Comparison of Higher Order Modes Damping Techniques for 800 MHz Superconducting Cavity
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INTRODUCTION
At present, applications of 800 MHz harmonic cavities in both bunch lengthening and shortening regimes are under consideration and discussion in the framework of the High Luminosity LHC project. The required bunch length variation can be achieved by proper phasing the harmonic signal with the bunch center and providing either positive or negative slope of the harmonic voltage along the bunch. Several design options of the second harmonic cavities with different higher order modes (HOM) damping techniques such as beam pipe grooves, coaxial-notch loads, fluted beam pipes etc. are investigated and compared. In this paper we study electromagnetic characteristics of HOMs for a single cell 800 MHz superconducting cavity and arrays of such cavities connected by drift tubes. The problems of multipactoring discharge in the considered structures are discussed and an estimate of the fundamental mode detuning due to the Lorentz force is evaluated.

Beneficial effects in the bunch lengthening regime:
• The charge density of bunches decreases with almost constant energy acceptance
• Beam lifetime increase
• Detector background improvement
• Reduced heating of vacuum chamber components arising due to wake fields
• Additional non-linearity of the RF fields helps to suppress the beam instabilities
• Flatter beam profiles also may result in some luminosity gain

An initial design of the harmonic cavity has been obtained by scaling (reducing) all the sizes of the LHC accelerating cavity operating at 400 MHz by a factor of 2. It is assumed in that HOMs damping is carried out, as in the case of an LHC accelerating cavity, with four couplers: two dipole and two broadband couplers.

Pros: • known technology in CERN
Cons: • couplers break the cylindrical symmetry of the electromagnetic field causing a negative impact on the performance of the accelerated beam (kick factor)
• Placing the robust main coupler and the HOM couplers on the same beam pipe may complicate the final design.

In such structure the operating mode can be locked and all HOMs (including quadrupole) will easily propagate into the drift tube with subsequent absorption in the load if we will adjust the dimensions of drift tube. In the structure with 3 flutes Qext of quadrupole modes is 5 orders lower than in structure with 4 flutes

Pros: • HOMs Qext<100 including quadrupole modes
• Effective preventing of operating mode spreading to the load
Cons: • Tricky design may cause a problem with power input

In order to avoid multiple transitions between cryogenic and “warm” areas we can place more harmonic cavities in a single cryostat. But this is not an easy thing to do due to presence of trapped HOMs between them in array of two or more such cavities.

The problem can be solved by reducing the radius of the drift tube connecting the two cavities. In this way the HOM frequencies get lower and their fields do not penetrate inside the connecting tube.

In our opinion, this configuration shown can be considered optimal for several reasons:
• The geometry is perfectly azimuthally symmetric;
• there are no dangerous HOMs;
• no need to use any additional HOM couplers;
• the two cavities do not communicate due to the small radius of the connecting beam pipe
• No problems with input coupler placement

Conclusion
We have compared four different HOM damping techniques for the 800 MHz harmonic cavity. In our opinion, the solution with grooves is preferable due to its cylindrical symmetry, design simplicity and absence of dangerous HOMs. We have also proposed to combine two such cavities connected by smaller radius beam pipe in a single cryostat.