VACUUM SYSTEM FOR THE ACCELERATING STRUCTURE OF THE IFUSP MICROTRON

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Abstract

This paper describes the vacuum system adopted for the accelerating structures of the IFUSP Microtron accelerator. The structure uses the Los Alamos side-coupled cavities and presents a vacuum port at each coupling cavity. We describe the vacuum system, the advantages of the adopted configuration, some construction details and calculations on the expected performance.

1 INTRODUCTION

The Laboratório do Acelerador Linear do Instituto de Física da Universidade de São Paulo (LAL-IFUSP) finished the construction of a β = 1 continuous wave accelerating structure [1] for the IFUSP microtron [2], which presented excellent properties [3]. The structure is a 1.04-m long standing wave, side coupled (SCS) design, with 17 accelerating cavities and 16 coupling cavities.

One of the main advantages of the side-coupled accelerating structure, as compared to other structure designs, is the possibility of pumping each of the coupling cavities. This is an important feature, for it allows a quick pumping of the degassing produced by RF heating or sparking in the structure. Our structure presents 16 coupling cavities, each of them connected by a tube with a conductance of 12 *l*/s. Figure 1 shows a schematic drawing of the structure, with dimensions and details of the cavities.

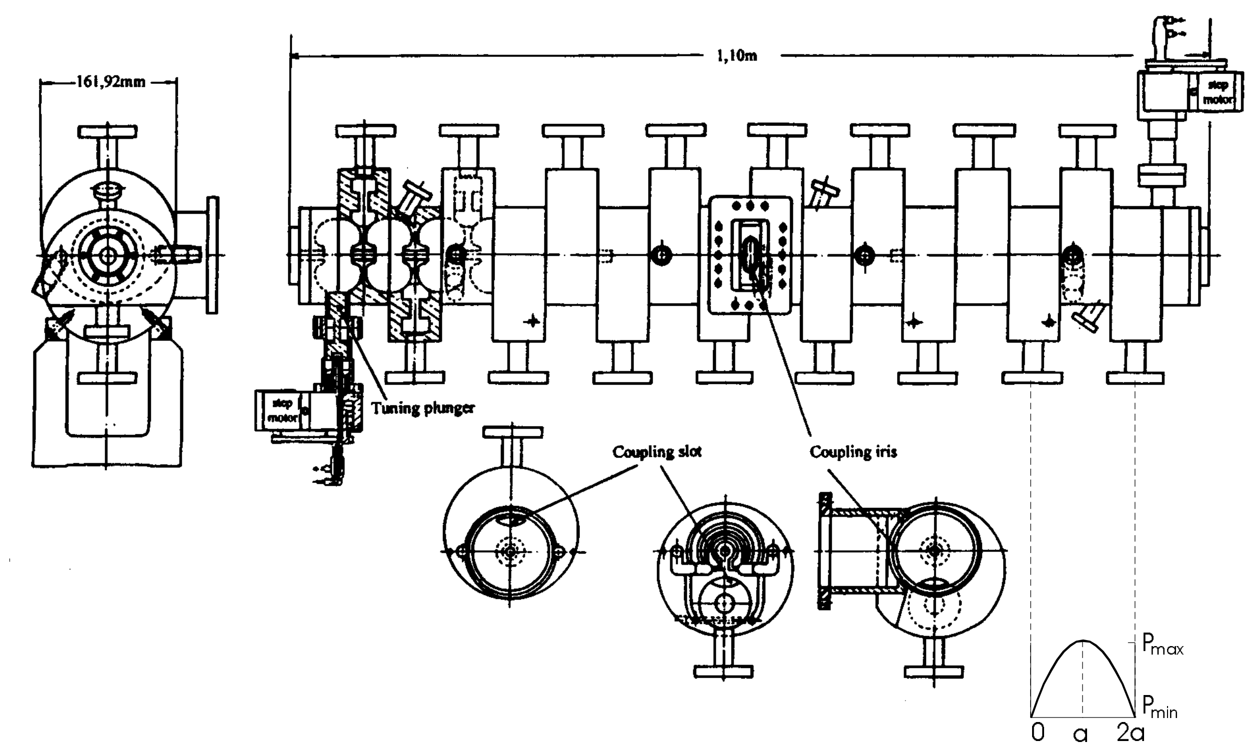

Figure 1: Schematic drawing of the structure, with detail showing the pressure along the length of a “module” (see text).

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To ease the mechanical design of the vacuum system we decided to use only the ports facing downwards, as shown in Fig. 2, which presents a side view of the structure and the manifold.

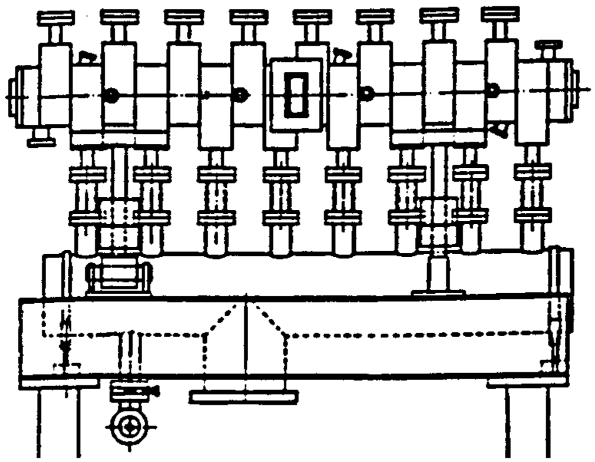

Figure 2: Side view of the structure, showing the coupling with the manifold.

2 MODELING

There are two basic options on how to pump the 8 vacuum ports: with 8 vacuum pumps of about 40 *l*/s pumping speed, or with a manifold connecting the 8 ports to a single 300 *l*/s vacuum pump. Figure 3 shows a schematic drawing of the manifold used.

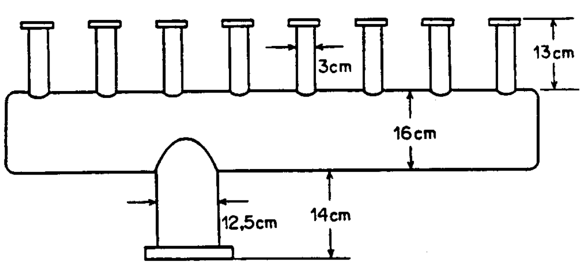

Figure 3: Schematic drawing of the manifold.

A simplified model was used to evaluate the effective pumping speed of the system and also the steady state pressure along the length of the structure. We divided the structure in 8 modules composed of one half of a coupling cavity, two full accelerating cavities, one coupling cavity (facing down) and another one half of a coupling cavity, as depicted in Fig. 1. We then proceeded to evaluate the conductance and the degassing of the main parts of this module. Beginning with the conductance, to pump the gas in the furthermost volume, the coupling cavity facing up, it has to go through the accelerating cavity, down to the coupling cavity facing down, to the exit tube, to the connecting tube of the manifold, the manifold itself and finally to the pump. In the evaluation of the pressure profile along the structure, we need the effective pumping speed at the accelerating cavity, because that is where the electric field is most intense.

The effective pumping speed can then be written as

$$\frac{1}{S_{eff}} = \frac{1}{C_T} + \frac{1}{S_p} \tag{1}$$

where S_{eff} is the effective pumping speed at the accelerating cavity, S_p is the pumping speed of the vacuum pump and C_T is the total conductance of the system. C_T can be calculated by

$$\frac{1}{C_T} = \frac{1}{C_W} + \frac{1}{C_{CC}} + \frac{1}{C_{ET}} + \frac{1}{C_{CT}} + \frac{1}{C_M} + \frac{1}{C_{PT}} \tag{2}$$

where C_W is the conductance of the window between the coupling and accelerating cavities (approximated by an ellipse shape), C_{CC} the conductance of the coupling cavity, C_{ET} the conductance of the exit tube, C_{CT} the conductance of the connecting tube (between the exit tube and the manifold), C_M the conductance of the manifold, and C_{PT} the conductance of the tube that connects the manifold to the vacuum pump. We consider the gas to be N_2, at 298 K and molecular flow. Several simplifications were done, mainly in the geometry of the cavities, which are very complex.

C_W was calculated considering the window to be elliptical, with major and minor axes equal to 2.4 cm and 1.6 cm, respectively. Then C_W = 36 *l*/s. The coupling cavity was approximated by two curved tubes of rectangular cross section, forming a shape close to a toroid, resulting in C_{CC} = 94 *l*/s. The exit and connecting tubes present the most restricted conductance of the whole system, being narrow (2- and 3-cm in diameter, respectively) and long (5.4- and 20.6-cm long, respectively), resulting in C_{ET} = 12 *l*/s and C_{CT} = 11 *l*/s. The conductance of the manifold will depend on the port which is being pumped. We calculated the two extreme cases (850 and 1300 *l*/s) and used the average, C_M = 1075 *l*/s. The pumping tube of the manifold presents C_{PT} = 780 *l*/s (which includes the whole distance from the manifold to the ion pump). Then, using Eq. (2), the total conductance of the system is C_T = 4.7 *l*/s. Substituting this value in Eq. (1) and considering S_p = 300 *l*/s, we obtain for the effective pumping speed on each module, at the entrance of the accelerating cavity, S_{eff} = 4.6 *l*/s.

If, instead of the manifold, eight 40 *l*/s pumps were used, connected at each port by 100-cm long and 7.5-cm in diameter tubes, the effective pumping speed at the accelerating cavity would be 4.9 *l*/s. The difference is less than 7 %. So the effective pumping speed with the manifold and a 300 *l*/s pump, is equivalent to eight 40 *l*/s pumps, but the manifold solution costs about 30 % of the other.

To determine the pressure distribution along the structure, we must calculate the degassing of the cavities and the local effective pumping speed. In our simple model, we consider the pumping volume to be that of one accelerating cell plus one half of the volume of the coupling cell and exit tube (closed) facing upwards. This corresponds, in the structure depicted schematically in Fig. 1, to the portion between points *0* and *a*. The accelerating cavity presents a degassing surface of approximately 190 cm^2, while the coupling cell plus exit tube add up to 180 cm^2. Since we are considering just one half of this last surface, the total degassing surface will be 280 cm^2. Since the window between the coupling and accelerating cavities presents the lowest conductance, to simplify the calculation we will model the system by a cylindrical cavity with internal surface of 280 cm^2 over a length *a*, and conductance of 36 *l*/s, with pumping ports separated by a distance 2*a* (*a* = 6 cm). This model presents a quadratic solution that can be written as

$$p(x) = \frac{-q}{c} x^2 + \frac{2qa}{c} x + \frac{qa}{S_{eff}} \text{ , for } 0 \le x \le 2a \qquad (3)$$

Where *p(x)* is the pressure at the point *x* along the structure, *q* is the degassing per unit length, and *c* is the specific conductance. For our specific conditions, we find $p(0) = 3.7\times10^{-8}$ Torr and $p(a) = 3.9\times10^{-8}$ Torr.

3 CONCLUSIONS

The adopted configuration worked well. The final pressure at the manifold should be better than 3×10^{-8} Torr. The manifold option presents a performance very close to the one using 8 individual pumps, with a cost about 70 % lower. The difference of about 10 % between the maxima and minima of the pressure distribution along the structure is acceptable and supports the decision to close the vacuum ports facing up.

4 ACKNOWLEDGMENTS

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