HIGHER ORDER MODES DAMPING FOR 9-CELL STRUCTURE WITH MODIFIED DRIFT TUBE

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Abstract

This paper is focused on HOM damping in 9-cell superconducting cavities. We are considering HOM propagation outside from the cavity ridged and fluted drift tubes. The analysis of the influence of the parameters of the drift tube on the HOM damping was conducted. The considered methods were analysed and compared.

INTRODUCTION

Development of accelerating structures for modern types of accelerators, such as Energy recovery linacs (ERLs), requires special attention to higher order modes (HOMs) damping. HOMs excitation could create high losses on the cavity walls, beam instability and beam break up (BBU). HOMs couplers are often used in such structures for HOM damping but they could lead to violation of the axial symmetry of the accelerating field and create transverse field components (kick-factor) that can negatively affect on the beam emittance. Also these devices are subject for multipactor discharge and all kinds of pollution. Here we are studying different options of beam pipes to provide better HOMs propagation from the cavity, assuming that they will be dissipated away from the cavity.

INITIAL DESIGN

As a reference point for simulation HOMs propagation was taken 9-cell 1300 MHz superconducting electron accelerating cavity (Fig. 1) [1]. In order to estimate efficiency we decided to calculate HOM electrodynamics characteristics for the structure without couplers and put at the end of drift tubes RF port boundary conditions, representing ideal loads away from the cavity.

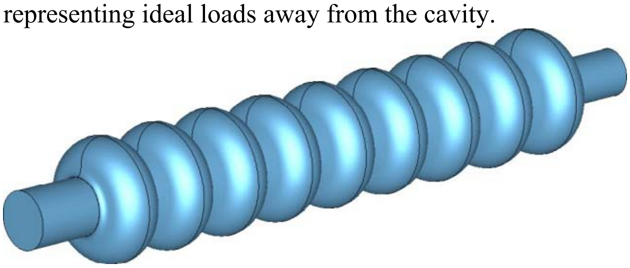

Figure 1: Superconducting 9-cell cavity model.

In order to estimate HOM frequency range, we calculated dispersion characteristics (Fig. 2) for E_{010} modes and HOMs. The most dangerous HOMs for the structure are dipole modes H_{111}, E_{110}, EH_{11}; quadrupole modes H_{211} and E_{210} and monopole mode E_{011}.

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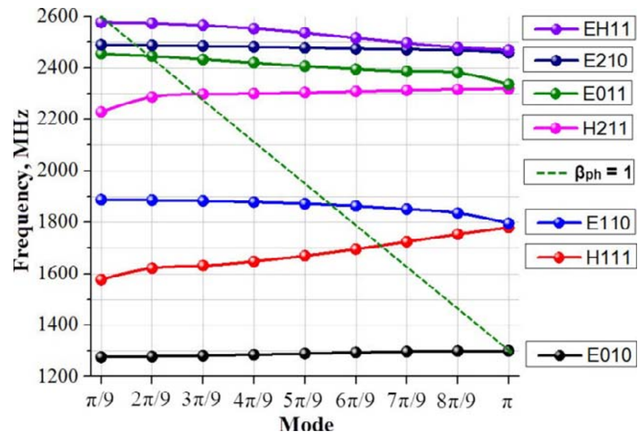

Figure 2: Dispersion characteristics for main wave and for HOMs and β-phase = 1 line.

β-phase = 1 line is shown on the dispersion characteristic on fig 2. Intersection points of dispersion characteristics with β-phase = 1 line (synchronous point) represent modes with the largest interaction between particles and waves and those points needs an additional attention.

External Q-factor values for HOMs and operational mode are presented on Fig 3. Q_{ext} values were calculated in CST Microwave Studio [2].

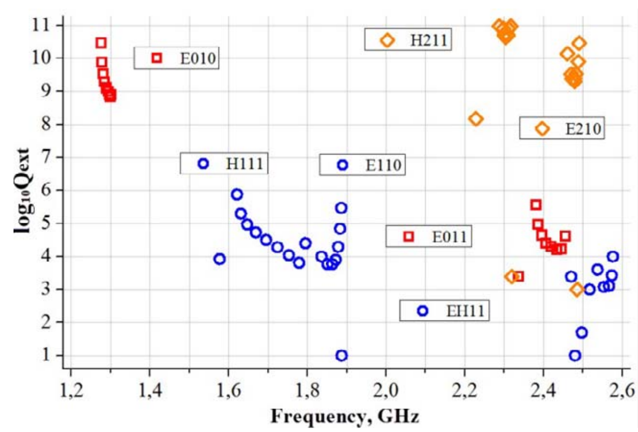

Figure 3: External Q-factor calculations results for HOMs in 9-cell elliptical cavity with beampipes loaded with RF ports. Square (red) – monopole waves, circle (blue) – dipole waves, diamonds (orange) – quadrupole waves.

Comparison of the results with results for similar structures [3] showed that Q_{ext} for operating mode is nearly the same, three orders higher for dipole modes, 4-5 order higher for quadrupole modes and for 2^{nd} monopole HOM it's two times higher.

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FLUTED BEAM PIPE

We decided to simulate the 9-cell structure with fluted beam pipes that was successfully applied for HOMs damping in single cell cavities [4].

Fluted beam pipes are presented on Fig. 4. Quantity and form of those flutes can be chosen on purpose to get more damping of HOMs. The best results for damping of dipole and quadrupole HOMs were obtained for a structure with fluted beam pipes with 3 flutes [5]. The structure with 4 flutes has the problem with quadrupole HOMs damping with certain polarization.

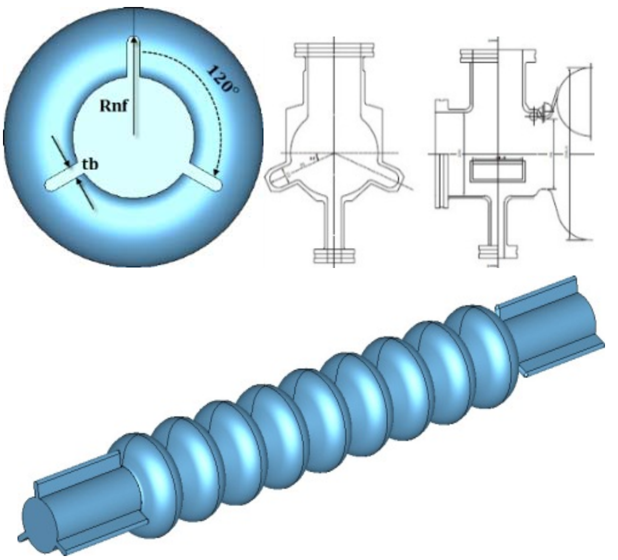

Figure 4: Upper left: fluted beam shape with 3 inhomogeneities; upper right: schematic view of eccentric-fluted beam pipe, designed for KEK-ERL model-2 [6]; bottom: fluted beam pipe cavity model.

The main advantage of fluted beam pipe is that H_{21} cut-off frequency is below of the quadrupole HOMs band. This is true not only for quadrupole but also for dipole HOMs. The operational mode remains trapped in the structure due to high cut-off frequency of E_{01} mode. Cut-off frequency values for different modes in fluted beam pipe are presented in Table 1. Field distribution in fluted beam pipe for E_{01}, H_{11} and H_{21} waves are presented on Fig 5.

Table 1. Cut-off frequencies for different mode in fluted beam pipe

H_{11}	1330
E_{01}	1972
H_{21}	2004

In order to get the same cut-off frequency cylindrical beam pipe beam pipe radius should be 65.5 mm for H_{11} wave and 72.8 mm for H_{21}, however it will cause reduction for E_{01} cut-off frequency (on 248MHz and 396MHz correspondingly). It could create to negative effect for shunt impedance of operating mode.

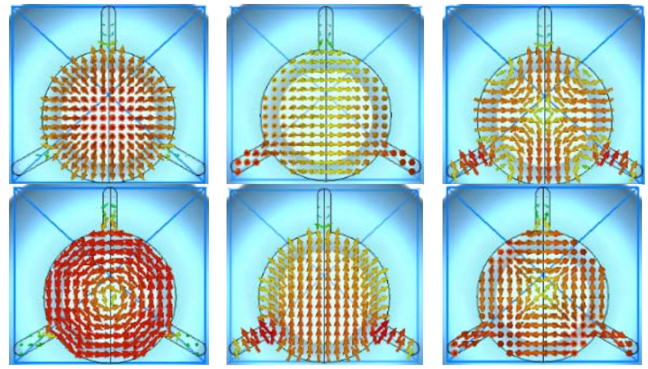

Figure 5: Electric (first line) and magnetic (second line) fields distribution in fluted beam pipe for E_{01}, H_{11} and H_{21} waves.

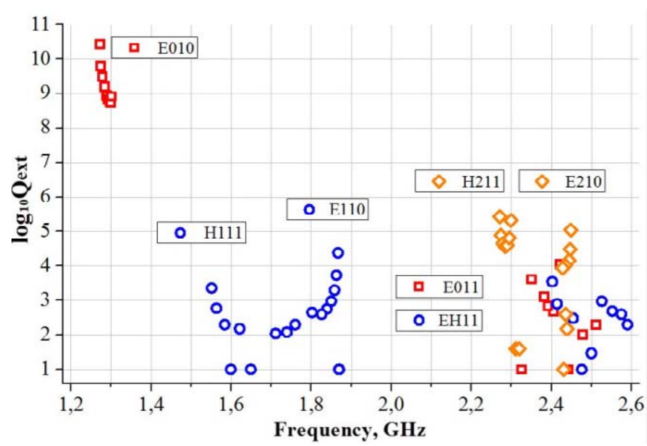

Figure 6: External Q-factor calculations results for 9-cell elliptical structure with fluted beam pipes loaded at the ends with RF ports. Square (red) – monopole waves, circle (blue) – dipole waves, rhombus (orange) – quadrupole waves. Beam pipe length 300 mm, inner radius 54 mm, flutes radius 90 mm

Comparing Q_{ext} results for the 9-cell structure with fluted (Fig. 6) and for cylindrical beam pipes (Fig. 3) and results obtained for the similar structures [3], we can conclude that this method is very effective because of we see reduction of Q_{ext} values were reduced by two orders of magnitude monopole and dipole and by five orders for quadrupole HOMs.

RIDGED BEAM PIPE

Another structure that provides conditions for HOMs propagation is ridged beam pipe structure (Fig. 7). The ridged beam pipe geometry is symmetrically opposed to fluted beam pipe. Typically it has 3 grooves in beam pipe, evenly distributed on azimuth on 120º angle.

After the change initial design to fluted and ridged beam pipe structures we used standard method [7] of modifying geometry of end cells for field flatness of operating mode (Fig 8).

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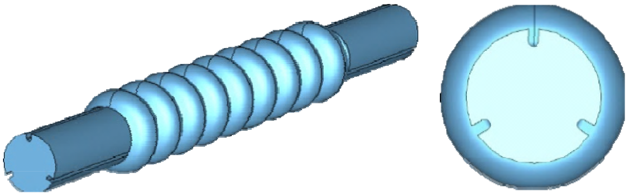

Figure 7: Ridged beam pipe 9-cell cavity model.

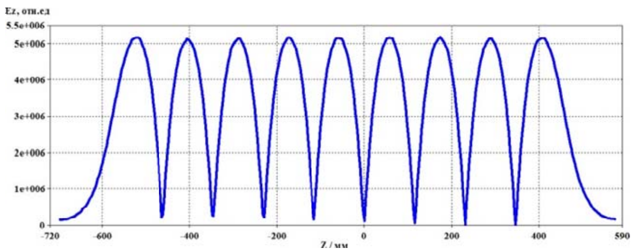

Figure 8: Electric field distribution for operational mode in symmetrical 9-cell cavity.

Results for Q_{ext} in 9-cell structure with ridged beam pipes are presented on Fig 9.

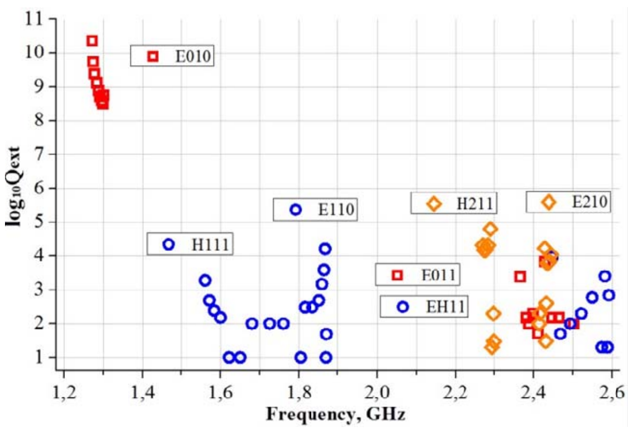

Figure 9: External Q-Factor calculations results for 9-cell elliptical structure with ridged beam pipes. Square (red) – monopole waves, circle (blue) – dipole waves, rhombus (orange) – quadrupole waves. Beam pipe length 350 mm, inner radius 56,5 mm, ridged outer radius 75 mm.

We found that the results for ridged beam pipe are even better than for fluted beam pipe. All the dipole and monopole modes have Q_{ext} values > 10^4, quadrupole modes > 10^5.

CONCLUSIONS

Propagation of HOMs from 9-cell structure was compared for cylindrical, fluted and ridged beam pipes. The comparison has been done based on calculated external quality factor Q_{ext} in the models with beam pipes loaded with RF ports at the ends. In the result the fluted and ridged beam pipes shown Q_{ext} for HOMs 2-6 orders of magnitude less than cylindrical pipes. Such a way fluted and ridged beam pipes provide much better HOM propagation then cylindrical.

We are planning to proceed development of HOM dampers for 9-cell structure based on this result.

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