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ACCELERATOR STRUCTURE DEVELOPMENT FOR NLC*

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Abstract

In the program of work directed towards the development of an X-Band Next Linear Collider accelerator structure, two different test accelerator sections have been completed, and a third is being fabricated. The first is a simple 30-cell constant-impedance section in which no special attention was given to surface finish, pumping, and alignment. The second is an 86-cell section in which the cells were precision diamond-turned by Texas Instruments Inc. The structure has internal water-cooling and vacuum pumping manifolds. Some design details are given for the third section, which is a 206-cell structure with cavities dimensioned to give a Gaussian distribution of dipole mode frequencies. It has conventional-machining surface finishes and external water and pumping manifolds. Component design, fabrication, and assembly brazing are described for the first two experimental sections.

I. INTRODUCTION

All three structures described are designed to operate in the $2\pi/3$ mode at four times the SLAC frequency, or 11.424 GHz.The first is of the simplest construction, with constant-impedance cavities and rudimentary water-cooling, intended primarily as a first test at SLAC of high rf fields in an X-Band traveling-wave structure, following on from earlier work on cavities and a standing-wave section [1]. It was also the test vehicle for our newly-developed symmetrical double-input coupler [2], and it provided the first accelerator 'load' for the X-Band high-power klystrons under development [3]. Results of the first tests in the Accelerator Structures Test Area (ASTA) [4] have been reported elswhere [5].

The second structure is also constant-impedance. However, it represents our first attempt at improving accuracy of construction, smoothness of surface finish, and vacuum pumping along the beam path. It is also intended to be primarily a vehicle for high-field breakdown and dark current tests, although it will later be used to accelerate an electron beam.

The third will be the first prototype of the quasi constant-gradient structure with Gaussian dipole mode detuning which is being developed for the Next Linear Collider Test Accelerator (NLCTA). It will be 1.8 m long, and will also be tested in ASTA, as will similar sections which will follow it. However it is also planned to install this section in the SLC for wake-field measurements in the Accelerator Structure Setup (ASSET) experiment.

II. 30 CELL STRUCTURE

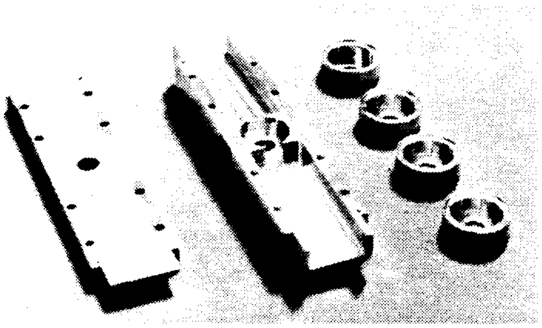

Figure 1. Input coupler and four cells of 30–cell structure.

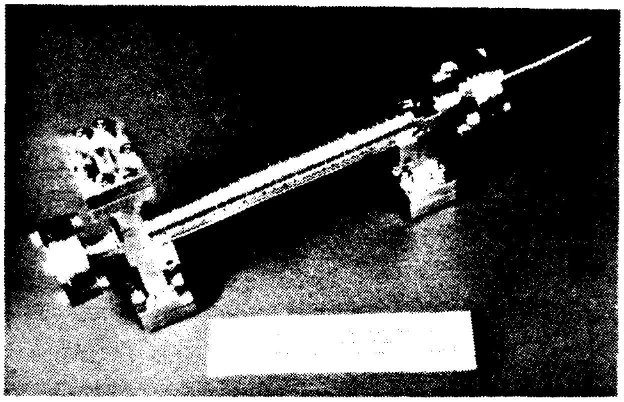

Figure 2. Completed 30–cell accelerator.

The small, 30-cell accelerator structure comprises simple nesting cups, as shown with the two halves of the symmetrical double-input coupler in Figure 1. The complete section, brazed with 35/65 Au/Cu shims, is shown in Figure 2.

III. THE 75 cm STRUCTURE

This structure is designed to achieve 100 MV/m when driven by 220 MW pulses generated using the SLED II system [6]. There are 84 cells plus two coupler cavities. The latter have symmetrical double coupling irises, very similar to those shown in Figure 2. The cell design is illustrated in Figure 3. Water cooling tubes and parallel vacuum pumping manifolds are integrated into each cell. Two additional holes provide thin wall segments on two opposite sides of each cavity. Stainless steel tuning studs are brazed on the outsides of these segments, allowing the cavities to be tuned either up or down in frequency by pushing or pulling on the studs. Pumping slots connecting the accelerator cavity to the manifolds can be seen. It was originally intended to use these slots in every cell, but concerns arose about the cumulative effects of leakage of rf power from every cavity into the pumping manifolds. Vacuum calculations showed that a tenfold increase in conductance

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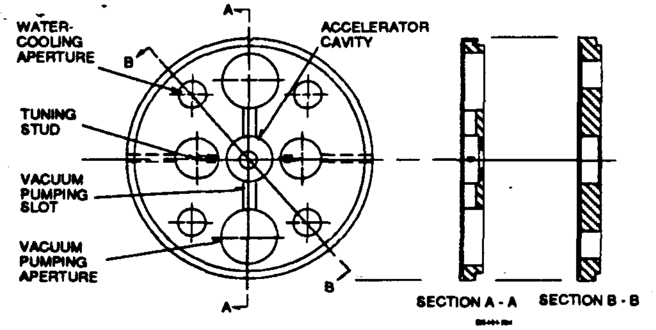

Figure 3. Features of 75 c structure cell.

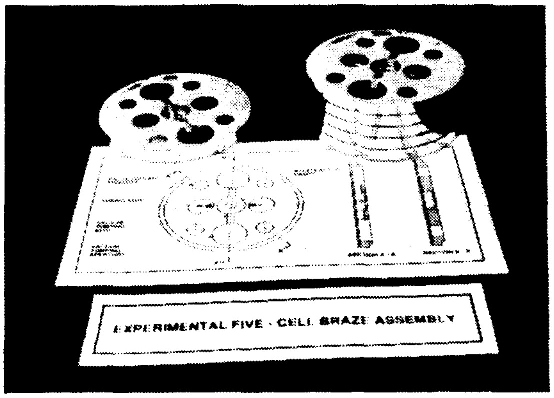

Figure 4. Test braze five-cell assembly.

between the middle of the accelerator section and pumps at each end could be achieved by using only four pumping cells approximately evenly spaced along the section, so this approach was followed.Theoretical work has shown [7] that cell-to-cell misalignment in structures that rely upon dipole mode detuning to achieve wake-field suppression needs to be kept about 5 µm. We also know that the tuning rate for the $2\pi/3$ mode as a function of cavity diameter is about 0.6 MHz/µm. As a first step towards the alignment goal, and also to improve the cavity dimensional tolerances and possibly reduce dark current, we decided to have the cells made by single-point diamond turning (SPDT). The work was done by Texas Instruments Inc., Dallas, Texas. SPDT utilizes a single crystal, gem quality, diamond tool along with ultra-precision machine tool refinements to produce optical quality surface finishes on nonferrous metals. Diamond has excellent wear characteristics, and can be micro-polished chip-free at a magnification of 800X. The machine in which the tool is used employs air bearing spindles and slideways along with a 10 nm resolution laser interferometer tool positioning system.

The OFE copper blanks were first machined with 75 µm of excess material on the surfaces to be finished by SPDT. The first SPDT operation was to flycut the back surface flat to 1 µm to mate with the lathe vacuum chuck, which was faced to the same flatness to establish a Z-axis zero reference. This reference was used in the multiple-pass CNC program for cutting both sides of the cell. The part was then positioned in the vacuum chuck and indicated to the spindle to less than 2.5 µm. Multiple tooling was used to reduce the wear rate on the finishing diamond tool. The latter was designed with a .38 mm radius and 120° sweep in order to be able to machine flat surfaces and inside and outside diameters in the same setup. The .38 mm tool radius allowed the .50 mm internal fillet radius called for to be profiled rather than plunged, eliminating tool chatter and surface degradation. The cavity diameter was held to ±2.5 µm and measured on the machine with an LVDT probe. Centering of the cavity diameter with respect to the outer surface was held to 5 µm. To avoid additional set-ups and associated tolerance accumulations, the two surfaces were machined in the same operation, necessitating a reversal of spindle rotation in the middle of the CNC program. The part was then reversed in the vacuum chuck and indicated on the outside diameter to less than .6 µm. This ensured that the two sides of the iris radius blended smoothly. After dimensional verification, the parts were vapor degreased, wrapped in lens tissue, sealed in air-tight dessicant bubble bags, boxed and shipped to SLAC.

The first five cells test-brazed at SLAC are shown in Figure 4. Brazing shims of 35/65 Au/Cu alloy 50 µm thick were used. It was a great disappointment to find that the assembly had multiple vacuum leaks. Theories advanced for the failure included contamination on the surfaces of the copper cells and the brazing shim, inadequate flatness of all surfaces, inadequate hydrogen ventilation of the brazing surfaces to reduce oxides and carry away the products of reduction, and surfaces too smooth to permit the braze to 'wet' and flow. Many tests were run under a variety of conditions. Sections were taken, etched, polished and examined. The belief that inadequate hydrogen ventilation was the problem led to a radical change of design for the first 1.8 m section to follow. However, it turned out that the problem lay in the brazing cycle: the time allowed for the temperature of all parts to 'equalize' below the true brazing temperture was too long. This allowed excessive diffusion of copper into the brazing alloy, making it copper-rich and raising its melting point so that, when the assembly was taken up to the expected brazing temperature, the shim did not melt uniformly. The combination of a slightly higher furnace temperature, and a shorter time for 'equalization' cured the problem. However, these troubles did underline the fact that the use of shims with multiple air/water/vacuum internal interfaces was very undesirable. The probability of a failure in a stack of 200 cells so joined would not be negligible. The design had looked attractive in the first place because it afforded a clean outer surface comprised of a stack of precisely machined cells, the surfaces of which could be used for precision alignment.

Continuing nervousness about vacuum leaks in the final assembly led us to use thicker brazing shim (75 µm) than was probably necessary. Tests had shown that the residual braze region would add 52 µm per cell to the period of the structure, so the machined length of each cell was reduced by this amount. The design of the input and output couplers was done using MAFIA and confirming and fine-tuning the dimensions by means of accurately machined and brazed copper models.

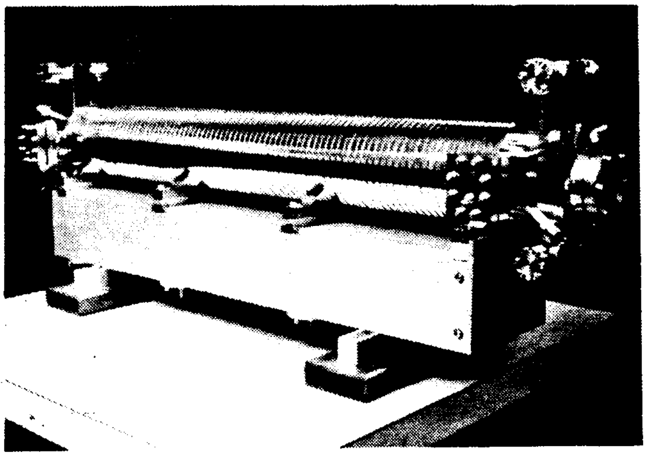

Figure 5. Completedf 75 cm accelerator.

The detuning caused by the slots in the pumping cavities wasalso computed and confirmed by low-power measurements onaluminum model cells.

The final assembly of the structure was done in stages. First. subassembly brazes of three stacks of cells were made. Two stacks had 25 cells, and one 26 cells. After brazing, it was easy to check them and confirm that they were leak-tight. They were also checked for straightness on a coordinate measuring machine (CMM). Secondly, the two couplers were brazed with beam tubes, end pumping manifolds, and the first (and last) two cells which were of special design. Finally, the subassemblies were stacked together vertically, with the output coupler at the bottom, and with pumping cells inserted beween each subassembly. The completed accelerator section, leak-checked, mounted on its strongback, and awaiting low-power testing, is shown in Figure 5.

IV. THE 1.8 m STRUCTURE

A first model of the structures intended to be used in the NLCTA is being built. It has 204 cavities plus two coupler cavities, and is approximately 1.8-m long. The filling time is 100 ns, and it is designed for final operation at 100 MV/m gradient, requiring an input power of 346 MW. However, the first goal is to run it successfully at 50 MV/m. The cavity diameter, iris diameter and iris thickness are different for each cavity. Details of the theory leading to this design are given in [6] and [7]. As mentioned earlier, brazing problems with the 75 cm section led to a more conventional and conservative design for this structure. External water tubes and pumping manifolds are employed, and the diameter of the cells containing the cavities is reduced to 50 mm. General design features are illustrated in Figure 6.

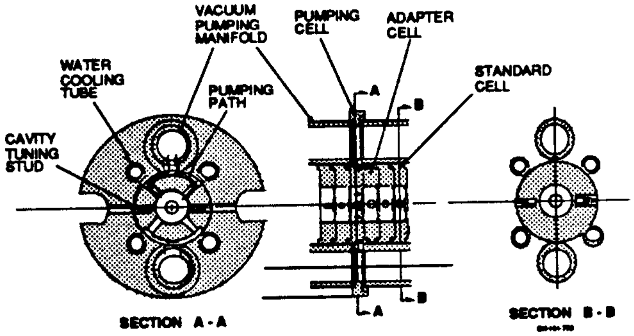

Figure 6. Design features of the 1.8 m sructure.

In order to expedite the fabrication of this first section, it was decided to use conventional machining techniques Tolerances and concentricities are about 10 μm and the surface finish is about 0.4 μm. So far, 190 of the cells have been made. Brazing shims and nesting cells are still employed, so the structure periodicity and cell-to-cell alignment will not meet our goals. However, it is expected that much will be learned from the first excercise in putting such a long X-Band structure together. A special furnace is being constructed to accomodate the accelerator length.

V. REFERENCES

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