen, Superconducting Spoke Cavities for High Velocity Applications, Phys. Rev. STAB **16**, 102001 (2013).
[4] M. Sawamura, R. Hajima, R. Nagai, T. Kubo, H. Fujisawa, Y. Iwashita, H. Tongu, Development of Superconducting Spoke Cavity for Laser Compton Scattered Photon Sources, Proc. IPAC'14, WEPRO005.