SUPERCONDUCTING RF DEVELOPMENT AT SACLAY FOR A 2-4 GeV ELECTRON FACILITY

A. Mosnier, B. Aune, R. Bergère, J.M. Cavedon, Ph. Damsin, K. Djidi, A. Godin
M. Juillard, F. Koechlin, Ph. Leconte, S. Leray, A. Veyssière
Département de Physique Nucléaire
CEN Saclay, 91191 Gif-sur-Yvette Cedex, France

Introduction

The stretcher ring project at Saclay [1] has been abandonned in favor of a superconducting solution. For our project of a 2 to 4 GeV machine, delivering a 100 μA beam, a machine consisting in 4 passes in a 0.5 to 1 GeV linac is under study. This machine would be installed on the existing ALS site, using most of the technical and experimental facilities. The RF frequency for the linac has been chosen to be 1.5 GHz, i.e. the same frequency as the CEBAF machine. Preliminary calculations on beam-break-up have been made [2]. The design of the cavity is being made both with the help of computer programs and by cold measurements. On parallel a laboratory for testing and developing superconducting cavities is under equipment and should be ready by the end of March 87.

Present status of the laboratory

Approximatively 20 people from Saclay (Departement de Physique Nucléaire) and Orsay (Institut de Physique Nucléaire) are working, since September 86, on the development of superconducting cavities for use in an electron linac in a common group named GECS (Groupe Etude de Cavités Supraconductrices). This group is working in close collaboration with the CERN group headed by Ph. Bernard. The goal of this work is to design and build, within two years, a prototype for the future linac (cavity in a horizontal cryostat). Theoretical studies on the cavity are reported below. A laboratory for testing superconducting cavities in vertical cryostats is under equipment located in an unused experimental room of the existing linac. This lab should be ready for the first test at the end of March 87. A first cylindrical 1.5 GHz niobium cavity was fabricated at Saclay and will serve as a test for the experimental facility. In parallel we have ordered a few single cell cavities made of high RRR niobium from french industry, they should be ready for tests in June.

A laboratory for RF tests on copper models have been equipped and is ready to start measurements of the coupling impedances of different higher order modes of the cavity. Two copper cavities have been fabricated by spinning and electron-beam welded (one with 5 cells, one with 7 cells) and are being measured.

Optimisation of the cavity

We present here some of the results of calculations made with the computer code URMEL [3] in order to optimize the cavity needed by the project of accelerator, taking into account different constraints.

Given the accelerating frequency (f_0=1.5 GHz), remain to be chosen the shape of the cells, the iris aperture, the number of cells per cavity and the type of couplers.

A spherical shape for the cells was chosen, with a rough scaling of the CERN design for LEP cavities, except for the iris aperture, in order to avoid problems with multipacting. A tilting of the endplates of approximately 15° is provided. Table 1 gives the variation of the main parameters of the accelerating mode with the iris diameter ø : r/Q, K = coupling coefficient, E_p/E_{acc} and H_p/E_{acc}.

Table 1

Main parameters of the single cell for different iris apertures

ø (mm)	R/Q(Ω)	E_p/E_{acc}	K %	H_p/E_{acc} (G/MV/m)
50	130	1.93	1.1	38
60	116	2.11	2.2	40
70	98	2.43	3.6	44

The main concern of our study is the coupling of the beam with higher order modes which eventually can lead to beam instabilities. The longitudinal modes are not dangerous in our design, as opposed to the case of SC cavities used in storage ring, for several reasons : the beam induced power in these modes is negligible, because of the time structure of the beam which is bunched at the fundamental frequency. In that case no coherent interaction can take place, except in the case of a mode at a frequency which is exactly equal to an harmonic of the accelerating frequency, within a very narrow bandwidth. On the other hand longitudinal instabilities are not of concern in our design, mainly because the path lengh of the recirculating arcs is independant of energy. The influence of these modes on an increase of the energy dispersion within a bunch remains to be calculated, but it is anticipated that this effect should not be severe.

Numerous calculations on transverse instabilities (beam-break-up) in recirculating superconducting linacs have been made, most recently for the CEBAF machine [4]. We found that, in order to accelerate a beam current of at least 100 μA up to 4 GeV with our design, the dipole modes should be damped to a level for which the loaded Q is less than 10^5 for the modes having the highest coupling impedance ($Z''/Q \simeq 10^5$ Ω/m^3). For the damping of the higher order modes we apply the concept of beam tube couplers. The design of the cavity must then guarantee that sufficient field level for each mode be present in the last cell and in the beam tube. The frequency separation of the different modes in a pass band must also be sufficient, taking into account the mechanical tolerances of the fabrication process. These constraints give a strong limitation on the number of cells a cavity can be composed of. We have studied different configurations of cells for three iris apertures (50, 60, 70 mm).

The properties of the dipole modes have been studied using the theory of coupled resonators [5] which allows to predict the behavior of a chain of coupled resonators from the knowledge of the field distributions for the different modes in a single cell. The field distributions were calculated by the code URMEL. A strong mode mixing appears starting with the third pass band even in the case of the lowest aperture. The calculations in single cell shows that the pass band of the TE_{112}-like mode is very large and includes the pass bands of TM_{111}-like and TE_{121}-like modes. This property is true also with a cell of different shape (rectangular or triangular). The effect of mode mixing is to distort the dispersion curves and can lead to poor separation between adjacent modes.

CH2387-9/87/0000-0863 $1.00 © IEEE

PAC 1987

Figure 1 shows the first two pass bands (TE_{111} TM_{110}) for an iris aperture of 70 mm. The dashed lines represent the dispersion curves obtained from the single cell mode frequencies without taking into account any mode coupling. The solid lines represent the results obtained from the coupled resonators theory. The frequencies of the modes calculated by URMEL in a multicell cavity are exactly the same than the theoretical ones.

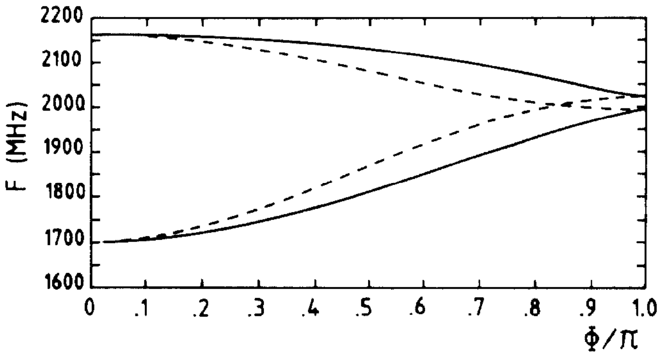

Fig. 1

Figure 2 shows the three higher pass bands for an iris aperture of 50 mm (2a) and 70 mm (2b). It appears clearly that the third dispersion curve (TM_{111}-like, around 2800 MHz) is descending for 70 mm and ascending for 50 mm, and thus for some intermediate value of the iris aperture, the pass band is very small. The same situation occurs for the fifth pass band.

A choice of 50 mm for the iris aperture leads to small coupling for the accelerating mode and large impedances for dipole modes. Thus we chose to study in more details the RF properties of a cavity with an aperture of 70 mm, although the impedance of the accelerating mode is rather low.

Moreover, the mode with the lowest phase shift in the TM_{111} pass band is near the synchronism condition and presents a high coupling impedance. For a five cell cavity the $\pi/5$ mode has an impedance of $Z''/Q \approx 10^5$ Ω/m^3.

Without any special treatment, this mode presents a very low field level in the last cell and thus will be difficult to damp. The tuning of the last cell was made - by calculation - not only for the accelerating mode but also for this one, for obtaining a reasonable field level in the tube. On the other hand, for all the modes in the fifth pass band, which is very narrow, the field level is very low in the tube and these modes will be difficult to damp and can be dangerous although the impedance Z''/Q is low.

The RF measurements on a 5 cell and a 7 cell cavity are being made. We plan to measure the impedances of the dipole modes, and the Q's obtained with HOM couplers.

References

[1] B. Aune et al., "ALS II : the Saclay proposal for a 2-GeV, CW electron facility, IEEE Trans. Nucl. Sci. NS-30, n°4, August 1983.

[2] A. Mosnier et al., "Feedback system analysis for beam break-up in a multipass multisection electron linac", 1986 Linear Accelerator Conference, Stanford, USA, 2-6 June 1986.

[3] T. Weiland (DESY) private communication.

[4] J. Bisognano, "Multipass beam break-up in the CEBAF superconducting linac", 1986 Linear Accelerator Conference, Stanford, USA, 2-6 June 1986.

[5] R. Bevensee, "Electromagnetic slow wave systems", (J. Wiley, Inc., New York) 1964, chapter 5.

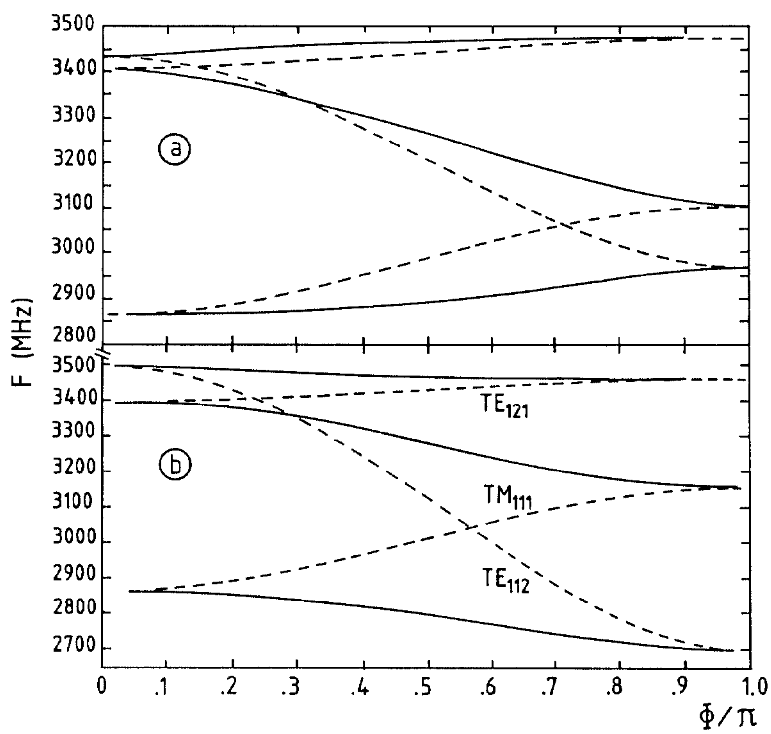

Fig. 2