DAMPING OF THE HOM'S IN A MULTICELL SUPERCONDUCTING CAVITY

A. Mosnier, B. Aune, J. Bourbonneux, K. Djidi, M. Juillard and J.P. Nicolaï
Service de l'Accélérateur Linéaire, CEN Saclay, 91191 Gif-sur-Yvette Cedex, France

Introduction

The damping of higher order modes is crucial for the design of a recirculating linac with superconducting cavities and an adequate BBU current threshold. We report in the first part of this paper the measurements on a large iris aperture 5-cell copper cavity equipped with two coaxial HOM-couplers especially designed for the 1.5 Ghz high frequency accelerating mode. In the second part, we propose another cavity design with smaller numbers of cells and iris diameters, associated with simpler couplers, resulting in a better optimisation for the HOM-damping and the fundamental mode parameters.

First results on HOM measurements with a 5-cell cavity

After preliminary calculations [1] a large iris-aperture 5-cell copper model has been fabricated. The main parameters are listed in table I. The classical beadpull technique employing two independent measurements - on axis and off axis - revealed a very good agreement with the Urmel calculations [4] for both the frequencies and the coupling impedances of the dipole modes. Two HOM-couplers were then mounted on the beam-tubes with at wist angle of 115°.

Table I
Main-parameters for a 5-cell cavity and a 3-cell cavity

PARAMETERS		5-cell CAVITY	3-cell CAVITY
Frequency	(Mhz)	1500	1500
Wavelength	λ (m)	0.2	0.2
Active length	(m)	0.5	0.3
Iris diameter/λ		0.35	0.25
Shunt impedance	r/Q Ω/m	960	1300
Geometry factor	G (Ω)	280	265
E_p/E_{acc}		2.5	1.75
H_p/E_{acc}	(gauss/Mv/m)	45	39
$2(F_\pi-F0)/(F_\pi+F0)$		3.6%	0.9%
Nearest mode dist (Mhz)		5.0	3.4

Fundamental mode rejection

These coaxial type couplers have been described in [2] and have been especially designed for guaranting an external Q of the 1.5 Ghz fundamental mode greater than 5×10^{10} without severe mechanical tolerances. Each coupler consists of a two-cell notch filter which exhibits a large stopband around the accelerating mode frequency (300 Mhz for an attenuation of 40 dB) and a very flat response curve for the higher order modes.

Deflecting modes damping

The measurements of the damping of the dipole modes showed [2] that the external Q for the first 4 dipole passbands were sufficiently low, but the modes of the 5^{th} passband were insufficiently damped ($Q_{ex} > 10^7$). Calculations of these modes showed that the field level along the beam tube is very low and then cannot be evacuated. These modes can therefore be responsible for the current limitation in the machine in contrast with the more classical situation where the limitation arises from the two first passbands (TM110 or TE111-like modes).

New cavity and couplers design

The study of multicell cavities with varying iris-apertures and varying numbers of cells shows that if the HOM-couplers are located on the beam-tube, the iris hole diameter must be small enough ($< \lambda/4$) in order to obtain a nonvanishing field in the beam-tube, especially for the 5^{th} passband. The number of cells must also be reduced for an acceptable fundamental mode coupling parameter. Several features of the accelerating π-mode are improved by this design :

- the accelerating field level in a multicell cavity is statistically increased by reducing the number of cells, since the maximum value is given by the worst cell ;
- the shunt-impedance is higher, which reduces helium consumption ;
- the ratio peak/effective electric field can be greatly reduced, thereby delaying to higher fields the effects of field emission, which is actually the main limitation at high accelerating gradients.

The main argument against a low number of cells is the cost of the increased number of couplers per unit length. We are confident that the HOM-couplers can be made much simpler and their number kept acceptably low in using a modular configuration. The main reasons which lead to this new design are reviewed in detail below.

The higher order mode coupler

In a recirculating linac the HOM-couplers only need to damp the deflecting modes because the longitudinal modes are of less concern [1]. Since the dipole modes couple mainly to the TE_{11} mode of the beam tube, the HOM-compler can be a simple loop normal to the tube axis such that only the axial magnetic field component is coupled. This avoids the use of costly niobium filters for rejecting the fundamental mode, which has no such component. The second main avantage of using a magnetic loop instead of an electric antenna is the larger coupling efficiency. For a same "coupling strength" on the TE_{11} mode, the surface of an antenna tip needs to be 10 to 20 times the loop surface in the frequency range of concern. ($S_{antenna}/S_{loop} \approx 4\ \lambda/r$, λ being the deflecting mode wavelength and r the tube radius). If the main coupler is used as HOM-damper, a loop, rotated in such a way to have the correct accelerating mode external Q and to strongly couple the HOM modes, is also preferable to an antenna.

The iris-aperture and the number of cells

We mentioned in [1], where the dispersion curves were studied according to the theory of coupled resonators, that there is a strong mode mixing of the 5^{th} passband with the adjacent ones. Urmel calculations predict that for a multicell-cavity with a large iris-aperture these dipole modes couple poorly to the beam tube. Figure 1 shows the plots of one such mode in comparison with a TM_{110}-like mode for an iris hole

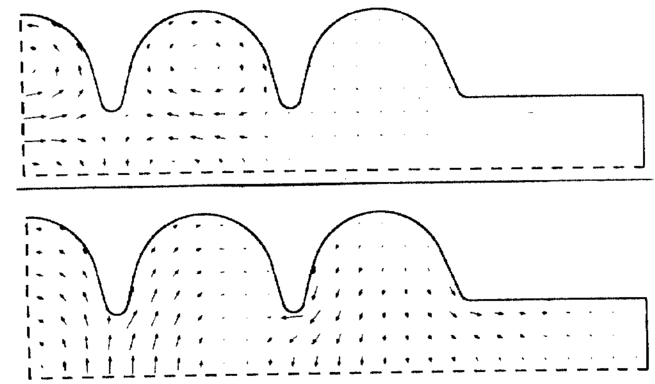

Figure 1 - Plots of the longitudinal magnetic field of two modes in the 5^{th} (top) and 2^{nd} (bottom) dipole passband for a 5-cell cavity with large iris aperture.

diameter of 70 mm (= 0.35λ). The damping by the HOM-couplers is very poor, and is very sensitive to the boundary conditions. We could hope to evacuate the power by propagating waves through the beam tube, but the calculated power flow is too low, leading to a typical Q on the order of 10^5 for a single 5-cell cavity isolated from the others with the two beam pipes terminated by perfectly matched resistive loads [3].

The situation is improved by reducing the iris aperture and lowering the number of cells. From Urmel calculations we can evaluate the necessary damping of each mode for a given impedance and therefore the required loop surface as we know the field level at the coupler location. Table II lists the results for two 3-cell cavities with large and small iris apertures. For the smallest diameter we find again the classical situation where the most dangerous modes are in the two first passbands. These cavities also require smaller and more feasable loops.

The accelerating mode point of view

Reducing the iris diameter from 70 to 50 mm reduces the coupling parameter k from 3.6 to 0.9 % but the distance between the accelerating π-mode and the nearest longitudinal mode, which is the important parameter for the mechanical tolerances, is about the same because the dispersion curve is less distorted and the number of cells has been reduced. The shunt impedance is improved by 30 % and the ratio peak/effective electric field is also improved, especially if we adopt an elliptical shape for the iris region, but the equator region can keep the spherical shape. The main parameters are listed in table I.

The overall chain structure

Figure 2 shows a possible cryostat containing several 2-cell or 3-cell cavities joined together with beam pipes on which are mounted two couplers per cavity : the main loop coupler and the regulation loop coupler. Both couplers serve to damp the HOM modes and the two adjacent couplers make an azimuthal angle of a little more than 90°. This structure is equivalent to several independent 2-cell or 3-cell cavities for the accelerating mode and the nonpropagating HOM modes but must be treated as a single cavity with many cells for the propagating HOM modes. The beam tube radius and length between the cavities are adjusted to give the maximum field level for the most dangerous modes. Urmel calculations on a whole chain of several 2-cell or 3-cell cavities have confirmed that the field level between the cavities is sufficient for the damping of all the deflecting modes by the alternated simple loop couplers. In the possible scenario envisaged in figure 2, four main couplers and four auxilliary couplers without sophisticated filters are needed for an active length of 0.80 or 1.20 m if we use respectively 2-cell or 3-cell cavities. The development of a copper prototype composed of several such short cavities with their couplers is under way.

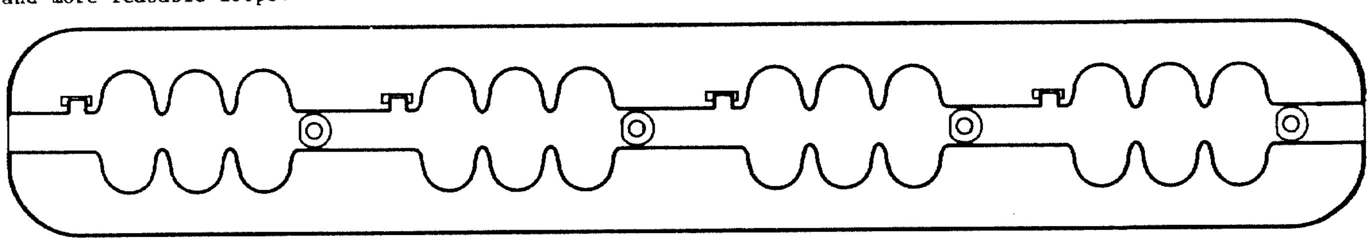

Figure 2 - A possible scheme of a chain of four 3-cell cavities in a cryostat.

Table II

Estimation of the loop surface in cm^2 for the most dangerous modes in each passband for two 3-cell cavities with large and small iris apertures

IRIS DIAMETER (mm)	70	50
Passband n°1	0.2	0.6
Passband n°2	0.5	1.5
Passband n°3	0.3	0.4
Passband n°4	0.1	0.1
Passband n°5	5.2	0.2

Acknowledgments

The author would like to acknowledge the many fruitful discussions with E. Haebel from CERN.

References

[1] A. Mosnier et al., "Superconducting RF developments at Saclay for a 2-4 GeV electron facility", Particle Accelerator Conference, Washington, 1987.

[2] B. Aune, "Superconducting RF activities for electrons at Saclay", Workshop on RF Superconductivity, Argonne, 1987.

[3] A. Mosnier, Calcul de l'amortissement des modes supérieurs, Internal report DPhN/AL.88-R04.

[4] T. Weiland, "On the computation of resonant modes in cylindrical symmetric cavities, Nucl. Instr. and Meth. vol. 216, 1983.