DAΦNE Accelerating Cavity: R&D

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Abstract

Multibunch instability is one of the most serious concerns for the high luminosity, high current DAΦNE Storage Rings which will be built at Frascati. Much effort is presently put in on the development of a true 'single-mode' cavity, with the lowest contents of Higher Order Modes (HOMs). Various damping techniques are currently investigated, in order to optimize the final design of the cavity. The first theoretical and simulation results, and experimental tests on prototypes are described, together with the HOM Tuning technique to get rid of multibunch instabilities.

1. INTRODUCTION

One of the basic requirements of DAΦNE is an accelerating RF cavity with the lowest possible interaction of the HOMs with the beam . This is to minimize both single bunch and multibunch instabilities, which are a serious concern for the machine performance. Extensive and thorough calculations and simulations of such instabilities are still in progress [1], showing the need for very low HOM shunt impedance, even in the presence of a fast digital feedback system. A careful design of the cavity geometry is required, together with the use of various techniques (HOM global damping with waveguides, Insertion of lossy materials, Shifting, i.e. Tuning of some very dangerous HOMs), which are described in this paper.

2. RF CAVITY DESIGN

The main feature of the DAΦNE accelerating cavity is the presence of very long tapers, which provide a smooth transition from the cell iris to the ring vacuum pipe (Fig. 1). This design is rather unconventional as compared with the usual geometry of both normal conducting and superconducting structures, which include, besides the tapers, two straight, large-radius beam tubes where RF and HOM couplers are installed [2]. Nevertheless, the longitudinal loss factor to the HOMs, k_{pm}, is very low as compared to the total loss factor k_l, hence this cavity offers a very small contribution to the whole impedance budget. Furthermore also the transverse loss factor k_t' is definitely lower than in the usual design, and in general the contribution of dipolar modes is less significant.
Much work was done on the optimization of the cell profile. The original requirement was to have a cavity with a shunt impedance $R_s = V^2 / 2P = 3$ MΩ on the fundamental mode, low impedance on the transverse modes, and no special care was taken on the lowest monopolar mode, the TM_{011} mode, which must be strongly damped anyway. These requirements are well satisfied with a geometry like that of superconducting cavities, often called 'bell-shaped' cavities. An example is shown in Fig. 2, which displays a smooth, rounded profile (i.e. high Q) with a straight insertion to allow the connection of one or more waveguides to the lateral surface of the resonator. Later on, the requirements on the R_s were made less stringent, while it seemed more useful to have a very low design value also for the R/Q of the TM_{011} mode. Following an idea of SLAC-LBL people, we introduced nose cones (Fig. 3), which decrease the Q's noticeably, but increase the R/Q and the loss factor k_0 of the TM_{010} and the R'/Q of the TM_{110}, while strongly reducing the TM_{011} mode. A full comparison of the two cell parameters is shown in Table I.
An elliptical contour was adopted for the upper part of the nosecone cell, since extensive studies of multipactoring effects have clearly shown the risk of other designs. For instance, in the case of a square shaped profile, a simulation with the multipactoring code NEWTRAJ [3] has revealed the existence of three thresholds at the cavity voltages of 180, 250 and 370 kV in the upper part of the cavity, where the resonant RF discharges are located. To avoid such troubles, a multipactoring-free elliptical contour was chosen.

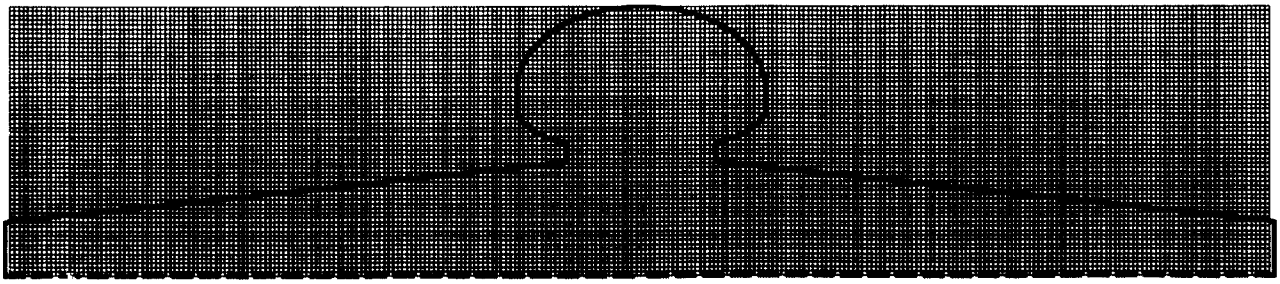

Figure 1. The Long Tapered Cavity.

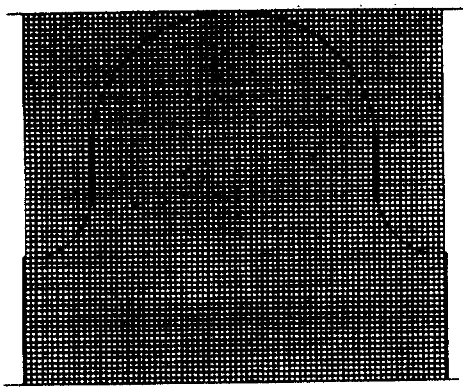

Figure 2. The 'Bell Shaped' Cell.

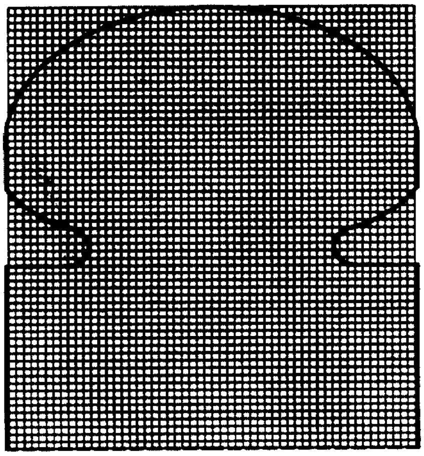

Figure 3. The 'Nosecone' Cell.

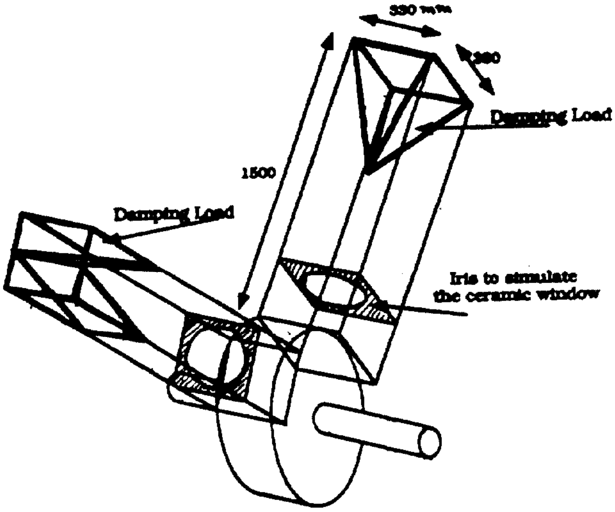

Figure 4. The Large Waveguide Test Cavity.

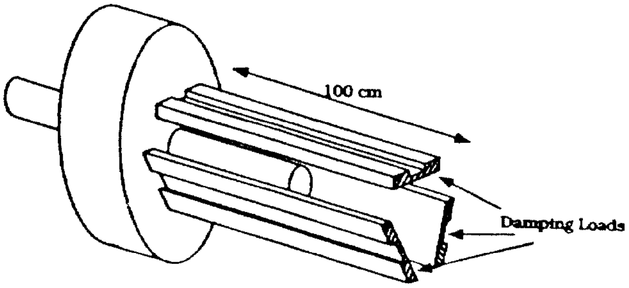

Figure 5. The Small Ridged Waveguide Test Cavity.

Table I
Design parameters for the DAΦNE nosecone cavity and comparison with a typical bell-shaped structure

	Nosecone	Bell-shaped
Frequency (MHz)	367.0	368.5
R/Q (Ω)	70.0	62.2
Q	34000	46800
R_s (MΩ)	2.37	2.91
k_l (V/pC)	0.101	0.121
k_0 (V/pC)	0.077	0.068
k_{pm} (V/pC)	0.024	0.053
k_t' (V/pC/m)	1.16	1.26
k_{pm} / k_l	0.24	0.44
k_t' / k_0 *1 mm	0.015	0.019
TM_{011} mode:		
Frequency (MHz)	703.7	733.7
R/Q (Ω)	4.0	13.9
Q	30400	49000
R_s (kΩ)	120	680
TM_{110} mode:		
Frequency (MHz)	564.0	531.5
R'/Q (Ω)	30.6	15.7
Q	41200	52500
R'_s (MΩ)	1.26	0.82

3. HOM DAMPING STUDIES

Several laboratory measurements on a copper pill-box cavity resonating at 370 MHz were done and are still in progress. Two main approaches have been followed to couple off the parasitic HOMs:

a) by means of large waveguides, which directly look at the beam axis (Fig. 4) according to the proposal of Conciauro and Arcioni [4];

b) by means of small, ridged waveguides, parallel to the beam axis (Fig. 5), according to the SLAC-LBL Design [5].

In both cases the cut-off frequencies are adjusted to be little below the frequency of the lowest HOM and the waveguides are filled with highly dissipative materials, like graphite loaded polyurethan foams, which are properly shaped for RF broadband matching.

The amount of global damping is excellent in the a) case, as shown in Fig. 6, but some problems have to be faced:

- high degradation of the Q of the accelerating mode (≈30% less than the unperturbed Q_0);
- large size ceramic windows must be used in the waveguides to separate the cavity main body, which is under deep vacuum, from the damping loads;
- multipactoring will very likely occur on the waveguide inner surface, where the e.m. fields are evanescent; TiN coating will therefore be necessary;
- efficient cooling of the damping loads has to be provided.

In the b) the HOM damping is less effective than in a) case (Fig. 6), but it displays some advantages:

- the accelerating mode Q_0 is almost unaffected;
- the waveguide ceramic windows may be smaller;
- the reduced size and compact structure make manufacturing and operation easier.

TiN coating will be necessary, anyway, and also great care is needed for the cooling of the absorbers.

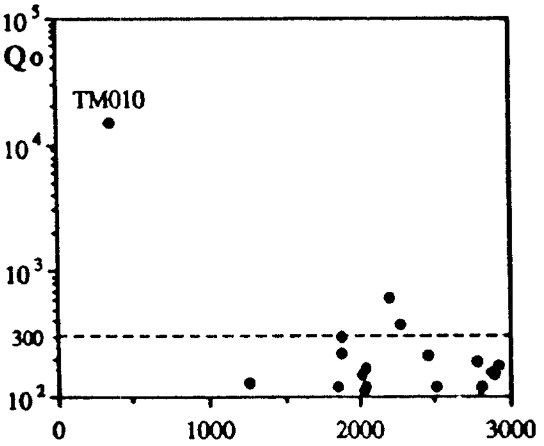

Figure 6a. Damped HOM Spectrum of the Cavity in Fig. 4.

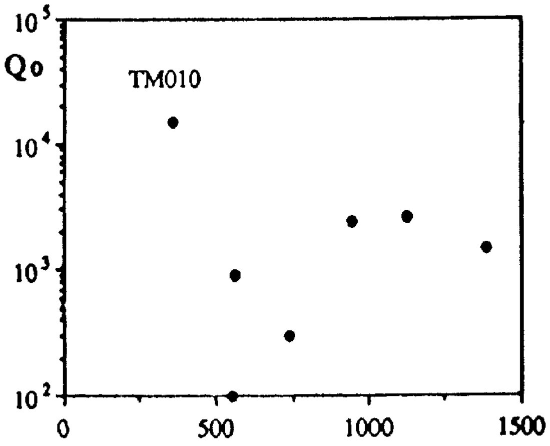

Figure 6b. Damped HOM Spectrum of the Cavity in Fig. 5.

3. HOM TUNING

An alternative way to fight collective coupled-bunch instabilities consists in shifting the HOM frequency, without affecting the fundamental mode, by means of perturbing metallic objects, which are located in some appropriate positions on the inner surface of the cavity. Preliminary measurements on a test pill-box cavity at Frascati gave encouraging results [6] and showed the validity of the principle. Further studies on a more realistic cavity model are presently in progress at the INFN Laboratories in Genoa. As an example, the shift of the TM_{011} mode by the presence of a movable small metallic cylinder is shown in Fig. 7. The Q degradation is very small, while the fundamental mode TM_{010} remains absolutely unaffected. The amount of frequency shift is 1.4 MHz, what corresponds to about half distance between two adjacent lines in the coupled-bunch mode spectrum. This result seems very promising, and suggests that this technique can be applied to decouple a particularly offending HOM from an unstable relative mode in a real cavity. Since the perturbing object must be used in connection with the cavity tuning system, a careful control of the operation of both tuners is required to fully assess the feasibility of the method.

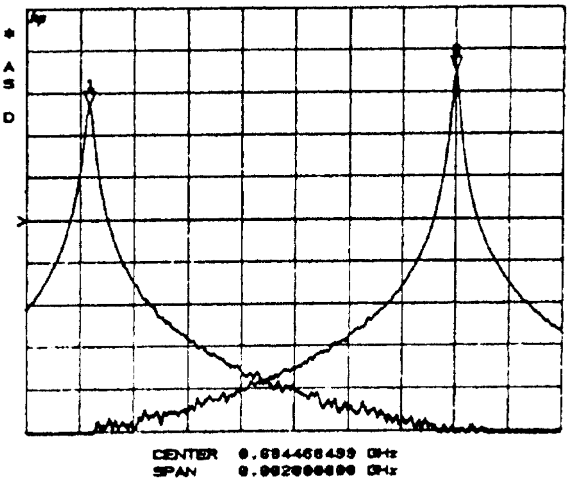

Figure 7. Frequency Shift of the TM_{011} Mode.

4. REFERENCES

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