ISG3 Injector Working Group (WG2)

1/26/99

NLC Damping Ring RF Cavity development

R. A. Rimmer

LBNL

outline:

Parameters

Baseline design (scaled PEP-II)

R&D
- HOM damping waveguides
- HOM loads
- Window and Coupler
- Tuner
- Tapers
- Fabrication issues

Conclusions

Parameters:

	DR	PPDR
frequency	714 MHz	714 MHz
number of cells	3	4
total voltage	1.5 MV	2 MV
voltage/cell	500 kV	500 kV
wall power	41 .7 kW	41.7 kW
beta	5.7	5.7 (opt=3.1)
beam current	750 mA	800 mA
forward power/cell	238 kW	142 kW
equiv. window power	238 kW	238 kW
klystron power	733 kW	582 kW

Baseline design:

Scaled PEP-II cavity meets requirements

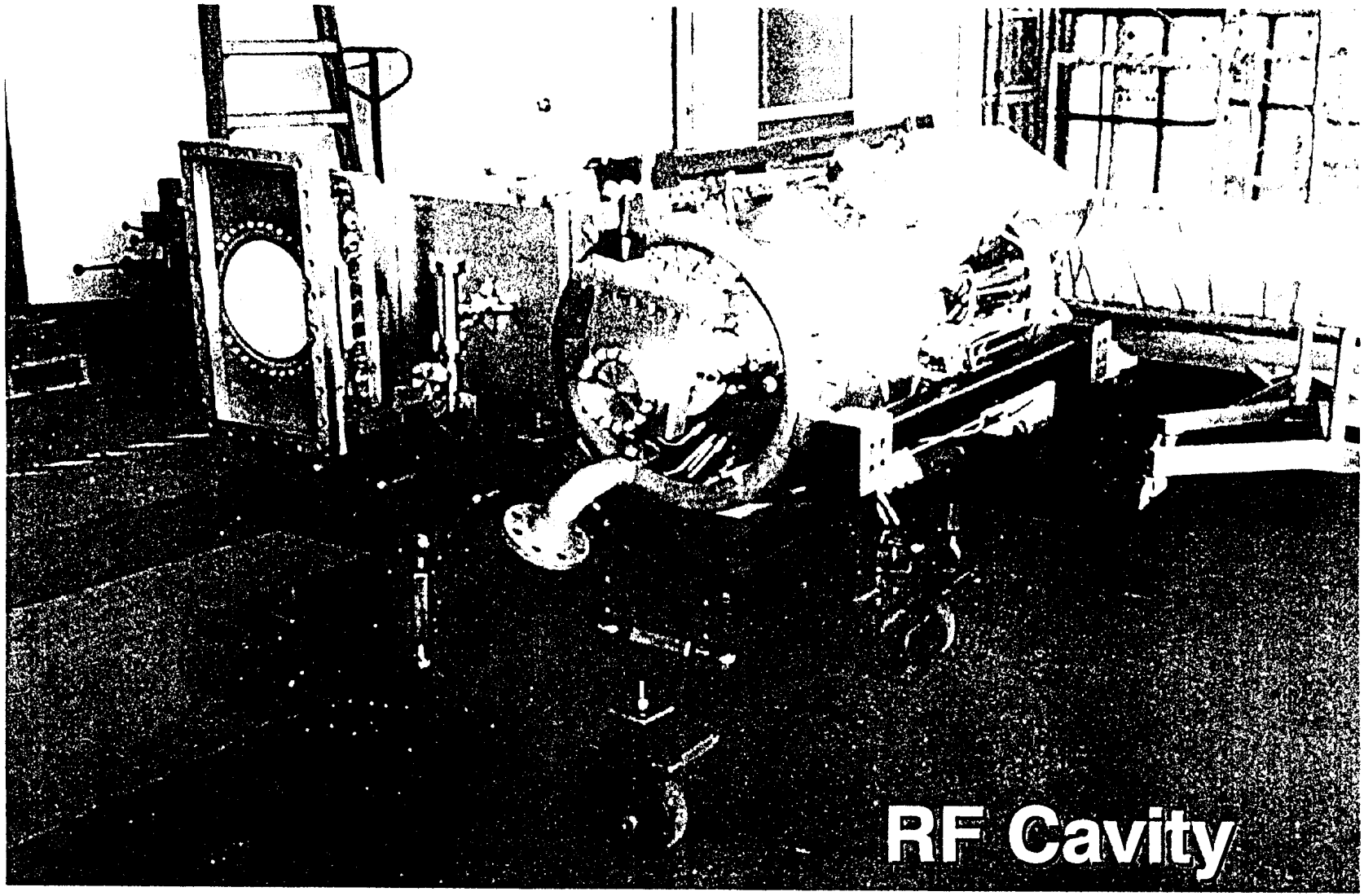
- Peak surface field below Kilpatric (similar to PEP-II)
- Wall power density high but within design limits
  (72 W/cm^2, c.f. PEP-II operating 67 W/cm^2, max design 116 W/cm^2)
- High window power
  (238 kW, 44% area of PEP-II)

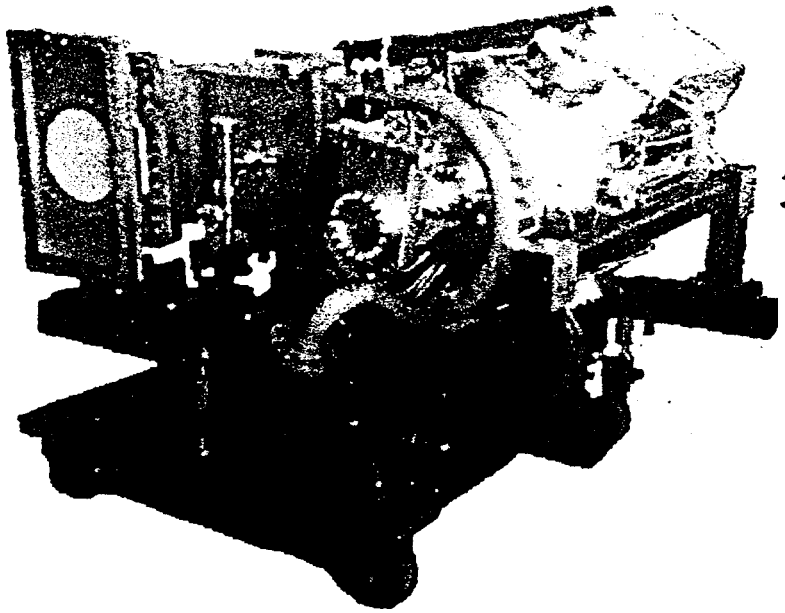
But:

- Expensive to manufacture
- Stresses caused by HOM-port hot spot

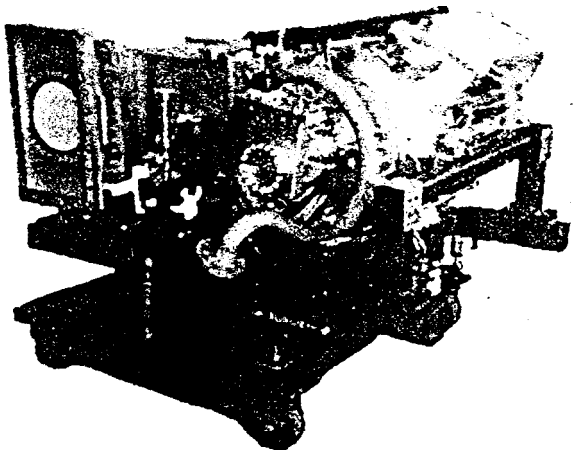
R&D effort focused on scaling and simplifying designs

PEP-II *B*-Factory

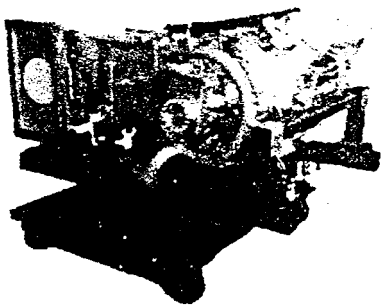




357 MHz



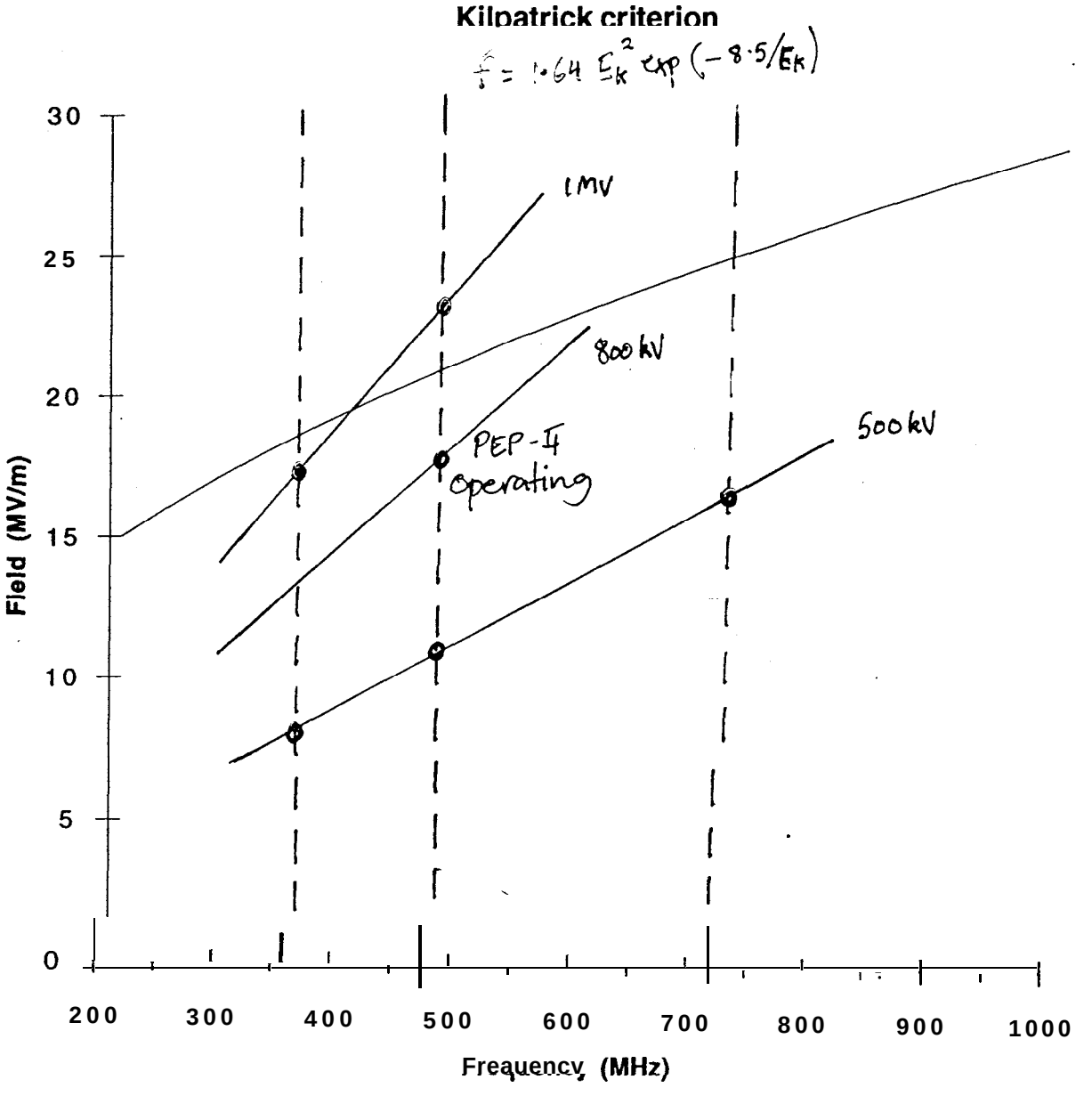
476 MHz



714 MHz

2856 MHz

Simple scaling of PEP-II design


Kilpatrick criterion
$f = 1.64\, E_K^2 \exp(-8.5/E_K)$
1MV
800 kV
500 kV
PEP-II
operating
Field (MV/m)
30
25
20
15
10
5
0
200
300
400
500
600
700
800
900
1000
Frequency (MHz)

R&D: HOM damping waveguides

Peak surface power loss at ends of HOM waveguides

- look at alternative shapes
- reduce heat load
- eliminate iris

but:

- must not lose effectiveness of damping!

MAFIA

FRAME: 3 11/01/93 - 19:43:12 VERSION[HP731K]

BFC3DE.DRC

PEP-II B FACTORY RF CAVITY - 1/2 GEOMETRY
- WITH 3 WG, 0 COUPLER PORT [KKO]

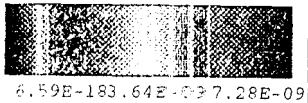
SURFACE CURRENT POWER LOSS DENSITY IN VA/M**2

#3DCONTOUR

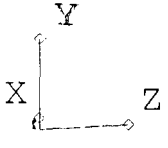
COORDINATES/M
FULL RANGE/ W II E OW
X[.0000, .36480]
.0000, .36480]
Y .28604, - 35210]
-.28604, .35210]
Z: -.21200, .42396]
-.21200, .42396]

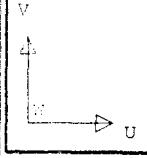
SYMBOL: B/1/FWE
COMPONENT: X

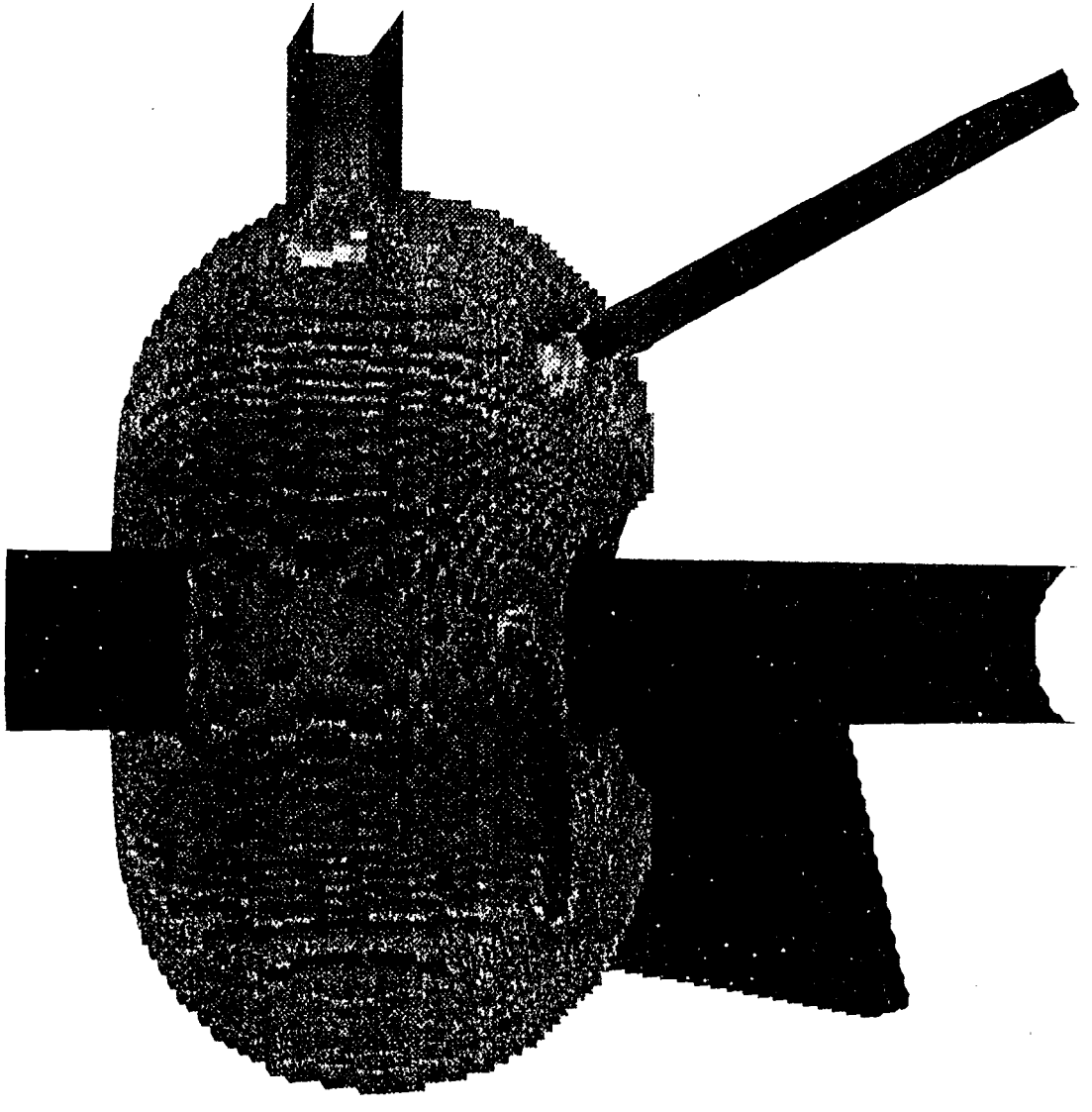
MATERIALS: 1,
FILAMENTS:

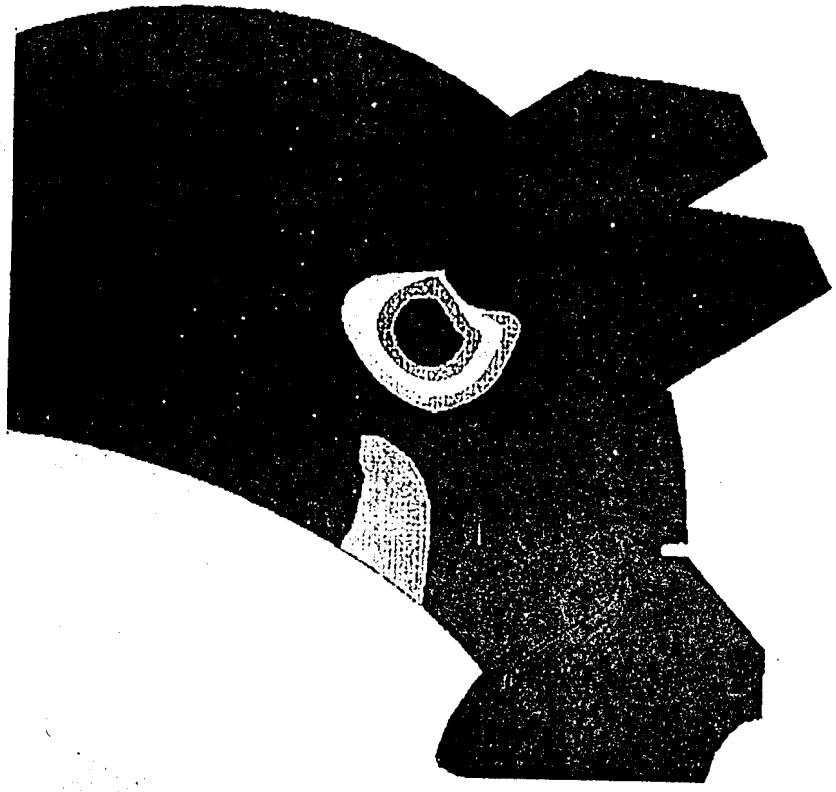


6.59E-18 3.64E-09 7.28E-09









ANSYS 5.0 A
APR 4 1994
23:38:03
PLOT NO. 9
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP
TEPC=4.561
SMN =40.318
SMX =104.278

	40.318
	47.425
	54.531
	61.638
	68.745
	75.852
	82.958
	90.065
	97.172
	104.278 °C

150 kW dissipation

PEP2rf cav, HOM port only, 12in. ext, .5in. edge R, h=14-18kW/m**2/K, Tb=35-44C

Temperature distribution around HOM port

papier [illegible]

MAFIA

RAME: 7 24/01/99 - 10:40:54 VERSION[V4.016] WG2.DRC

FREQUENCY/HZ	5.9897030400000E+08
MAXIMUM ERROR OF CURLCURL-E	-4.9745194701245E-05
MEAN ERROR OF CURLCURL-E	1.2051416888426E-05
MAXIMUM ERROR OF DIVERGENCE-D	1.3886069893942E-07

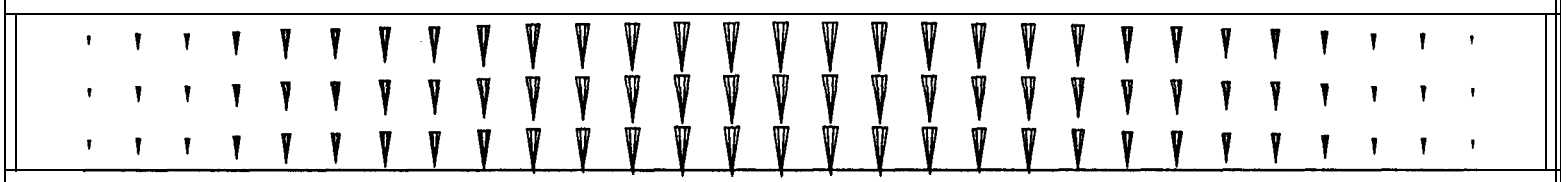
REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

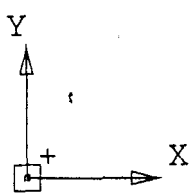
#ARROW

:OORDINATES/M
'ULL RANGE / WINDOW
'[-0.12500, 0.12500]
'[-0-0.12500 00.12500]

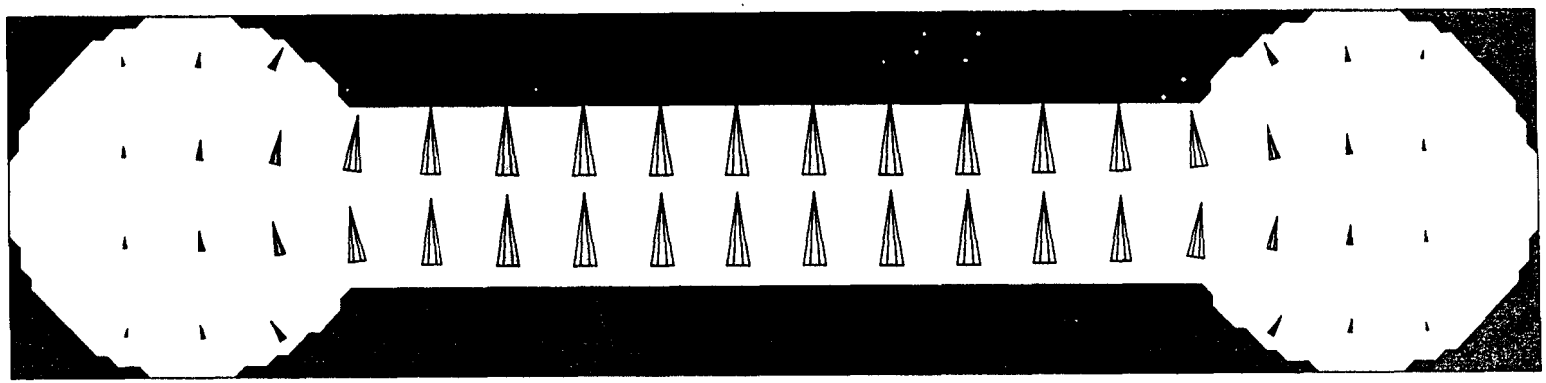
[-0.012700, 0.012700]

:YMBOL = ERE_1
NTERPOLATE.= 0
.OGSCALE....= 0.
IAX ARROW = 0.85488

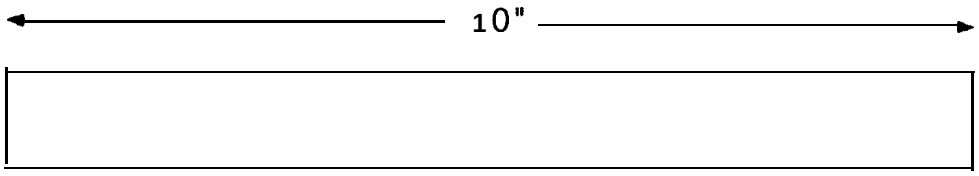




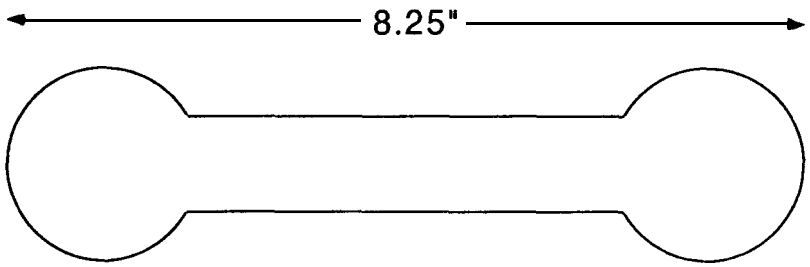
9	24/01/99 - 14:47:22	VERSION[V4.016]	./DUMBELL.DRC
NCY/HZ		5.9856396800000E+08	
M ERROR OF	CURLCURL-E	7.0855935518921E-06	
ERROR OF	CURLCURL-E	8.6579353819616E-07	
M ERROR OF	DIVERGENCE-D	1.7264923712901E-07	REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

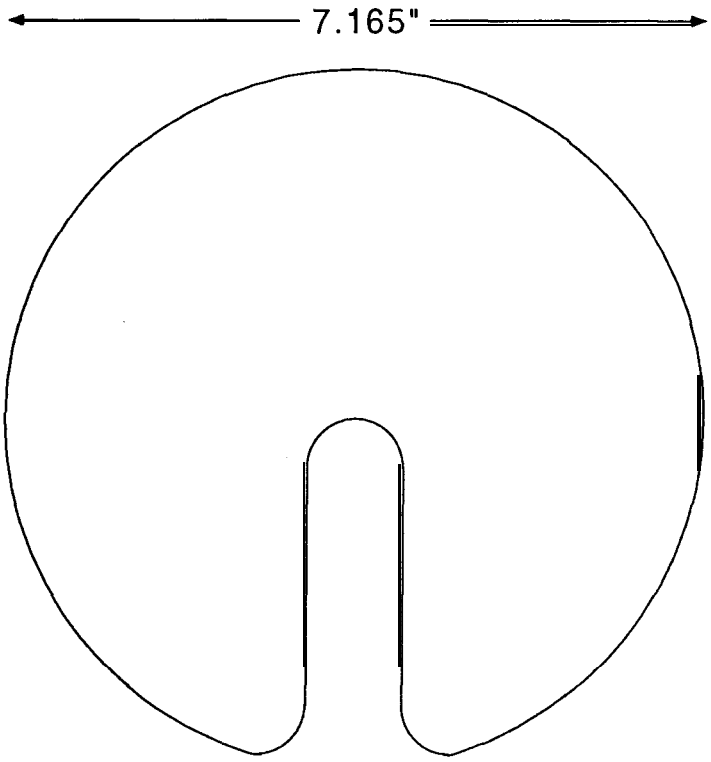


Alternative HOM port profiles



(PEP-II, fc=600 MHz)



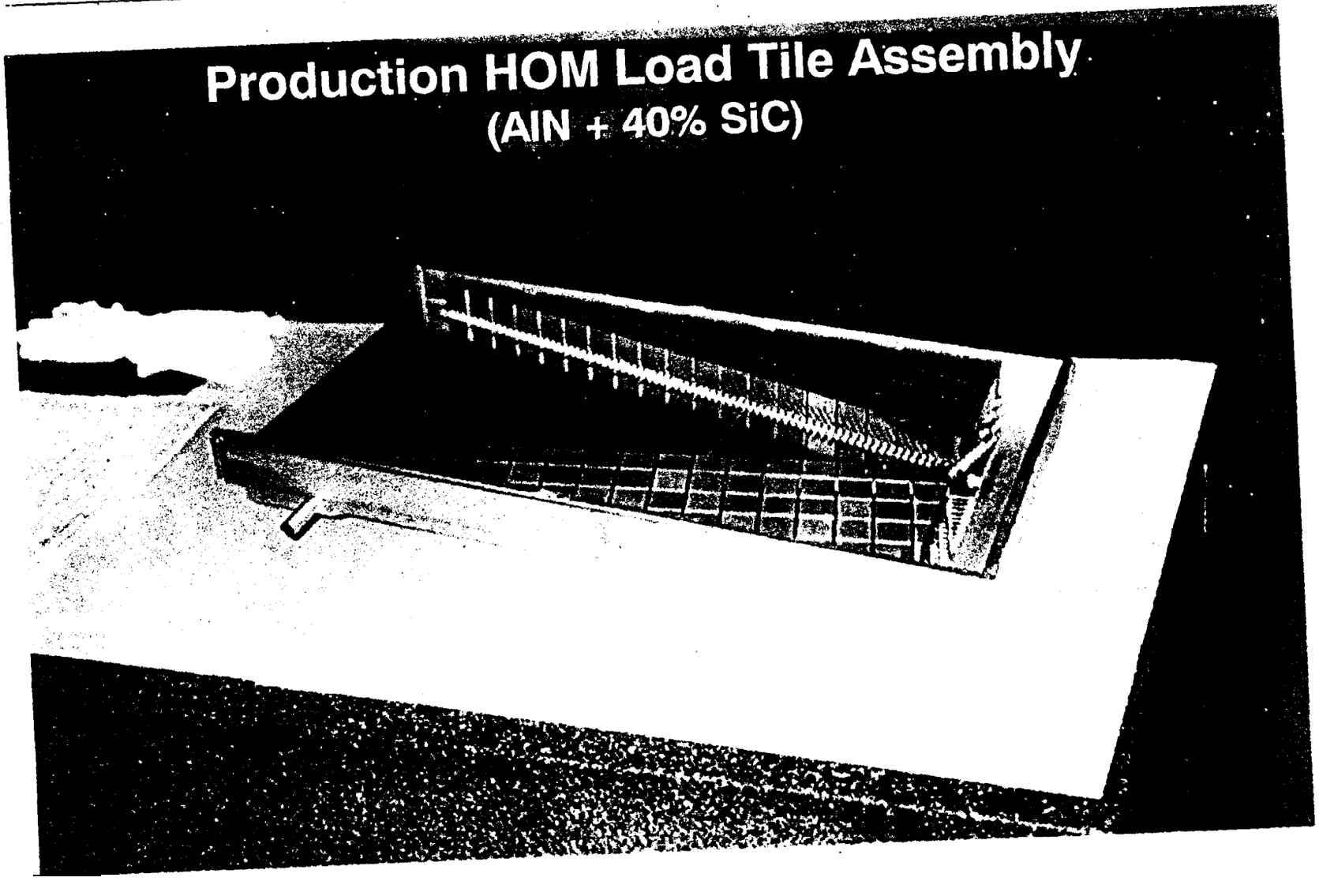


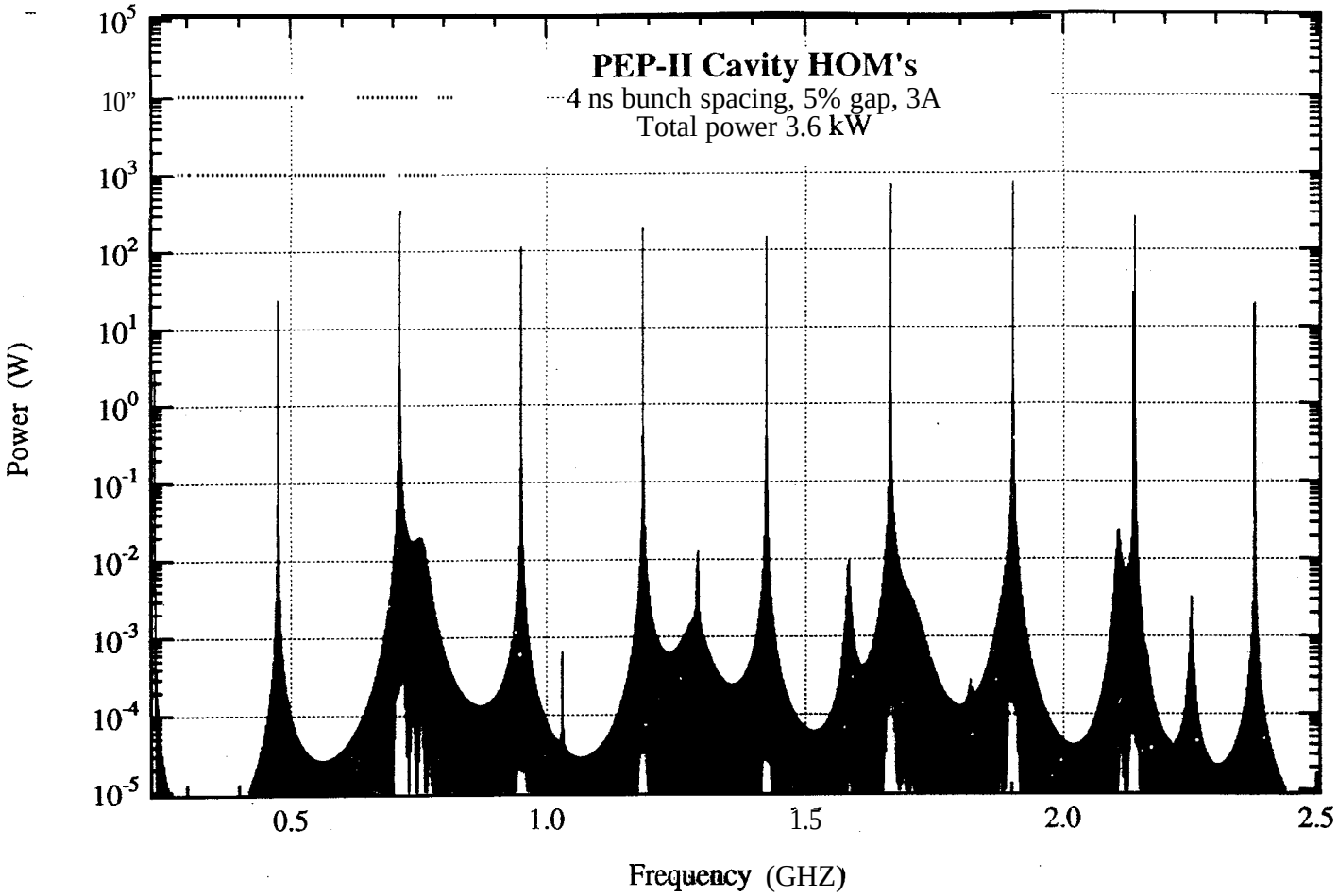
R&D: HOM loads

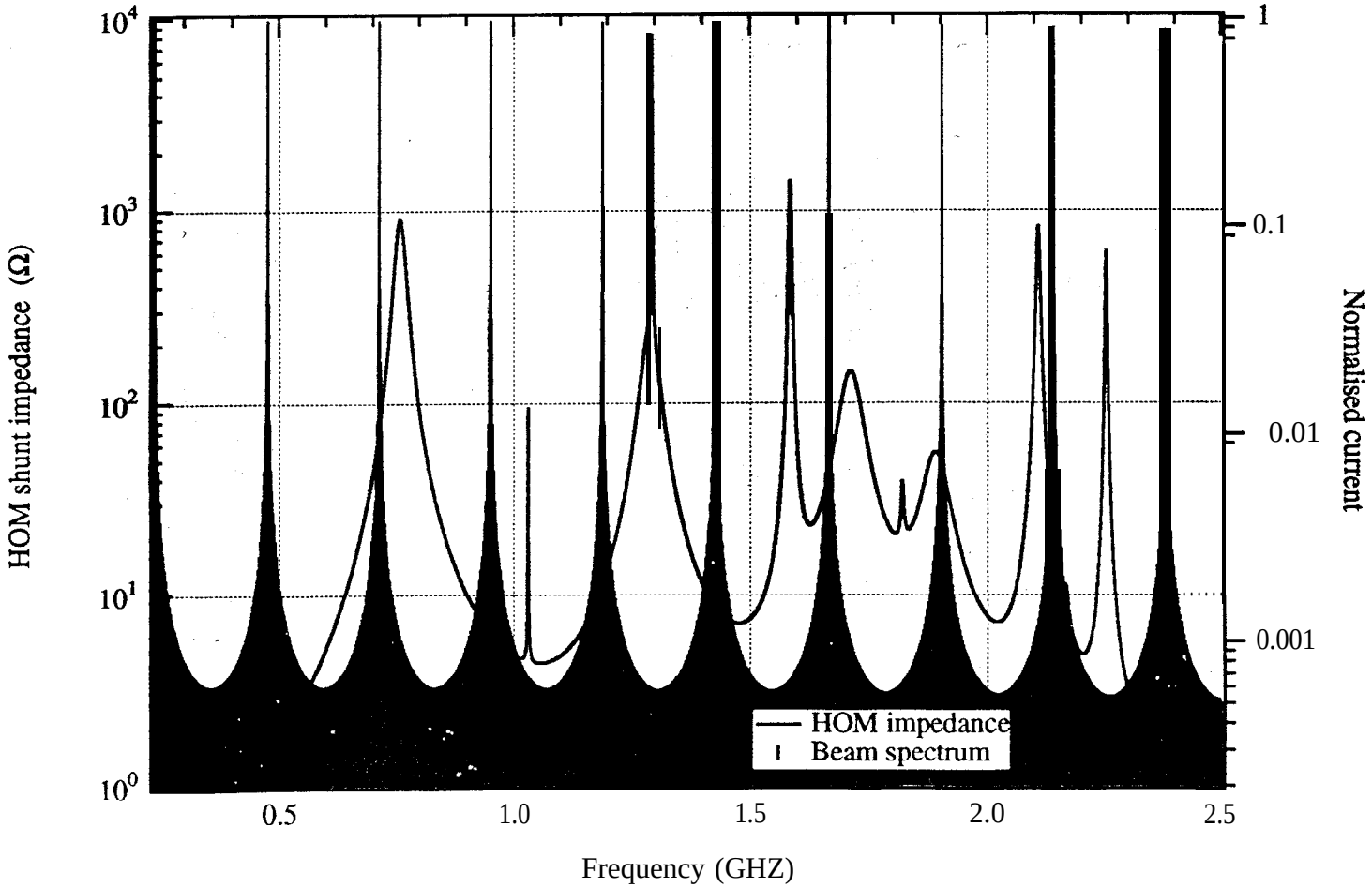
Lower beam current may reduce power but variable fill patterns may make things worse

- baseline design is scaled PEP-II load
- assess heating once impedance spectrum is confirmed
- investigate all likely fill patterns
- lower heat load would allow simpler design
- must be very broad-band (900 MHz - 7.65 GHz)

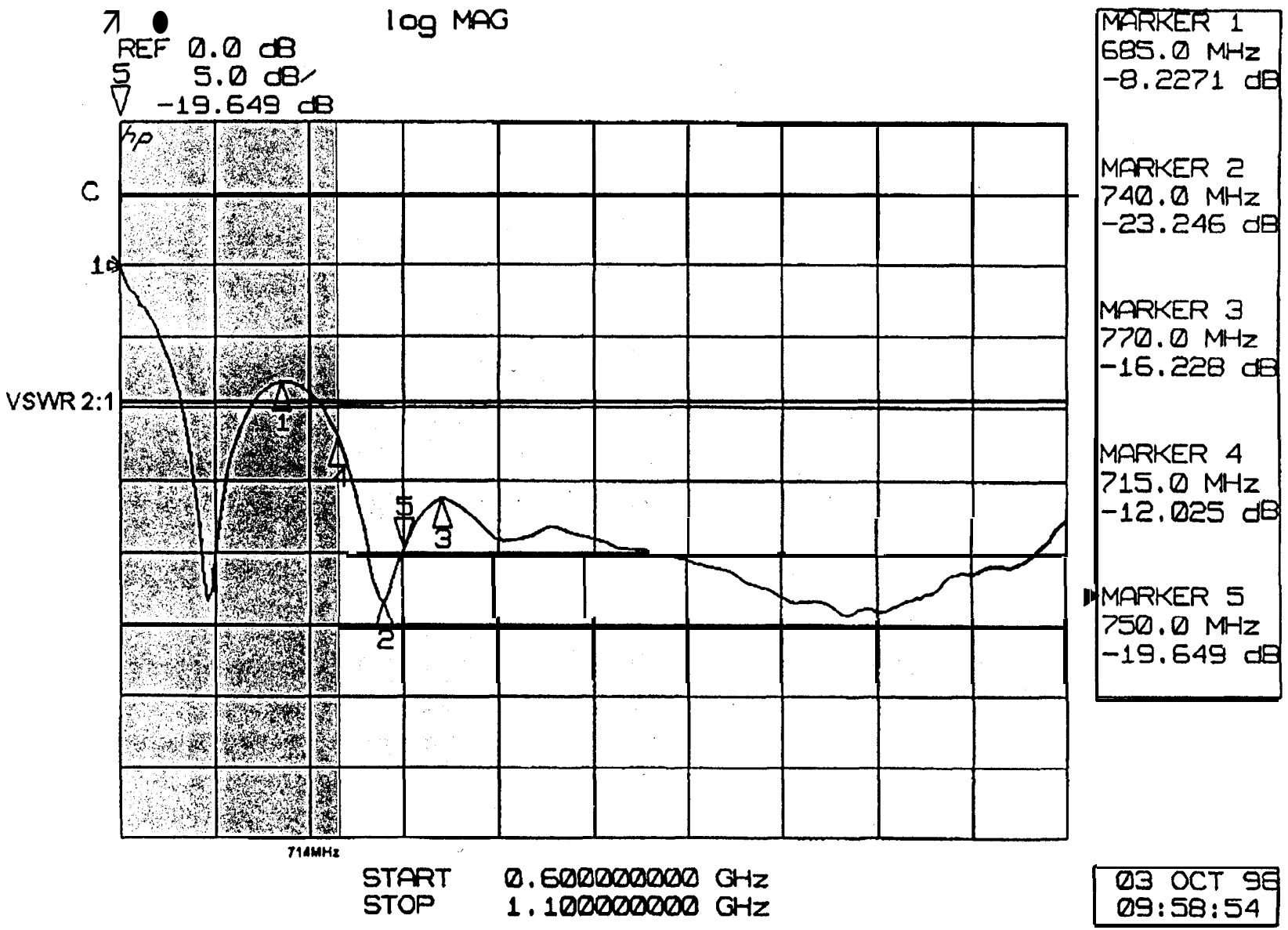
Production HOM Load Tile Assembly
(AlN + 40% SiC)




PEP-II Cavity HOM's
4 ns bunch spacing, 5% gap, 3A
Total power 3.6 kW
Power (W)
Frequency (GHZ)


HOM shunt impedance (Ω)
Normalised current
HOM impedance
Beam spectrum
Frequency (GHZ)

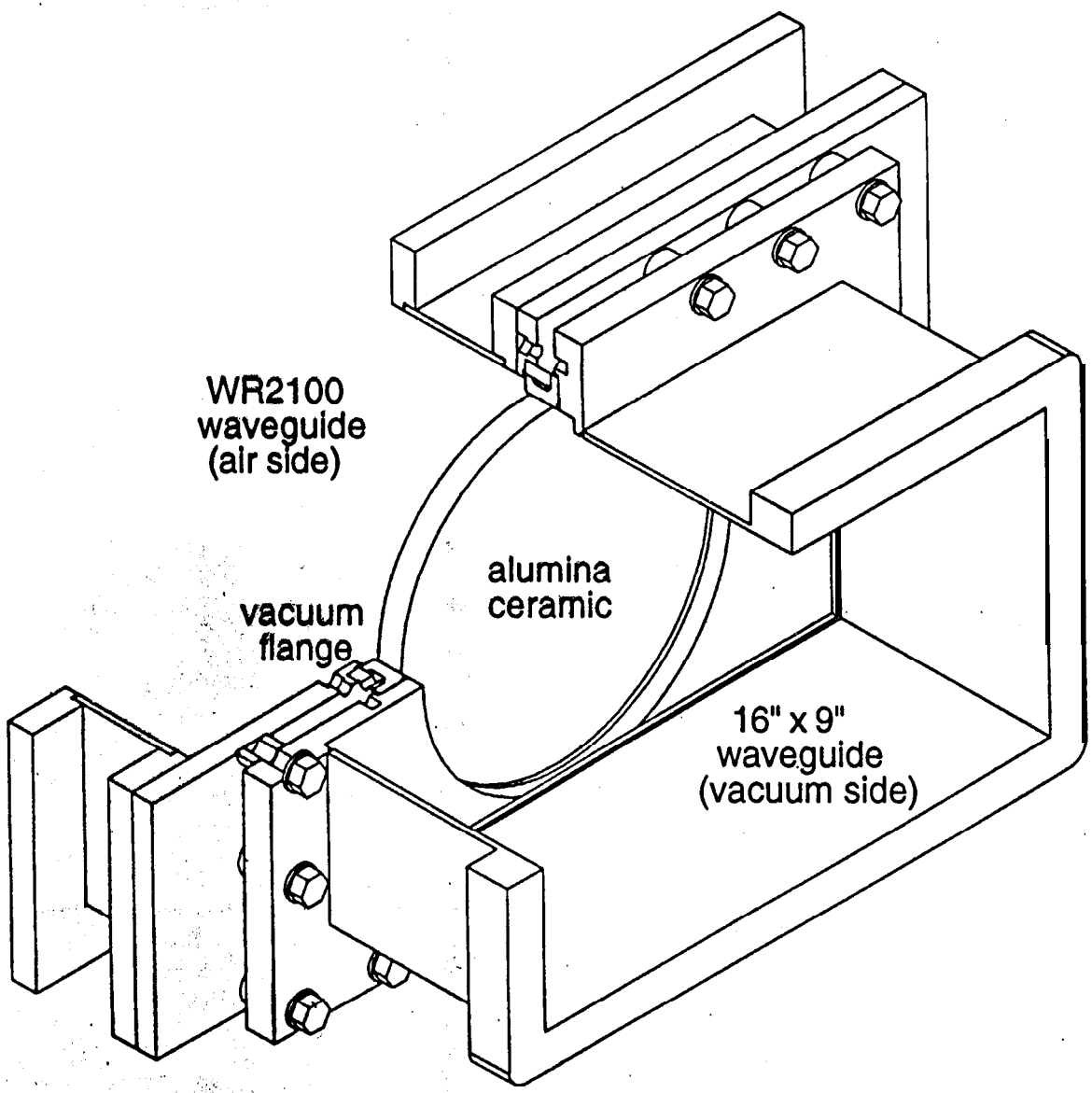
Low-End Frequency Measurement of Production Hom Load



R&D: Window and Coupler

Follow PEP-II scheme

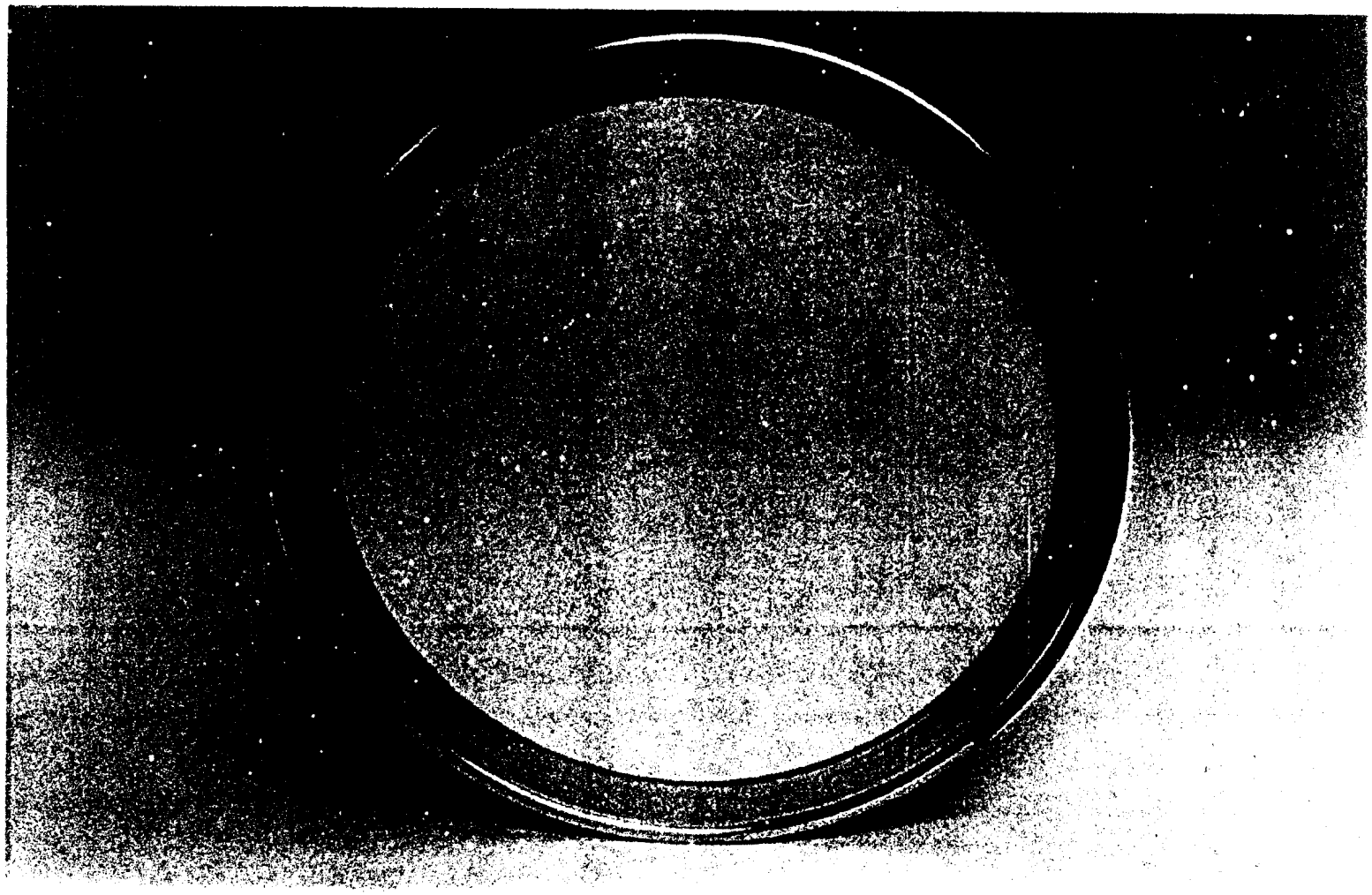
- power density similar to PEP-II
- rugged pre-stressed window
- aperture coupling into cavity
- coupler box incorporates HOM filter

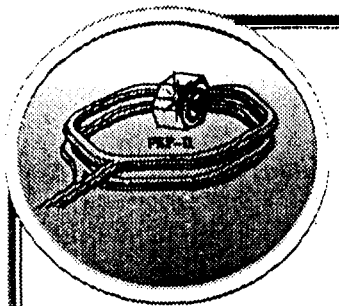


PEP-II RF cavity window module

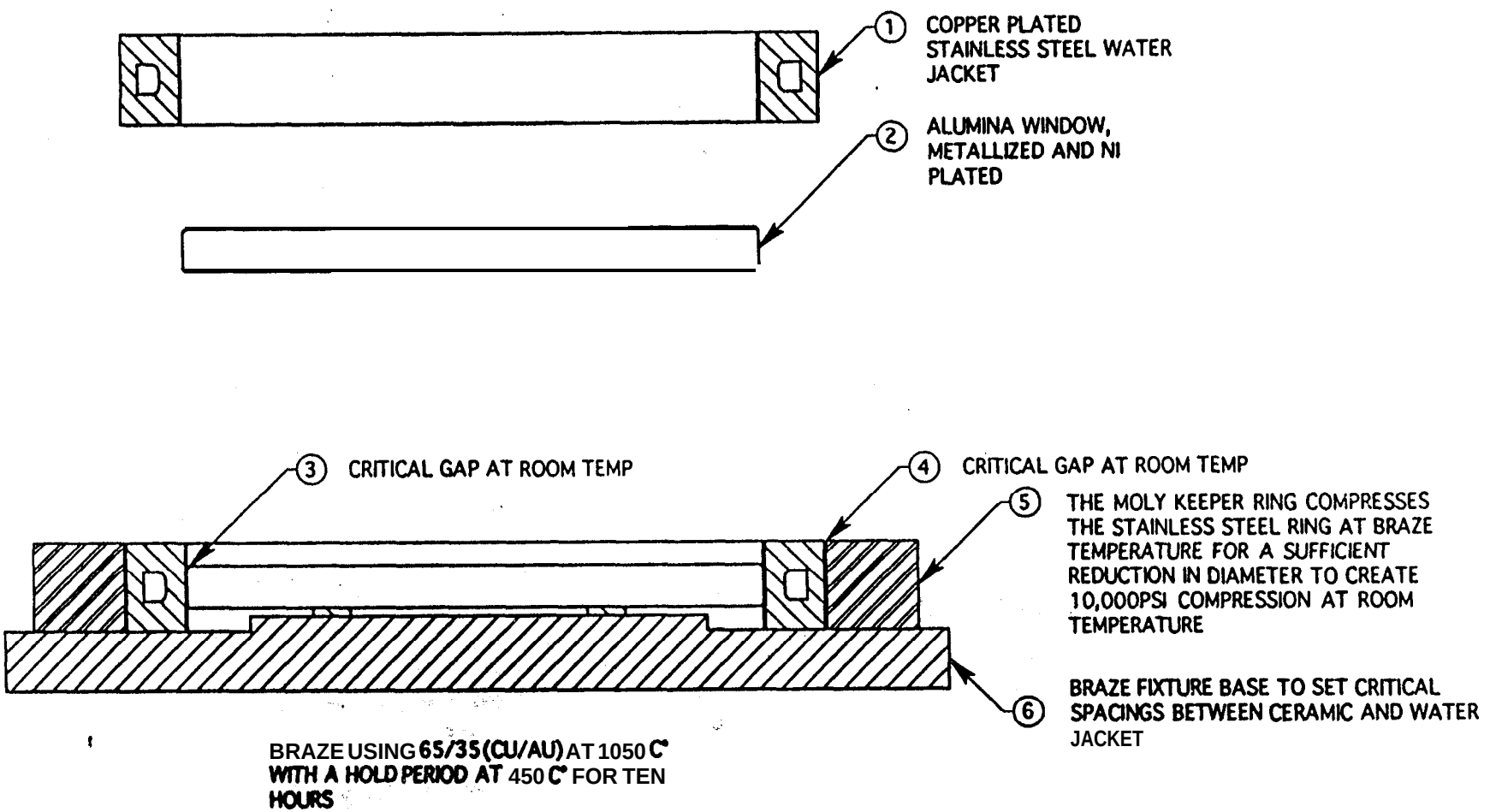
PEP-II *B*-Factory

High-Power Window with Knife-edge





COMPRESSED ASSEMBLY SEQUENCE



MAFIA

FRAME: 2 24/01/99 - 14:06:53 VERSION[V4.016] ./WG2.DRC

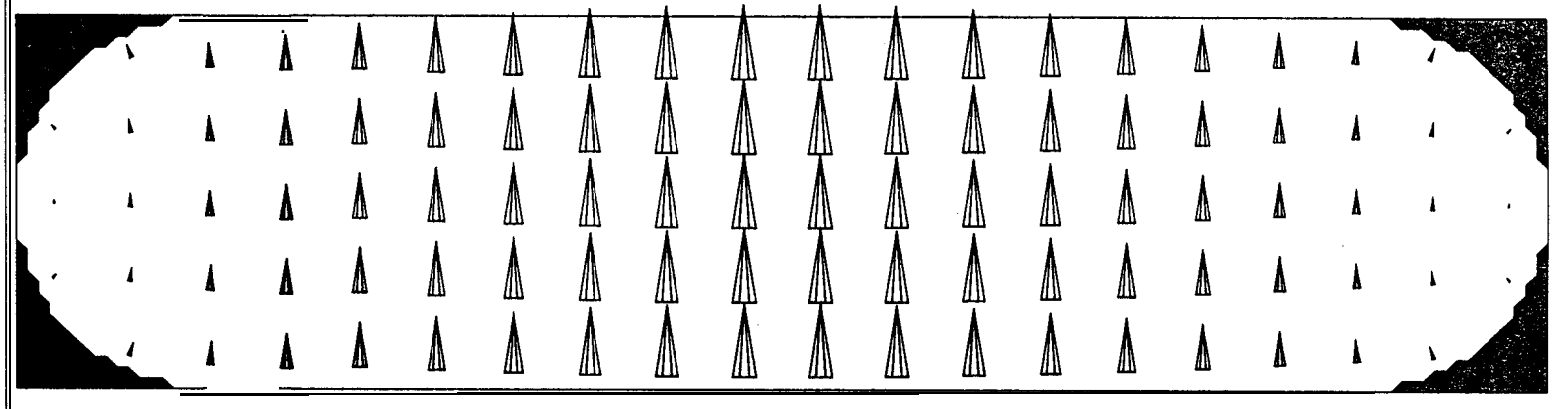
FREQUENCY/HZ 7.7883232000000E+08
MAXIMUM ERROR OF CURLCURL-E -8.0105410233955E-06
MEAN ERROR OF CURLCURL-E 1.1078450370405E-06
MAXIMUM ERROR OF DIVERGENCE-D 1.5753943216623E-07

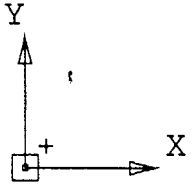
REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

#ARROW

COORDINATES/M
FULL RANGE / WINDOW
X[-0.10160, 0.10160]
[-0.10160, 0.10160]
Y[-0.025400, 0.025400]
[-0.025400, 0.025400]

SYMBOL = ERE_1
INTERPOLATE.= 0
LOGSCALE....= 0.
MAX ARROW = 0.99560





MAFIA

FRAME: 2 24/01/99 - 14:21:50 VERSION[V4.016] ./WG3.DRC

FREQUENCY/HZ 7.8842457600000E+08
MAXIMUM ERROR OF CURLCURL-E 4.4206121856405E-06
MEAN ERROR OF CURLCURL-E 3.8771429444751E-07
MAXIMUM ERROR OF DIVERGENCE-D 1.3003719345761E-07

RIDGED CIRCULAR WAVEGUIDE

REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

#ARROW

COORDINATES/M
FULL RANGE / WINDOW
X[-0.069800, 0.069800]
[-0.069800, 0.069800]
Y[-0.069800, 0.069800]
[-0.069800, 0.069800]

SYMBOL = ERE_1
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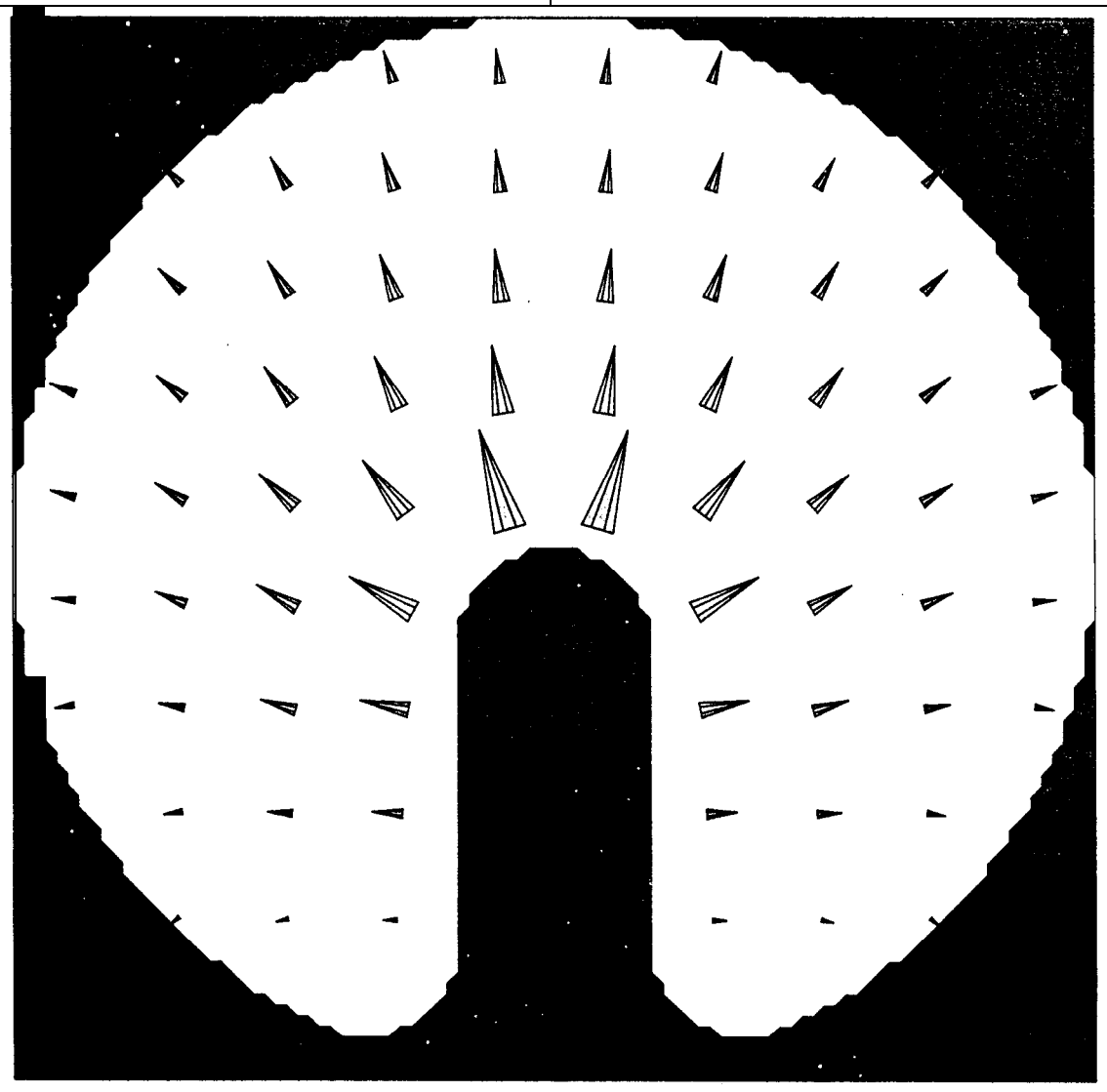
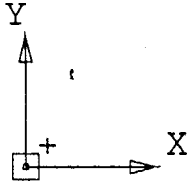
LOGSCALE....= 0.
MAX ARROW = 0.61672





MAFIA

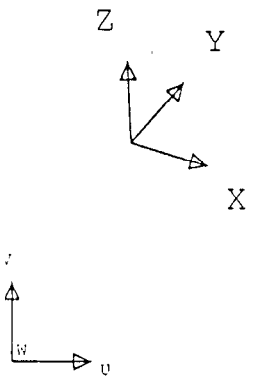
P--:3.22

#3DPLOT

COORDINATES/M
FULL RANGE / WINDOW
X[-0.041275, 0.041275]
Y[-0.041275, 0.041275]
Z[-0.12600, 0.076500]
U[-0.12600, 0.076500]
V[-0.076500, 0.28357]
W[-0.076500, 0.28357]

MATERIALS: T1,

PROJECTION: 0.5



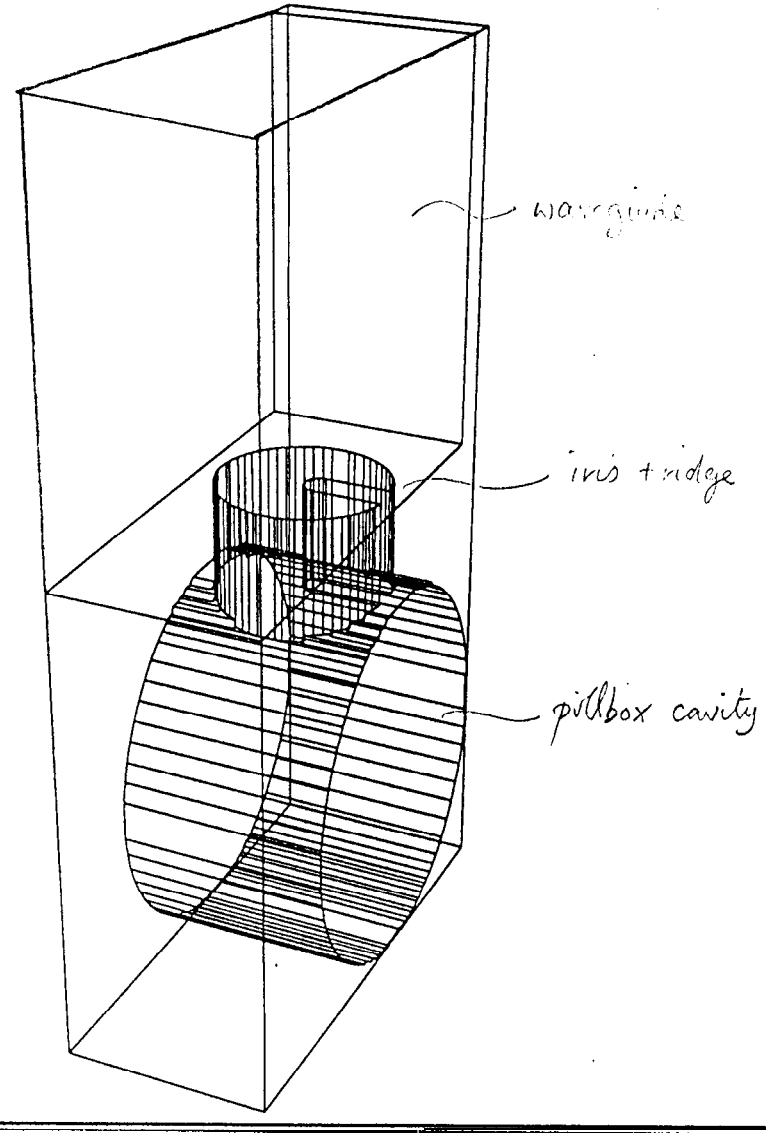
FRAME: 5 06/08/98 - 18:09:14 VERSION[V322.0]

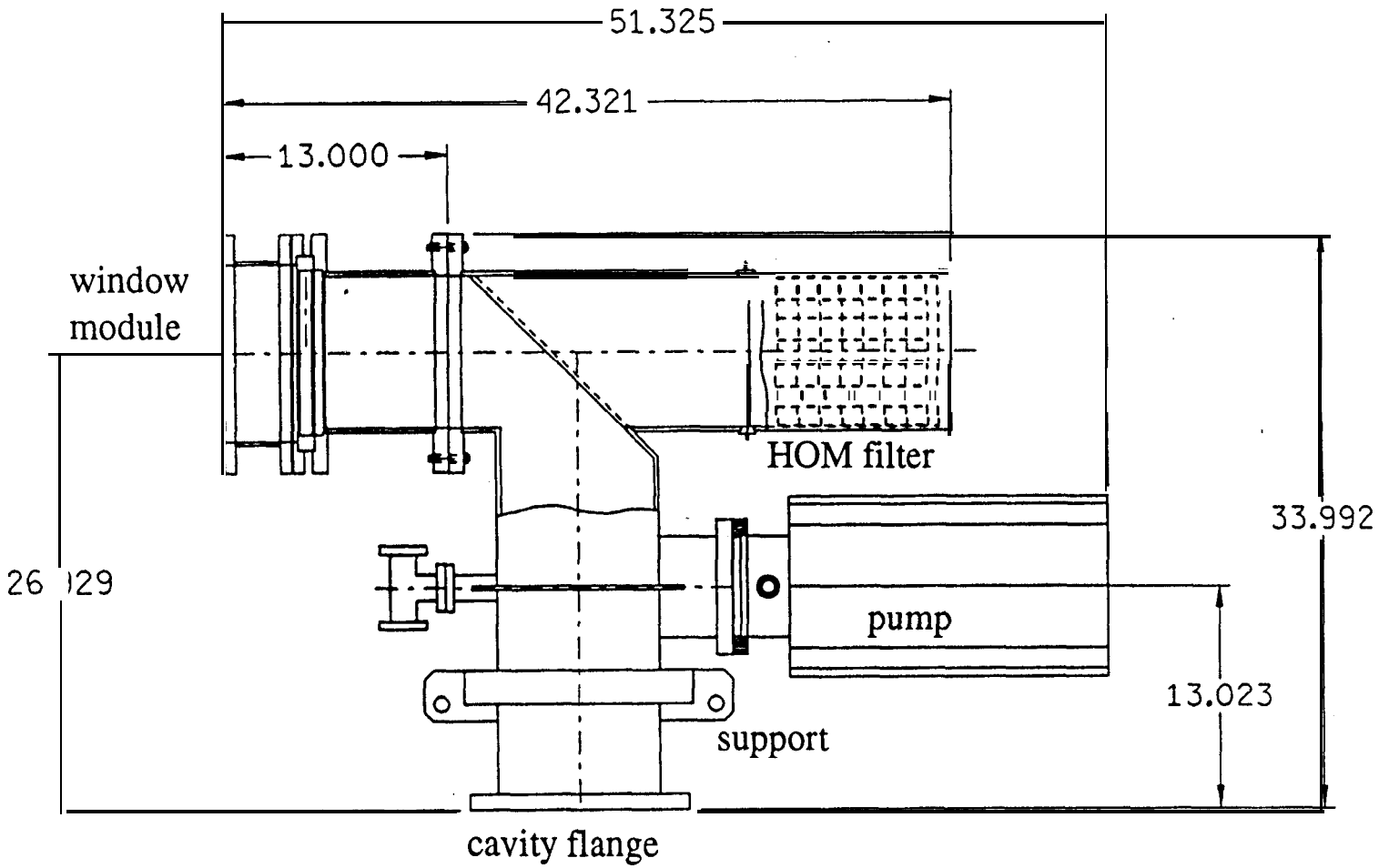
PB8.DRC

DESIGN RESONANT FREQUENCY: =1.498974592 GHZ : LM
WG COUPLED AT NAR WALL STUB AT 6.3 CM IL=1.6525 WITH RIDGE IN.
COUPLING TO HIHGER ORDER MODE:EXCIT MODE TM010

3D PLOT OF THE MATERIAL DISTRIBUTION IN THE MESH

no ridge $\beta \approx 2$
with ridge $\beta > 10$



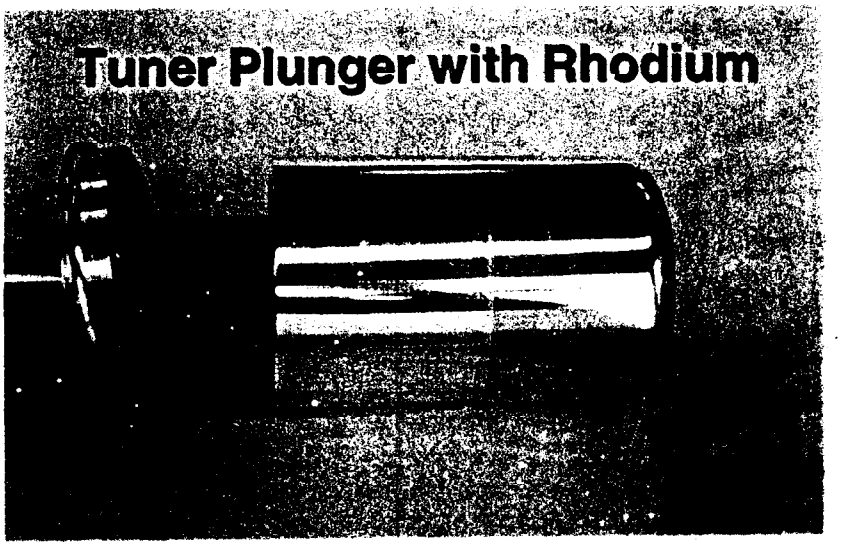


High-power coupler, plan view

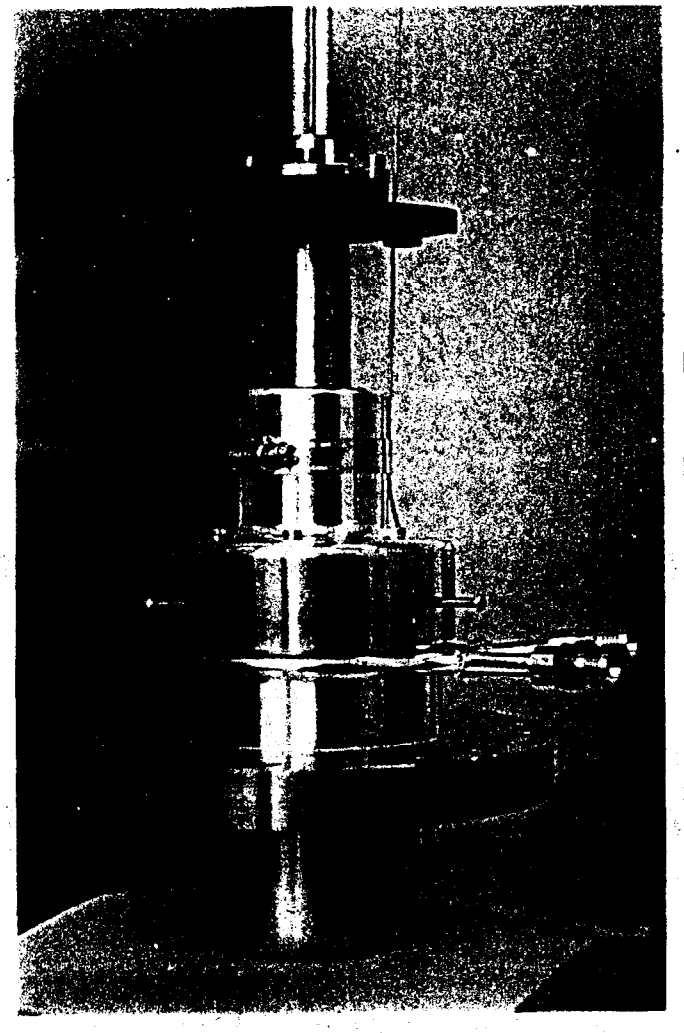
R&D: Tuner

Follow PEP-II scheme

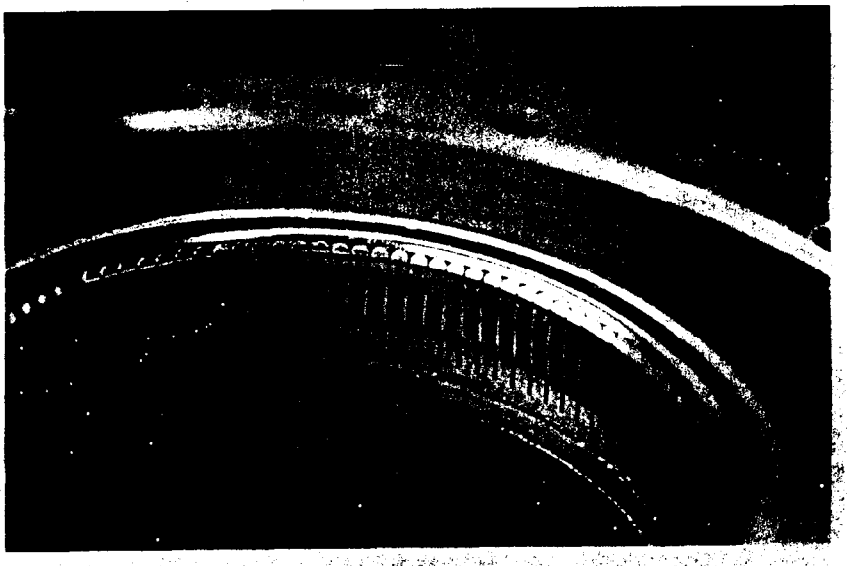
- water-cooled piston type tuner
- moderate gap to accommodate alignment tolerances
- straight Glidcop fingers with silver plating
- rhodium plated tuner body
- commercial actuator (if available)



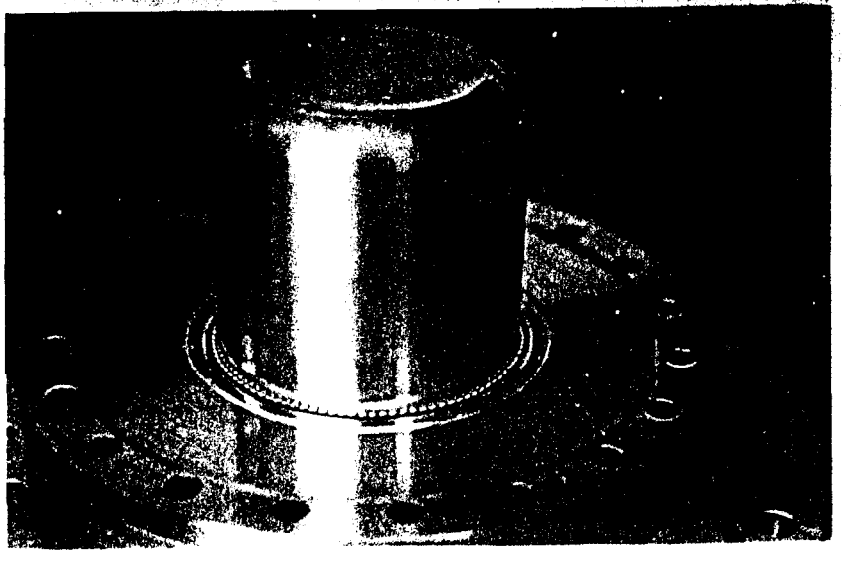
Tuner Plunger with Rhodium



Glidcop Fingers

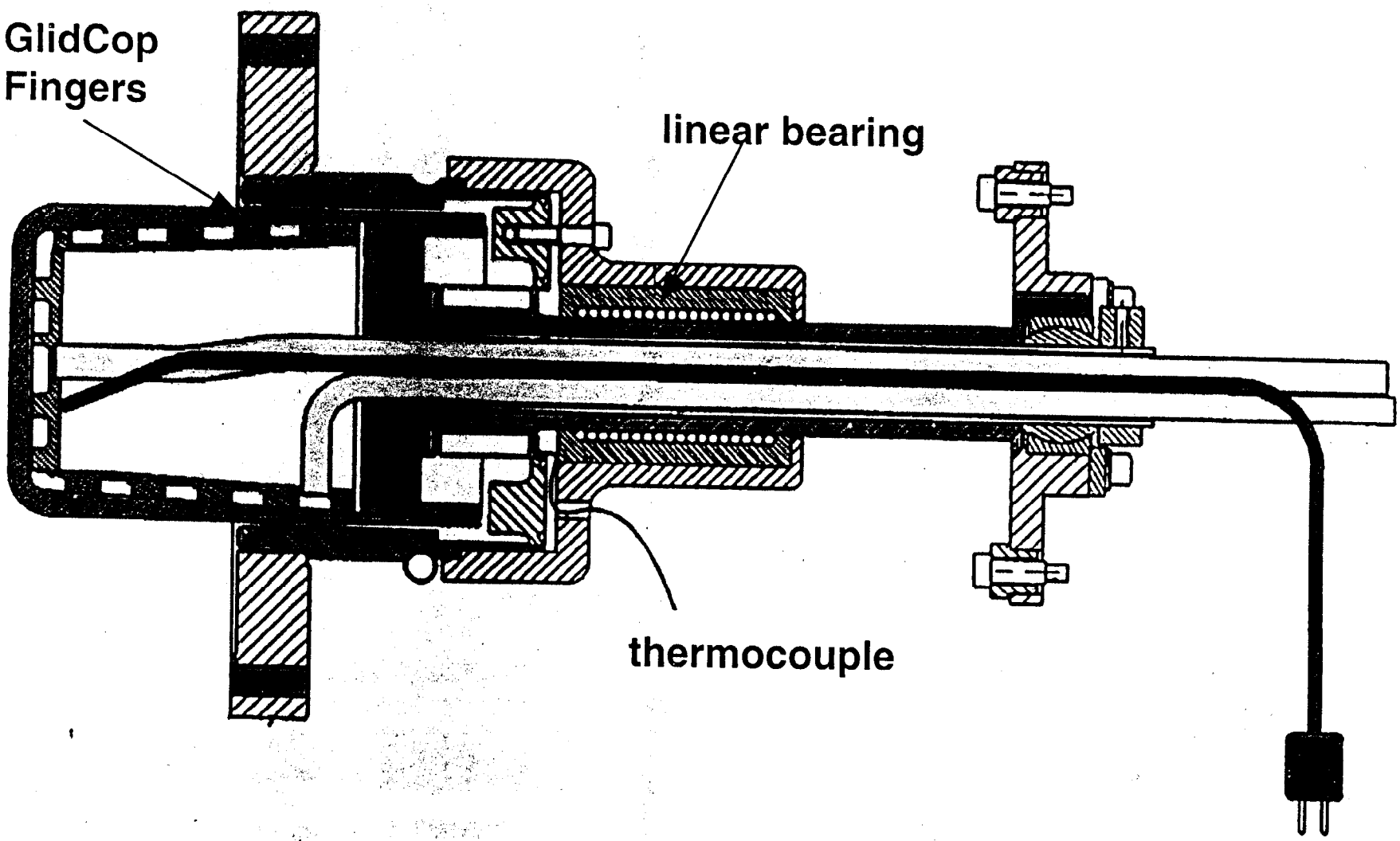


Assembly



PEP-II RF Cavity Tuner

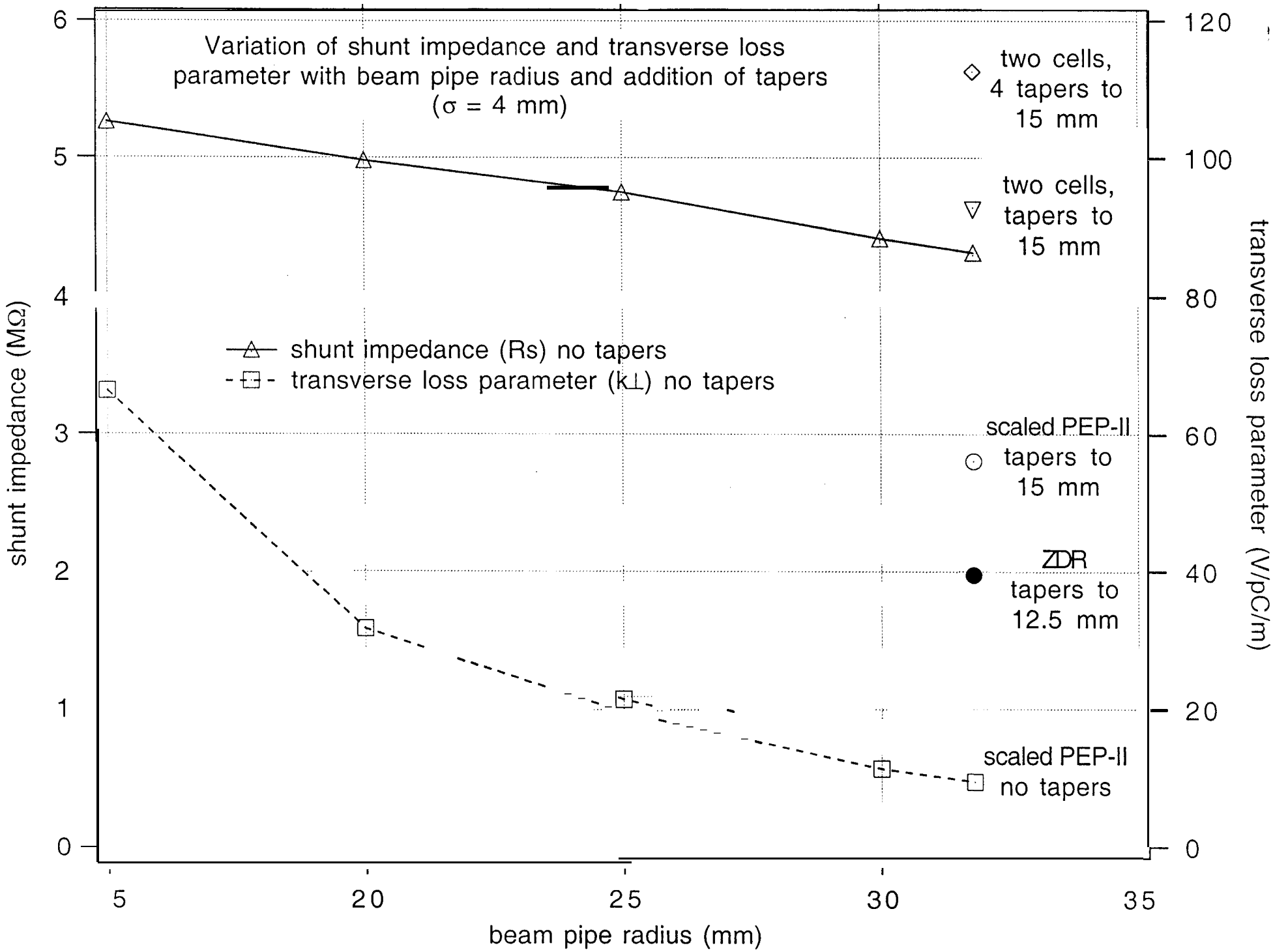
PEP-II Production Tuner



R&D: Tapers

Tapers needed to transition to small beam pipe

- add transverse impedance ($k_\perp$) comparable to cavity!
- need long smooth transition
- look at non-linear tapers
- look for HOMs trapped by tapers / between cavities


Variation of shunt impedance and transverse loss parameter with beam pipe radius and addition of tapers
(σ = 4 mm)
shunt impedance (Rs) no tapers
transverse loss parameter (k⊥) no tapers
two cells, 4 tapers to 15 mm
two cells, tapers to 15 mm
scaled PEP-II tapers to 15 mm
ZDR tapers to 12.5 mm
scaled PEP-II no tapers
shunt impedance (MΩ)
transverse loss parameter (V/pC/m)
beam pipe radius (mm)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
5
20
25
30
35

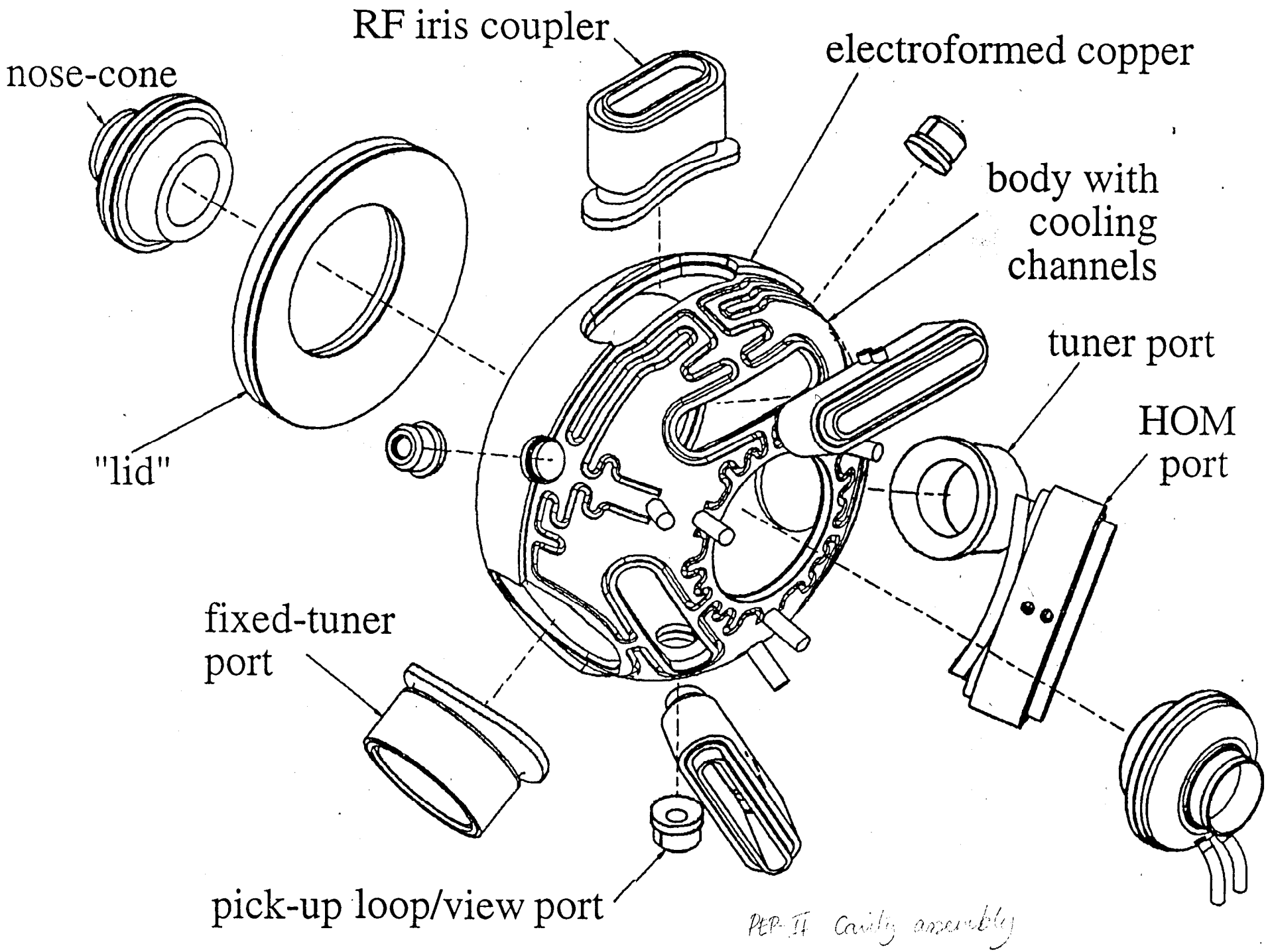
R&D: Fabrication issues

PEP-II cavity successful but expensive

- some simple geometry changes may simplify design
  - e.g.: HOM ports
- reordering assembly sequence may reduce parts count
  - e.g.: port cooling jackets
- reduced size may allow alternative materials / parts
  - e.g.: forgings, flanges
- some ideas already tried on ALS Landau cavity

but:

Easy to spend more on R&D than saved in manufacture!

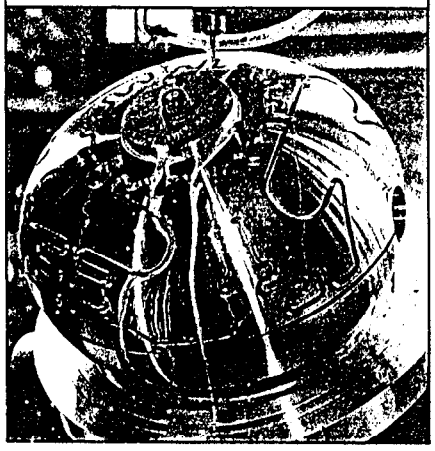

RF iris coupler
electroformed copper
nose-cone
body with
cooling
channels
tuner port
HOM
port
"lid"
fixed-tuner
port
pick-up loop/view port
PEP-II Cavity assembly

PEP-II RF Cavity produced by Lawrence Livermore National Laboratory

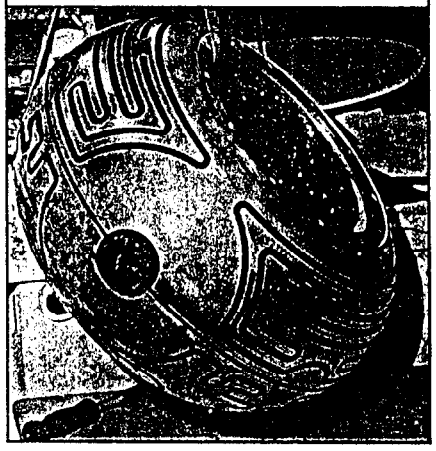
PEP-II fabrication process

RF cavity blanks are cold formed from 1" thick flat plate material.

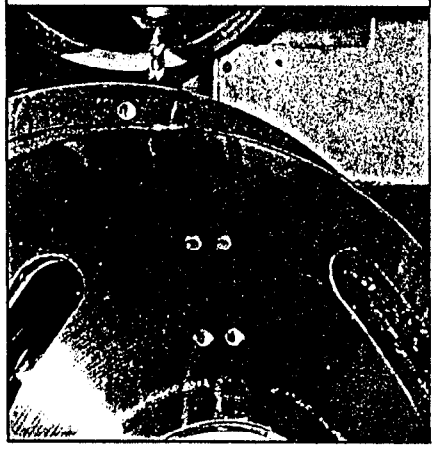
Machined bowls are electron beam welded to form a cavity, then the water channels are cut into the outer contour.



Wax is placed into the water channels prior to plating 3/8" thickness of OFE copper. Note future port location.

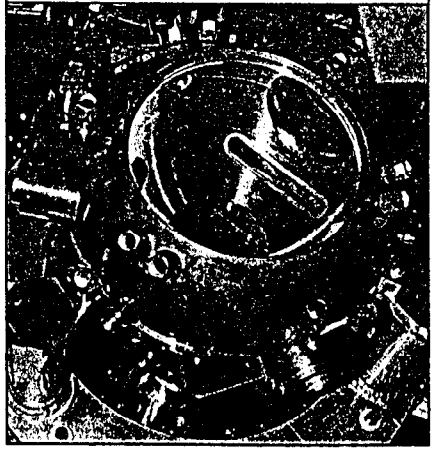


Penetrations for various ports are cut through the electroplated cavity body. Note the blue wax in 4 holes.

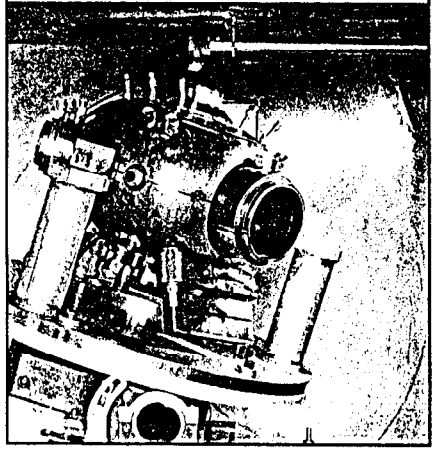


Full penetration EB vacuum welds attach tuner, Iris and HOM ports.

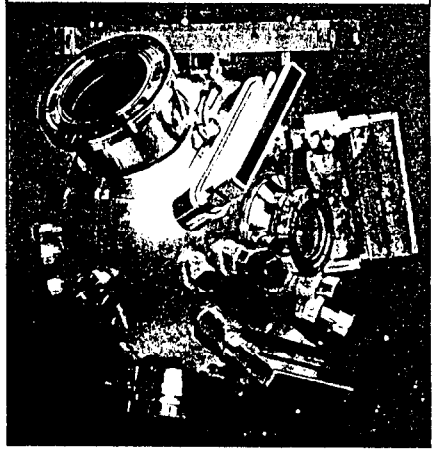
The RF surface is finish turned to a 16 Ra finish using LLNL's Diamond Turning Machine #3.



The beams noses are EB welded into the cavity following a precise tuning process.



The final product is cleaned for UHV and ready for shipment.



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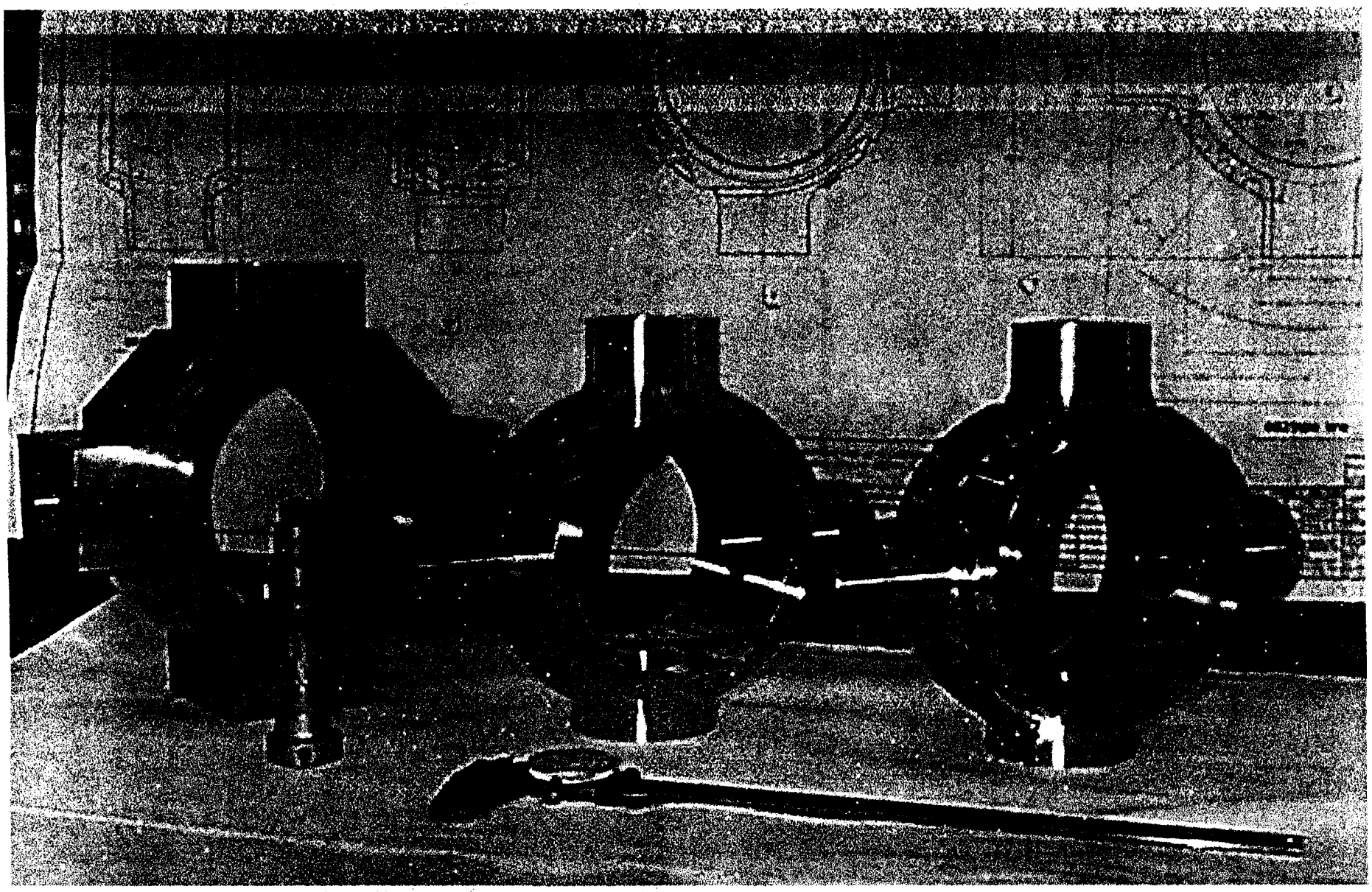

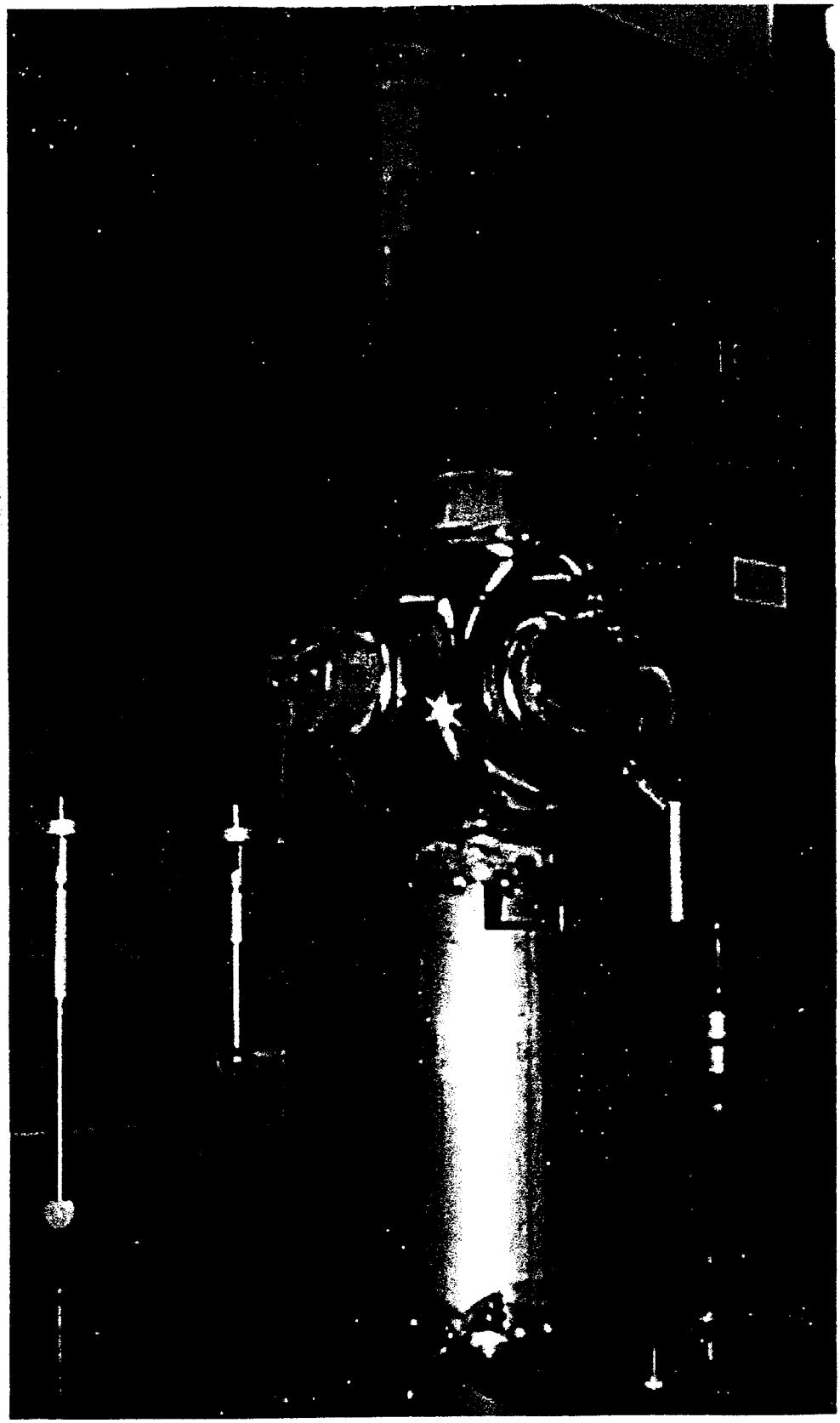

Conclusions

PEP-II RF cavity is a good baseline design

Modest improvements may be worthwhile

R&D program, level of effort designed to address all issues by time of CDR