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Measurement of electrodynamics characteristics of higher order modes for harmonic cavity at 2400 MHz

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Abstract. In the frameworks of the High Luminosity Large Hadron Collider (HL-LHC) upgrade program an application of additional superconducting harmonic cavities operating at 800 MHz is currently under discussion. As a possible candidate, an assembly of two cavities with grooved beam pipes connected by a drift tube and housed in a common cryomodule, was proposed. In this article we discuss measurements of loaded Q-factors of higher order modes (HOM) performed on a scaled aluminium single cell cavity prototype with the fundamental frequency of 2400 MHz and on an array of two such cavities connected by a narrow beam pipe. The measurements were performed for the system with and without the matching load in the drift tube..

1. The first section in your paper

At present the project aimed at Large Hadron Collider luminosity upgrade (HL-LHC) is being developed at CERN [1]. The implementation of 800 MHz harmonic cavities should provide a possibility to vary the length of colliding bunches in LHC which can lead in several positive effects [2]. In order to supply the required harmonic voltage several single cell superconducting cavities are to be used.

One of the main goals of the cavity design is to fulfill strict Higher Order Modes (HOM) damping requirements. That is why in order to check the simulation results and to investigate eventual HOM electrodynamics characteristics [3] the scaled version of such an array of two cavities with grooved beam pipe has been manufactured and the HOM parameters have been measured.

2. Another section of your paper

In [4] it was shown that it is possible to reduce the loaded quality factor of the most dangerous dipole HOM (TM110 and TE111) lower 100 and below 1000 for HOM in the higher frequency range. In order to verify the results obtained with numerical simulations a scaled aluminium cavity prototype at fundamental mode resonance frequency of 2400 MHz was built. The prototype was designed in a modular form (Figure 1) so that it is possible to carry out measurements for different lengths and shapes of the drift tubes and to further carry out measurements for a chain consisting of two such

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cavities. The prototype assembly consists of the beam pipe with a larger radius, the cavity body, beam tube with a smaller radius having and power input feed through and two shorting plates at the ends.

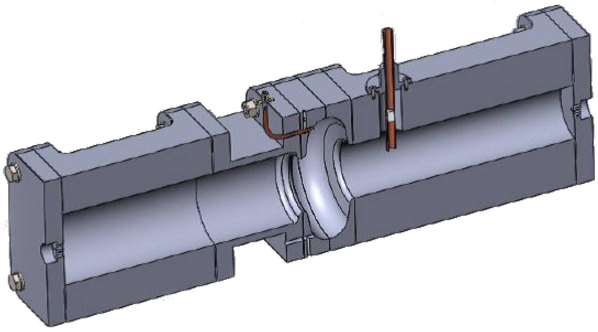

Figure 1. General view of single cell cavity

The measurements were performed for the length of the drift tube of 200 mm [5]. In the structure with loads in grooved beam pipe the loaded Q-factor (Q_{load}) of the most dangerous HOMs were significantly reduced. But it also appeared that it also affected on the operation mode. For this reason the length of the drift tube was extended up to 400 mm. After the drift tube length increase the Q_{load} of the operation mode returned to its initial value while the HOM Q_{load} values remained the same. The simulated Q_0, measured Q_0 (without load in beam pipe) and measured Q_{load} are presented in Figure 2.

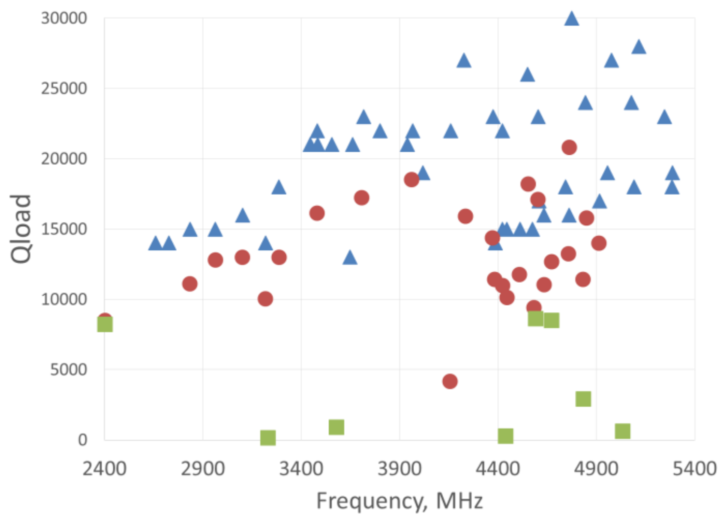

Figure 2. Q values of the cavity with a grooved beam pipe. Triangles – Q_0 calculation, circles - Q_0 measurements, square - Q_{load} measurements

It can be seen that the calculated in CST Microwave studio and measured Q_0 results are in a good agreement for the modes that we were able to detect. The Q_{load} values for most of the modes are lower than 1000. Other modes have significantly lower values of Q_{load} and could not be identified. The modes with resonant frequencies about 4500 MHz are the quadrupole TM210 and TE211 modes with effective transverse shunt impedance Q ($R_{\perp eff}$ /Q) values of 10^{-4} and therefore they do not pose any effect for the beam. Q_{load} for these modes are of the order of 10^4-10^5.

3. Measurements in array of two cavities

In order to reduce the number of transitions between "cold" and "warm" parts of the accelerator vacuum chamber it has been suggested to place two harmonic cavities in a single cryostat. In order to keep the HOM parameters under control and to avoid additional HOM it has been proposed to connect the two cavities with grooved beam pipes with a pipe of a smaller radius. The respective scaled prototype (2400 MHz) has been built and HOM parameters measurements in such a structure have been performed. General view of the assembled two cell prototype is presented in Figure 3. The Q_{load} values are presented in Figure 4.

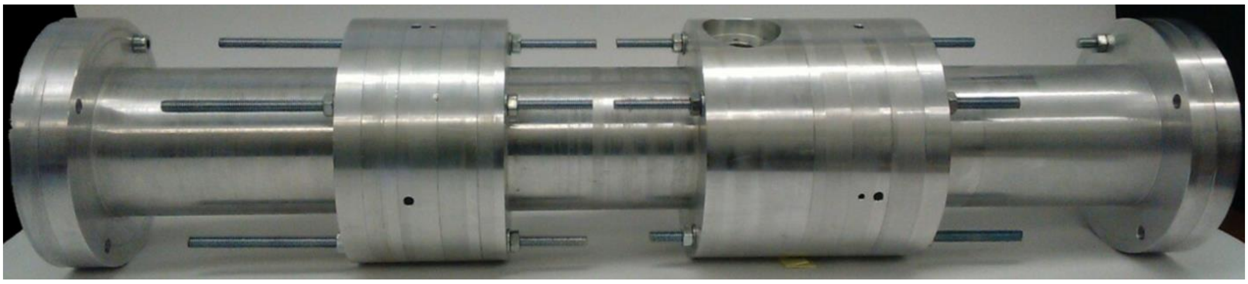

Figure 3. General view of the assembled prototype

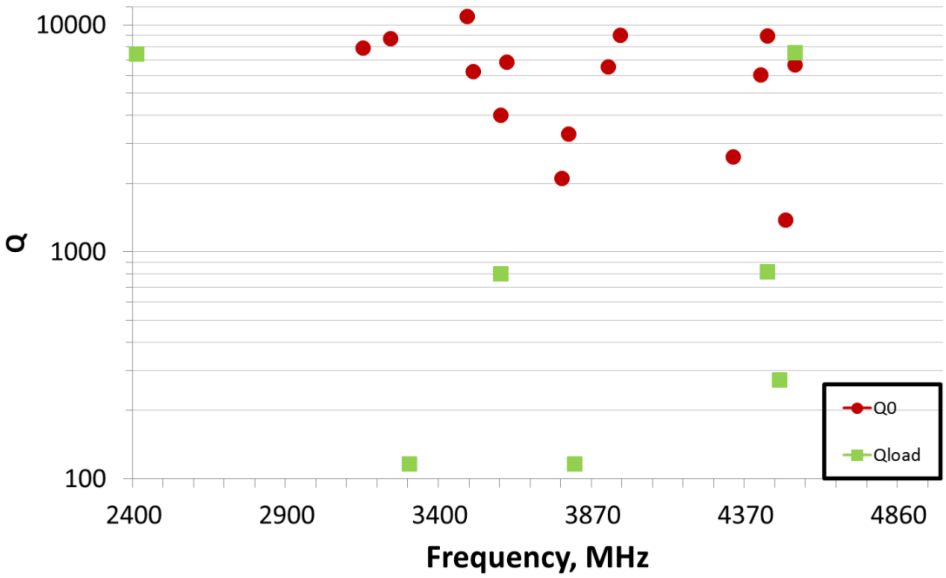

Figure 4. Q_{load} of the array of two cavities with a grooved beam pipe. Circles - Q_0 measurements, square - Q_{load} measurements

As it can be seen in Figure 4, similarly to the single cell case the Q_{load} values of the most dangerous HOM are lower than 1000. The modes in the region around 4500 MHz are the quadrupole ones with low $R_{\perp eff}/Q$ values of the order of 10^{-4}. Therefore they should not create any problem, neither for beam dynamics nor for the vacuum chamber heating, despite Q_{load} for these modes are of the order of 10^4-10^5.**Conclusion**

Thus, the performed measurements have confirmed that there are no dangerous trapped HOM both in the single cavity with grooves and in the structure composed of two such cavities. The presence of some residual HOM detected experimentally and having $Q_{load} < 1000$ is explained by the fact that the prototype was built with the shorting plates at the ends (or using the damping load only from one side) and others are the HOM with R/Q lower than 10^{-4}. This situation is reproduced very well by simulations.

Acknowledgments

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