FIELD COMPUTATIONS AND MEASUREMENTS ON A BIPERIODIC BUNCHER STRUCTURE

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Abstract: A biperiodic bunching section of new design is built for upgrading the Frascati S band Linac. The parameters of the structure have been determined by computation with OSCAR-2D code and checked by measurement on models.

I. INTRODUCTION

A program for improving positron production from the Frascati S-band linac is actively pursued in order to increase injection efficiency in the storage ring. This asks for short and intense electron pulses to produce positrons. A new electron injector includes a 90 kV 15 A 10 ns gun together with a E-coupled biperiodic structure operating at high field level. Constraints on adjustments of sensitive parameters have been eliminated by the new concept of integrating the prebuncher at a first cell of the structure. This paper is devoted to RF problems, giving the main electrical parameters and the field simulations together with the results of measurements made on S-band models. A companion paper [1] covers the design problems related to the beam dynamics.

II. INJECTOR ELECTRICAL PARAMETERS AND GEOMETRY

The main electrical parameters values for the injector are given in Table I, for the maximum level of 10 MW RF power (the design point for dynamics has been set at 7.5 MW).

In Fig. 1 we show a sketch of the initial cells of the standing wave buncher.

The geometry is rather similar to the small bore hole HERA profile [2].

Table I

Frequency	2856 MHz
Shunt impedance	zT^2 = 49 MΩ/m
Length	1.10 m
RF power	10 MW
Maximum energy for the first bunches	23 MeV
Peak field on axis	37 MV/m
Peak field on iris	50 MV/m
RF energy stacked per meter	11 J
Energy given to the 10A 10 ns 100 nC beam	2.1 J
Energy spread due to loading	10 %
Gun current	15 A
Capture ratio	60 %

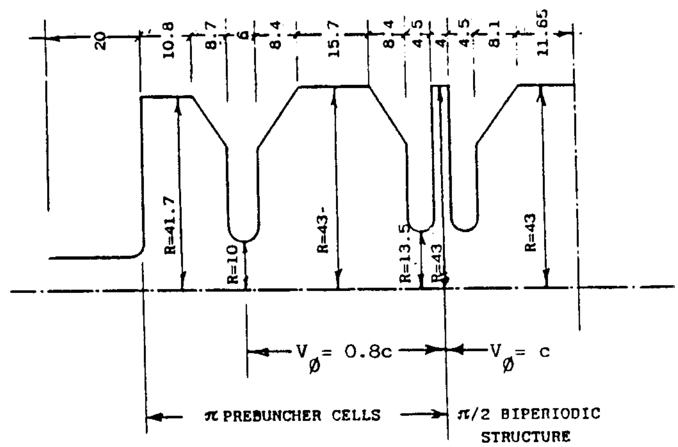

Fig. 1 - First cells of Frascati injector project.

The E-coupling choice allows for large and intense beams. The geometry of revolution allows for precise field and cell geometries computations. The biperiodic vs triperiodic geometry choice simplifies the terminal cells determinations. This is of interest here as a first cell of lower field is included. This cell is dephased by π and somewhat undercoupled with respect to the second cell. Empty cell between them has not been used in the present design to reduce the drift length and the geometry complexity.

Experience and computer simulations have shown that a very high capture efficiency of the current emitted by the gun is obtained if the electric field in the first cell has a moderate level (around 10 MV/m). This level is higher in the Frascati case but capture remains better than in conventional design [1].

III. COMPUTATIONS AND MEASUREMENTS

The uniform part of the structure has been simulated by the computer code OSCAR-2D [3,4]. Field distributions and dispersion curves have been obtained.

It is known that the double periodicity of the structure may introduce a stop band in the dispersion curve, that must be closed in order to optimize the structure performances. It will be shown in the Appendix that a procedure to close the stop band consists in varying the diameters of the coupling cells until the frequencies of the two $\pi/2$ modes whose field distributions have zeros in the long or in the short cells respectively are equal. These two resonant modes have been simulated on a single period of the structure by imposing boundary conditions as indicated in Fig. 2a,b; for better precision 40,000 mesh points have been used.

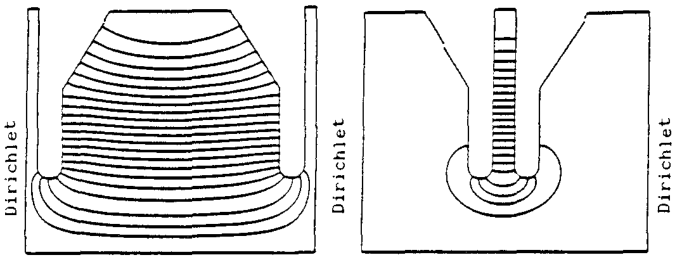

Fig. 2

In Fig. 3a,b are shown dispersion curves evidencing open and closed stop band cases. The mode frequencies needed to draw these curves have been obtained by simulating (with less mesh points) the same single period as in Fig. 2b with different combinations of Dirichlet (magnetic mirror) and Neumann (electric mirror) boundary conditions on symmetry planes: N-N for 0, accelerating $\pi/2$; N-D for $\pi/4$, $3\pi/4$; D-D for the other $\pi/2$.

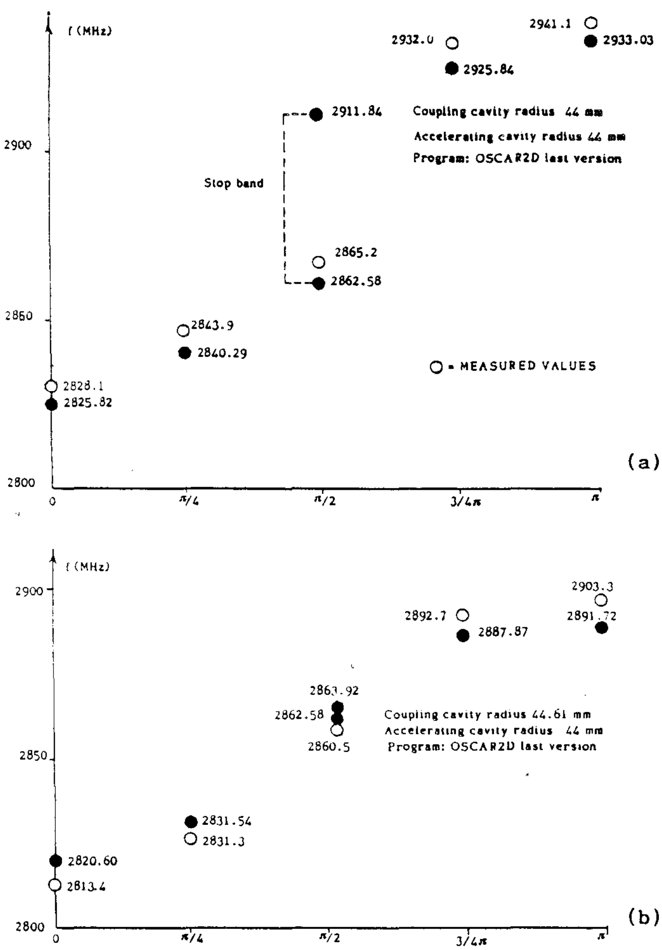

Fig. 3

On the same figures are given the measured frequencies on precisely machined copper models. Agreement is good for the curve shapes with as without stop-band.

A critical point was the RF feasibility and precise dimensions of the new geometry at the beginning of the structure where a 2:1 field ratio at π coupling was asked for dynamics reasons [1].

To this purpose we have built a full scale brass model of which a section is shown in Fig. 4. Field distribution on the axis has been measured as usual by pulling a bead through the cavity and detecting the frequency perturbation.

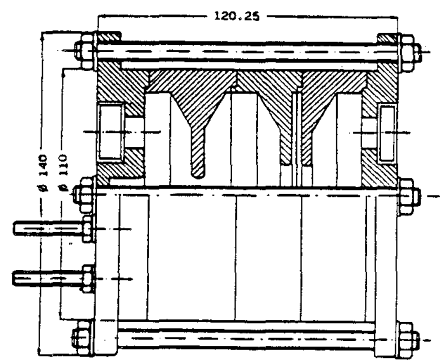

Fig. 4

In Fig. 5 we show a measured field distribution. The field ratio in the first two cavities can be adjusted by acting on the iris aperture and on the diameter of the first cavity.

These computations and measurements confirmed the RF feasibility of the buncher design. The final whole geometry (including a slight modification of the first cell) will be measured in the next months.

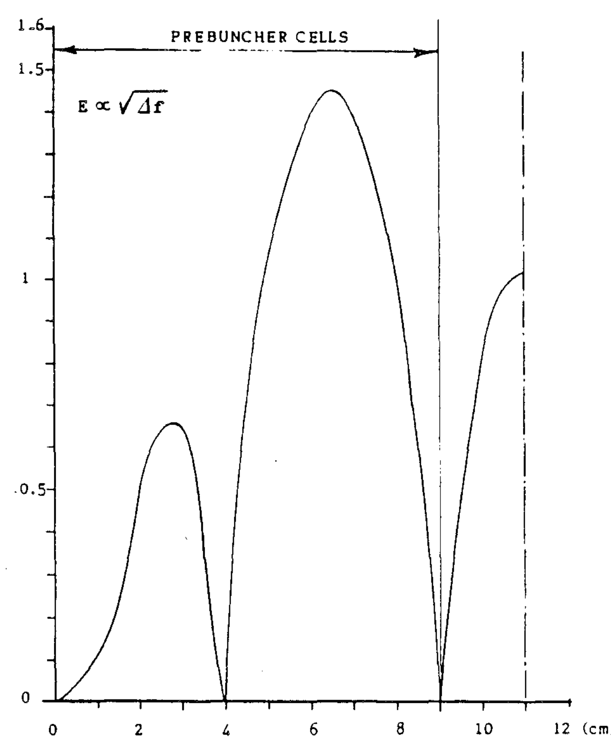

Fig. 5 - Electric field distribution in prebuncher cells.

APPENDIX

To close the stop band we used the method below.

With reference to the biperiodic structure shown in Fig. 6, let ω_e and ω_o be the resonant frequencies of respectively even and odd cavities and K_1, K_2, K_3 the coupling coefficients between adjacent and second nearest cells. From a well known lumped parameter model [5] it follows that the field amplitudes in even and odd cavities, which we will indicate by X_e and X_o respectively, are related by

$$X_e\left(1-\frac{\omega_e^2}{\omega^2}\right)+\frac{K_1}{2}X_o\left(e^{-j\varphi}+e^{j\varphi}\right)+\frac{K_2}{2}X_e\left(e^{-2j\varphi}+e^{2j\varphi}\right)=0$$

$$X_o\left(1-\frac{\omega_o^2}{\omega^2}\right)+\frac{K_1}{2}X_e\left(e^{-j\varphi}+e^{j\varphi}\right)+\frac{K_3}{2}X_o\left(e^{-2j\varphi}+e^{2j\varphi}\right)=0$$

where φ is the cell-to-cell phase shift.

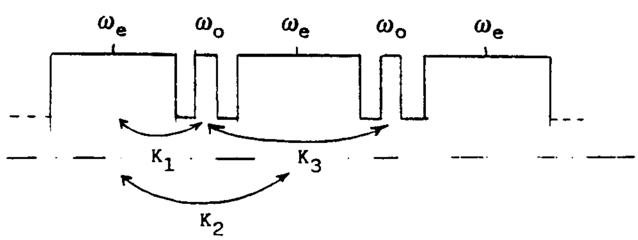

Fig. 6 - Scheme of biperiodic structure.

For any $\varphi \neq \pi/2$ system above uniquely determines ω and X_e/X_o (excluding the trivial solution $X_e=X_o=0$) but for $\varphi=\pi/2$ the $e^{-j\varphi}+e^{j\varphi}$ terms vanish and we are left with

$$X_e\left(1-\frac{\omega_e^2}{\omega^2}-K_2\right)=0\ , \qquad X_o\left(1-\frac{\omega_o^2}{\omega^2}-K_3\right)=0$$

from which two independent solutions are obtained

$$\omega_a^2=\frac{\omega_e^2}{1-K_2}\ , \qquad X_e\neq 0, \qquad X_o=0\ ;$$

$$\omega_b^2=\frac{\omega_o^2}{1-K_3}\ , \qquad X_e=0, \qquad X_o\neq 0.$$

In other words there are two different resonant modes with the same cell-to-cell phase shift $\varphi=\pi/2$: in one of them (the working mode) only even (accelerating) cavities are excited, in the other one only odd (coupling) cavities are.

Closing the stop band consists in making equal the frequencies of these two modes and it is usually done by making $\omega_e^2/\omega_o^2 = 1-K_2$ (having neglected K_3 as it is much smaller than K_2).

We simulated instead the aforementioned modes directly by a computer code (OSCAR-2D) changing the radius of the coupling cells until equal frequencies were obtained. For sake of preciseness the working mode was computed by imposing Dirichlet conditions on the midplanes of two nearest coupling cells and the other one $\pi/2$ mode by imposing Dirichlet conditions on the midplanes of two nearest accelerating cells. A better accuracy is achieved by direct simulation because we need not compute or measure any K_i and all of them are nevertheless automatically taken into account with other things the model may neglect. Indeed the model is used here only to qualitatively understand what kind of field distributions are expected for the two $\pi/2$ modes in order to correctly set the problem to be solved by OSCAR-2D. So the attained accuracy is essentially that of the computer program used.

References:

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