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Beam Dump Impedance

V. Mane

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Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

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I. Introduction

The eigenmodes of the beam dump geometry were determined using MAFIA. All modes calculated upto a frequency of 2 GHz were of Transverse Electric (TE) type. As explained by Panofsky and Wenzel [1], these modes are not harmful to the beam. This note explains why the geometry does not have any Transverse Magnetic (TM) modes upto a frequency of 2.9 GHz.

II. Determining the Eigenmodes

Figure 1 is a drawing of the beam dump [2]. As shown in this Figure, there is an incoming beampipe of diameter of 8.24 cm and an outgoing beampipe of diameter 5.47 cm. Between these two pipes is a slot of width 5 cm and length 5.92 m. The slot opens into a rectangular tapered cavity with carbon block at the end. The height of the cavity is 6.1 cm (y-direction) and the maximum width (x-direction) is 5.9 cm. The distance between the far end of the slot and the carbon block is 2.5 m.

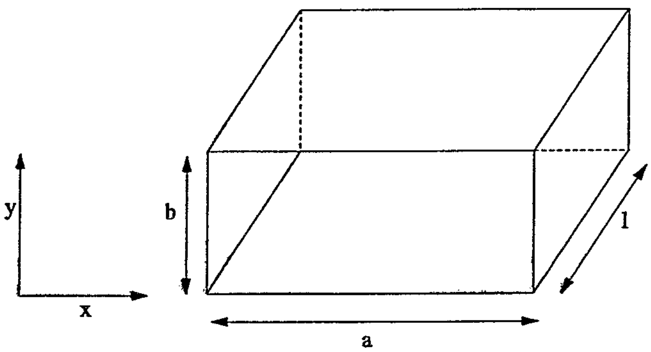
The longitudinal eigenmodes of this geometry were determined numerically using MAFIA [3]. 20 eigenmodes were calculated upto a frequency of 2 GHz. All the modes calculated upto this frequency were TE modes. Figure 2 shows the lowest TE mode at a frequency of 1.44 GHz.

The frequency f, shunt impedance R_{sh}, and Q of these modes are given in Table 1. As the TE modes do not couple with the beam, the shunt impedance of all these modes is close to zero.

No TM modes were found upto a frequency of 2 GHz. In a quest to understand and determine the frequency of the lowest TM mode in this geometry, the modes of a rectangular cavity and some simple geometries were studied.

III. Estimating the Frequency of the TM Mode

Consider a rectangular cavity, of width a, height b and length l. The frequencies of the lowest TE and TM modes depend on the transverse dimensions a and b. The frequency of the TE_{10} mode is given by



. Rectangular Cavity

$$f_{te} = \frac{c}{2a} \tag{1}$$

where c is the speed of light. The frequency of the TM_{11} mode is given by

$$f_{tm} = \frac{c}{2}\sqrt{\left(\frac{1}{a}\right)^2 + \left(\frac{1}{b}\right)^2} \tag{2}$$

The eigenmodes of two simple geometries were calculated using MAFIA. The geometry consists of a cylindrical beampipe with a rectangular cavity on the side, Figures 3 - 8. The diameter of the beampipe is 8 cm. The width a of the rectangular cavity is 14 cm, the height b is 14 cm and the length l is 15 cm (Cavity I). In the second calculation, the width and the height of the rectangular cavity are 14 cm and 6 cm, respectively (Cavity II).

Table 2 compares the frequencies of the TE_{10} and TM_{11} modes of these geometries considered as rectangular cavities, with those obtained from MAFIA. The frequencies compare well, except for the TE_{10} mode of Cavity II, as the dimensions of this cavity are comparable to the beampipe dimensions. Note that with Cavity II, the frequency of the TM_{11} mode at 2.68 GHz is much higher than 1.41 GHz of the TE_{10} mode. Considering the beam dump as a rectangular cavity of width 10.5 cm and height 6 cm, (see cross section Figure 2), the frequency of the TE_{10} mode is at 1.43 GHz. This compares with 1.44 GHz, as obtained from MAFIA. The frequency of the the TM_{11} mode is at 2.9 GHz. This explains why the beam dump geometry shows no TM modes upto a frequency of 2 GHz. Therefore the beamdump satisfies the criteria that it should not have any significant resonances upto 3.3 GHz, the cutoff frequency of the RHIC beampipe of diameter 6.91 cm [4].

IV. Conclusion

The eigenmodes of the beam dump geometry were determined using MAFIA, upto a frequency of 2 GHz. All modes were TE modes. Comparing the beam dump geometry with some simpler geometries, we understand why there are no TM modes upto a frequency of 2.9 GHz. The TE modes do not couple with the beam, and hence do not pose any problem. The rectangular cavity of height 6 cm can be twice as wide without causing any impedance problems for the beam.

V. References

[1] W.K.H. Panofsky and W.A. Wenzel, Rev. Sci. Instr. 27, p 967 (1956).

[2] E. Rodger, Private Communication, May 1995.

[3] T. Weiland, Particle Accelerators 15 (1984), pp. 245-292.

[4] Collective Instabilities in RHIC, Eds. S. Peggs, W.W. Mackay, September 1994

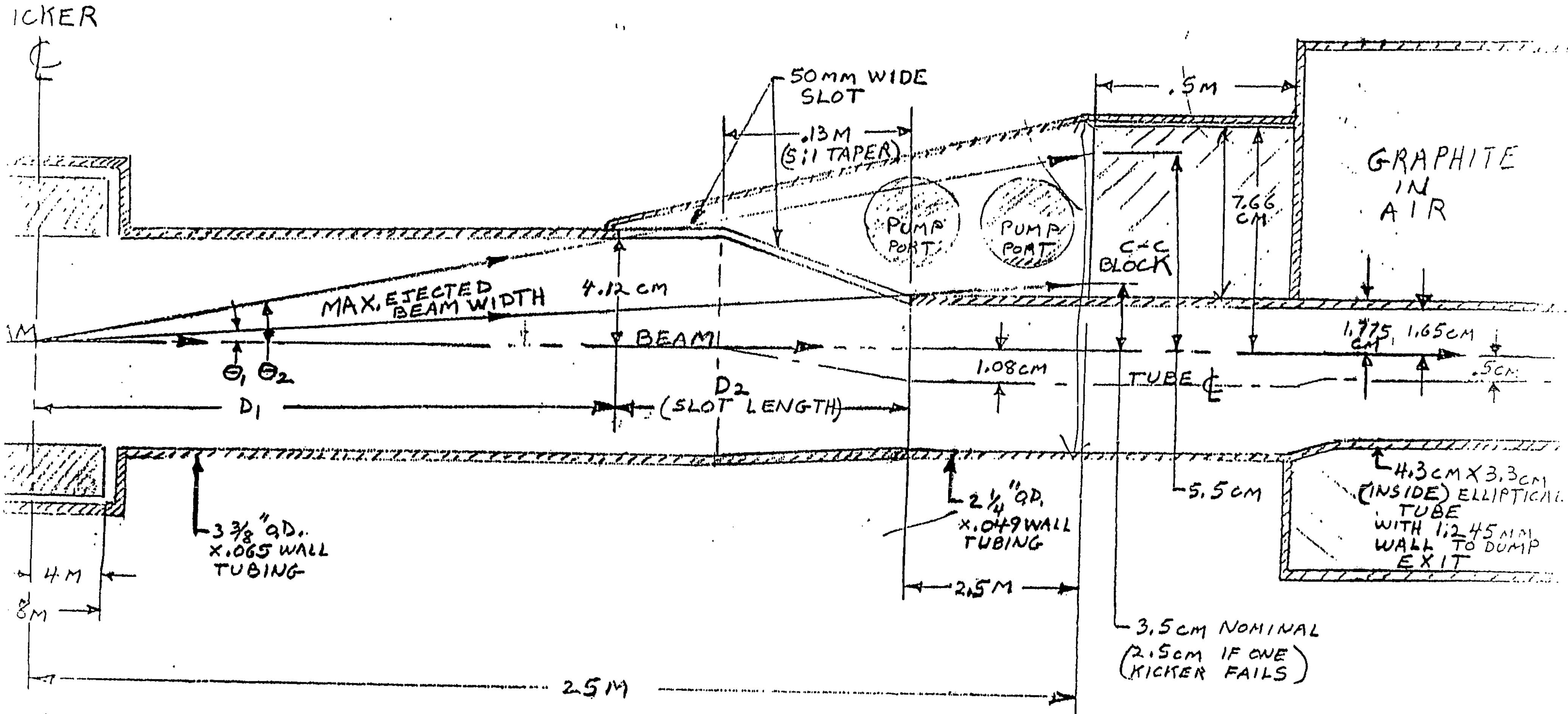
Table 1: Longitudinal TE Modes of the Beam Dump Cavity

f [MHz]	$R_{sh}[\Omega]$	Q
1442	.78e-9	2120
1461	.40e-8	2170
1492	.31e-7	2240
1528	.18e-7	2210
1535	.13e-7	2160
1552	.90e-9	2170
1573	.26e-6	2280
1593	.12e-7	2340
1619	.89e-6	2340
1637	.10e-6	2080
1646	.29e-6	2330
1657	.13e-6	2200
1674	.13e-7	2350
1689	.76e-6	2310
1710	.47e-7	2440
1727	.44e-10	2440
1747	.11e-7	2510
1759	.90e-8	2060
1767	.12e-6	2340
1777	.40e-8	2190

Table 2: Comparing Rectangular Cavity Modes with MAFIA Modes of Similar Geometry

			Rectangular Cavity Modes		MAFIA modes	
Geometry	a [cm]	b [cm]	TE_{10} [GHz]	TM_{11} [GHz]	TE_{10} [GHz]	TM_{11} [GHz]
Cavity I	14	14	1.07	1.51	1.19	1.43
Cavity II	14	6	1.07	2.72	1.41	2.68
Beam Dump	10.5	6	1.43	2.88	1.44	Not Determined

Figure 1: Beam Dump Geometry



$\Theta_1 = .0014R$ (NOMINAL)

$= .0010R$ MIN. (ONE FAILED KICKER)

$\Theta_2 = .0022R$ MAX.

$D_1 = \frac{.0412}{.0022} = 18.73M$ (MAX.) let $D_1 = 16.58M$

$D_2 = \frac{.01775}{.001} - D_1 = 17.8 - 16.58 = 1.2M$ (MIN.) let $D_2 = 22.5 - 16.58 = 5.92M$

let $D_1 = 16.58M$, $D_2 = 5.92M$ (GIVES 4.7MM CLEARANCE TO EJECTED BEAM ℄ AT U/S & D/S END OF SLOT.)

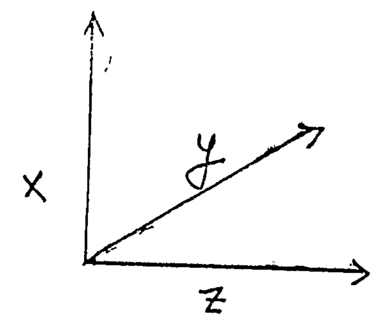


Figure 2: Beam Dump Cross Section
TE_{10} Mode

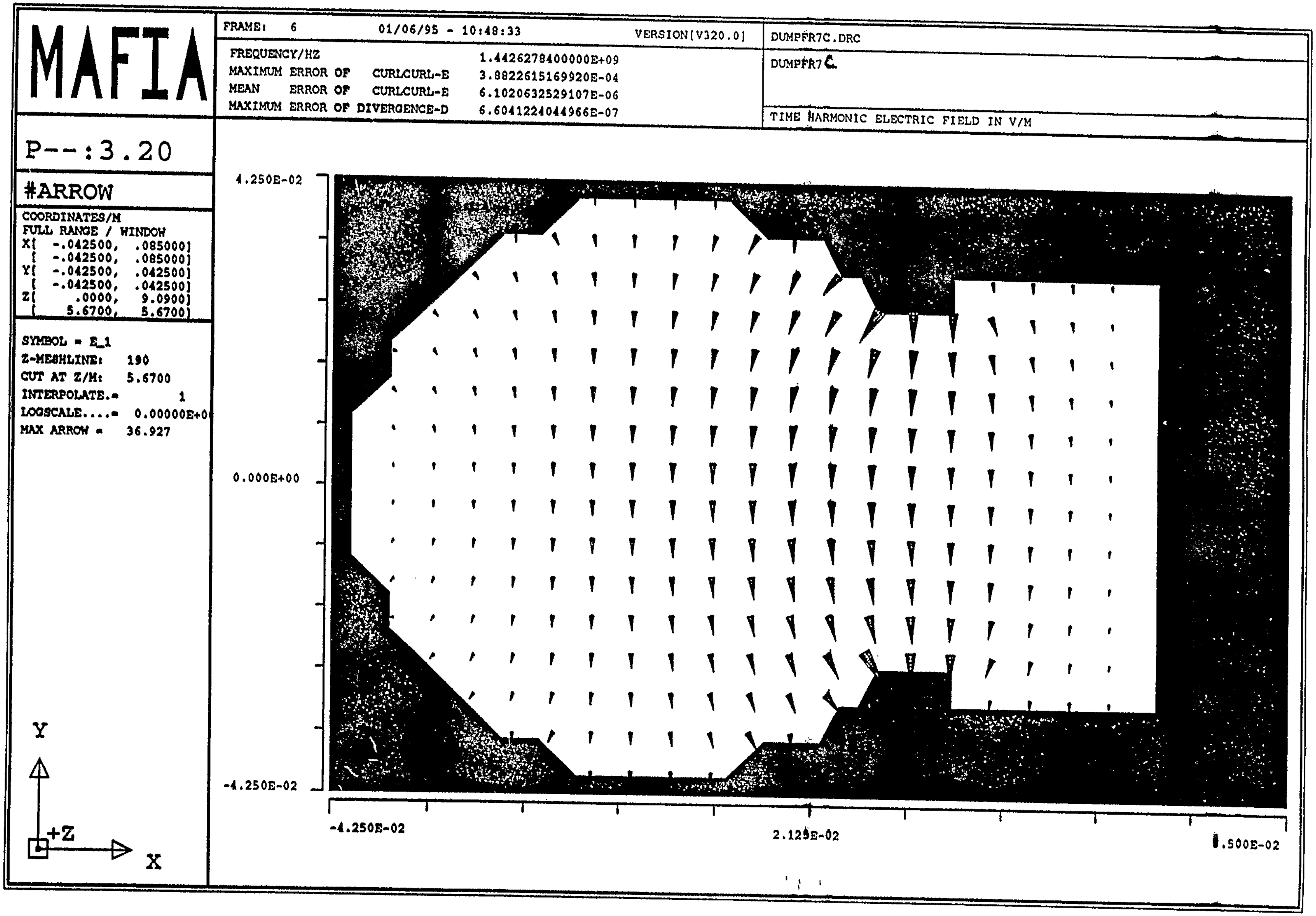


Figure 3 : Cavity I

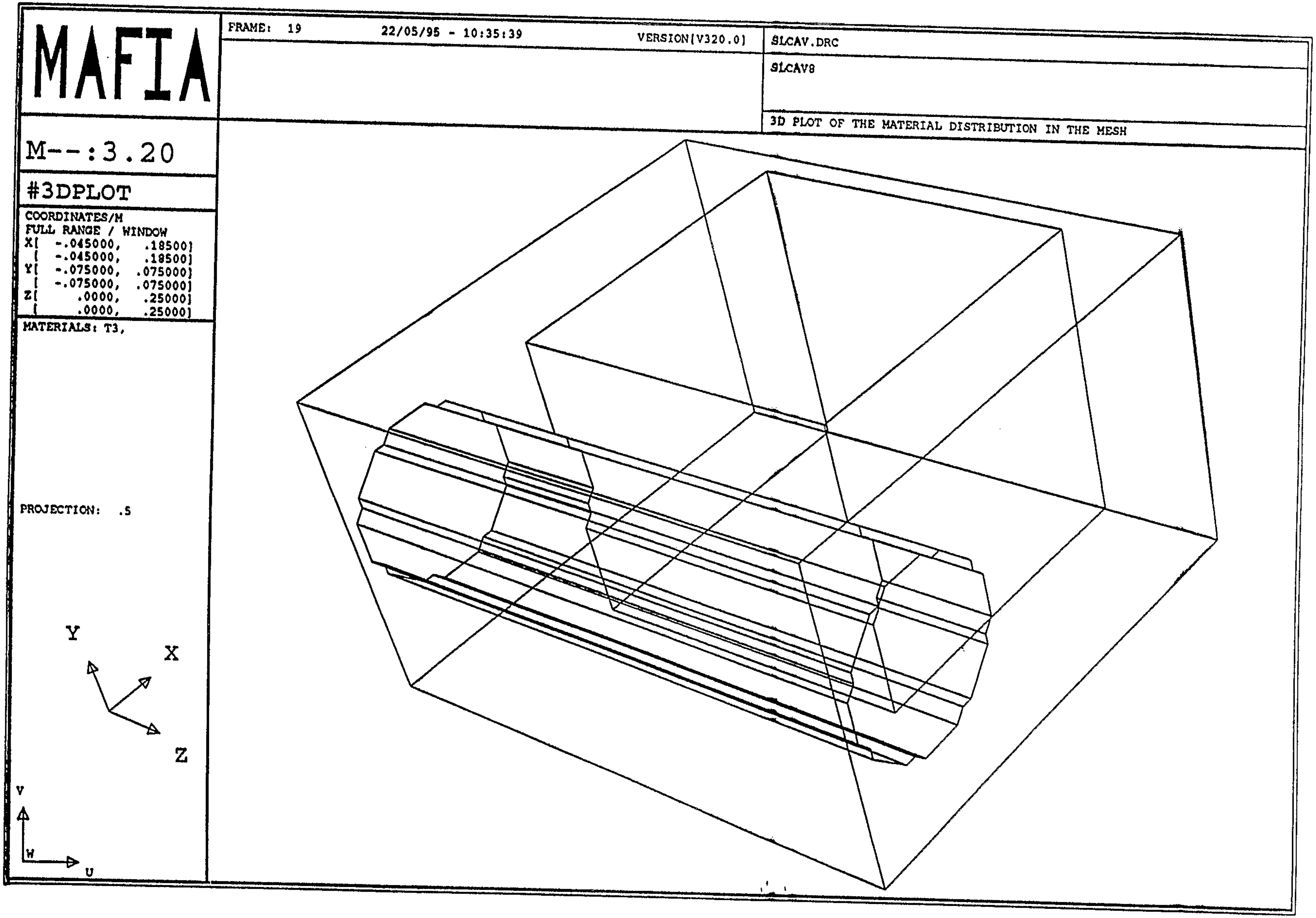


Figure 4: Cavity I Cross Section
TE_{10} Mode

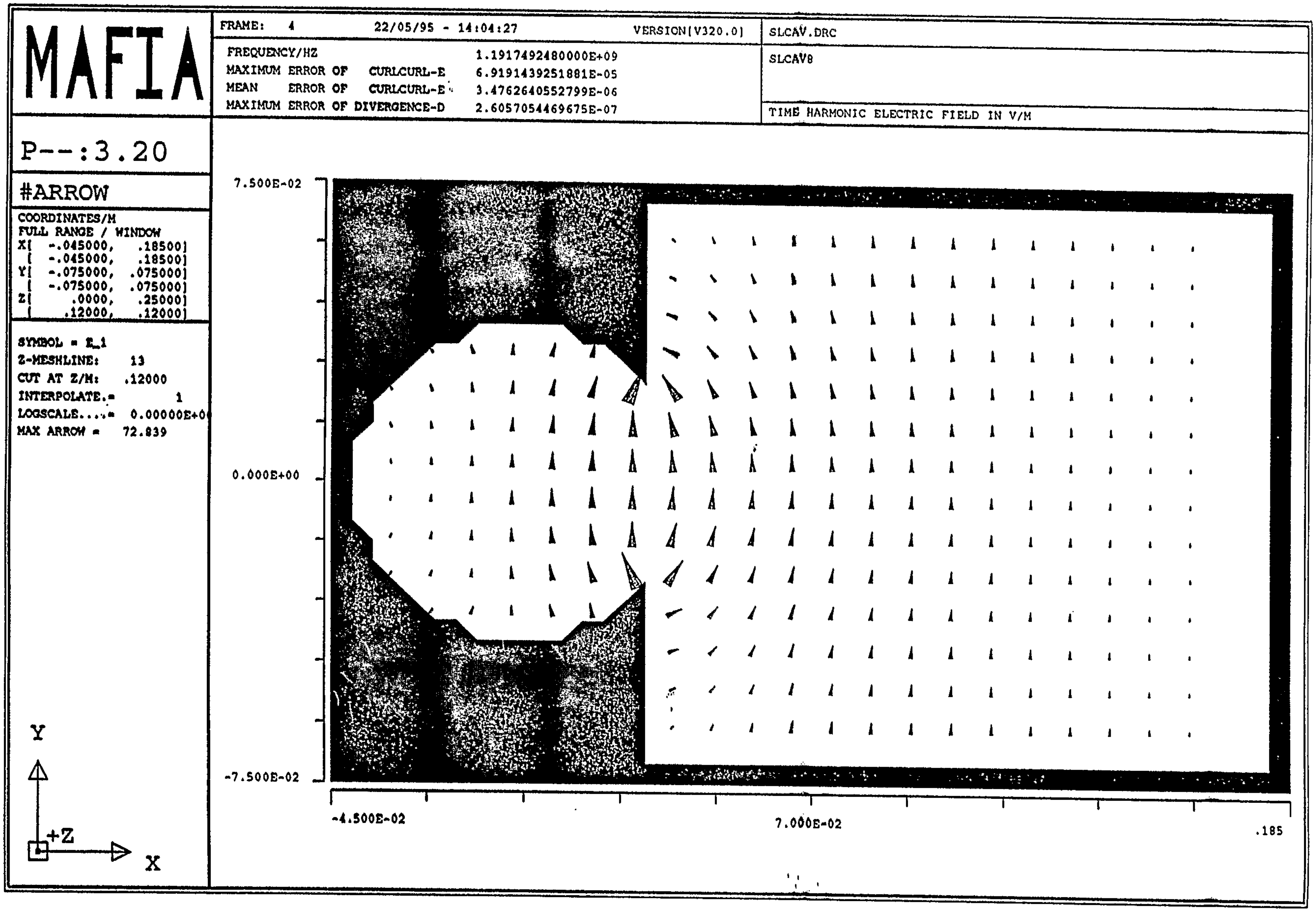


Figure 5: Cavity I
TM_{11} Mode

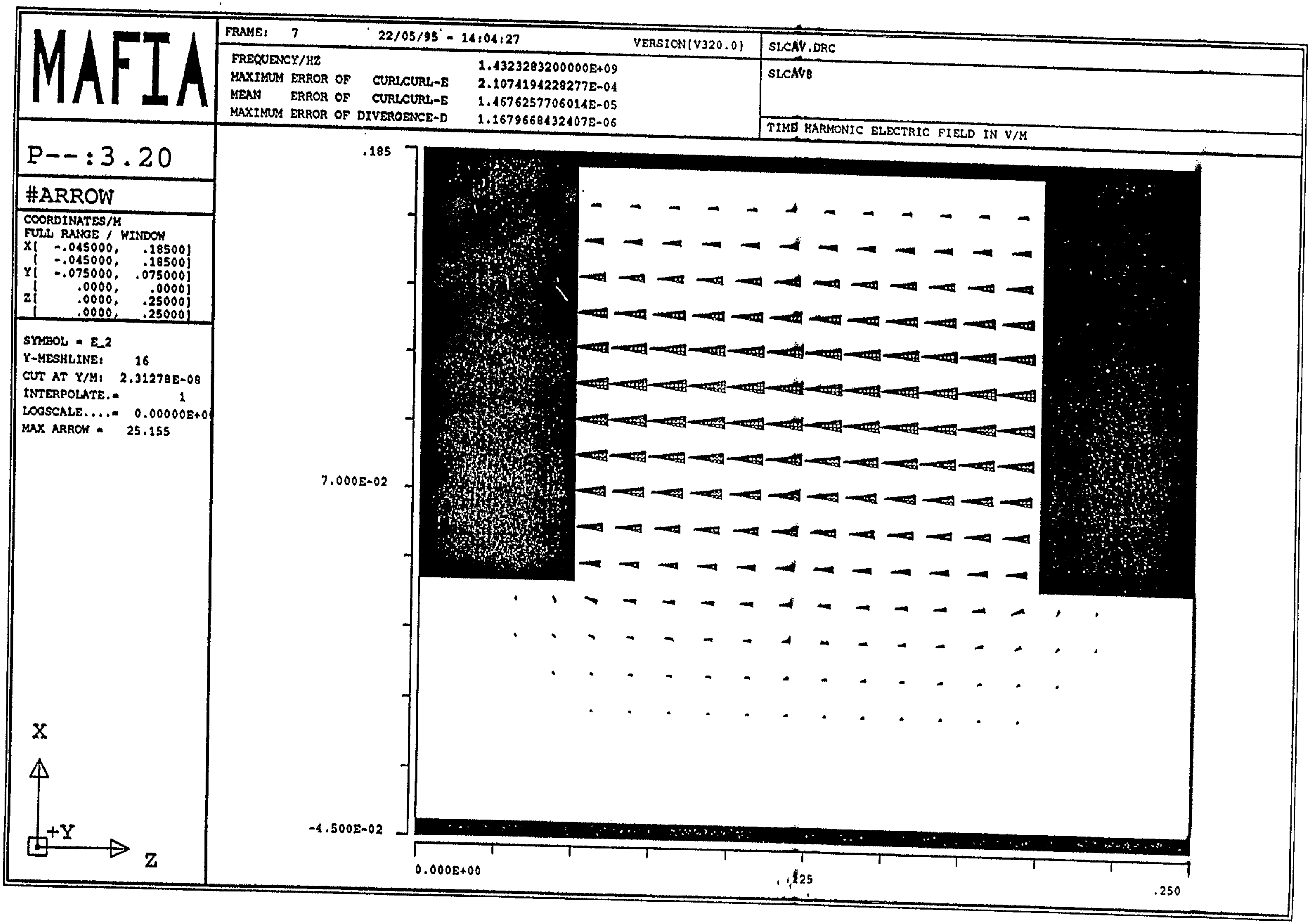


Figure 6: Cavity II

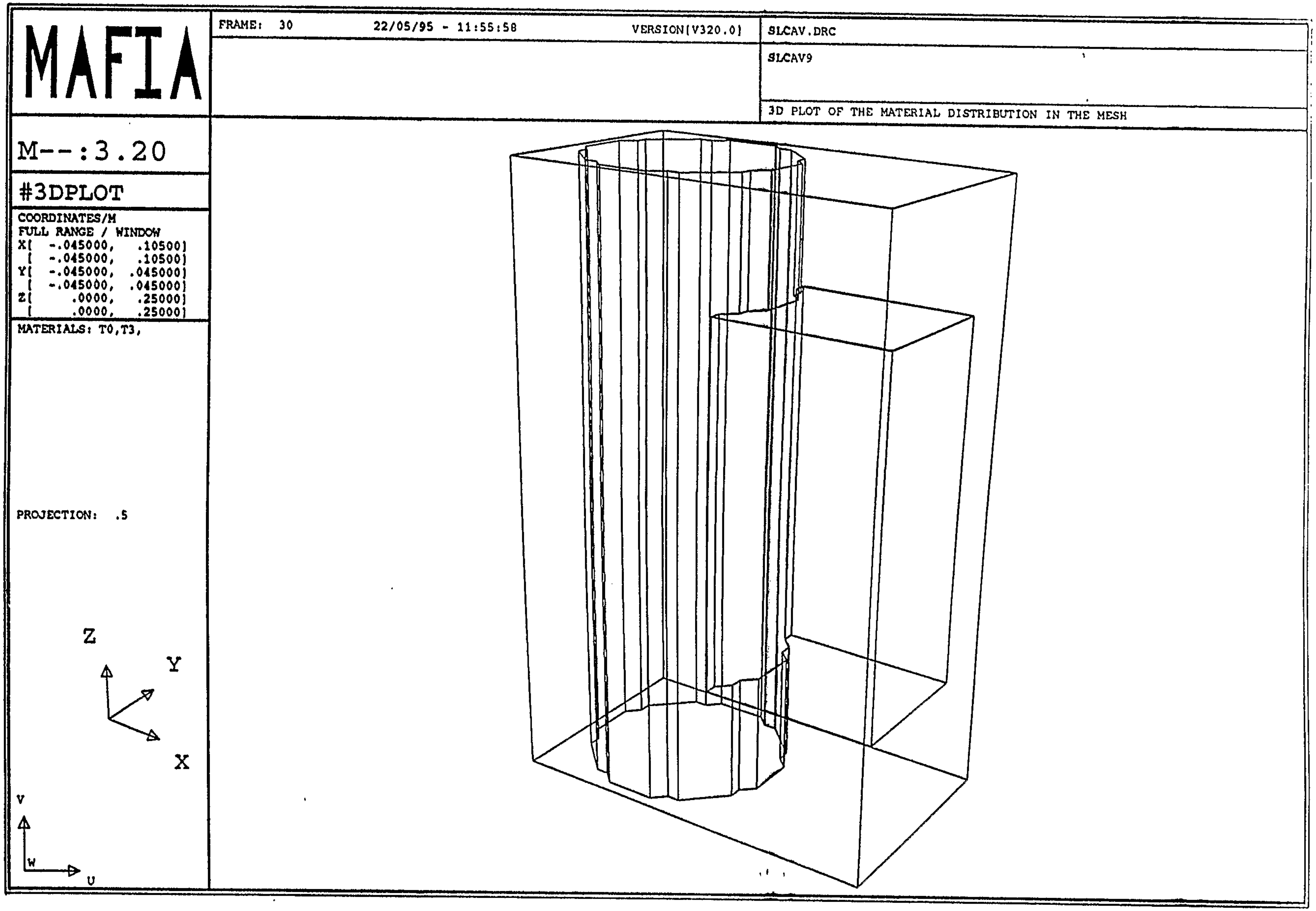


Figure 7: Cavity II Cross Section TE10 Mode

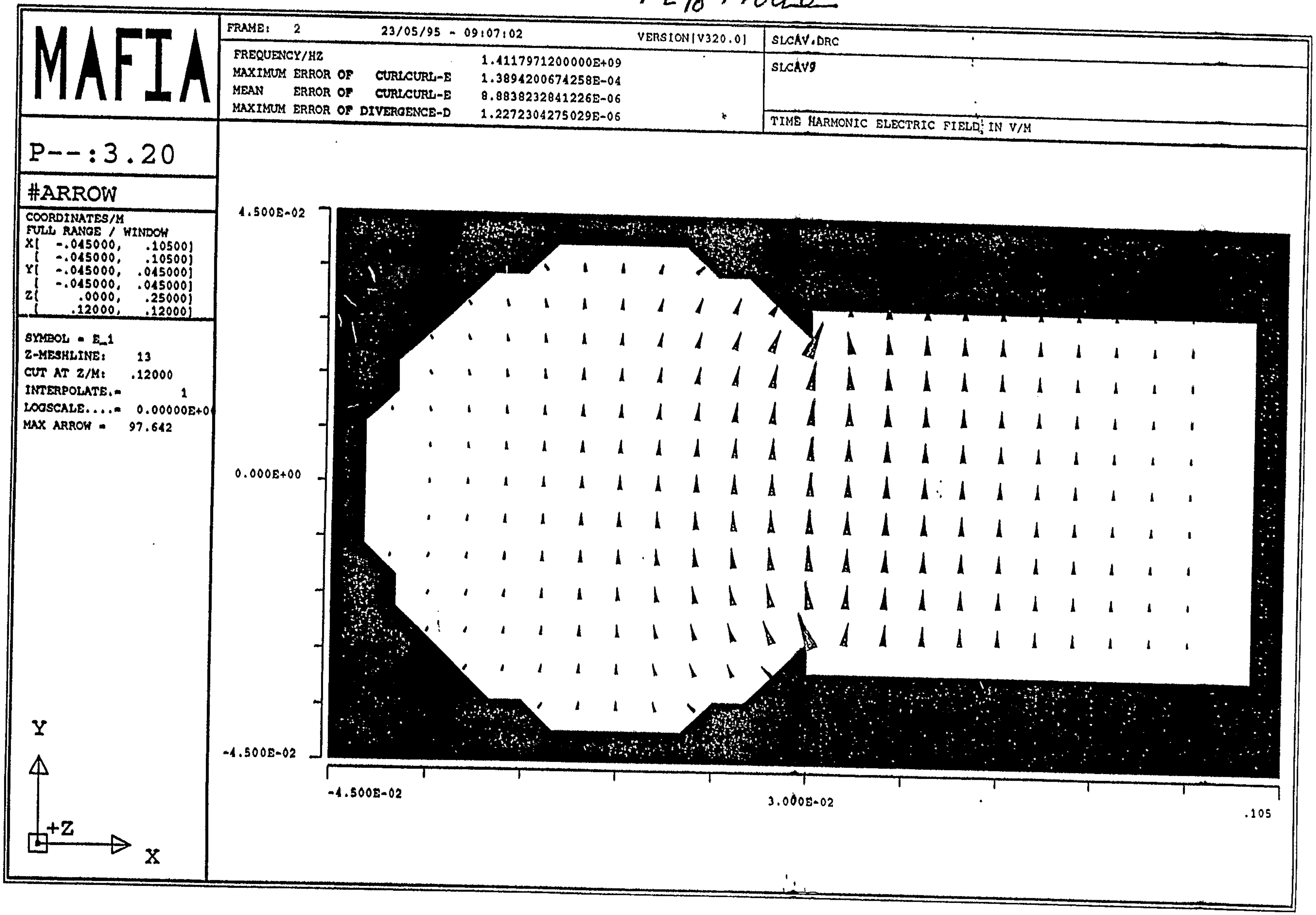


Figure 8: Cavity II
TM11 Mode