PLUNGER FREQUENCY CONTROL OF THE SIDE COUPLED ACCELERATING STRUCTURE FOR THE IFUSP MICROTRON

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Abstract

A β = 1 accelerating structure for the IFUSP Microtron has been built. The 17-cavity structure and the tuning plungers placed at both ends of the structure are described. Details from some of the processes, like machining and pre-tuning of the cavities, brazing of the pieces and the final tuning of the whole structure are given. The final results obtained for the structure are presented and the dynamic tuning system based on moving plungers described.

1 INTRODUCTION

The Instituto de Física da Universidade de São Paulo (IFUSP) is building a 31 MeV cw racetrack mictrotron (RTM). This is a two-stage microtron that includes a 1.93 MeV injector linac feeding a five-turn microtron booster (RTM-1). After 28 turns, the main microtron (RTM-2) delivers a 31 MeV continuous electron beam. The injector linac consists of a 0.97 m long capture section and a 1.35 m long pre-accelerator. The whole accelerator uses only 38 kW of RF power, provided by a single 50 kW cw klystron, operating at 2.450 MHz. The 100 keV injection beam line, the end magnets for the microtron booster and the β = 1 accelerating section for the main microtron have been assembled. The fabrication of the other 3 RF sections is under way.

2 THE β=1 IFUSP STRUCTURE

The 1.04 m long β = 1 structure for the main microtron is composed of 17 accelerating cells (AC) and 16 coupling cells (CC) brazed together as showed in Fig. 1. The

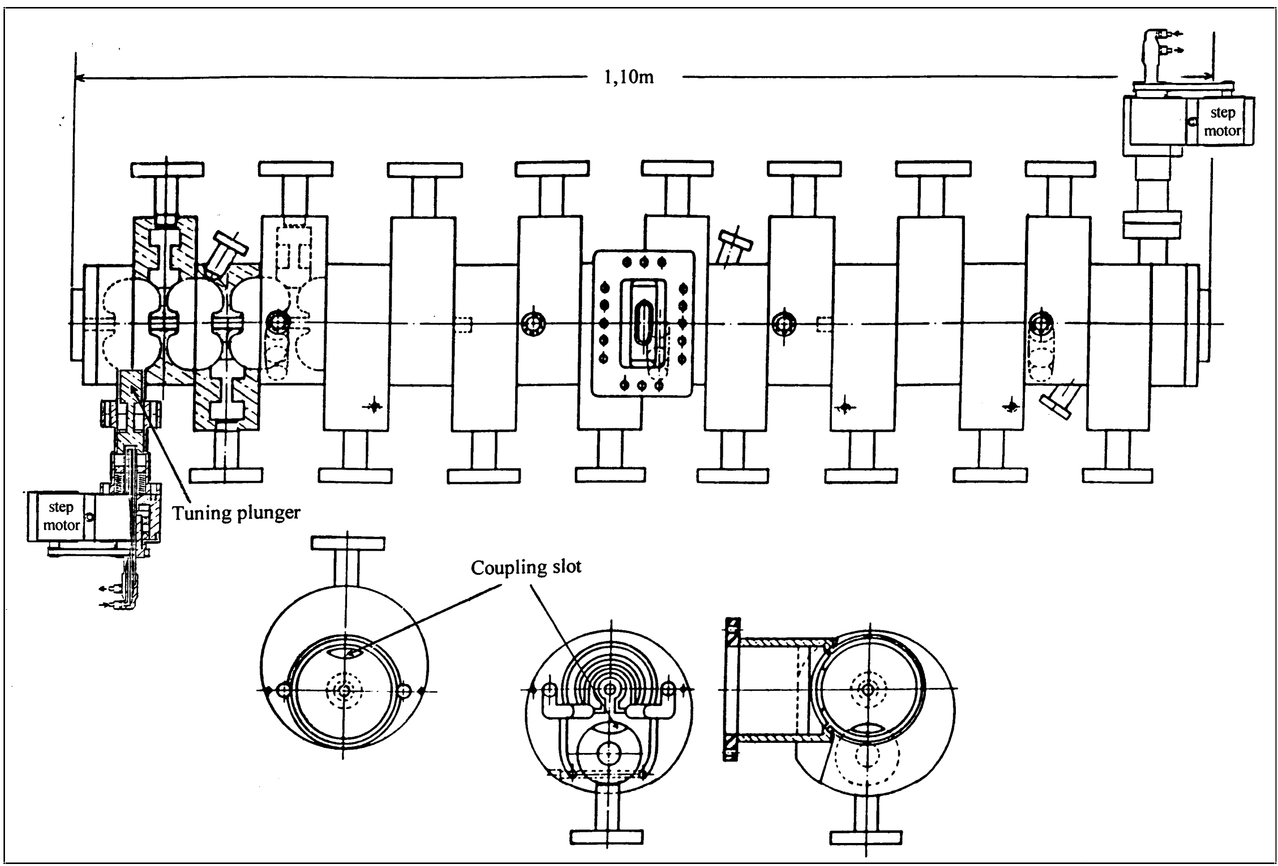

Figure 1: Schematic drawing of the β=1 structure

engineering project is a side coupled design (SCS) developed at Los Alamos National Laboratory [1]. We chose the side coupled design because the vacuum properties are better and the power flow droop is lower than those of the coaxially coupled design, and it presents a shunt impedance better than 81 MΩ/m with a coupling factor between 3 to 5 %.

Two tuning plungers located at both end cells of the accelerating section compensate automatically for the resonance frequency variations caused by eventual changes in the structure temperature. The tuning plunger design (see Fig. 2) is based on the one used in the Mainz Microtron [2]. The plunger is moved whenever a phase difference between the RF input and one of the structure cavities is detected. The position of the plungers was chosen by practical considerations (see Fig. 1). Each section carries three 50 dB diagnostic probes, two with the same phase difference relative to the RF input.

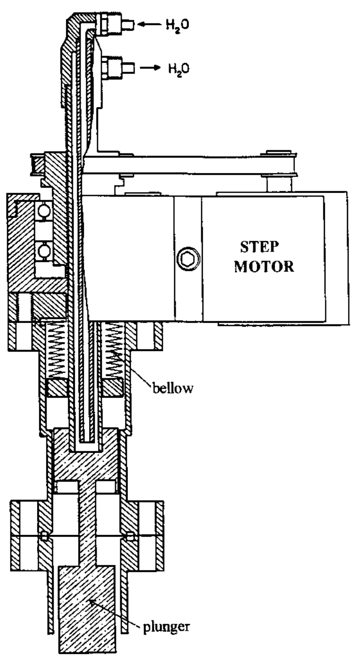

Figure 2: Schematic drawing of the plunger

3 FABRICATION

3.1 Machining

The segments were rough machined to 0.2 mm, annealed under vacuum for 4 hours at 600°C and then fine machined for their final dimensions, except for the lengths of the nose cone of the accelerating cavity and the cylindrical nozzle of the coupling cavity, that were kept longer by 1 mm and 0.5 mm, respectively. Then, instead of trying to determine the nose cone length with the required mechanical accuracy for the tuning, the nose cone was machined to its final dimension by measuring the resonance frequency of the cavity with it still fastened to the lathe. During this procedure the temperature of the cavity was kept constant. An analogous procedure was adopted for the coupling cavities. The quality factor, Q, of the accelerating cavities was rather sensitive to the finishing of the surface. The finishing was performed with a diamond tool with a 0.5 mm radius semicircle profile. A surface roughness of 0.3 μm (RMS) was measured.

The final step before brazing was the machining and tuning of the cavity with the wave guide coupling, to be placed in the midst of the structure. The dimensions of the opening slot (8.8×33.4 mm^2) were determined empirically to give a slightly overcritical coupling. The SWR is 1.18 without beam loading and 1.05 with a beam loading of 10% (corresponding to a 50 μA current).

3.2 Brazing

Due to the complex shape of the side coupled structure, the brazing of its several components could not be done in a single step. The number of steps was reduced to three by the use of special supports and dynamic guides developed in order to allow the brazing of pieces in both horizontal and vertical positions simultaneously.

The following brazing alloys were used: for copper/copper-joints the eutectic Ag/Cu (Cusil, 780°C), for stainless steel/copper-joints Ag/Cu/Pd (Palcusil 10, 832-853°C), and for the wave guide and the wave guide coupling cavity joints, Ag/Cu/Pd (Palcusil 15, 853-900°C). All brazings were done in a vacuum furnace (made in the lab) with molybdenum heating elements and, therefore, a highly oxygen free vacuum (~5×10^{-6} torr at 850°C). Thus, nickel plating of the stainless steel pieces was not necessary. Due to the extreme care taken to machine and braze the cavities and to the excellent characteristics of the vacuum furnace, no vacuum leaks were detected in any of the 64 junctions of the structure.

3.3 Final Tuning

During the brazing procedure, small changes in the geometry of the cavities may happen, due to the thickness of the filling alloy. They affect the frequency of the cavities, thus changing the resonance frequency of the structure. Four methods were developed in order to allow changing the frequency either up or down on both accelerating and coupling cavities [3]. Those methods allow corrections of ± 2 MHz in the frequencies. Every cavity was tuned to within ± 10 kHz of the nominal frequency. Fig. 3 shows the accelerating field distribution after the tuning, measured by the bead pull method.

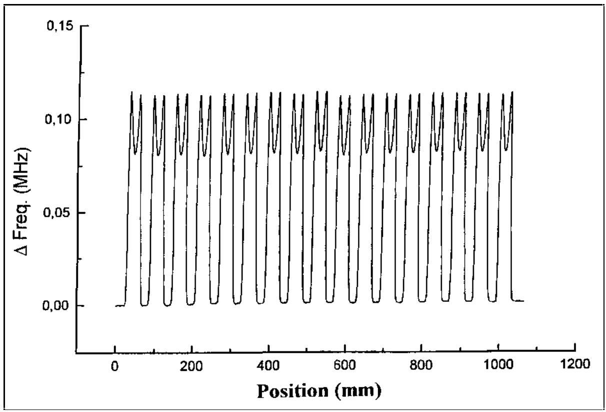

Figure 3: Accelerating field distribution

4 RESULTS

After the brazing and the final tuning of the structure, its parameters were measured in order to have an accurate description of its performance. Table 1 shows the parameters that were directly measured, while Table 2 presents the parameters that were derived from those measured**.**

TABLE 1. Parameters of the structure (measured)

Parameter	Value
Resonance frequency	2,450,000(5) kHz
Ratio Z_{ef}/Q_0	5,580(36) Ω/m
Quality factor	16,000
SWR (standing wave ratio)	<1.18
SWR with a 10% beam loading	<1.05

TABLE 2. Parameters of the structure (derived)

Parameter	Value
Frequency of accelerating cavity	2,458.31 MHz
Frequency of coupling cavity	2,444.67 MHz
Nearest neighbor coupling constant, k	3.2%
Direct coupling between accelerating cells, k_a	-0.68%
Direct coupling between coupling cells, k_c	0.46%
Stop band width	510 kHz

5 DYNAMIC TUNING

The accelerating field amplitude is controlled by the RF power injected in the structure and also by the resonance frequency of the structure. There are two ways to control the resonance frequency: controlling the temperature of the structure or de-tuning the frequency of some of the cavities. The second method can be achieved by the use of moving plungers that change the geometry, and thus de-tune the frequency, of the two extreme accelerating cavities. A de-tuning of the two end cavities by 425 kHz produces a change of 50 kHz in the resonance frequency of the structure. Frequency changes of that order can be made very fast through the plungers and are very slow through the temperature. The accelerating field distribution was measured along the structure for several positions of the plungers. We noticed that changes of up to 80 kHz (~2°C) in the structure frequency can be made without any noticeable change in the structure parameters. We developed an automatic system, using a Double Balanced Mixer to probe the structure frequency, to control the step motor that move the plungers. With this system we managed to keep the frequency tuned and the accelerating field stable within 0.15%, with the temperature of the structure kept within ± 2°C.

6 CONCLUSION

The accelerating structure built at IFUSP has been tested, showing excellent parameters. The effective shunt impedance is 10% higher than expected, which is very promising, since this will allow us to operate the RTM using ~9% less RF power than initially planned.
The dynamic tuning system that uses moving plungers in the extreme cavities, developed at IFUSP, proved to be very efficient and fast in keeping the structure tuned, even when submitted to conditions worse than the expected to occur during normal operation.
The machining and brazing of the pieces that compose the structure, which were done at the lab, proved to be of excellent quality, since the structure performance was higher than the expectations.

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