Numerical Simulation of Waveguide Input/Output Couplers for a Planar mm-wave Linac Cavity *

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Abstract

A double-sided planar mm-wave linear accelerating cavity structure has been studied. The input/output couplers for the accelerating cavity structure have been designed using the Hewlett-Packard High Frequency Structure Simulator (HFSS). The program is a frequency domain finite element 3-D field solver and can include matched port boundary conditions. The power transmission property of the structure is calculated in the frequency domain. The dimensions of the coupling cavities and the irises at the input/output ports are adjusted to have the structure matched to rectangular waveguides. The field distributions in the accelerating structure for the $2\pi/3$-mode traveling wave are shown.

1 INTRODUCTION

The Argonne Advanced Photon Source (APS) is developing a millimeter wavelength relativistic electron linear accelerator system [1,2]. The goal is to construct a compact electron linac with an energy of 50MeV for production of coherent tunable wavelength synchrotron radiation. The millimeter frequency range was chosen for the smaller size of the accelerating structures and possible cost reduction through mass production of the accelerating structures. For a millimeter wave operation, the dimensions are a few millimeters or smaller. The recent advances in the precision micromachining or LIGA (a German acronym: Lithographie, Galvanoformung, Abformung) technology enable mass production of cavity structures for millimeter wave applications. The LIGA process uses a deep x-ray lithography, electroforming, and moulding to construct a planar 3-D structure.

For proper excitation of the cavity structure, input/output couplers must be used. For power handling capability and the application of the LIGA process, a rectangular waveguide transmission system is desirable. In this paper numerical simulations and the design of the waveguide input/output coupler are considered. The operation frequency of the system was chosen to be around 120GHz ($\lambda = 2.5mm$). The accelerating structure is a constant impedance structure and operates at a $2\pi/3-$mode traveling wave. Present LIGA processes allow only one depth in the indentations; the physical constraint on the coupling structure design is that the depth of the coupling cavity and the waveguide section must be identical to the depth of the accelerating cavities.

*Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

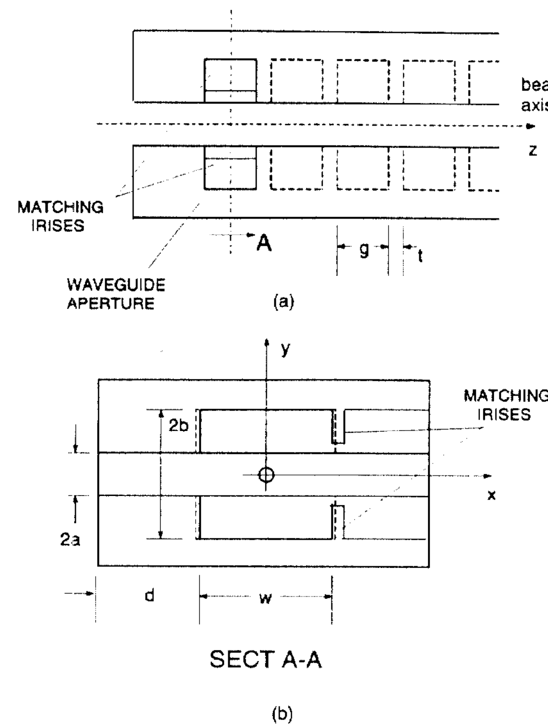

Figure 1: The double-sided mm-wave accelerating structure with the input coupler. a) longitudinal b) transverse

Conventional cavities for linear accelerators are the cylindrical disk-loaded structures. The coupling cavities had been designed experimentally for matching and tuning until numerical simulation was used. Numerical simulations of the coupling cavities have been performed for the cylindrical structures and showed good agreement between the simulation and measurements [3,4,5]. In these works, the computer simulation of the input coupler was done using the MAFIA code in the time domain. These works proved the single input and the symmetrical double input couplers for X-band accelerator structures can be designed with numerical simulations. This simulation can save time and effort by minimizing the empirical steps for tuning the structure.

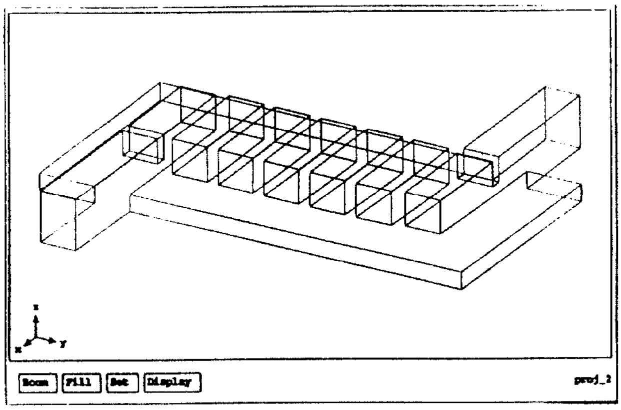

Figure 2: Geometry of a 7-cell structure with input/output waveguide sections. Upper half is shown.

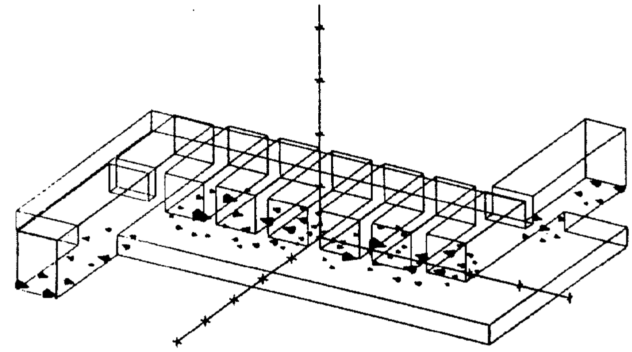

Figure 4: Field in the plane of symmetry of the double-sided structure

2 GEOMETRY

A constant impedance accelerating structure was designed using the MAFIA code and the various electrical properties of the structure were determined [1]. The double-sided planar accelerating structure design is different in many ways from the conventional disk loaded structure. Since the coupling cavities also have side openings, the coupler input waveguide apertures have to be matched to regular waveguides. The structure is symmetrical with respect to the x-z plane; only the upper half is used in the simulation as shown in Figure 2. For accelerating modes which are transverse magnetic (TM) to the z-direction, a magnetic wall is used at the plane of symmetry. Both side openings are terminated with electric walls.

As a first step with the following constraints, a coupler with a single waveguide input in each port, as shown in Figure 1, was designed. The waveguide input aperture is located on one side of the structure so that the waveguides can be constructed and assembled in the same plane. The side openings are not properly modeled in the simulation software. Other difficulties are modeling the coupling cavity and the waveguide junction.

This condition was tested and the accelerating mode was found to be insensitive to these side openings if the length is greater than $W/2$. The input/output waveguide apertures have dimensions of $0.633mm \times 1.8mm$.

3 SIMULATION

The double-sided cavity structure is shown in Figure 1 and a 7-cell structure used in the simulation is shown in Figure 2. For proper coupler design, the transmission line input and output must be reflectionless boundaries in the simulation. For periodic structure, dimensions found from MAFIA simulation were used. The input/output coupler design for a planar linac structure is performed using the High Frequency Structure Simulation (HFSS) program. This program is a frequency domain solver and models matched boundary conditions for defined ports. If an aperture is defined as a port, the program assumes an infinitely long waveguide that has no reflection. Frequency is swept in a specified range with supplied increment, and s-parameters between the ports are found. The displayed

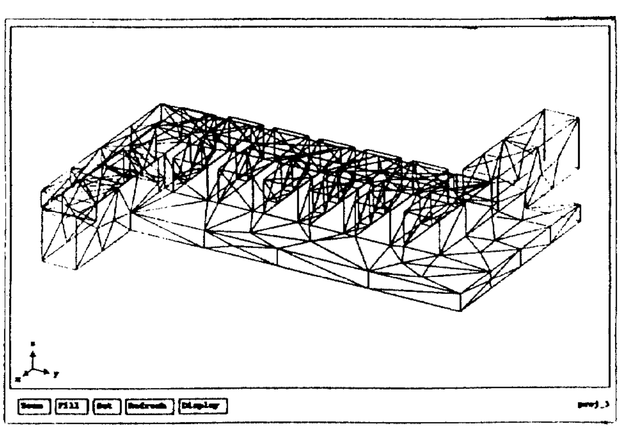

Figure 3: Wire mesh generated for the structure

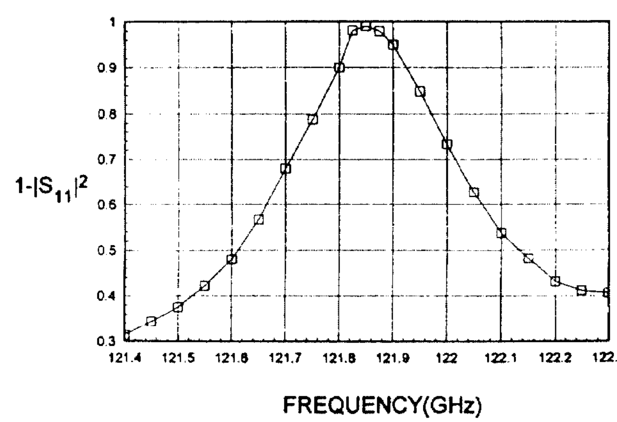

Figure 5: Input frequency response

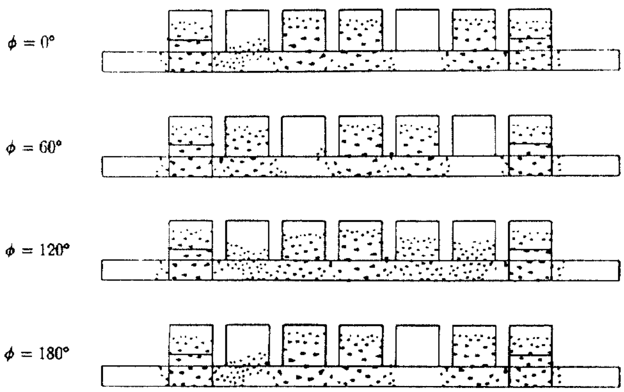

Figure 6: Wave traveling through the structure

wire mesh view is shown in Figure 3. The number of meshes is increased until the s-parameter converges within a specified limit. When the selected s-parameter converges to a desired limit, the simulator breaks out of the loop.

One of the goals in this design is to find a coupling structure which is best suited for the LIGA fabrication processes. In the simulation the aperture area is kept identical to the dimensions of the cavity cells for the micromachining process. The waveguide to accelerating structure junction has a discontinuity since the waveguide section next to the iris has openings at the center of the broad wall. It has been shown that this discontinuity can be tuned out with the matching irises at the coupling cavities.

An 80-cell structure will be used in the fabrication of the accelerating section. The number of cells used in this simulation is limited to seven in order to save computation time. For the traveling waves, the dimensions of the input/output couplers must be independent of the number of cells if it is matched properly.

The coupler has been designed to find the right width of the coupling cavity and height of the coupling iris by varying these dimensions for minimum reflection at the input waveguide port. The depth of the coupling cavity must be identical to the depth of other accelerating cavities. After adjustment, the width of the coupling cavity was found to be smaller than the width of regular accelerating cavities. The input power transfer with respect to frequency is shown in Figure 4. The electric field vector of the wave traveling through the structure is shown in Figure 5. The electric field on the plane of symmetry of the structure is shown in Figure 6.

4 CONCLUSION

The input/output couplers of a double-sided planar accelerating structure were designed by computer simulation. The design is sensitive to dimensional changes of the coupling cavities and the matching irises. The actual cavities being developed with the LIGA process for the 120GHz frequency range will employ the coupling cavities designed as shown in this simulation. This single coupler design is asymmetric with respect to the beam axis of the structure. A symmetrical dual coupler design will be needed for a better performing structure.

5 REFERENCES

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